

# **The Sustainability of Seaweed Aquaculture for Blue Growth and Climate Change Adaptation in Small Island Developing States: The Case of Belize**

**Ruth Julianna Gutierrez-Corley**

Dissertation submitted for the degree of Doctor of Philosophy

(Research on Islands and Small States)

Islands and Small States Institute

University of Malta

30<sup>th</sup> September, 2024



## **University of Malta Library – Electronic Thesis & Dissertations (ETD) Repository**

The copyright of this thesis/dissertation belongs to the author. The author's rights in respect of this work are as defined by the Copyright Act (Chapter 415) of the Laws of Malta or as modified by any successive legislation.

Users may access this full-text thesis/dissertation and can make use of the information contained in accordance with the Copyright Act provided that the author must be properly acknowledged. Further distribution or reproduction in any format is prohibited without the prior permission of the copyright holder.



## **UNIVERSITY OF MALTA LIBRARY – ELECTRONIC THESIS & DISSERTATIONS (ETD) REPOSITORY**

The copyright of this thesis/dissertation belongs to the author. The author's rights in respect of this work are as defined by the Copyright Act (Chapter 415) of the Laws of Malta or as modified by any successive legislation.

Users may access this full-text thesis/dissertation and can make use of the information contained in accordance with the Copyright Act provided that the author must be properly acknowledged. Further distribution or reproduction in any format is prohibited without the prior permission of the copyright holder.

This research was completed with funding and support from Maltese Ministry of Foreign and European Affairs (MFEA), Government of Malta, under the auspices of Islands and Small States Institute (ISSI) of the University of Malta (UM).

# DECLARATION STATEMENT

I, Ruth Julianna Gutierrez-Corley, declare that the work contained in this thesis, “*The Sustainability of Seaweed Aquaculture for Blue Growth and Climate Change Adaptation in Small Islands Developing States: The Case of Belize*”, has been substantially accomplished during my enrolment in the degree of Doctor of Philosophy (PhD) in Research on Islands and Small States.

This thesis does not contain material that has been submitted for the award of any other degree or diploma in my name, in any university or other tertiary institution.

In the future, no part of this thesis will be used in a submission in my name for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Malta and, where applicable, any partner institution responsible for the joint award of this degree.

This thesis does not contain any material previously published or written by another person, except where due reference has been made in the text and, where relevant, in the Authorship Declaration that follows.

This thesis does not violate or infringe any copyright, trademark, patent, or other rights, whatsoever of any person.

The research involving human data reported in this thesis was assessed and approved by both the University of Malta Research Ethics Committee (UREC) and the Belize Institute for Social and Cultural Research (ISCR) under the National Institute of Culture and History (NICH), ensuring compliance with ethical standards and guidelines for research on human subjects.

This thesis contains work prepared for publication, some of which has been co-authored.

I certify that help received in preparing this thesis and all sources used have been duly acknowledged.

I have attempted to use inclusive language throughout the thesis.

Word count (excluding appendices and references): 93,282 words.



Ruth J. Gutierrez-Corley

## DEDICATION

This thesis is dedicated to all the seaweed farmers of Belize, the Caribbean region, and beyond, whose unwavering commitment and resilience are paving the way for a sustainable and prosperous future in seaweed mariculture livelihoods. To the pioneers of the Belize Seaweed Mariculture Industry, Lowell Godfrey and Cleveland Davis - may your legacy live on. Your vision and pioneering efforts have laid the foundation for a thriving industry that holds the promise of sustainable livelihoods and environmental stewardship. Rest in peace, knowing that your work continues to inspire generations of seaweed farmers and researchers. This work is also dedicated to the future of seaweed mariculture in Belize. It is our hope that the laws and policies derived from this research will place the seaweed farmers at the forefront, ensuring they receive the support needed to scale up their efforts and secure further investment. The prosperity of this emerging industry lies in their hands and their support network, of which they must be empowered to lead it forward with the recognition, resources, and respect they deserve.

Photograph Courtesy of Linda Garcia (personal communication, October 20, 2025)



The Westby family (father of Llowel ‘Japs’, Kurt ‘Mambo’, and Louis Godfrey) from Placencia Village were the first growers and harvesters of *Eucheuma isiforme* in southern Belize, particularly around Tobacco Caye.

Quote (CDB, 2018, p.13):

*To position ourselves to keep more economic benefits at home, SIDS and LDCs cannot wait for technology transfer handouts. We need to build on our own institutions, our own scientists, our own intellectual properties, and our own entrepreneurs. Failing to do so can be another generation of lost opportunities, and we have lost enough already.*

– Dr. the Rt. Hon. Keith Mitchell, Prime Minister of Grenada

# ACKNOWLEDGMENTS

First and foremost, I would like to express my deepest gratitude to my supervisors, Professor Stefano Moncada (Primary Supervisor) and Professor Alan Deidun (Co-supervisor). From the very beginning, they have shared my enthusiasm for this thesis, “The Sustainability of Seaweed Aquaculture for Blue Growth and Climate Change Adaptation in Small Island Developing States: The Case of Belize”. Their expertise, passion, and unwavering support throughout the supervisor committee meetings from late 2021 to early 2022, and most recently in Malta, have been invaluable. It has been a truly rewarding experience to conduct this PhD research at the Islands and Small States Institute (ISSI) of the University of Malta (UM), under the auspices of the Maltese Ministry of Foreign and European Affairs (MFEA) and UM International Office. I am extremely grateful for the opportunity to work with such a dynamic and committed team of students, professors, and personnel at UM International and MFEA.

Over the past three years, I have had the privilege to attend multiple international conferences and workshops, both in Malta and in hybrid settings. However, the fieldwork that took place in 2023 stands as a major milestone in my life. Interacting firsthand with seaweed farmers from Belize, Jamaica, Grenada, and St. Lucia (after completing my year of coursework from the M. Phil to the PhD) has been an incredible experience that has profoundly shaped this research and my outlook on seaweed/seamoss livelihoods in the Caribbean region.

I would also like to extend heartfelt thanks to my colleagues and friends from the Sustainable Ocean Alliance (SOA), Future Leaders Network (FLN) of the Caribbean Development Bank, Commonwealth Youth Climate Change Network (CYCN) of the Commonwealth Secretariat, and the Caribbean Aquaculture Network (CAN)/Women in Caribbean Aquaculture (WiCA). Their unwavering support of this research initiative from the very early stages has been greatly appreciated.

To my friends, seaweed farmers, and seaweed enthusiasts: Juli-Anne Russo, Robert Hernandez, Omar Cowo, Olga Sho, Stacy-Ann Gray, Denzil Williams, Sweelan Renaud, Ricardo Morris, Linda Garcia, Kelvin Tillett, Melissa Cabral, Areli Perez, Yamani Magliore, Deidra Mahler, Leon ‘Randy’ Tucker, Jhoanna Williams, Dowlath Budhram, Abigail Parham, Gareth Longworth, Kurt Godfrey, Louis Godfrey, Wilbur Dubon, Godfrey Arzu, Isela Martinez, Shermaine Faux, Jalima Gold, Maya Trotz and Alfonso Marin – your support and involvement have been instrumental to the success of this research, and I am deeply thankful. Lastly, to my colleagues and friends in the Latin America and Caribbean region who I have come in contact with during this PhD journey, I thank you for supporting this research and may our contribution to knowledge stand on the shoulder of giants and may we see betterment in our society through evidence-based decision-making using studies like these for future policymaking.

Finally, I wish to express my profound gratitude to my family, especially my husband, Ieuan Corley, whose patience and encouragement have been constant sources of strength. To my family, my parents Maria and Eduardo ‘Dungo’, my sisters Lisa and Nazaria, my uncle Oscar Gutierrez, my mother-in-law Patricia Buckingham, father-in-law John Corley, step-mother-in-law Ruth Hartley, sisters-in-law Jasmine and Amethyst - thank you for your unwavering belief in me. Everyone, in their own unique way, has helped to shape this PhD research, and for that, I am eternally grateful.

# TABLE OF CONTENTS

|                                                                                                   |      |
|---------------------------------------------------------------------------------------------------|------|
| UNIVERSITY OF MALTA LIBRARY - ETD REPOSITORY .....                                                | i    |
| DECLARATION STATEMENT .....                                                                       | ii   |
| DEDICATION.....                                                                                   | iii  |
| ACKNOWLEDGMENTS.....                                                                              | iv   |
| TABLE OF CONTENTS .....                                                                           | v    |
| LIST OF TABLES.....                                                                               | x    |
| LIST OF FIGURES.....                                                                              | xiii |
| ABBREVIATIONS .....                                                                               | xvi  |
| ABSTRACT .....                                                                                    | xix  |
| 1. INTRODUCTION .....                                                                             | 1    |
| 1.1. Background.....                                                                              | 1    |
| 1.2. Small Island Developing States (SIDS) and the Blue Economy.....                              | 3    |
| 1.3. Context and Rationale.....                                                                   | 6    |
| 1.3.1. Global context .....                                                                       | 7    |
| 1.3.2. National context.....                                                                      | 8    |
| 1.4. Case Study: Belize.....                                                                      | 9    |
| 1.4.1. Seaweed mariculture in Belize .....                                                        | 11   |
| 1.4.2. National approach to seaweed mariculture.....                                              | 14   |
| 1.5. Sustainable Livelihoods Framework (SLF) approach .....                                       | 16   |
| 1.5.1. Human capital.....                                                                         | 16   |
| 1.5.2. Social capital .....                                                                       | 16   |
| 1.5.3. Financial capital.....                                                                     | 16   |
| 1.5.4. Physical capital.....                                                                      | 16   |
| 1.5.5. Natural capital .....                                                                      | 16   |
| 1.5.6. Cultural capital .....                                                                     | 17   |
| 1.6. Challenges and Information Gaps.....                                                         | 17   |
| 1.7. Hypothesis and Research Questions .....                                                      | 19   |
| 1.8. Research Approach .....                                                                      | 20   |
| 1.9. Outline of the Thesis.....                                                                   | 21   |
| 2. CLIMATE CHANGE ADAPTATION, LIVELIHOODS, SEAWEED MARICULTURE,<br>AND BLUE ECONOMY IN SIDS ..... | 22   |
| 2.1. Overview.....                                                                                | 22   |
| 2.2. Definition of concepts .....                                                                 | 23   |
| 2.2.1. Livelihoods.....                                                                           | 23   |
| 2.2.2. Hazards.....                                                                               | 24   |

|        |                                                                                                                                              |    |
|--------|----------------------------------------------------------------------------------------------------------------------------------------------|----|
| 2.2.3. | Climatic hazards .....                                                                                                                       | 24 |
| 2.2.4. | Non-climatic hazards.....                                                                                                                    | 25 |
| 2.2.5. | Coping mechanisms.....                                                                                                                       | 26 |
| 2.2.6. | Adaptation versus maladaptation.....                                                                                                         | 26 |
| 2.2.7. | Policy measure/responses.....                                                                                                                | 29 |
| 2.3.   | Climate Change Adaptation and Livelihoods .....                                                                                              | 29 |
| 2.3.1. | Development and climate change adaptation .....                                                                                              | 30 |
| 2.3.2. | Adaptation in SIDS compared to more developed countries.....                                                                                 | 32 |
| 2.4.   | Framework Approach of PhD Thesis.....                                                                                                        | 32 |
| 2.4.1. | Importance of mixed methods frameworks for community-level and policy-level climate adaptation strategies operational in local context ..... | 34 |
| 2.4.2. | Policy analysis toolkit.....                                                                                                                 | 35 |
| 2.5.   | Summary and Research Gap .....                                                                                                               | 36 |
| 3.     | SEAWEED MARICUTLURE LIVELIHOOD AS A CLIMATE CHANGE ADAPTATION AND BLUE ECONOMY STRATEGY .....                                                | 38 |
| 3.1.   | Nexus Between Seaweed Mariculture, Blue Economy and Adaptation .....                                                                         | 39 |
| 3.1.1. | Characterization of seaweed mariculture globally .....                                                                                       | 40 |
| 3.1.2. | Overview of blue economy.....                                                                                                                | 41 |
| 3.1.3. | Characterization of seaweed mariculture in SIDS.....                                                                                         | 45 |
| 3.1.4. | Seaweed mariculture production and blue economy .....                                                                                        | 49 |
| 3.1.5. | Belize Seaweed Mariculture Production .....                                                                                                  | 52 |
| 3.2.   | Contextualizing The Theoretical and Conceptual Underpinnings of Thesis .....                                                                 | 54 |
| 3.2.1. | Context to SIDS, with a focus on Belize .....                                                                                                | 57 |
| 3.2.2. | Importance of community participation in sustainable seaweed mariculture development.....                                                    | 59 |
| 3.2.3. | Community participation in adaptation and seaweed mariculture in SIDS.....                                                                   | 60 |
| 3.2.4. | Key trends in systematic literature review.....                                                                                              | 61 |
| 3.3.   | Summary and Research Gaps .....                                                                                                              | 63 |
| 4.     | METHODOLOGY .....                                                                                                                            | 66 |
| 4.1.   | Overview of Mixed Methods Approach.....                                                                                                      | 66 |
| 4.2.   | Research Timeline and Roadmap.....                                                                                                           | 69 |
| 4.3.   | Data Collection .....                                                                                                                        | 70 |
| 4.4.   | Qualitative Assessment .....                                                                                                                 | 71 |
| 4.4.1. | Systematic Literature Review.....                                                                                                            | 71 |
| 4.4.2. | Participatory Focus Groups and the CRiSTAL tool .....                                                                                        | 72 |
| 4.4.3. | Qualitative Surveys .....                                                                                                                    | 75 |
| 4.4.4. | Elite interviews.....                                                                                                                        | 75 |
| 4.4.5. | Thematic Content and Reflexive Analysis by PESTEL .....                                                                                      | 76 |



|        |                                                                         |     |
|--------|-------------------------------------------------------------------------|-----|
| 4.4.6. | Policy Analysis by PESTEL .....                                         | 78  |
| 4.5.   | Quantitative Assessment .....                                           | 79  |
| 4.5.1. | Correlations for hazards and responses associations .....               | 79  |
| 4.5.2. | Model for measuring livelihood capitals .....                           | 82  |
| 4.6.   | Ethics and Data Protection.....                                         | 84  |
| 4.6.1. | University of Malta Research Ethics Committee (UREC) Approval .....     | 84  |
| 4.6.2. | Approval from the Belize Ethics Committee.....                          | 85  |
| 4.7.   | Summary.....                                                            | 86  |
| 5.     | RESULTS .....                                                           | 87  |
| 5.1.   | Quantitative Assessment .....                                           | 87  |
| 5.1.1. | Quantitative Surveys.....                                               | 87  |
| 5.1.2. | Description of participants.....                                        | 88  |
| 5.1.3. | Comparison of household surveys to National Statistics Belize SIDS..... | 90  |
| 5.1.4. | Hazards and responses in seaweed farming.....                           | 92  |
| 5.1.5. | Hypothesis testing using linear regression models .....                 | 98  |
| 5.1.6. | Summary of Quantitative Assessment using Linear Regression Model.....   | 105 |
| 5.2.   | Qualitative Assessment .....                                            | 105 |
| 5.2.1. | Focus Group Discussions .....                                           | 105 |
| 5.2.2. | Qualitative surveys .....                                               | 112 |
| 5.2.3. | Summary of focus group discussions and qualitative surveys .....        | 132 |
| 5.2.4. | Elite Interviews.....                                                   | 134 |
| 5.2.5. | Policy Analysis .....                                                   | 149 |
| 5.2.6. | Summary of elite interviews and policy analysis by PESTEL .....         | 155 |
| 5.3.   | Summary.....                                                            | 157 |
| 5.3.1. | Community-level integration in seaweed mariculture development .....    | 157 |
| 5.3.2. | Policy-level integration in the seaweed farming governance .....        | 159 |
| 6.     | DISCUSSION.....                                                         | 161 |
| 6.1.   | Qualitative analysis with CRiSTAL and implications .....                | 161 |
| 6.2.   | Qualitative analysis with surveys and implications .....                | 163 |
| 6.3.   | Conclusion of the qualitative assessment.....                           | 168 |
| 6.4.   | Policy Analysis using PESTEL Tool.....                                  | 168 |
| 6.4.1. | Challenges and Opportunities in Seaweed Mariculture Livelihoods.....    | 171 |
| 6.5.   | Conclusion of the PESTEL Policy Analysis .....                          | 174 |
| 6.6.   | Quantitative analysis with surveys and implications .....               | 176 |
| 6.6.1. | Hazards and responses in seaweed farming livelihoods.....               | 177 |
| 6.6.2. | Model for measuring and strengthening seaweed livelihoods.....          | 177 |
| 6.7.   | Conclusion of quantitative assessment .....                             | 179 |

|        |                                                                                              |     |
|--------|----------------------------------------------------------------------------------------------|-----|
| 6.8.   | Limitations and Shortcomings of Study .....                                                  | 181 |
| 6.8.1. | The use of PRAs and the CRiSTAL toolkit .....                                                | 182 |
| 6.8.2. | Sampling of survey respondents and survey data .....                                         | 183 |
| 6.8.3. | Sampling of Elite Interviewees.....                                                          | 184 |
| 6.8.4. | Socio-economic and Socio-legal Overlap of PESTEL tool .....                                  | 184 |
| 6.8.5. | Analytical and Methodological Challenges of the Mixed Methods Design..                       | 185 |
| 6.9.   | Summary.....                                                                                 | 187 |
| 7.     | CONCLUSION AND RECOMMENDATION .....                                                          | 190 |
| 7.1.   | Introduction.....                                                                            | 190 |
| 7.2.   | Overall Key Findings (structured by research questions) .....                                | 191 |
| 7.3.   | Synthesis of Findings and Theoretical and Conceptual Implications .....                      | 194 |
| 7.3.1. | Integrating Livelihood Capitals and Adaptation Strategies .....                              | 194 |
| 7.3.2. | Adaptation as a Livelihood Practice in SIDS .....                                            | 195 |
| 7.3.3. | Linking Local Practices to Policy and Governance.....                                        | 195 |
| 7.3.4. | Theoretical Extensions to the Sustainable Livelihoods Framework (SLF) ...                    | 196 |
| 7.3.5. | Synthesis of Implications.....                                                               | 196 |
| 7.4.   | Novel Findings in Seaweed Farming Livelihoods in Belize.....                                 | 196 |
| 7.4.1. | Seaweed Farming as a Dual Adaptation and Livelihood Strategy in SIDS...                      | 196 |
| 7.4.2. | Identification of Non-Climatic Hazards as Major Threats .....                                | 197 |
| 7.4.3. | Development and Implementation of Long-Term Adaptation Strategies .....                      | 197 |
| 7.4.4. | Strengthening of Community-Based Adaptation Mechanisms.....                                  | 198 |
| 7.4.5. | Synthesis of Novel Findings.....                                                             | 198 |
| 7.5.   | Contribution of This Research .....                                                          | 198 |
| 7.5.1. | Empirical Contributions .....                                                                | 198 |
| 7.5.2. | Theoretical Contributions.....                                                               | 199 |
| 7.5.3. | Methodological Contributions .....                                                           | 199 |
| 7.5.4. | Policy Contributions .....                                                                   | 200 |
| 7.5.5. | Regional and Global Relevance .....                                                          | 200 |
| 7.6.   | Community and Policy Recommendations.....                                                    | 200 |
| 7.6.1. | Community-Level Recommendations.....                                                         | 201 |
| 7.6.2. | Policy-Level Recommendations.....                                                            | 201 |
| 7.6.3. | Regional and International Collaboration.....                                                | 203 |
| 7.7.   | Directions for Future Research .....                                                         | 203 |
| 7.7.1. | Expanding the Mixed-Method Tripartite Hazard-Assessment Framework...                         | 203 |
| 7.7.2. | Integrating the Sustainability-Focused Livelihood Model with Global Climate Frameworks ..... | 203 |
| 7.7.3. | Longitudinal and Comparative Studies of Seaweed Mariculture .....                            | 204 |

|        |                                                                       |     |
|--------|-----------------------------------------------------------------------|-----|
| 7.7.4. | Digitalization and Technological Innovation in Seaweed Farming .....  | 204 |
| 7.7.5. | Methodological Refinement and Capital Weighting.....                  | 204 |
| 7.7.6. | Gendered and Cultural Dimensions of Adaptation .....                  | 204 |
| 7.7.7. | Linking Livelihood Adaptation to Blue Economy Transitions .....       | 205 |
| 7.7.8. | Summary of Future Research Directions.....                            | 205 |
| 7.8.   | Concluding Reflections and Global Significance .....                  | 205 |
| 8.     | REFERENCES .....                                                      | 208 |
| 9.     | APPENDICES .....                                                      | 244 |
| 9.1.   | APPENDIX A (Scoping Literature).....                                  | 244 |
| 9.2.   | APPENDIX B (Systematic Literature Review) .....                       | 248 |
| 9.2.1. | Data: Systematic Literature Review (PRISMA) Publication Listings..... | 248 |
| 9.2.2. | Analysis: PRISMA Findings .....                                       | 251 |
| 9.2.3. | Key findings in the systematic literature review .....                | 253 |
| 9.3.   | APPENDIX C (Survey Instrument and Analysis) .....                     | 258 |
| 9.3.1. | Survey Data Collection: Seaweed Farmers Survey Instruments .....      | 258 |
| 9.3.2. | Quantitative assessment: Survey Data Analysis .....                   | 264 |
| 9.4.   | APPENDIX D (Ethics and Protection Supporting Documents) .....         | 288 |
| 9.4.1. | University Social Research Permit Approval .....                      | 288 |
| 9.4.2. | Case Study Country Social Research Permit Approval .....              | 289 |
| 9.4.3. | Participants Information Sheet .....                                  | 290 |
| 9.4.4. | Participants Consent Form.....                                        | 291 |
| 9.5.   | APPENDIX E (Focus Group Discussions and CRiSTAL Toolkit).....         | 292 |
| 9.5.1. | Focus Group Discussion 1 (FDG #1): Placencia Village .....            | 293 |
| 9.5.2. | CRiSTAL Toolkit: Seaweed Producers FDG #1.....                        | 301 |
| 9.5.3. | Focus Group Discussion 2 (FDG #2): Placencia Village .....            | 314 |
| 9.5.4. | CRiSTAL Toolkit: Seaweed Producers FDG #2.....                        | 322 |
| 9.5.5. | Focus Group Discussion 3 (FDG #3): Riversdale Village.....            | 340 |
| 9.5.6. | CRiSTAL Toolkit: Seaweed Producers FDG #3.....                        | 346 |
| 9.5.7. | Focus Group Discussion 4 (FDG #4): Belize City .....                  | 362 |
| 9.5.8. | CRiSTAL Toolkit: Seaweed Producers FDG #4.....                        | 368 |
| 9.6.   | APPENDIX F (Elite Interviews) .....                                   | 383 |
| 9.6.1. | Data: Summary of Elite Interview Transcriptions .....                 | 383 |
| 9.6.2. | Analysis: Elite Interviews Code Book.....                             | 391 |
| 9.7.   | APPENDIX G (PESTEL dataset and codebook).....                         | 412 |
| 9.7.1. | Data: Legislative Frameworks .....                                    | 412 |
| 9.7.2. | Analysis: PESTEL Codebook.....                                        | 419 |

|                                                                                                                               |     |
|-------------------------------------------------------------------------------------------------------------------------------|-----|
| 9.8. Appendix H (Conferences, Workshops, Professional Development Activities and Peer-Reviewed Publications (2021–2025))..... | 479 |
|-------------------------------------------------------------------------------------------------------------------------------|-----|

## LIST OF TABLES

|                                                                                                                                                                              |     |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Table 1.1. The world red seaweed mariculture production value and quantity.....                                                                                              | 2   |
| Table 1.2. Global Utilization of Seaweed.....                                                                                                                                | 6   |
| Table 1.3. Summary of Challenges in Global Seaweed Mariculture and their Implications for Sustainability Blue Economy and Adaptation in SIDS. ....                           | 18  |
| Table 3.1. Global Seaweed Industry Dynamics in 2022: A Comparative Analysis of Production, Value, and Pricing Across Regions.....                                            | 54  |
| Table 4.1. Overview of research design and methods for the mixed methodological approach to answer the thesis research questions. ....                                       | 68  |
| Table 4.2. Key Types of Assets in the SLF.....                                                                                                                               | 74  |
| Table 4.3. Key categories according to the PESTEL tool.....                                                                                                                  | 77  |
| Table 4.4. Independent variables categorized according to the SLF.....                                                                                                       | 83  |
| Table 5.1. Comparison of this study household surveys to the national statistical data of Belize, the Caribbean SIDS case study.....                                         | 91  |
| Table 5.2. Descriptive statistics of hazards and responses data showing the general characteristics of the quantitative survey dataset. ....                                 | 92  |
| Table 5.3. Hazards in seaweed farming.....                                                                                                                                   | 93  |
| Table 5.4. Responses in seaweed farming.....                                                                                                                                 | 93  |
| Table 5.5. The crosstabulation table showed the frequency distribution of hazard categories across response categories.....                                                  | 94  |
| Table 5.6. Chi-square, Likelihood Ratio, Fisher-Freeman-Halton Exact, and Linear-by-Linear Association tests of hazards and responses in the seaweed farming community ..... | 97  |
| Table 5.7. Hazards and responses correlations using Pearson's r and Spearman's to identify strength and direction relationship. ....                                         | 98  |
| Table 5.8. Key variables selected for measuring seaweed farming livelihoods. ....                                                                                            | 100 |
| Table 5.9. Descriptive statistics of key variables in the livelihood capitals measured in the multiple linear regression model.....                                          | 101 |
| Table 5.10. Summary of correlation and regression model output for livelihood factors based on Model 13 using the backward method.....                                       | 103 |
| Table 5.11. Aggregated key livelihood resources identified in focus group discussions.....                                                                                   | 107 |
| Table 5.12. Key climatic hazards and resources identified by participants that impact seaweed livelihoods group discussions.....                                             | 109 |
| Table 5.13. Main short and long-term responses coping strategies against identified hazards from focus group discussions.....                                                | 111 |
| Table 5.14. Socio-demographic profile of seaweed farmers: age, gender, ethnicity, education, and household composition.....                                                  | 114 |
| Table 5.15. Seaweed farming practices and characteristics: ownership, techniques, and species cultivated. ....                                                               | 115 |
| Table 5.16. Diversified livelihoods and work patterns among seaweed farmers: characteristics of income generating activities. ....                                           | 117 |
| Table 5.17. Drivers and support systems in seaweed farming: a comprehensive overview of farmer motivation and resources.....                                                 | 119 |
| Table 5.18. Seaweed farmers' perception of climate change and its impacts on communities and crops. ....                                                                     | 122 |
| Table 5.19. Key opportunities and challenges in seaweed farming: community-level perspectives in survey question prompts and response options. ....                          | 123 |

|                                                                                                                                                                                                                                                                               |     |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Table 5.20. Summary of the Pearson correlation coefficients among seaweed farmers by communities in the case study country, Belize. ....                                                                                                                                      | 124 |
| Table 5.21. Prevalence of main themes identified in qualitative survey on seaweed farming opportunities. ....                                                                                                                                                                 | 127 |
| Table 5.22. Prevalence of main themes identified in qualitative survey on seaweed farming challenges. ....                                                                                                                                                                    | 128 |
| Table 5.23. Elite interviews demographic information and institutional affiliation of the interviewees in this study. ....                                                                                                                                                    | 135 |
| Table 5.24. Prevalence of main themes identified in elite interviews. ....                                                                                                                                                                                                    | 135 |
| Table 5.25. Main thematic coding across six elite interviews indicating the prevalence and focus areas discussed according to transcription files uploaded in NVivo software. ....                                                                                            | 137 |
| Table 5.26. Correlation analysis of theoretical themes from elite interviews. ....                                                                                                                                                                                            | 138 |
| Table 5.27. Pairwise Similarity (Pearson correlation coefficient) interviewees' code profiles. ....                                                                                                                                                                           | 140 |
| Table 5.28. Overview of the key characteristics of seaweed farming by PESTEL dimension. ....                                                                                                                                                                                  | 141 |
| Table 5.29. The climatic factors according to their significance and the rationale behind their prioritization in the sustainability of seaweed farming operations. ....                                                                                                      | 143 |
| Table 5.30. The non-climatic factors were based on their prioritization in ensuring sustainability of the seaweed farming sector. ....                                                                                                                                        | 145 |
| Table 5.31. Summary of the key opportunities and challenges identified in the elite interviews across the different thematic areas, identified as factors impacting seaweed mariculture livelihoods. ....                                                                     | 147 |
| Table 5.32. Summary of the main themes and their key subthemes. ....                                                                                                                                                                                                          | 147 |
| Table 5.33. Inventory of legislative frameworks relevant to the seaweed mariculture industry in Belize. ....                                                                                                                                                                  | 151 |
| Table 5.34. Summary of the files and references in PESTEL policy analysis. ....                                                                                                                                                                                               | 153 |
| Table 5.35. Correlation strengths among PESTEL factors in policy analysis. ....                                                                                                                                                                                               | 155 |
| Table 9.1. A summary of hazards classification of livelihood hazards and definitions. ....                                                                                                                                                                                    | 247 |
| Table 9.2. Key findings from a systematic review of literature on seaweed farming and its role in climate change adaptation using PRISMA protocol. ....                                                                                                                       | 251 |
| Table 9.3. Summary of PRISMA findings and their research methodologies applied. ....                                                                                                                                                                                          | 253 |
| Table 9.4. Frequency and perceived impact of hazards in Belize seaweed mariculture. ....                                                                                                                                                                                      | 265 |
| Table 9.5. Key selection of variables identified in linear regression model ....                                                                                                                                                                                              | 266 |
| Table 9.6. Spearman's rho correlation coefficients and significance levels of variables associated with the monthly harvest of seaweed under the assumption of no hazards. ....                                                                                               | 270 |
| Table 9.7. Categorical variables considered for the model to measure and strengthen the productivity of seaweed farming livelihoods. ....                                                                                                                                     | 272 |
| Table 9.8. Description of the correlations between monthly seaweed harvest assuming no hazards and various demographic and socioeconomic variables. ....                                                                                                                      | 274 |
| Table 9.9. The ANOVA table provides further insights into the significance and fit of the regression model ....                                                                                                                                                               | 274 |
| Table 9.10. Summary of the model showing the overall fit of the regression model, which included all selected livelihood capitals and predictors. ....                                                                                                                        | 275 |
| Table 9.11. The Coefficients table shows the effect of each independent variable on the dependent variable (seaweed harvest). ....                                                                                                                                            | 277 |
| Table 9.12. Overview of the residuals' behavior in the multiple linear regression model ....                                                                                                                                                                                  | 281 |
| Table 9.13. The performance of models in the evaluation of various statistical metrics, to identify the model best fits the data for measuring seaweed farming productivity (Dependent: Wet weight of harvested seaweed in pounds and Independent: Livelihood capitals). .... | 286 |
| Table 9.14. Key livelihood resources identified from female focus group discussion. ....                                                                                                                                                                                      | 294 |
| Table 9.15. Key hazards and resources impacted in first focus group discussion (FDG #1). ....                                                                                                                                                                                 | 297 |
| Table 9.16. Main responses coping strategies to the identified hazards (FDG #1). ....                                                                                                                                                                                         | 299 |
| Table 9.17. Description of first focus group (FDG #1). ....                                                                                                                                                                                                                   | 301 |
| Table 9.18. Seaweed farming community profile (FDG #1). ....                                                                                                                                                                                                                  | 302 |

|                                                                                             |     |
|---------------------------------------------------------------------------------------------|-----|
| Table 9.19. Identification of seaweed farming resources and accessibility (FDG #1). .....   | 302 |
| Table 9.20. List of seaweed farming resources (FDG #1). .....                               | 305 |
| Table 9.21. List of top three hazards to seaweed farms (FDG #1). .....                      | 305 |
| Table 9.22. List of seaweed farming training (FDG #1). .....                                | 306 |
| Table 9.23. List of climatic hazards (FDG #1). .....                                        | 306 |
| Table 9.24. List of non-climatic hazards (FDG #1). .....                                    | 307 |
| Table 9.25. List of threats to seaweed farms (FDG #1). .....                                | 308 |
| Table 9.26. Analysis of hazards and responses (FDG #1). .....                               | 309 |
| Table 9.27. External hazards/threats to seaweed farms (FDG #1). .....                       | 310 |
| Table 9.28. Future perspectives of seaweed farming sustainability (FDG #1). .....           | 313 |
| Table 9.29. Contact information of lead seaweed farmer (FDG #1). .....                      | 313 |
| Table 9.30. Key livelihood resources from focus group discussion 2 (FDG #2). .....          | 315 |
| Table 9.31. Key hazards and resources identified in focus group discussion (FDG #2). .....  | 318 |
| Table 9.32. Main Coping Strategies to Hazards (FDG #2). .....                               | 320 |
| Table 9.33. Description of second focus group (FDG #2). .....                               | 322 |
| Table 9.34. Seaweed farming community profile (FDG #2). .....                               | 323 |
| Table 9.35. Identification of seaweed farming resources and accessibility (FDG #2). .....   | 323 |
| Table 9.36. List of seaweed farming resources (FDG #2). .....                               | 327 |
| Table 9.37. List of top three hazards to seaweed farms (FDG #2). .....                      | 327 |
| Table 9.38. List of seaweed farming training (FDG #2). .....                                | 328 |
| Table 9.39. List of climatic hazards (FDG #2). .....                                        | 329 |
| Table 9.40. List of non-climatic hazards (FDG #2). .....                                    | 330 |
| Table 9.41. Hazards/threat to seaweed farms (FDG #2). .....                                 | 332 |
| Table 9.42. Analysis of hazards and their responses (FDG #2). .....                         | 333 |
| Table 9.43. Analysis of external hazards/threats to seaweed farms (FDG #2). .....           | 335 |
| Table 9.44. Future Perspectives of seaweed farming sustainability (FDG #2). .....           | 339 |
| Table 9.45. Future communication with seaweed farmers (FDG #2). .....                       | 339 |
| Table 9.46. Key Livelihood Resources from focus group discussion 3 (FGD #3). .....          | 342 |
| Table 9.47. Key hazards and resources impacted in focus group discussion (FGD #3). .....    | 343 |
| Table 9.48. Main Coping strategies to hazards (FGD #3). .....                               | 345 |
| Table 9.49. Description of third focus group (FGD #3). .....                                | 347 |
| Table 9.50. Seaweed farming community profile (FGD #3). .....                               | 347 |
| Table 9.51. Business environment for farming seaweed (FGD #3). .....                        | 348 |
| Table 9.52. List of seaweed farming resources (FGD #3). .....                               | 350 |
| Table 9.53. Summary of hazards to seaweed farms (FGD #3). .....                             | 351 |
| Table 9.54. Summary of seaweed farming training programmes (FGD #3). .....                  | 352 |
| Table 9.55. Analysis of climate-related hazards impacting seaweed farms (FGD #3). .....     | 354 |
| Table 9.56. Analysis of non-climate related hazards impacting seaweed farms (FDG #3). ..... | 355 |
| Table 9.57. Summary of hazards and threats to seaweed farming (FGD #3). .....               | 356 |
| Table 9.58. Analysis of responses to hazards affecting seaweed farms (FGD #3). .....        | 357 |
| Table 9.59. External hazards/risks and threats to seaweed farms (FGD #3). .....             | 358 |
| Table 9.60. Future perspectives of seaweed farming sustainability (FGD #3). .....           | 361 |
| Table 9.61. Future communication with seaweed farmers (FDG #3). .....                       | 361 |
| Table 9.62. Key Livelihood Resources from Focus Group Discussion 4 (FGD #4) .....           | 364 |
| Table 9.63. Key hazards and resources impacted in focus group discussion (FGD #4). .....    | 365 |
| Table 9.64. Main coping strategies to hazards (FGD #4). .....                               | 367 |
| Table 9.65. Description of fourth focus group (FGD #4). .....                               | 368 |
| Table 9.66. Seaweed farming community profile (FGD #4). .....                               | 368 |
| Table 9.67. Business environment for farming seaweed (FGD #4). .....                        | 369 |
| Table 9.68. Livelihood capitals and resources identified by seaweed farmers (FGD #4). ..... | 372 |
| Table 9.69. List of top three hazards to seaweed farms (FDG #4). .....                      | 373 |
| Table 9.70. Training and knowledge exchange among seaweed farmers (FGD #4). .....           | 374 |
| Table 9.71. Climate-related hazards and their impacts on seaweed farming (FDG #4). .....    | 374 |

|                                                                                                                                                                                                                |     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Table 9.72. Non-climate-related hazards and risks to seaweed farming (FGD #4).                                                                                                                                 | 375 |
| Table 9.73. Key hazards and potential risks to seaweed farming (FGD #4).                                                                                                                                       | 376 |
| Table 9.74. Responses to identified hazards in seaweed farming (FGD #4).                                                                                                                                       | 378 |
| Table 9.75. External hazards/threats to seaweed farming (FDG #4).                                                                                                                                              | 378 |
| Table 9.76. Current operations, scaling-up resources, challenges, training needs, and future policy directions for seaweed farming (FGD #4).                                                                   | 382 |
| Table 9.77. Future communication with seaweed farmers (FDG #4).                                                                                                                                                | 382 |
| Table 9.78. Summarizes the responses from elite interview participants regarding the existence and objectives of Belize’s Blue Economy Strategy Plan.                                                          | 384 |
| Table 9.79. Elite interview participants’ views on legislative frameworks safeguarding seaweed farming in Belize’s Blue Economy Plan.                                                                          | 385 |
| Table 9.80. Elite interview participants’ views on the extent to which seaweed mariculture activities are captured in the Belize Blue Economy Strategy Plan.                                                   | 387 |
| Table 9.81. Elite interview participants’ views on how the blue economy strategy plan captures the scaling up of seaweed farming activities in Belize through blue growth financial mechanisms or instruments. | 388 |
| Table 9.82. Elite interview participants’ views on whether seaweed farming in its current status is beneficial for sustaining the livelihoods of those engaged in it.                                          | 389 |
| Table 9.83. Elite interview participants’ views on the link between seaweed farming and climate change adaptation.                                                                                             | 390 |
| Table 9.84. Elite interview participants’ views on the space and development potential of seaweed aquaculture in Belize and the wider Caribbean region.                                                        | 391 |
| Table 9.85. Elite interview codebook at policy-level perspectives of seaweed farming as a climate change adaptation and blue growth in Belize.                                                                 | 408 |
| Table 9.86. Inventory of legal instruments relevant to seaweed mariculture in Belize.                                                                                                                          | 419 |
| Table 9.87. PESTEL policy analysis codebook identifying how legal and policy frameworks are addressing hazards in the seaweed mariculture sector in the SIDS of Belize.                                        | 474 |
| Table 9.88. Doctoral College workshops attended (2021-2025).                                                                                                                                                   | 480 |
| Table 9.89. Conferences, seminars, and events attended (2021–2024).                                                                                                                                            | 482 |

## LIST OF FIGURES

|                                                                                                                                                                        |    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Figure 1.1. Map of Belize showing the distribution of seaweed farms and seed banks adjacent to seaweed farming communities in urban coastal regions of Belize SIDS.    | 11 |
| Figure 1.2. Characteristics of seaweed farming in Belize: techniques, species, and market integration.                                                                 | 12 |
| Figure 1.3. Research framework for sustainable seaweed mariculture used in this thesis, balancing community and ecosystem approaches in climate adaptation strategies. | 20 |
| Figure 2.1. Summary of the guiding principles in sustainable development.                                                                                              | 31 |
| Figure 2.2. A visualization of Ecosystem-based Adaptation (EbA) and Community-based Adaptation (CbA) Principles and their overlap.                                     | 33 |
| Figure 3.1. Off-Bottom seaweed farming: utilizing submerged long rope techniques with recycled buoys and sand anchors.                                                 | 46 |
| Figure 3.2. Submerged plot seaweed cultivation: utilizing the tie-tie technique with anchored ropes and buoys.                                                         | 46 |
| Figure 3.3. Submerged square plot seaweed cultivation: raffia-tied seedlings anchored with ropes and buoys.                                                            | 47 |
| Figure 3.4. Floating raft seaweed cultivation: raffia-tied seedlings on anchored long lines.                                                                           | 48 |
| Figure 3.5. Floating raft seaweed cultivation: tubular nets for seedling propagation on anchored long lines.                                                           | 48 |
| Figure 3.6. Floating raft seaweed cultivation: mixed techniques using raffia and tubular nets on anchored long lines.                                                  | 49 |

|                                                                                                                                                                                                                                                      |     |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Figure 3.7. Global cultivated seaweed production by seaweed species in wet weight from 2000-2022.....                                                                                                                                                | 50  |
| Figure 3.8. Trends in global wild seaweed harvesting by type (1950–2019) based on fishstatj; march 2021.....                                                                                                                                         | 51  |
| Figure 3.9. Global seaweed production by country in 2022 (wet weight in tonnes).....                                                                                                                                                                 | 51  |
| Figure 3.10. Key milestones in the development of seaweed mariculture in Belize.....                                                                                                                                                                 | 53  |
| Figure 3.11. The theoretical and conceptual framework of this study’s case study using the lens of sustainable livelihood framework in seaweed mariculture through the integration blue economy paradigm and climate change adaptation theories..... | 57  |
| Figure 3.12. Theoretical and conceptual framework of this PhD Study highlighting the integration of community-based and ecosystem-based approaches for sustainable livelihoods in seaweed aquaculture management and science.....                    | 59  |
| Figure 4.1. Summary of mixed methodological framework used in this thesis for analyzing red seaweed, climate change adaptation, and sustainable livelihoods in Belize (Author’s own elaboration).....                                                | 69  |
| Figure 4.2. PhD phased research timeline for the investigation of climate adaptation strategies in seaweed aquaculture within Caribbean SIDS.....                                                                                                    | 70  |
| Figure 4.3. PRISMA flow chart showing the selection procedures of the studies.....                                                                                                                                                                   | 72  |
| Figure 5.1. Geographical diversity in seaweed farming livelihood encompassing individuals from several coastal regions of Belize.....                                                                                                                | 88  |
| Figure 5.2. Primary occupation and economic sector of head of household respondent.....                                                                                                                                                              | 89  |
| Figure 5.3. Gender percentage number of all respondents in the study.....                                                                                                                                                                            | 90  |
| Figure 5.4. Education levels of respondents from incomplete primary education to post-secondary/university completion in the seaweed farming community.....                                                                                          | 90  |
| Figure 5.5. The distribution of responses across different hazard categories, highlighting the response strategies commonly associated with each type of hazard.....                                                                                 | 95  |
| Figure 5.6. The location of seaweed farming communities in Belize highlighting Belize City and Placencia where data collection activities occurred.....                                                                                              | 106 |
| Figure 5.7. Word cloud of key themes in qualitative surveys of community-level perceptions of seaweed mariculture: governance, seaweed species, and environmental factors.....                                                                       | 125 |
| Figure 5.8. Tree map visualization depicted the frequency of key terms extracted from the analyzed dataset.....                                                                                                                                      | 126 |
| Figure 5.9. Distribution of legislative and policy frameworks relevant to the seaweed mariculture industry in Belize.....                                                                                                                            | 149 |
| Figure 5.10. Inventory of documents captured in policy analysis by PESTEL factors in NVivo software.....                                                                                                                                             | 150 |
| Figure 9.1. The number of publications on seaweed farming and climate change adaptation from 2006 to 2023.....                                                                                                                                       | 251 |
| Figure 9.2. World map displaying the geographical distribution of seaweed farming and climate change adaptation studies.....                                                                                                                         | 252 |
| Figure 9.3. World map showing the geographical distribution of climate change adaptation studies in seaweed farming initiatives.....                                                                                                                 | 252 |
| Figure 9.4. PRISMA key findings outlined thematically by the nature of the articles.....                                                                                                                                                             | 254 |
| Figure 9.5. Histogram of Regression Standardized Residuals.....                                                                                                                                                                                      | 283 |
| Figure 9.6. Normal P-P Plot of Regression Standardized Residual.....                                                                                                                                                                                 | 284 |
| Figure 9.7. Ethical Review and Data Protection (REDP) application approval record.....                                                                                                                                                               | 288 |
| Figure 9.8. Confirmation email of REDP application approval, FEMA-2022-00335.....                                                                                                                                                                    | 289 |
| Figure 9.9. Permit to conduct social research in Belize.....                                                                                                                                                                                         | 290 |
| Figure 9.10. Participant information sheet.....                                                                                                                                                                                                      | 291 |
| Figure 9.11. Consent forms.....                                                                                                                                                                                                                      | 291 |
| Figure 9.12. Visual resource map with female focus group (Placencia Village).....                                                                                                                                                                    | 294 |
| Figure 9.13. Visual Resource Map with male focus group (Placencia Village).....                                                                                                                                                                      | 314 |
| Figure 9.14. Visual resource map with female focus group (Riversdale Village).....                                                                                                                                                                   | 340 |



|                                                                                   |     |
|-----------------------------------------------------------------------------------|-----|
| Figure 9.15. Visual resource map with male focus group (Belize City).....         | 363 |
| Figure 9.16. Key Words from Elite Interviews on Seaweed Farming in Belize.....    | 409 |
| Figure 9.17. Tree map of Themes and Subthemes in the Elite Interviews. ....       | 411 |
| Figure 9.18. Key words captured in the word cloud analysis.....                   | 475 |
| Figure 9.19. Key themes in PESTEL policy analysis based on Belize Case Study..... | 477 |

## ABBREVIATIONS

|           |                                                                             |
|-----------|-----------------------------------------------------------------------------|
| AMF       | Adaptive Management Framework                                               |
| BAHA      | Belize Agricultural Health Authority                                        |
| BBFP      | Belize Blue Bond and Finance Permanence Unit                                |
| BE        | Blue Economy                                                                |
| BEDPS     | Blue Economy Development Policy, Strategy, and Implementation Plan (Belize) |
| BMEP      | Belize Maritime Economy Plan                                                |
| BWFA      | Blue Waters Fisherman Association                                           |
| BWSFA     | Belize Women's Seaweed Farmers Association                                  |
| BZD       | Belize Dollar                                                               |
| CABI      | Centre for Agriculture and Bioscience International                         |
| CANARI    | Caribbean Natural Resources Institute                                       |
| CARICOM   | Caribbean Community                                                         |
| CARIBSAVE | Caribbean Community Climate Change Centre                                   |
| CBA       | Community-based Adaptation                                                  |
| CBA       | Community-Based Approaches                                                  |
| CBD       | Convention on Biological Diversity                                          |
| CCCCC     | Caribbean Community Climate Change Centre                                   |
| CDB       | Caribbean Development Bank                                                  |
| CLME+     | Caribbean and North Brazil Shelf Large Marine Ecosystems                    |
| COMSEC    | Commonwealth Secretariat                                                    |
| COMPACT   | Community Management of Protected Areas Conservation Programme              |
| CPR       | Cardiopulmonary Resuscitation                                               |
| CRFM      | Caribbean Regional Fisheries Mechanism                                      |
| CRISTAL   | Community-based Risk Screening Tool for Adaptation and Livelihoods          |
| CSO       | Civil Society Organization                                                  |
| CZMAI     | Coastal Zone Management Authority and Institute (Belize)                    |
| DFID      | Department for International Development                                    |
| EBFM      | Ecosystem-Based Fisheries Management                                        |
| EbA       | Ecosystem-based Adaptation                                                  |
| EEZ       | Exclusive Economic Zone                                                     |
| EIU       | Economic Intelligence Unit                                                  |
| E-NGO     | Environmental Non-Governmental Organization                                 |
| FAO       | Food and Agriculture Organization                                           |
| FISHSTATJ | FAO Global Fishery and Aquaculture Statistics Software                      |
| FGD       | Focus Group Discussion                                                      |
| FoH       | Fragments of Hope (Belize)                                                  |
| GAP       | Global Aquaculture Practices                                                |
| GDP       | Gross Domestic Product                                                      |
| GDPR      | General Data Protection Regulation                                          |
| GNI       | Gross National Income                                                       |
| GOB       | Government of Belize                                                        |
| GSSCMR    | Gladden Spit and Silk Cayes Marine Reserve                                  |
| HACCP     | Hazard Analysis Critical Control Point                                      |
| HRI       | Healthy Reefs Initiative                                                    |

|           |                                                                                                     |
|-----------|-----------------------------------------------------------------------------------------------------|
| ICRAN     | International Coral Reef Action Network                                                             |
| ID & M    | Investment Development & Marketing                                                                  |
| IDB       | Inter-American Development Bank                                                                     |
| IISD      | International Institute for Sustainable Development                                                 |
| IKI       | International Climate Initiative                                                                    |
| IMTA      | Integrated Multi-Trophic Aquaculture                                                                |
| INVEST    | Integrated Valuation of Ecosystem Services and Tradeoffs                                            |
| IPCC      | Intergovernmental Panel on Climate Change                                                           |
| ISCR      | Institute for Social and Cultural Research                                                          |
| IUCN      | International Union for Conservation of Nature                                                      |
| KLRS      | Key Livelihood Resources                                                                            |
| KMO       | Kaiser-Meyer-Olkin Measure of Sampling Adequacy                                                     |
| LWC       | Little Water Caye                                                                                   |
| LWT       | Live Weight Per Ton                                                                                 |
| MAFFES    | Ministry of Agriculture, Fisheries, Forestry, the Environment, and Sustainable Development (Belize) |
| MBECA     | Ministry of Blue Economy and Civil Aviation                                                         |
| MCCAP     | Marine Conservation and Climate Adaptation Project                                                  |
| MER       | Minimum Eligibility Requirements                                                                    |
| MOUS      | Memoranda of Understanding                                                                          |
| MPAS      | Marine Protected Areas                                                                              |
| MSMES     | Micro, Small, and Medium Enterprises                                                                |
| MSP       | Marine Spatial Planning                                                                             |
| NAPS      | National Adaptation Plans                                                                           |
| NBS/NbS   | Nature-Based Solutions                                                                              |
| NDCs      | Nationally Determined Contributions                                                                 |
| NGO       | Non-Governmental Organization                                                                       |
| NICH      | National Institute of Culture and History (Belize)                                                  |
| NBAP      | National Biodiversity Strategy and Action Plan                                                      |
| OECD      | Organization for Economic Co-operation and Development                                              |
| OSPESCA   | Organization of the Fisheries and Aquaculture Sector of the Central American Isthmus                |
| P&C       | Principles and Criteria                                                                             |
| PESTEL    | Political, Economic, Social, Technological, Environmental, and Legal Factors                        |
| PIPS      | Policies, Institutions, and Processes                                                               |
| PPCSL     | Placencia Producers Cooperative Society Limited (Belize)                                            |
| PRA       | Participatory Rural Appraisal                                                                       |
| PRISMA    | Preferred Reporting Items for Systematic Reviews and Meta-Analyses                                  |
| PVC       | Polyvinyl Chloride                                                                                  |
| Q         | Question (as referenced in the survey of this research)                                             |
| RD&I      | Research, Development, and Innovation                                                               |
| RHI       | Reef Health Index                                                                                   |
| REDP      | Research Ethics and Data Protection                                                                 |
| <i>rs</i> | Spearman's rho                                                                                      |
| <i>r</i>  | Pearson's correlation coefficient                                                                   |
| SD        | Standard Deviation                                                                                  |
| SDGs      | Sustainable Development Goals                                                                       |
| SEA       | Southern Environmental Association (Belize)                                                         |
| SES       | Socio-Ecological System                                                                             |

|           |                                                                        |
|-----------|------------------------------------------------------------------------|
| SIDS      | Small Island Developing States                                         |
| SLF       | Sustainable Livelihoods Framework                                      |
| SOP       | Series of Projects                                                     |
| SPSS      | Statistical Package for the Social Sciences (Statistical Software)     |
| TAMR      | Turneffe Atoll Marine Reserve (Belize)                                 |
| TASA      | Turneffe Atoll Sustainability Association (Belize)                     |
| TNC       | The Nature Conservancy (Belize)                                        |
| TSG       | Turneffe Seaweed Growers (Belize)                                      |
| TSGA      | Turneffe Seaweed Growers Association (Belize)                          |
| UBEC      | Unleashing the Blue Economy of the Caribbean                           |
| UN        | United Nations                                                         |
| UNCTAD    | United Nations Conference on Trade and Development                     |
| UNDESA    | United Nations Department of Economic and Social Affairs               |
| UNDP      | United Nations Development Programme                                   |
| UNEP      | United Nations Environment Programme                                   |
| UNESCO    | United Nations Educational, Scientific, and Cultural Organization      |
| UNFCCC    | United Nations Framework Convention on Climate Change                  |
| UNU-INWEH | United Nations University Institute for Water, Environment, and Health |
| USD       | United States Dollar                                                   |
| VAT       | Value Added Tax                                                        |
| VIF       | Variance Inflation Factor                                              |
| WB/WBG    | World Bank/ World Bank Group                                           |
| WCED      | World Commission on Environment and Development                        |
| WWF       | World Wildlife Fund (Belize)                                           |

## ABSTRACT

This doctoral thesis investigated the sustainability of seaweed aquaculture in Belize, a Small Island Developing State (SIDS). While SIDS are inherently subjected to the extreme environmental and socioeconomic impacts of climate change, limited research has examined climate adaptation strategies within the context of sustainable livelihoods in seaweed farming. This study explores how seaweed farming contributes to sustainable livelihoods by integrating community-based (CbA) and ecosystem-based adaptation (EbA) strategies framed through the Sustainable Livelihoods Framework (SLF). The research is situated within the broader context of Blue Transformation and Blue Economy, addressing the connections between livelihoods, environmental management, and national development objectives aligned with global sustainability agendas such as the United Nations Sustainable Development Goals (SDGs).

A triangulated mixed-methods approach was employed, combining qualitative and quantitative data. The qualitative component included focus group discussions using the Community-based Risk Screening Tool-Adaptation and Livelihoods (CRiSTAL) toolkit, semi-structured interview household surveys, elite stakeholder interviews, and policy analysis using the Political, Economic, Social, Technological, Environmental, and Legal (PESTEL) tool. The quantitative component included descriptive statistics, Chi-square tests, cross-tabulation, and multi-linear regressions models to examine the relationship between livelihood capitals and seaweed production. This methodological integration provided a comprehensive understanding of both community-level and policy-level factors impacting the sustainability of seaweed farming livelihoods.

The findings reveal that seaweed farming in Belize represents a viable and environmentally sustainable livelihood, yet it faces challenges from both climatic and non-climatic factors. While ocean temperature rises and storms impact farm productivity, more persistent issues such as limited financial resources, inadequate infrastructure, and weak institutional support constrain the sector's long-term sustainability. The results show that EbA and CbA approaches positively impact production outcomes, while farm size, gender, and value-adding activities display complex associations with harvest levels. Qualitative findings highlight the importance of traditional knowledge, collective action, and environmental stewardship in sustaining seaweed mariculture practices.

The integration of these findings demonstrates coherence between household livelihood strategies, local community initiatives, and institutional frameworks. The research identifies the need for coordinated governance, improved policy coherence, and greater technical and

financial investment to strengthen seaweed aquaculture as part of Belize's Blue Economy strategy.

This thesis makes three key contributions. First, it provides new empirical evidence linking SLF with community and ecosystem-based approaches in the context of SIDS. Second, it broadens the conceptual scope of sustainable livelihoods by incorporating ecological and cultural dimensions, offering a transferable framework for analyzing marine-based livelihoods. Third, it contributes to policy and practice by identifying specific areas for targeted investment, technical training, and inclusive governance to enhance the long-term sustainability of seaweed farming.

The study concludes that seaweed aquaculture in Belize offers a sustainable and socially inclusive pathway for economic diversification and climate-aware development. Its continued success depends on integrating local practices with coherent policy frameworks that empower small-scale producers and align with national and international blue growth priorities. Future research should expand upon this tripartite hazard screening analysis to explore the interactions between risks, livelihoods, ecosystems, and governance across SIDS and beyond.

Keywords: Seaweed Mariculture, Sustainable Livelihoods, Climate Change Adaptation, Community-based and Ecosystem-based Adaptation Strategies, Blue Growth, Belize, SIDS.

# 1. INTRODUCTION

## 1.1 Background

Red macroalgae (*Rhodophyta*), also referred to as seaweed or sea moss, are cultivated worldwide and have emerged as a key component of livelihood development and adaptation to climate change in many Small Island Developing States (SIDS) (Rebours et al., 2014a; Yong et al., 2022). Red seaweed aquaculture is now a key part of the development of coastal communities worldwide because of its use in food and extractive products such as agar, and carrageenan use in nutritional, medical, nutraceuticals, cosmetics, and other products (FAO, 2022; UNCTAD, 2024; UNEP, 2023b). They are also useful for carbon sequestration and removing excess nutrients in our oceans that contribute to pollution and marine habitat degradation. This has led to increasing demand for red seaweed as its versatility addresses multiple global challenges at the local level, including environmental degradation, climate change, and food security (FAO, 2021, 2024; UNCTAD, 2024; UNESCO, 2024; World Bank, 2023). Climate change poses a great challenge for SIDS as red seaweed aquaculture in coastal communities are hindered by conflicts, governance challenges, environmental changes due to climate change, and other threats (Birkmann et al., 2023; Cottier-Cook et al., 2023; Moncada et al., 2021; Monnereau et al., 2015; Nurse et al., 2015).

Approximately, six million small-scale farmers and processors worldwide depend on seaweed livelihoods, with a significant portion residing in coastal communities in low- and middle-income countries, including SIDS (Cottier-Cook et al., 2021; UNEP, 2023b). The average annual value of the red seaweed production industry in SIDS was estimated at \$3.1 million USD, a relatively small but significant sum representing the highest value per ton it has ever been, despite a reduction in production quantity (-18%) (Author's own elaboration based on FAO STATAJ, 2024). This reduction was due to extreme production fluctuations in important species such as *Kappaphycus alvarezii* compared to *Eucheuma isiforme* and *Gracilaria* spp from 2015 to 2018. Therefore, due to this combination of socio-economic, political, and possible environmental impacts has impacted the sustainable production of red in the open ocean (Birkmann et al., 2023; FAO STATAJ 2024).

Red seaweed production in SIDS has shown volatility from 2000 compared to 2022 but has experienced a 349% increase in value per ton of live (wet) weight (LWT) during the same period (Table 1.1.). Production in the rest of the world also by 534% representing a value of 9 million USD as shown in Table 1.1. Collectively, SIDS make a relatively small contribution to global aquaculture production. Despite their small contribution, there is great potential and a positive outlook for the seaweed industry in SIDS for developing Blue Economies while contributing to climate change adaptation.

Among SIDS, red seaweed production in Saint Vincent and the Grenadines, Saint Lucia and Fiji was moderate and increasing (Author's own elaboration based on FAO STATAJ, 2024). On the other hand, the Solomon Islands showed steady growth starting around 2005 and further increased after 2016. From 2000 to 2022, the production in SIDS has primarily relied on *Kappaphycus alvarezii*, particularly in the Caribbean. Other countries such as Timor-Leste, Antigua and Barbuda, Saint Kitts and Nevis, Micronesia, Belize, Kiribati, Grenada, Dominica, Tonga, Marshall Islands, and Papua New Guinea had minimal or negligible production, indicating limited engagement in red seaweed aquaculture (Author's own elaboration based on FAO STATAJ, 2024). Therefore, among SIDS, production remains small

but growing in many cases while in others it remains relatively stagnant (Author's own elaboration based on FAO STATAJ, 2024).

| World Red Seaweed<br>Mariculture Sector | 2000                                |                            | 2022                                |                            | Movement        |              |
|-----------------------------------------|-------------------------------------|----------------------------|-------------------------------------|----------------------------|-----------------|--------------|
|                                         | Production<br>Quantity in<br>Tonnes | Production<br>Value in USD | Production<br>Quantity in<br>Tonnes | Production<br>Value in USD | Qty<br>+/-<br>% | USD<br>+/- % |
| SIDS                                    | 16,429.00                           | \$697,450.00               | 13,493.60                           | \$3,134,890.00             | -18%            | 349%         |
| Rest of<br>the<br>World                 | 1,988,308.00                        | \$1,420,045,680.00         | 20,382,211.91                       | \$9,007,274,920.00         | 925%            | 534%         |
| Total                                   | 2,004,737.00                        | \$1,420,743,130.00         | 20,395,705.51                       | \$9,010,409,810.00         | 917%            | 534%         |

*Table 1.1. The world red seaweed mariculture production value and quantity (LWT) for 2000 and 2022 (Author's own elaboration based on FishStatJ, 2024).*

Mariculture development for seaweed in SIDS and their vulnerability to the impacts of climate change are thought to be correlated (FAO, 2021; FAOSTAT, 2017; Galaitsi et al., 2024; Strittmatter et al., 2022). The socio-economic, ecological change, and resilience to these impacts are expected to be most profound in SIDS (IPCC, 2021). Anthropogenic driven climate change is defined as the observed and projected changes in the Earth's climate system, including rising global temperatures (warming), melting glaciers (ice mass loss), sea level rise (land loss), ocean acidification (biodiversity and wildlife loss), climate variability (precipitation patterns), and more frequent and severe extreme weather events (heavy precipitation, floods, storms, etc.). These are considered primarily anthropogenic that adversely affects society and the environment (IPCC, 2021, 2022b, 2023a). These impacts are interconnected and have negatively impacted red seaweed mariculture development, contributing to the vulnerability and low resilience in the affected coastal communities (Robinson, 2020; Birkmann et al., 2023; Mariño et al., 2019). For instance, the presence of diseases like *ice-ice* seaweed disease and pests, and the decline in genetic diversity among cultivated seaweeds has been observed (UNEP, 2023b). Fluctuations in production value per ton (wet weight) due to climate change undermine the red seaweed aquaculture industry as a sustainable development option for coastal communities in both the SIDS and the rest of the world (UNEP, 2023b).

SIDS are often characterized by low per capita income, low per capita emissions, low-lying geographical locations, small size, insularity, remoteness, and propensity for natural disasters, including climate variability and change (Briguglio, 2016; Nurse et al., 2015; Thompson, 2022). Many SIDS also have high import dependency, narrow export diversification, reliance on climate-sensitive sectors, low levels of human capital, and significant environmental fragility, making them vulnerable to climate change (Briguglio, 1995, 2008; Briguglio, 2016; Formosa et al., 2017).

Adaptation is crucial for SIDS in general and much needed specifically in the seaweed mariculture industry (Erundu & Anyanwu, 2011; Makame et al., 2023; Robinson, 2020). The various challenges like insufficient seaweed resources, unstable product quality, marketing difficulties, and regulatory constraints that impede the industry's development must also be considered along with the more common issues (World Bank, 2023). Tailored adaptation measures are necessary considering the specific local conditions and social, economic, and ecological context. This approach should also be practiced in policymaking to support the



long-term sustainability in parallel with establishing a process of monitoring and evaluation of said policies (Monnereau et al., 2015; Msuya et al., 2022; Robinson, 2018). This balanced approach to seaweed industry development in SIDS can maximize positive impacts while minimizing potential hazards and exploring new opportunities in the emerging Blue Economy (Hoerterer et al., 2020; UNEP 2023).

## 1.2 Small Island Developing States (SIDS) and the Blue Economy

In the context of the BE and climate change adaptation, seaweed mariculture has emerged as key investment strategy in SIDS where ocean resources are vast. BE includes, but are not limited to, livelihoods opportunities for offshore mariculture activities in the exclusive economic zones (EEZ) (Spillias et al., 2022). At the same time there is also an opportunity to conserve the vital ecosystem services provided by the oceans, which support economies and the environment. The oceans constitute approximately 72% of the Earth's surface, representing a vast reservoir of resources and ecosystems for supporting human life and economies (Hoegh-Guldberg et al., 2019). The Organization for Economic Co-operation and Development (OECD) (Jolly, 2017) reported that the global ocean economy in 2010 contributed approximately USD 1.5 trillion in value added, representing around 2.5% of the world's gross value added, which was approximately USD 59 billion at that time. In the Caribbean Ocean economy was estimated to be USD 407 billion in 2012 (Hughes et al., 2016). Ocean-based industries accounted for approximately 31 million direct full-time jobs, constituting 1% of the global workforce in 2010 (Jolly, 2017). In 2010 industrial capture fisheries were the largest employer (36%), followed by maritime industries and coastal tourism (23%). By comparison, the remaining industries, including offshore oil and gas, maritime equipment, port activities, offshore wind, water transport, shipbuilding, and repair, ranged from 1% to 8% (Jolly, 2017).

SIDS constitute less than 1% of the world's population or approximately 65 million people originating from diverse regions, share common social, cultural, technological, economic, and environmental challenges (ComSec, 2021). The term “SIDS” refers to a group of countries sharing specific socioeconomic, demographic traits, and similar developmental challenges. This UN designation considers characteristics such as a small population size, geographical isolation, susceptibility to environmental adversities/natural disasters, and economic vulnerabilities to external shocks, a high reliance on imports, and a general scarcity of certain natural resources including freshwater, energy, and arable land. These together represent great developmental challenges especially in the face of climate change which will disproportionately affect SIDS. These vulnerabilities impose constraints on economic development, necessitating the enhancement of resilience within economic sectors while effectively addressing the impacts of climate change on SIDS (Thomas et al., 2020), such as in the seaweed mariculture industry (UNEP, 2023b). Examples of SIDS who advocate for increased ambition in mitigation, adaptation, and addressing loss and damage are found in regions such as the Caribbean, the Pacific, and the Indian Ocean, including nations like Barbados, Fiji, and the Maldives.

Therefore, this thesis investigates the sustainability of seaweed farming at a local level in the face of climate change within the context of blue economy. This thesis has the objective of assessing whether, and to what extent, are the experiences of seaweed farmers in combatting the impacts of climate-related hazards captured in the legal framework to enhance adaptation strategies and prevent maladaptation practices in the future. Hence, this thesis identifies the Key Livelihood Resources (KLRs), climate and non-climate related hazards, corresponding impact to resources (assets) and the existing coping strategies to those respond to those hazards in the case study of a SIDS. These experiences are supported by also presenting seaweed farmers' socio-economic and demographic status to further understand how blue economy interventions are creating an enabling environment for seaweed farming livelihood activities in a Caribbean SIDS. The Blue Economy (BE) concept has been widely

recommended and adopted by SIDS as the framework for building resilience and sustainable economic development of ocean resources (EIU, 2015; Pengra, 2012). Also referred to as Blue Growth, BE purports a win-win scenario for sustainable development where global economic prosperity and a healthy ocean system can be achieved while addressing changing climate and a growing population (Das, 2023; WBG and UNDESA, 2017).

The BE envisions an alignment of industries' goals and the protection of the ocean environment and biodiversity, improving socioeconomic structures, and utilizing advanced technologies with a positive biospheric impact (UNEP, 2023b). While the interpretation of BE varies among nations, it broadly involves leveraging bodies of freshwaters, ocean and maritime resources to drive sustainable development such as nature-based solutions for conservation and alternative livelihood development within the country (Martínez-Vázquez et al., 2021). Therefore, the seaweed industry can be a main driver in achieving multiple SDGs, including SDG 8, SDG 9, SDG 13, and SDG 14 (Alleway et al., 2021; Hossain et al., 2021; Sudarwati et al., 2020a; UNEP, 2023b). Through the creation of employment opportunities, particularly in coastal areas, seaweed cultivation promotes economic growth and poverty alleviation, aligning with SDG 8 (Zamroni et al., 2020). Additionally, industry can stimulate innovation and infrastructure development in aquaculture practices as per SDG 9 (UNCTAD, 2024). This includes the cultivation, processing, and trade of seaweed present a sector teeming with prospects for sustainable growth by 2030, with notable emphasis on the gender dynamics inherent in seaweed farming as a trading commodity (UNCTAD, 2023).

Moreover, seaweed farming's capacity to mitigate climate change impacts, such as carbon sequestration and offering renewable energy sources, directly contributes to SDG 13 (Bhuyan et al., 2021; Krause-Jensen & Duarte, 2016; Ross et al., 2023). Furthermore, by reducing pressure on marine ecosystems and promoting biodiversity, it supports the conservation and sustainable use of marine resources, in line with SDG 14 (Duarte et al., 2022; Fakhraini et al., 2019; Farrelly et al., 2013). Thus, the seaweed industry represents a holistic approach to sustainable development many countries looking to tackle climate change impacts, while bridging socio-economic advancement with environmental stewardship. However, uncertainties persist regarding seaweed farming practice within the blue economy. Especially in regards the sustainability and reliability of their implementation the socio-economic and environmental consequences realities especially in SIDS (Martínez-Vázquez et al., 2021). There is ambiguity surrounding the seaweed mariculture as a viable alternative or supplementary livelihood activity given the market conditions, current knowledge and practices (Alleway, 2023).

One of the main strengths of the seaweed industry is its many uses and potential applications across different sectors of which are further elaborated in Table 1.2. Seaweed mariculture has been rapidly expanding reaching half a million tonnes in 2020 and was up by 1.4 percent from 34.6 million tonnes in 2019 (FAO, 2022b). Notably, the average annual growth from 2000 to 2018 was 6.2%, was approximately 51.3% of global mariculture production. Contributing to this production is the relative ease at which seaweed can grow, requiring no feed or cutting of trees as well as the demand for its value-added products (Alleway, 2023; Sudarwati et al., 2020b; Yang et al., 2015). Seaweed mariculture generates diverse direct economic and environmental benefits, serving as natural nursery grounds and grow-out habitats for juvenile commercial fish and invertebrates (Alleway et al., 2019). Additionally, it contributes to the protection of the underlying seabed and coastal areas (Buschmann et al., 2017). The comprehensive scope of seaweed applications is presented by many scholars (Farghali et al., 2023), offering an overview of the various products, uses, and services derived from seaweed on a global scale.

| Sector                         | Product, Use or Ecosystem Service                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Conservation                   | <ul style="list-style-type: none"> <li>• Restorative mariculture (Liu et al., 2023)</li> <li>• Habitat provision and enhancement (Zhang et al., 2022)</li> <li>• Removal of excess nutrients(Alleway et al., 2019)</li> <li>• Enhance biogeochemical cycles (Sun et al., 2023)</li> <li>• Coastal protection (TNC, 2024b)</li> <li>• Carbon offsetting and sequestration (Ross et al., 2023; Tang et al., 2011)</li> <li>• Ocean acidification alleviation (Brown, 2012; Hurd et al., 2022; Paine et al., 2021)</li> <li>• Alternative or supplementary livelihood for fishers (Rebours et al., 2014b; Sato et al., 2023)</li> </ul> |
| Nature-based climate solutions | <ul style="list-style-type: none"> <li>• Bioactive compounds such as polysaccharides, unsaturated fatty acids, phenols, peptides, terpenoids (Cotas et al., 2020; Holdt and Kraan, 2011)</li> <li>• Bioplastics (Chudasama et al., 2021)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                  |
| Food industry                  | <ul style="list-style-type: none"> <li>• Direct consumption (FAO, 2022c)</li> <li>• Cooking ingredients (bakery products, pastries, additives) (Alemañ et al., 2019; Cai et al., 2021)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Cosmetics and skin care        | <ul style="list-style-type: none"> <li>• Antioxidants (Jesumani et al., 2019)</li> <li>• Antiaging (Lomartire et al., 2021)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Medicine                       | <ul style="list-style-type: none"> <li>• Bioactive compounds (Echave et al., 2021)</li> <li>• Anti-inflammatory (Ismail et al., 2020)</li> <li>• Antioxidants (Zhong et al., 2020)</li> <li>• Antiviral (Begum et al., 2021)</li> <li>• Antitumor (Tanna &amp; Mishra, 2019)</li> <li>• Anticarcinogenic (Purcell et al., 2022)</li> <li>• Antifungal (Hrólfssdóttir et al., 2022)</li> <li>• Antibacterial (Riyaz et al., 2020)</li> </ul>                                                                                                                                                                                          |
| Energy                         | <ul style="list-style-type: none"> <li>• Biofuels (Gegg &amp; Wells, 2017)</li> <li>• Biorefinery Alvarez-Viñas et al., 2019)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Agriculture                    | <ul style="list-style-type: none"> <li>• Biostimulant (El Boukhari et al., 2020; Samuels et al., 2022)</li> <li>• Fertilizers (phosphorus and nitrogen) (Mannino et al., 2020)</li> <li>• Fish meal for aquaculture (Mustafa et al., 1995; R. Mwendwa et al., 2023)</li> <li>• Livestock feeds (Ford et al., 2020)</li> </ul>                                                                                                                                                                                                                                                                                                        |
| Cultural services              | <ul style="list-style-type: none"> <li>• Traditional livelihoods, foods and customs(Makame et al., 2021; Sultana et al., 2023; van der Velden, 2022a)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Construction                   | <ul style="list-style-type: none"> <li>• Green roofing material (Vijayaraghavan and Joshi, 2015)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Aquaculture                    | <ul style="list-style-type: none"> <li>• Integrated multi-trophic aquaculture (IMTA) (Corey et al., 2014)</li> <li>• Biofiltration (Rajendran &amp; Hu, 2016; Sondak et al., 2017)</li> <li>• Bioremediation and wastewater treatment (Farghali et al., 2023; Gao et al., 2022)</li> <li>• Biotechnology application (Baweja et al., 2009; Rotter et al., 2021)</li> </ul>                                                                                                                                                                                                                                                           |

Table 1.2. Global Utilization of Seaweed for Various Economic Sectors and Ecosystem Services.

### 1.3 Context and Rationale

Seaweed mariculture has been recognized as a nature-based solution for adapting to climate change, and thus tackling food security, coastal pollution, and providing sustainable and inclusive livelihoods (UNCTAD, 2024; UNEP, 2023b; UNESCO, 2024). This study focuses on aspects of the adaptation component of red seaweed (*Rhodophyta*) mariculture in SIDS in relation to socioeconomics and blue economy development opportunity in the coastal communities of the Caribbean SIDS, Belize. The study looks at red seaweed species cultivated in the open ocean as an emerging sector in the blue economy <sup>1</sup>. The *Rhodophytes* considered in this study include three main species from 2 groups namely: eucheumatoid carrageenophytes (Adel et al., 2020), *Eucheuma* sp. and *Kappaphycus* sp. (CABI, 2023) and agarophytes, such as *Gracilaria* sp. (Crouan and Crouan, 1866).

This thesis investigates key climate adaptation response strategies at both the community and policy levels for the development of seaweed mariculture in Belize. Using a mixed-methods approach, it focuses on assessing the impact of various livelihood capitals on seaweed farming productivity (measured in wet weight harvested) by combining qualitative methods, such as participatory rural appraisal (PRA), with quantitative regression models to evaluate the impact of these factors on the sustainability and development of the seaweed industry. The variables of interest studied in this thesis include seaweed productivity as the dependent variable, and independent variables categorized under human capital (education, health, experience), social capital (gender, use of community-based strategies), natural capital (ecosystem-based strategies), physical capital (farm size, value-adding activities), financial capital (remittances, seaweed income), and cultural capital (traditional knowledge and informal adaptation strategies), alongside control variables such as climatic and non-climatic factors (assuming no hazards impacted the production of harvest seaweed in weight wet (pounds (lbs))).

The PRA approach used the Community-based Risks Screening Tool for Adaptation and Livelihoods (CRiSTAL) toolkit along with semi-structured interview household surveys (questionnaires), elite interview surveys (open-ended interview questions), and policy analysis tools. Moreover, this study applied the Political, Economic, Social, Technological, Environmental, and Legal (PESTEL) framework to analyze policy measures for tackling climatic and non-climatic hazards. In addition, an assessment is made in understanding the role of community-based (CbA) and ecosystem-based (EbA) adaptation strategies used in supporting emerging sustainable livelihoods while adopting international frameworks for the further development of the seaweed mariculture sector. Thus, making seaweed crops a great example of this livelihood option as an adaptation strategy in SIDS.

The quantitative assessment considers the sociodemographic and income factors affecting seaweed farmers (Aslan et al., 2018; Krishnan and Narayanakumar, 2013; Narayan and Pritchett, 1999). CbA and EbA strategies are also linked to characterize practical applications (Reed et al., 2013a; Reid, 2016) such as in seaweed-farming communities (Hassan and Othman, 2019). It is recognized that the seaweed mariculture sector will play a significant role in the blue economy; therefore, this work seeks to fill research gaps that will lead to effective adaptation strategies for the communities involved (Yong et al., 2022). These include using the sustainable livelihood framework (SLF) to understand the key livelihood resources (capital), hazards, coping mechanisms, challenges, opportunities, and policy measures

---

<sup>1</sup> Scientifically, there are two types of seaweed cultivation: (1) Sea1 – EC1: Open Sea; (2) Sea2 – C2: control environment)

governing the sustainable development of seaweed resources as a livelihood activity for blue growth and climate change adaptation (UNDP, 2017). Climate risk was treated as the interaction of hazards, exposure and vulnerability (according to Intergovernmental Panel on Climate Change (IPCC)), with the CRiSTAL toolkit activities used as hazard screening; exposure and vulnerability were evidenced through livelihood capitals and stakeholder data.

### 1.3.1 Global context

As seaweed farming has been recognized as a nature-based solution while simultaneously providing subsistence and commercial livelihood opportunities development in coastal communities, global efforts have increased to prioritize seaweed as an important sea crop. The United Nations (UN), Commonwealth Secretariat, World Bank, and Organization of the Fisheries and Aquaculture Sector of the Central American Isthmus (OSPESCA), among other global organizations, have developed global frameworks for climate change adaptation and blue growth using community-based and ecosystem-based approaches which include seaweed. These approaches are in alignment with frameworks such as the Paris Agreement (UN, 2015), 2030 Agenda for Sustainable Development and its Sustainable Development Goals (SDGs) (United Nations, 2015), the Food and Agriculture Organization (FAO) Blue Growth Initiative which include SIDS (FAO, 2017a), the UN Conference on Trade and Development (UNCTAD) Biotrade Initiative in establishing voluntary sustainability standards (UNCTAD, 2024), The World Bank's Initiative to Unleash the Blue Economy of the Caribbean (UMBEC) project (World Bank, 2022), and OSPESCA Fisheries and Aquaculture Integration Policy for the Central American Isthmus (OSPESCA, 2015).

Seaweed mariculture aligns with the SDGs, particularly Goal 13 (Climate Action) and Goal 14 (Life Below Water), as they contribute to climate change mitigation and adaptation through carbon sequestration reducing atmospheric carbon concentration (Bhuyan et al., 2021; Duarte et al., 2017; Froehlich et al., 2019a) and provide sustainable mariculture, such as integrated multi-tropic aquaculture systems (Neori, 2009) and restorative, regenerative, and nature-based solutions (TNC, 2024a). Moreover, it also contributes to broader objectives such as food security (SDG 2), economic growth (SDG 8), and innovation (SDG 9) (Hurtado et al., 2019; Sultana et al., 2023; World Bank Group, 2016). Seaweed can play a role in protecting shorelines from surges and improving water quality of marine ecosystem while promoting economic growth (de Jong Cleynert et al., 2021; Sultana et al., 2023). However, many scholars have recognized that there are challenges, such as the lack of regulations and social, economic, and knowledge inequities, that can be addressed in order to achieve the long-term adaptation goals within the seaweed aquaculture sector (Landuci et al., 2021; Spillias et al., 2022; Strittmatter et al., 2022).

The Blue Economy (hereinafter referred to as 'BE') concept for development of large ocean states has been widely adopted by all countries especially SIDS of which seaweed mariculture is identified as a key emerging sector in BE (World Bank, 2022; World Bank and United Nations Department of Economic and Social Affairs, 2017). The cultivation of seaweed is a sustainable alternative to wild harvesting that can lead to overexploitation and ecosystem degradation and can address issues in food security, socioeconomic development, environmental sustainability, and climate change. For example, seaweed farming has proven to be a reliable and sustainable source of income for marginalized coastal communities in Tanzania and has built well-needed adaptation and flexibility against climate-related challenges (Matoju et al., 2022).

The importance of seaweed development in climate adaptation has fostered transdisciplinary and collaborative approaches with local and international stakeholders, scientists, environmental practitioners, impact investors, and regulators. The partnerships between

entities in civil society and seaweed farming communities are necessary vehicles for mainstreaming SDGs and this collaborative approach contributes to improving the governance of resources and overall environmental sustainability (Gutierrez-Corley et al., 2023). The Adaptation Fund provides climate adaptation finance to SIDS, yet the gap remains. SIDS should allocate funding towards conducting research on adaptation in complex and delicate environments and ensure that their findings are published in prestigious publications with significant influence. The growing interest in expanding seaweed offers a unique investment opportunity for all involved to achieve the desired long-term outcomes. Achieving these outcomes will require multiple partnership agreements and collaborative memorandum of understandings (MOUs) (Gutierrez-Corley et al., 2023). These kinds of agreements are formulated amongst seaweed farmers, farming groups (hereinafter refer to as ‘clusters’), environmental non-governmental organizations (E-NGOs) and regulators (hereinafter refer to as ‘policymakers’) to develop or refine regulations, policies, strategy and management frameworks and plans that support the industry (Gutierrez-Corley et al., 2023). Furthermore, these innovative BE development initiatives have sensitized the development of spatial management plans, upgraded farm designs, and modified institutional frameworks (McKoy and Dubon, 2021; Ortiz-Carabantes, 2020).

### 1.3.2 National context

Belize is an emerging player in sustainable red seaweed mariculture in the Caribbean region (MBECA, 2021, p.16) and has adopted it as part of its blue growth and climate change adaptation strategy (McKoy and Dubon, 2021). The development of seaweed mariculture in Belize intricately linked to the country's commitment to achieving both global and national sustainability goals to enhance its management (MBECA, 2021). Belize's Nationally Determined Contributions (NDCs) and adaptation under the Paris Agreement have been estimated to require investment of USD \$318 million for the period 2021 and 2030 (GOB, 2021). An investment which may not be enough to achieve the targets set, however the development of other seaweed industry can contribute the achieving NDC targets in the medium term (GOB, 2021, p.1).

The Government of Belize (GOB) has leveraged its strategic partnerships with various international and local organizations, including E-NGOs and seaweed farming clusters, to foster an environment conducive to seaweed mariculture development (ID and M, 2021). This includes the small-scale fisheries marine resource management models, like Belize Marine Conservation and Climate Adaption Project (MCCAP) under the country's national fisheries policy, strategy and action plan, which integrates marine tenure, harvest control, and the establishment of protected areas with the empowerment of fisherfolk and multi-stakeholder partnerships (ID and M, 2019). Within this framework, ecosystem-based approach to fisheries management (EBFM) and the precautionary principle have been adopted and replicated in Belize's National Mariculture Policy (ID and M, 2021). At the inception of seaweed farming Belize farms were often associated with marine protected areas (MPAs) and which were used as seeds banks for farms and encouraged community involvement and monitoring (Gutierrez-Corley et al., 2023; ID and M, 2019; Salas and Shal, 2015).

Belize's local legal frameworks for mariculture development place great importance on empowering marginalized groups, such as women and youth, especially in the fisheries industry (ID and M, 2019). It promotes community-based approaches, fisheries and mariculture development interventions that ensure community involvement to foster a sense of ownership, responsibility, environmental stewardship and align with local capacity building and educational outreach to local needs and cultural practices (Shal, 2014). Community-based approaches have promoted socio-economic benefits of seaweed mariculture development through employment and entrepreneurial opportunities for women

residing in coastal regions (TNC et al., 2014). Using this approach SIDS like Belize aims to develop and strengthen its seaweed farming sector through strategic integration of global sustainability goals with local adaptation and take advantage of high-value niche markets for seaweed value-added products, thus contributing to the overall country's blue growth, environmental sustainability, climate change adaptation, and community development.

#### 1.4 Case Study: Belize

Belize is a SIDS in the Caribbean, bordered by Mexico to the north and Guatemala to the west (Figure 1.1. ). The country spans an area of 22,960 km<sup>2</sup> of land and 23,660 km<sup>2</sup> of territorial waters, and a coastline of 280 km in the Caribbean consisting of mostly healthy mangroves, coral reefs, and seagrass ecosystem along with river deltas, estuaries, and coastal lagoons. The offshore reef system includes the second-largest barrier reef in the world, three atolls, and over 300 cayes all of which are vital for biodiversity and the economy, particularly tourism and fisheries. Over 60% of the population resided in coastal areas. Belize has membership with several international organizations, including the Caribbean Community (CARICOM), the Central American Integration System (SICA), the Organization of American States (OAS), and the Group of African, Caribbean, and Pacific Countries (ACP) (GOB & CDB, 2010). Its memberships in CARICOM and OAS highlight its geographical position in Central America while reflecting its cultural, historical, and linguistic ties to English-speaking Caribbean nations (GOB & CDB, 2010). Through its ACP membership, Belize benefits from European Union-funded aid programs designed to mitigate the negative effects of reduced preferential access for its agricultural products, stemming from World Trade Organization decisions and evolving EU policies (GOB & CDB, 2010).

The population of Belize consist of 390,353 multicultural citizens with a per capita GDP of USD 4,815.16. The country comprises 6 districts, 9 municipalities, and over 263 villages, and biodiversity of approximately 7,046 species. Belize employs an integrated environmental adaptation strategy, combining community involvement with ecosystem management (FAO, 2017b). The Belize Barrier Reef Reserve System is a UNESCO World Heritage Site and an important part of coastal protection and other ecosystem services. Belize has 68 natural ecosystem types, 11 of which are coastal and marine, and is home to approximately 1.2% of the world's terrestrial species and about 4% of the world's marine species (Meerman, 2011). According to IUCN, Belize's coastal and marine ecosystems are home to 2 species, including *Elacatinus colini* and *Cathorops belizensis*, with one listed as "Least Concern" and the other as "Data Deficient," representing approximately 8.7% of the total species assessed in the dataset of 2024 (IUCN, 2024). Although ocean flora is not captured in IUCN as yet, there is anecdotal data on the red seaweed species population (i.e. *Eucheuma isiforme*, *Gracilaria crassissima* and *Kappaphycus alvarezii*) which is shown in Figure 1.1. displaying a map of Belize with its active seaweed farms, wild sites and seed banks (TNC, 2020). The map displays various seaweed farming operations and seedbanks along Belize's coast, with symbols indicating their locations which include Riversdale Seaweed Farms, Placencia Seaweed Farms, Placencia seed bank, Turneffe Seaweed Farms, Turneffe seed bank, Wild Seaweed Sites, and Seaweed Farming Communities (Author's own elaboration based on the literature and personal communication with the Belizean seaweed farmers).

The biodiversity and natural resources of Belize face significant threats from climate change and environmental degradation (Luis Martín-Ortega et al., 2021; MAFFES, 2016; C. A. Young, 2008). Climate change's impacts on freshwater and marine ecosystems pose a threat to the distribution of fish and the production of fish stocks (Alves et al., 2022). The Belize Barrier Reef is at risk as a result of the rising temperatures of the sea surface (Gomez, 2004; Kramer et al., 2000). This has garnered considerable attention due to the potential for

substantial losses and the threat it poses to coastal ecosystems (Adaptation Fund, 2020). According to the InVEST Habitat Risk Assessment, 83% of Belize's coral reefs are somewhat threatened by human activities (CZMAI, 2016). Belize has a high ranking on the Global Climate Risk Index and is expected to face elevated temperatures, decreased rainfall, and more severe storms in the future (CARIBSAVE, 2012; IMF, 2018). Although the Southern Belize Barrier Reef has been evaluated as having an 'excellent' health status according to the HRI in 2018, the entire reef health index (RHI) declined from 3.0 to 2.0, moving from a 'Fair' to a 'Poor' rating by 2022 (Healthy Reefs, 2022). Healthy Reef (2022) reported that Belize's coral cover, which ranges from 11% to 47%, is classified as 'Fair' as a result of a decline in larger reef-building species caused by Stony Coral Tissue Loss Disease. Meanwhile, gelatinous macroalgae are classified as 'Poor'. For these reasons, Belize places a high importance on ecosystem-based adaptation strategies, such as the establishment of Protected Areas (Gutierrez-Corley et al., 2023; Mitchell et al., 2017), to enhance resilience and minimize susceptibility to the impacts of climate change, especially along the coastal areas (CZMAI, 2016).



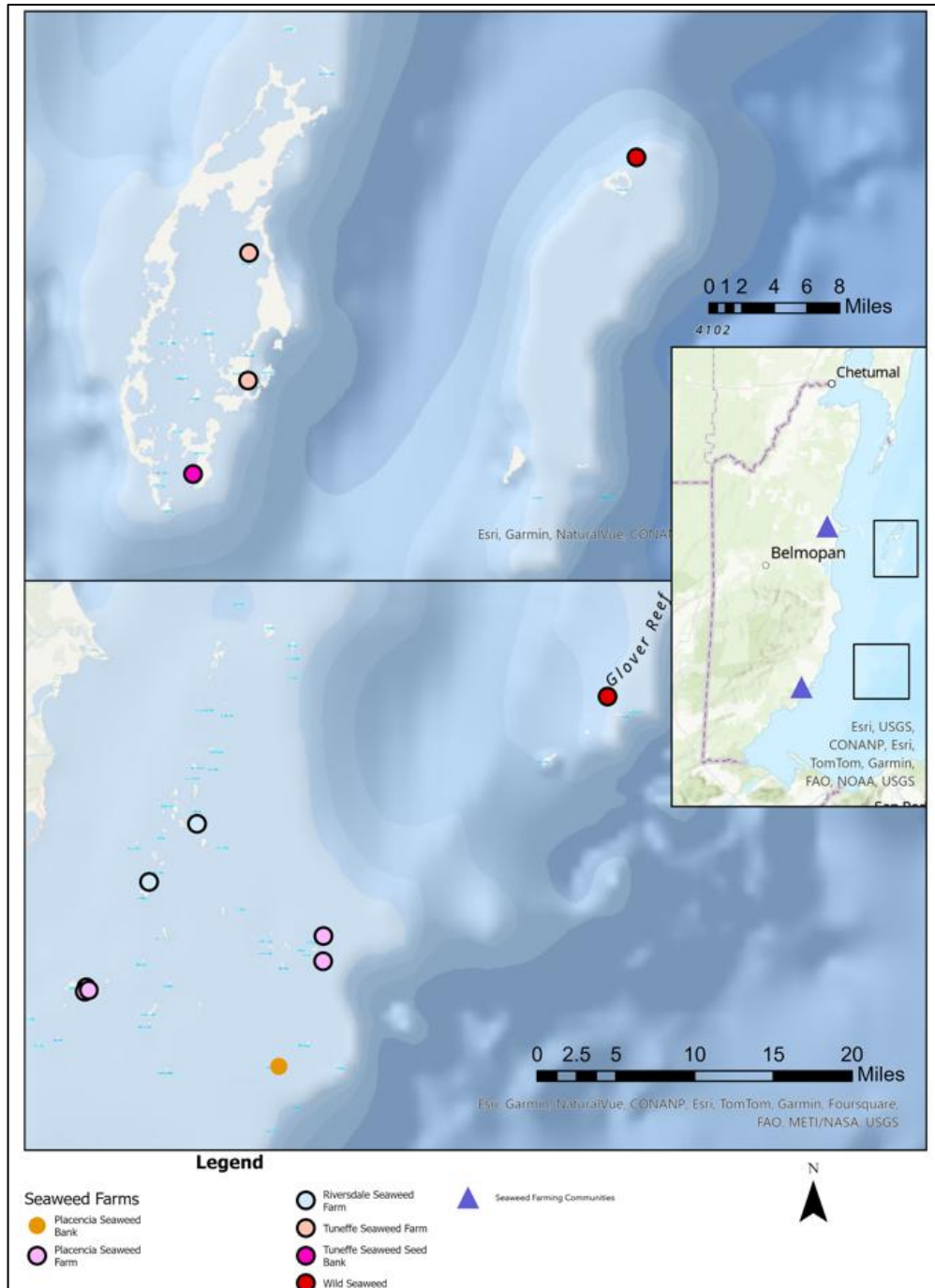


Figure 1.1. Map of Belize showing the Distribution of Seaweed Farms and Seed Banks adjacent to seaweed farming communities (Belize City and Placencia Peninsula) in urban coastal regions of Belize SIDS (Author's own elaboration in collaboration with Robert Hernandez, a Belizean GIS specialist).

#### 1.4.1 Seaweed mariculture in Belize

Belize is implementing BE initiatives including sustainable fisheries, eco-tourism, coral reef restoration, and seaweed mariculture. Legislative measures such as the Fisheries Resource Act (2020) and Marine Protected Areas System Act (2020) are a tangible testament to this approach. Fishing has historically been a crucial source of food and income for Belize's coastal communities, including wild seaweed harvesting since the pre-1980s (Ortiz-Carabantes, 2020; TNC, 2017). The concept of Managed Access was introduced to further develop and

incorporate comprehensive data collection, monitoring, and evaluation of the fisheries product to ensure its effectiveness (Alves et al., 2022). However, it doesn't address collecting seaweed farming data as part of fisheries products. Similarly, co-management of marine reserves has been widely implemented but require improvement to be expanded and incorporate seaweed farming as part of E-NGOs management plans and reporting (Wade et al., 2019).

Leveraging local and international partnership with E-NGOs and community-based organizations is a key part of the national BE strategy including seaweed mariculture. The decline of traditional fisheries stocks like conch, lobster, and shrimp due to overexploitation and destructive practices, has resulted in the need for alternative livelihoods to be sought. Since the 1990s, fishers began exporting wild-harvested *Eucheuma isiforme* and *Gracilaria crassissima* to the USA and selling seaweed products such as drinks and supplements to locals and tourists (McKoy and Dubon, 2021). These two species were initially farmed at low densities in shallow coastal waters then later another species, *Kappaphycus alvarezii* was introduced in 2017 (McKoy and Dubon, 2021). This early development was partly supported through the leveraged public-private partnerships including farmer exchanges and training programs (TNC, 2021, 2024b). The main characteristics of the industry in Belize are summarized in Figure 1.2. (TNC, 2021, 2024b).

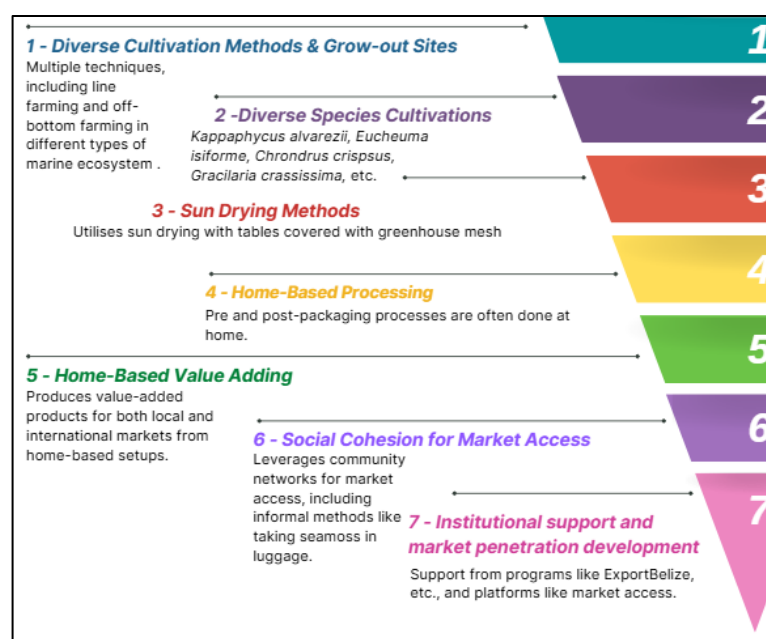


Figure 1.2. Characteristics of Seaweed Farming in Belize: Techniques, Species, and Market Integration (Author's own elaboration).

Fishing cooperatives and associations in the seaweed industry, such as the Placencia Producers Cooperative Society Limited (PPCSL), Belize Seaweed Women Association (BSWA), and Turneffe Seaweed Growers Association (TSGA), have received support for seaweed cultivation and harvesting (McKoy and Dubon, 2021). The seaweed farming sector in Belize, particularly through PPCSL established in 1962, is a key economic entity in Placencia, initiating other entities like BSWA and TSGA. Despite a membership decline from over 100 to about 57, the cooperative remains vital to the local economy by offering training opportunities. Seaweed farming gained momentum in 2005 with workshops supported by organizations such as the Caribbean Regional Fisheries Mechanisms (CRFM is a branch from CARICOM), World Wildlife Fund (WWF), International Coral Reef Action Network (ICRAN), United Nations Environmental Programme (UNEP), The Nature Conservancy

(TNC), Blue Ventures, Organization of the Fisheries and Aquaculture Sector of the Central American Isthmus (OSPESCA, a branch from SICA), and local entities like the Southern Environmental Association (SEA), Turneffe Atoll Sustainability Trust (TASA), and Fragments of Hope (FoH) (TNC, 2020). In 2010, a grant from the Community Management of Protected Areas Conservation Programme (COMPACT) enabled PPCSL to lease seabeds and expand its farming operations, establishing a seedbank at Little Water Caye near the Gladden Spit and Silk Cayes Marine Reserve (GSSCMR), with additional pilot sites in the conch restoration zone of GSSCR and near Ray Caye (formerly known as Hatchet Caye).

Due to insufficient funding, the grow-out sites had to be abandoned, leading to the establishment of the Belize Women's Seaweed Farmers Association (BWSFA) in 2019. The association started cultivating *Kappaphycus alvarezii* and *Eucheuma isiforme* in the vicinity of Ray Caye close to the town. The women who formed the BWSFA received seaweed cultivation training from PPCSL and currently sit on the National Seaweed Working Group, with TNC and the government to develop the seaweed industry. Additionally, members of the BWSFA have received cultivation training around 2015 and 2019 (TNC, 2024b). The BWSFA has also been involved in the production of value-added products, such as seaweed powder and seaweed gel, which were marketed to local businesses and resorts in Placencia through the micro, small, and medium enterprises (MSMEs) grant award program provided by the Belize Trade and Investment Development Service (BELTRAIDE) (British High Commission Belmopan, 2024).

The Turneffe Atoll Marine Reserve (TAMR) and local groups located in the northwest of the country are also important groups involved in seaweed development. The TAMR ecosystem is characterized by high density of seagrass, large reef formations, mangrove islands, and a higher concentration of fishing camps and fishers compared to the south of the country (TNC, 2020). The TSGA commenced their seaweed farming operations in the western parts of Turneffe Atoll in 2015, which were later registered under the Business Names Act, Chapter 247 of the Laws of Belize (McKoy and Dubon, 2021). The organization has partnered with the E-NGO co-managers of TAMR, TASA, and collaborated with 11 local farmers to develop seaweed farms. Some of its members have received training in seaweed cultivation and primary processing (McKoy and Dubon, 2021).

The development of seaweed mariculture in Belize has been slowed due to several issues including institutional, regulatory, and legislative ones (ID and M, 2021; Ortiz-Carabantes, 2020; Sjöblom, 2018). The enactment of the Fisheries Resources Act in 2020 which aims to establish a comprehensive legal framework for an ecosystems-based approach to mariculture development has been a vital step in the right direction and set in motion the development of the National Mariculture Policy (ID and M, 2021). This policy includes a detailed mariculture management plan designed to safeguard biodiversity and address the socio-economic needs of all stakeholders in industry (ID and M, 2021). Therefore, the regulatory and legal framework governing seaweed now involves obtaining permits and seabed leases, and consideration for smart siting in or around sensitive ecosystems and MPAs (MEBCA, 2021). This framework is designed to ensure that seaweed farming practices are environmentally sustainable and responsibly managed. Importantly, this policy and legislative changes serve to strengthen the traditional users of ocean spaces including seaweed farmers and new entrants to the industry (ID and M, 2021).

As previously mentioned, there are three main species of red seaweed cultivated in Belize: *Eucheuma isiforme*, *Gracilaria crassissima*, and *Kappaphycus alvarezii* (TNC, 2024b). Farms are often located 10 to 15 miles from the coastline and operated by fishers who use submerged tubular nets, floating PVC lines, and square plots for growing the algae (TNC, 2024b). The monthly production of seaweed is approximately 1,000 pounds, which is marketed in both dried and gel forms. A market analysis conducted in 2010 estimated the

potential annual revenue at around \$746,992 BZD, noting significant potential for growth potential of the industry (McKoy and Dubon, 2021). Among the most important obstacle to this growth are those due to climatic issues, such as hurricanes and fluctuating ocean conditions (MBECA, 2021) which can impact product quality and cause market volatility (ID and M, 2021).

Seaweed cultivation in Belize is conducted at low densities in shallow, clear coastal waters, resulting in high-quality products and benefiting the ecosystem (McKoy and Dubon, 2021). Although *Kappaphycus alvarezii* is farmed in the same way as the other native species, this species is farmed at a higher density regardless of it being a non-native seaweed species with higher growth rate (Reis et al., 2009). The main production areas are in the vicinity of southern Belize, near the Gladden Spit and Silk Cayes Marine Reserve and Little Water Caye (LWC) and Ray Caye (formerly known as Hatchet Caye) (Figure 1.1. ). Expansion plans are now focusing on the northwestern region of Turneffe Atoll Marine Reserve (TAMR), with the goal of extending cultivation throughout the area (TNC, 2017). TAMR boasts greater seagrass density, an increased number of reef formations, a larger concentration of mangrove islands, and a higher fishing camp density in comparison to LWC. While LWC is closer to Big Creek Port, TAMR is nearer to the Port of Belize. Expansion in TAMR is scheduled to commence in 2020. Despite the regional differences, Belize's extensive 240-mile coastline places these areas relatively near each other. Presently, Belize utilizes the floating PVC raft method for seaweed cultivation, which entails three main stages: assembling raft components on land, deploying and planting seedlings, and performing maintenance and harvesting tasks (McKoy and Dubon, 2021). Moreover, the country is also exploring alternative techniques such as the Tubular Net and Twisted Rope methods. The tubular netting method involves distributing seaweed seedlings within a 15 ft to 30 ft polyethylene net attached to a floating raft (Reis et al., 2015), whereas the Twisted Rope Method intertwines seaweed seedlings with polypropylene rope strands, this method is also known as tie-tie method (de Góes and Reis, 2011).

Farmers are implementing various adaptation strategies including adopting more sustainable farm management practices, sustainable sourcing high-quality seaweed seeds, and partnering to build community-based sustainability initiatives through locally driven community-based organizations (Akhtar et al., 2022; Msuya, 2006). These efforts have attracted the attention of many researchers, funders, and academics looking for trade, health, and environmental opportunities (Rebours et al., 2014b).

#### 1.4.2 National approach to seaweed mariculture

Research on Caribbean SIDS, including Belize, is limited and poorly coordinated, with insufficient studies on local livelihoods including seaweed production and value chains (CDB, 2018; IDB, 2020). Inadequate knowledge about the resources supporting vulnerable coastal households and the impacts of specific events on their resilience continue to undermine development (IPCC, 2023b). Belize has followed a sustainable development model that prioritizes governance of natural resources, biodiversity conservation and livelihood sustenance among others (Climate Resilient Food Systems Alliance, 2022; Morozova, 2016; Vernon, 2013). With a relatively small population of 390,353, large sea and land area, and a rich biodiversity including 68 natural ecosystem types and 118 globally threatened species, Belize's places priority on its coastal and marine environments that are crucial to its economy and livelihoods (MAFFES, 2016).

In this way, the Sustainable Livelihoods Framework (SLF) has been adopted which focuses on enhancing capabilities and assets for sustainable livelihoods (Chambers and Conway,

1991). These principles have been integrated into environmental strategies, supporting eco-tourism, fisheries, forestry and biodiversity. The SLF promotes community involvement in co-management and education initiatives to strengthen environmental conservation and livelihood security for climate adaptation (Schipper et al., 2014; Schipper, 2007). Belize has created supportive legislation such as the Fisheries Resource Act and Marine Protected Areas Act, continuous monitoring of project-funded initiatives, and integrated ecosystem management through co-management agreements with E-NGOs and other community stakeholders (Gutierrez-Corley et al., 2023).

Belize's adaptation strategies are based on community and ecosystem approaches, addressing environmental challenges while fostering sustainable livelihoods such as through the protection and restoration of mangroves to safeguard ecosystem services (Schipper et al., 2014, p. 257). Legislative measures, demonstrate Belize's dedication to managing and safeguarding marine resources. Enhancing the Managed Access program requires improved data collection, monitoring, and evaluation. Effective data management is vital for sustainable fisheries resource access. Co-management of marine reserves needs clearer definition and institutionalization, with standardized metrics across all co-managers to enhance reserve management effectiveness and ensure consistent outcomes (Gutierrez-Corley et al., 2023; Pomeroy and Goetze, 2003).

Community-based adaptation (CbA) strategies have allowed for mobilizing resources towards co-management of protected areas, educational programs, and sustainable fisheries management (Gutierrez-Corley et al.). The Fisheries and Forest Department's co-management system for protected areas and local education programs have shown their support in collaboratively improving environmental stewardship with local stakeholders (Young and Horwich, 2007). However, much of the impetus for these has originated from civil society actors such as the initiatives that changed regulations on fishing practices to support marine resource sustainability (Gutierrez-Corley et al.). Concurrently, ecosystem-based adaptation (EbA) strategies led by community-based organizations have contributed significantly to climate change adaptation including protecting mangroves, MPAs, and riparian forests (Cooper et al., 2009). For example, mangroves, covering 3.4% of the land area, offer vital coastal protection and pollutant filtration. There are gaps in the technical expertise needed to enhance decision-making and management practices (Horwich and Lyon, 1998; ID and M, 2019; Salas and Shal, 2015). All this has been done using multi-stakeholder adaptation initiatives, such as in the Belize Spiny Lobster Fishery Improvement Project where diverse objectives have included broader fisheries management goals and fostered collaborative solutions (Foley et al., 2014). Additional measures include the establishment of limited seasons, gear restrictions, access rights, and no-take zones, all of which are based on scientific principles and are subject to regular review in accordance with the Adaptive Management Framework (AMF) (McDonald et al., 2017). Implementing these strategies in turn helped to maximize the value derived from fisheries production under the country's BE mandate (GOB MBECA, 2021). These strategies focus on developing value-added products and encouraging private sector leadership in developing the fisheries sector, including investment in seaweed, thereby supporting economic growth and sustainability (MBECA, 2021). This type of effort in adapting to climate change is a critical challenge captured under BE. Developing climate-ready fisheries management and marine and coastal ecosystem approaches has been promoted at a policy-level to address the impacts of climate change effectively and safeguard the future of Belize's fisheries and mariculture industry (MBECA, 2021; Ortiz-Carabantes, 2020). Furthermore, capacity building of regulatory agencies in building institutional readiness has been reported to work in fulfilling the government's mandate and meeting its commitments under the Fisheries Resources Law that captures the mariculture sector as it is supported by the national mariculture development policy, ensuring that the department is well-equipped to manage the sector effectively (ID and M, 2021).

## 1.5 Sustainable Livelihoods Framework (SLF) Approach

This case study explores the link of community-based and ecosystem-based adaptation strategies in Belize using the SLF and climate adaptation concepts. The SLF focuses on understanding the causes of poverty and livelihood underdevelopment to improve livelihoods. The seaweed mariculture industry in Belize focuses on its role as a climate adaptation strategy and a driver of blue growth for realizing its potential GDP contribution and as livelihood option. SLF has several components to address livelihood development. In Belize, these components are summarized with regards to Belize in the following sub-sections.

### 1.5.1 Human capital

The seaweed farming industry in Belize has benefited from various educational initiatives and training programs. Fisher group associations such as the Placencia Producers Cooperative Society Limited (PPCSL) and the Belize Women's Seaweed Farmers Association (BWSFA) have received training to cultivate and harvest seaweed. Workshops conducted by organizations like WWF, BFCA, ICRAN, and UNEP since 2005 have been pivotal in building the capacity of local communities (TNC, 2017). The seaweed mariculture industry provides direct employment opportunities for local communities. The PPCSL, established in 1962, continues to play a crucial role in the local economy despite a reduction in membership. The industry also offers training opportunities for single mothers, enhancing their skills in processing, packaging, and record-keeping (McKoy and Dubon, 2021).

### 1.5.2 Social capital

CbA initiatives are integral to Belize's environmental strategies. Co-management of protected areas, like the Forest Department's system for 24 protected areas, involves local communities in managing and adapting to environmental changes. This collaborative approach enhances environmental stewardship and building adaptation strategies to climate change. Regarding farming clusters in Belize, farmers organize themselves legally into associations and cooperatives such as the PPCSL and the BWSFA which exemplify successful community involvement in seaweed farming. These organizations not only provide economic benefits but also foster social cohesion and collective action. The BWSFA formed in 2019, has been instrumental in developing value-added seaweed products and marketing them locally (TNC, 2017).

### 1.5.3 Financial capital

Seaweed farming in Belize has significant economic potential, with an estimated annual revenue of \$746,992 BZD (McKoy and Dubon, 2021). The industry supplies local and international markets, with increasing interest from companies like Big H and Bowen and Bowen. Funding and grants have been crucial for the growth and sustainability of the seaweed mariculture industry, such as a grant from the Community Management of Protected Areas Conservation Programme (COMPACT) in 2010 (Sale et al., 2010).

### 1.5.4 Physical capital

Belize's seaweed farming uses various techniques like floating PVC rafts, tubular nets, and twisted rope to protect seaweed from environmental stressors and predators (MBECA, 2021). The PPCSL has established processing and bottling facilities for local and export markets, enhancing the value chain and ensuring high-quality seaweed products (MBECA, 2021).

### 1.5.5 Natural capital

Belize's marine biodiversity, including the Belize Barrier Reef Reserve System, is crucial for seaweed farming. Primary production areas like Gladden Spit, Silk Cayes Marine Reserve,

and Turneffe Atoll Marine Reserve offer ideal conditions for seaweed cultivation, enhancing biodiversity (MBECA, 2022).

#### 1.5.6 Cultural capital

The seaweed farming industry in Belize combines traditional knowledge and modern practices, preserving local customs and traditions related to marine resource use (TNC, 2017). This industry strengthens community identity and heritage by fostering pride and ownership among residents. The industry's focus on sustainable practices aligns with the cultural values of conservation and respect for nature prevalent in Belizean communities, ensuring the preservation of local customs and traditions (British High Commission Belmopan, 2024).

The seaweed mariculture industry in Belize serves as a model of sustainable aquaculture within SIDS, demonstrating how CbA and EbA strategies can enhance livelihoods and build strength against climate change (MBECA, 2021). By leveraging local expertise, adopting innovative farming techniques, and pursuing strategic market approaches, Belizean seaweed farmers are fostering a robust and promising industry. Collaborative efforts by BELTRAIDE, TNC (Belize), the Belize Fisheries Department, and TASA are crucial in establishing a sustainable seaweed farming industry, supporting entrepreneurial growth, and enhancing the value chain (TNC, 2021). This case study highlights the potential for future growth through targeted policies and adaptive strategies, reflecting Belize's commitment to sustainable development and blue growth (MBECA, 2021).

### 1.6 Challenges and Information Gaps

The complex issues surrounding seaweed aquaculture in SIDS, exacerbated by climate change, require a comprehensive understanding of the processes and systems involved. Unfortunately, there remains a dearth of data and limited capacities which continue to hinder sustainable development of seaweed mariculture. Most SIDS rely heavily on natural resource-based economies, such as tourism, fisheries, and farming, a characteristic which makes their economic development highly vulnerable to climate change impacts and environmental variability (UNCTAD, 2021). The ocean remains one of the biggest untapped resources within SIDS, yet it holds significant potential for sustainable economic growth if strategically managed.

A critical limitation is that the majority of participants in the seaweed sector across SIDS operate at an artisanal scale. While this approach sustains livelihoods and embeds traditional knowledge within local communities, it also creates significant barriers to expansion. Artisanal production is typically constrained by limited financial capital, inadequate infrastructure, and restricted access to technology, making it difficult to achieve economies of scale or to meet the quality and quantity demands of regional and international markets. Furthermore, gaps in technical training, weak institutional frameworks, insufficient product diversification, and a lack of coordinated research and development limit the sector's ability to adapt to evolving global markets and climate challenges. These constraints, coupled with the rapid growth of interest in seaweed aquaculture, create challenges that must be systematically addressed.

Table 1.3 provides a summary of these challenges and their implications for sustainability, the Blue Economy, and climate change adaptation in SIDS. The seaweed industry in SIDS requires further research on key factors that affect production, such as improved understanding of climatic and weather conditions for predicting seasonal changes at cultivation sites (e.g., storm events, wind and rainfall patterns) (Zamroni, 2021). These factors are directly linked to risks of disease outbreaks (Rusekwa et al., 2020), contamination of nursery sites and seed banks (UNU-INWEH and SAMS, 2017), reduced genetic diversity (Halling et al., 2012), the need for developing resilient strains (García-Poza et al., 2020), and the spread of non-native invasive species (Kambey et al., 2020). Other challenges include

biosecurity (FAO, 2022a) and the weak integration of policy and finance instruments to support seaweed biotechnology and bioprospecting (WBG and UNDESA, 2017). Collectively, these issues can undermine the long-term development of commercial seaweed species, particularly in offshore areas (Gentry et al., 2017).

The absence of reliable data, formal institutional frameworks, and effective management systems is a global constraint in seaweed mariculture, but it is especially acute in SIDS, which remains largely data deficient and faces critical capacity gaps (Thomas et al., 2020). Data limitations extend across the entire value chain, affecting both private and public sectors, with little information available on production volumes, market trends, input technologies, environmental monitoring, and climate change adaptation strategies (Kebede et al., 2024). This paucity of reliable data is a major obstacle to seaweed aquaculture development, as it hampers evidence-based decision-making and reduces efficiency (Robinson, 2018). Addressing these knowledge gaps is therefore vital. This research contributes to filling part of this void by providing additional insights on seaweed mariculture in the context of SIDS, thereby informing sustainable management towards blue growth and climate change adaptation.

| Challenges                                                                                                                                                                                                                                  | Reference                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| 1. Pests and diseases affecting seaweeds, such as ice-ice disease and epiphytic filamentous algae.                                                                                                                                          | (Ward et al., 2019)                                                                       |
| 2. Water quality degradation, which can lead to poor growth and health of seaweeds.                                                                                                                                                         | (Tahiluddin & Terzi, 2021)                                                                |
| 3. The occurrence of harmful algal blooms, which can negatively impact seaweed production and ecosystem health.                                                                                                                             | (Rotter et al., 2021)                                                                     |
| 4. Lack of capital and government support hindering the development and expansion of seaweed mariculture projects.                                                                                                                          | (Bokhtiar et al., 2022)                                                                   |
| 5. Limited knowledge and understanding of seaweed cultivation techniques and best practices, leading to inefficiencies and suboptimal yields.                                                                                               | (Darmi et al., 2018; Sobuj et al., 2023; Natale, 2015)                                    |
| 6. Limited access to markets and distribution networks, making it difficult to sell seaweed products and generate sufficient income.                                                                                                        | (Islam et al., 2023)                                                                      |
| 7. Inconsistent or unpredictable market demand for seaweed products, challenging farmers' ability to plan and maintain a stable income.                                                                                                     | (Busthanul et al., 2019)                                                                  |
| 8. Increasing pressure on marine resources and lack of regulations for supporting an equitable and sustainable seaweed-based mariculture sector, posing challenges to long-term adaptation to climate change and environmental degradation. | (Albasri et al., 2010; Burbridge et al., 2001; Salayo et al., 2012; Rodeldo et al., 2014) |

*Table 1.3. Summary of Challenges in Global Seaweed Mariculture and their Implications for Sustainability Blue Economy and Adaptation in SIDS.*

It also remains poorly understood how existing seaweed farmers in SIDS are coping with environmental changes while striving to generate a sustainable income (Thomas et al., 2020).



To achieve sustainable blue growth, there is a pressing need to identify and apply tools that strengthen political and institutional frameworks capable of facilitating adaptive and transformative planning (Hoerterer et al., 2020). Such frameworks must be science-based while supporting the livelihoods of coastal communities. Addressing this gap requires first investigating the perceptions of seaweed farmers and value chain actors regarding climate change risks and threats and then contextualizing adaptation strategies and tools within local development priorities. This anthropocentric approach provides a pathway to better understand the developmental needs of the seaweed industry in SIDS, while also identifying innovative practices to adapt to emerging climate realities.

## 1.7 Hypothesis and Research Questions

This doctoral research examines seaweed mariculture in SIDS with a specific focus on Belize, to identify the factors that impact development of this emerging sector and its role in sustaining livelihoods, combating climate change, and implementing adaptation strategies. In addition, the study highlights the inherent characteristics, opportunities, and challenges of seaweed aquaculture in SIDS while assessing the climatic and non-climatic hazards impacting seaweed stakeholders and other stakeholders. In parallel, this doctoral research evaluates the effectiveness and adequacy of existing policy frameworks in addressing the multifaceted challenges and in supporting the transition towards sustainable blue growth under conditions of climate uncertainty. Therefore, this doctoral research seeks to answer the following research questions:

1. What are the key characteristics of seaweed aquaculture in the context of SIDS?
2. What are the main opportunities and challenges faced by seaweed mariculture in SIDS?
3. What are the main climatic and non-climatic hazards impacting the livelihoods of seaweed farmers in SIDS?
4. What are the existing responses, practices, and strategies being implemented by seaweed farmers to cope with and adapt to climate- and non-climatic hazards in SIDS?
5. To what extent, if at all, are the policy measures in place in the SIDS of Belize capable of tackling climate and non-climatic hazards in relation to seaweed farming?

This study addresses critical gaps in the scientific literature on climate adaptation strategies in Caribbean SIDS, where empirical evidence remains limited despite the increasing emphasis on sustainable ocean economies. The hypotheses posited that despite the great potential of seaweed mariculture in SIDS to contribute to socioeconomic development and environmental sustainability, this sector faces substantial hazards from climate change and environmental variability, particularly affecting marginalized coastal communities. Currently, adaptation strategies are primarily driven at the individual and community level, with supplementary support from external actors. However, these strategies remain inadequately documented and lack integration into formal governance and policy structures, especially within the Caribbean context. Furthermore, existing policies and institutional frameworks in SIDS, using Belize as a case study, are inadequate for fully integrating climate change adaptation with Blue Economy priorities. This gap undermines the long-term sustainability of seaweed mariculture and limits its potential to contribute to resilient livelihoods and climate-ready fisheries management.

By addressing these research questions and testing these hypotheses, this study contributes new empirical insights into the interactions between hazards, livelihoods and adaptation strategies in seaweed farming. It also informs policy interventions to strengthen governance

framework, enhance the resilient of coastal communities and promote sustainable seaweed aquaculture as part the broader climate adaptation and blue economy strategies in SIDS.

## 1.8 Research Approach

The purpose of this research is to investigate the sustainability of the seaweed mariculture industry using a mixed quantitative and qualitative methods approach to understand this livelihood as a strategy for climate change adaptation and the blue economy in SIDS with Belize as case study. The research builds on the theoretical constructs linking seaweed mariculture industry and climate change adaptation evidently used in the development of sustainable livelihoods. It examines the perspectives of specifically CbA and EbA guided by BE principles (Figure 1.3.) in seaweed farming that include a broad list of stakeholders along the value chain and developmental path such as farmers, managers, researchers, high-level policymakers/regulators, consultations, and policy analysis. This research approach is further elaborated in Chapter 3, section 3.2.1.

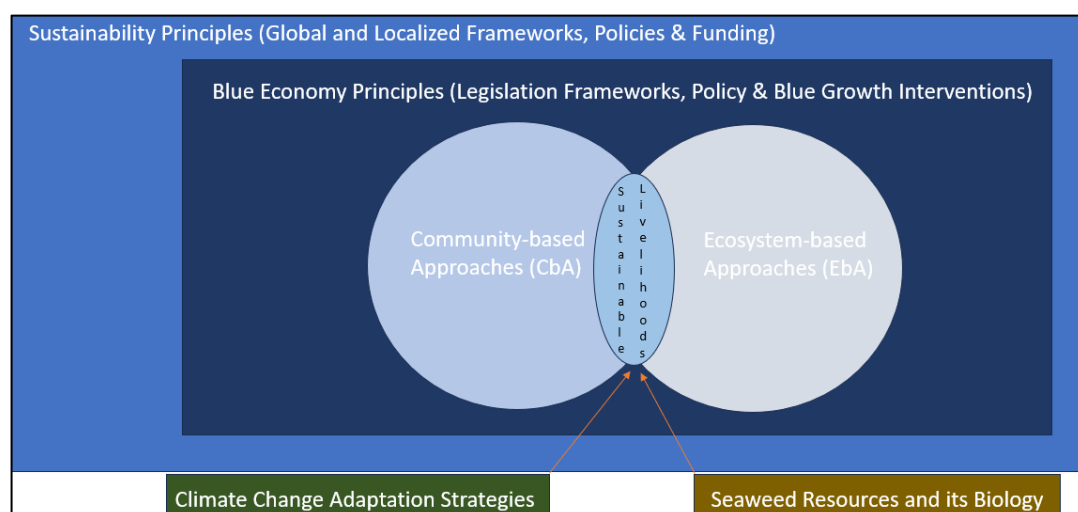


*Figure 1.3. Research Framework for Sustainable Seaweed Mariculture Used in this Thesis, Balancing Community and Ecosystem Approaches in Climate Adaptation Strategies (Author's own elaboration).*

The thesis therefore includes four main stages:

A systematic literature review to understand community participation in adaptation and seaweed mariculture in SIDS.

Focus group sessions on a workshop setting with seaweed farmers from local coastal communities in Belize to identify the issues in the seaweed mariculture linked to climate change.

Focus group discussions were guided by toolkits in the form of a workshop with seaweed farmers to identify perceptible climate and non-climate related hazards that can impact the sustainability of their livelihoods. Also, to identify their responses to those impacts.

Following up on the workshops, surveys were conducted in the form of semi-structured interviews on a one-to-one basis with the seaweed farmers to understand the most important issues identified during the first stage, and the impacts on the respective areas. This research established baseline data using socio-economic data and perceived adaptation strategies employed by seaweed farmers. Only seaweed mariculture activities operating in the open ocean were considered this study (no land-based aquaculture activities) and active seaweed farmers.

The fourth stage involved reviewing the existing policies in the national or regional landscape that addressed the issues that seaweed farmers reported that they are facing on the ground. The researcher did not focus on the dynamics between the institutional dimensions, influence, and impact of the current aquaculture policies governing but took note of the policy measures in place to ensure the sustainable development of the seaweed industry for blue growth and climate change adaptation in the Caribbean SIDS. The seaweed mariculture policy frameworks were closely observed to facilitate seaweed farmers in building a climate-smart industry in the ocean. Based on the findings from the second and third stage, an assessment was undertaken to explore and assess the legal, social, biological, and ecological issues of seaweed farming with a focus on the capacity needed of seaweed farmers to adopt the blue growth strategy and evaluate their existing capacity to adapt to climate change.

For this purpose, seaweed farmers' perspectives were considered and evaluated, and whether these have been sufficiently captured in the seaweed mariculture policy, climate change adaptation development plans and blue economy strategy within the country of study, and the Caribbean SIDS region. This was key to supporting the development of an in-depth understanding and appreciation of the multi-disciplinary and interconnected themes affecting the development of seaweed mariculture.

## 1.9 Outline of the Thesis

This thesis is organized into seven substantive chapters. Chapter 2 surveys literature on climate-change adaptation, livelihoods and policy responses in SIDS, defining key concepts and identifying gaps that motivate the study. Chapter 3 situates seaweed mariculture within the blue-economy paradigm and sustainable livelihoods, reviews global and regional practices, and develops the theoretical lens used to analyze the Belizean case. Chapter 4 sets out the mixed-methods research design, describing the systematic literature review, participatory focus groups, household surveys, elite interviews, policy analysis and quantitative techniques employed, together with ethical considerations. Chapter 5 presents the empirical findings, reporting qualitative insights from community and stakeholder engagement and quantitative analyses of socio-demographic characteristics, hazard-response patterns and hypothesis testing. Chapter 6 discusses these findings in relation to the conceptual framework and existing scholarship and notes methodological and practical limitations. Chapter 7 synthesizes the overall results, revisits the research questions, articulates the contributions of the study and offers recommendations for policy and further research. The thesis concludes with references and appendices containing supporting data, instruments and analyses.

## **2. CLIMATE CHANGE ADAPTATION, LIVELIHOODS, SEAWEED MARICULTURE, AND BLUE ECONOMY IN SIDS**

### **2.1. Overview**

Climate change is defined as the long-term shifts in Earth's surface temperatures and weather patterns (IPCC, 2022c). Climate change has been exacerbated by anthropogenic activities such as fossil fuel use over a period, especially since the industrial revolution when the burning of fossil fuels (i.e. coal, oil and gas) has led to large emissions of heat-trapping gasses (Gettelman and Rood, 2016; WMO, 2023). These greenhouse gases primarily include carbon dioxide in terms of volume but also include methane, nitrous oxide and others that also lead to global warming (IPCC, 2014). This includes natural processes that also contribute to the increased greenhouse effect through variations in the solar cycle, and natural phenomenon that emit these gases into the atmosphere such as volcanic eruptions. The combination of human and natural factors has contributed to accelerated global warming which is known as climate change (WMO, 2023). It is predicted that current rates of emissions and warming the world's ocean will experience higher temperatures, increased acidification, sea level rise, increased dangerous algal blooms and other impacts that threaten the coastal communities, marine-based industries and ecosystems (Perkins, 2013; Sarkar, 2018).

The Paris Agreement, a landmark treaty forged in 2015 at the United Nations Climate Change Conference (UNFCCC), stands as a testament to global unity in the face of an existential threat, climate change (UNFCCC, 2023). Rooted in the imperative to limit global warming to well below 2 degrees Celsius above pre-industrial levels, with an aspirational target of 1.5 degrees Celsius, the agreement signals a paradigm shift towards ambitious climate action (UNFCCC, 2023). Findings have been injected into Intergovernmental Panel on Climate Change (IPCC) reports to support government decision-making through the different components of climate change that have been delineated in its politically ecological setting in societies. This includes scientific information on climate change leading from its impacts, risks, mitigation measures, adaptation measures, resilience outcomes along with its transformational processes (Pelling, 2014) to corresponding socioeconomic and environmental conditions and futuristic modeling scenarios of a given country and/or region and beyond (Naylor et al., 2021). According to Moser and Boykoff (2013) there is a notable absence of a specific international goal for adaptation.

Nevertheless, the imperative of the Paris Agreement extends far beyond the geopolitical realm, resonating deeply with Small Island Developing States (SIDS), which confront existential threats from climate change (Ferdinand, 2020). SIDS are an established group of 38 member states recognized by the United Nations (UN) located in three main geographic regions of the world; the Atlantic, the Indian Ocean, the Mediterranean and the South China Sea (AIMS), Caribbean, and Pacific (Mercer et al., 2014; UNCTAD, 2021). SIDS are considered a special case for both environmental and developmental issues given the shared characteristics of small population size (usually below 1.5 million), limited resources (including limited infrastructure development), and geographic dispersion and isolation from markets due to remoteness (United Nations Framework Convention on Climate Change, 1992). They are largely coastal states and have high exposure to external economic shocks that puts this group of small economies at a disadvantage developmentally and prevents economies of scale (Briguglio, 2016; Moncada et al., 2021). Another major characteristic among SIDS is that they have fragile coastal and marine ecosystems that are highly susceptible to the impacts of climate change and environmental variability including sea level rise (Thomas et al., 2020). The unprecedented rate of changes in the environment over the last decades will continue to do so at an increasingly accelerating rate with SIDS experiencing the worst-case scenarios (IPCC, 2022a). Both terrestrial and ocean ecosystems

are already experiencing a higher frequency and severity of extreme climate events due to anthropogenic emissions of greenhouse gases and pollutants produced by growing populations. It must be acknowledged that SIDS adapting mechanisms and adaptation to a changing climate are constrained (Robinson, 2020) due to their inherent vulnerabilities such as small size, dependency on limited natural resources, remoteness from markets, geographic dispersion and small economy (Briguglio, 2016). Despite these realities, it is key for SIDS to build capacity in adapting to this new and changing environment at different levels and sectors of society, especially in the Caribbean region (Kalaidjian and Robinson, 2022). Many SIDS' economies are built on climate-sensitive sectors, such as marine-based industries, which tend to lack the means for adapting to climate-related shocks (Nurse et al., 2015). In such regions of SIDS, climate change adaptation should remain at the forefront of sustainable development along with a circular economy at heart such as the blue growth strategy for marine-based industries (ISSD, 2003; Martínez-Vázquez et al., 2021; Mead, 2021).

However, adaptation to climate change is a very complex and complicated process which requires an interdisciplinary approach to bridge the gaps and challenges through planned adaptation (Robinson, 2018). Climate change adaptation incorporates new challenges on its own as it relates to addressing sustainable development in coastal livelihoods such as seaweed mariculture. Policies within the sectors should incorporate necessary strategies to support adaptation to respond to both climate change adaptations and for climate-resilient developments, thus making a successful pathway for stakeholders to build capacity and undergo the desired transformation (Robinson, 2018). Planned adaptation has been strongly advocated to combat adverse impacts of climate change (Moser and Boykoff, 2013) which can be anticipated within development by implementing strategies and action plans aimed to reduce risks and damage preventions that may be caused (Bedsworth and Hanak, 2010). On the other hand, there is also adaptation that is unplanned or spontaneous that can also mean to take advantage of certain climatic-related opportunities that may, in the long run, prove to be beneficial for development (Moser and Boykoff, 2013) which is influenced by environmental factors (McClanahan and Cinner, 2012) such as invasive species that have commercial value and are climate resistant (Boulahia-Kheder, 2021; Isabelle and Westerlund, 2022).

Therefore, this chapter provides a comprehensive literature review on climate change adaptation and development and its interdependency with the environment and communities in SIDS. Key concepts in good climate change adaptation and maladaptation are discussed particularly focused on comparing how climate adaptation differs in SIDS and larger countries and opportunities presented in ecosystem- and community-based adaptation especially for the benefit of Caribbean SID. There are many nomenclatures in climate change adaptation of which this chapter provides definitions and explanatory frameworks to enhance conceptual clarity. Central to this thesis endeavor is the delineation of research questions and hypothesis, focusing on the critical evaluation of seaweed mariculture as a viable climate adaptation strategy. This multifaceted inquiry is linked to Chapter 3 that encompasses an exhaustive assessment of the susceptibility of seaweed mariculture to climate change-induced perturbations, coupled with an exhaustive exploration of adaptive measures and coping mechanisms employed by practitioners in the field in this chapter. Hence, by spotlighting innovative perspectives on the integration of nature-based livelihoods as effective climate change adaptation measures, the research aims to contribute substantively to the discourse on sustainable adaptation strategies in SIDS with a focus on the Caribbean SIDS.

## 2.2 Definition of Concepts

### 2.2.1 Livelihoods

Livelihoods involve the essential capabilities, assets (material and social), and activities necessary for living. A livelihood is sustainable when it can endure and recover from hazards and stressors, enhance its capabilities and assets, and provide future generations with opportunities without depleting their natural resources (Rakodi and Lloyd-Jones, 2014). This

concept is critical to frameworks and analyses, particularly for rural development and poverty reduction. However, applying a fixed asset model within a SLF has limitations, often neglecting historical power imbalances and indigenous cultural dynamics (Levine, 2014). Livelihood strategies are diverse and context-specific (Angelsen et al., 2011), as shown in the grassroots studies in the agriculture and fisheries sector (Adato and Meinzen-Dick, 2003; Allison and Ellis, 2001) of which face barriers that prevent engagement in more profitable activities. Livelihoods involve a complex interplay between natural, human, financial, social, and physical capital (Rakodi and Lloyd-Jones, 2014). The SLF serves as a tool for understanding and improving the livelihoods of marginalized groups, requiring adaptability and cultural sensitivity to address unique community challenges (Kamal and Martens, 2015). Understanding livelihoods is crucial for developing policies and interventions for sustainable rural development and poverty alleviation (Sapkota, 2021).

### 2.2.2 Hazards

Hazards are threats that have the potential to cause harm to people, property, and the environment (Dewan, 2013). Although the literature does not directly support categorizing hazards, this thesis attempts to summarize hazards into two main groups: climate-related and non-climatic (see *Table 9.1* in Appendix A). Hazards can emerge from natural processes such as climate change, which can cause abnormalities in the natural system, or anthropogenic processes such as changes in land use, rapid urban expansion, and existing policies (Dewan, 2013). Hazards can be natural (e.g., earthquakes), technological (e.g., chemical spills), or man-made (e.g., civil war) (Handmer and Dovers, 2007). They are typically characterized by location, time, intensity, and frequency (Wisner et al., 2003). Both external and internal drivers can worsen hazard conditions. For example, intense rainfall, combined with poor farming infrastructure in the ocean, can cause significant damage to farming systems (Rubekie and Bwathondi, 2022). Hazards negatively impact how individuals, households, and communities sustain themselves and secure essential life necessities, arising from environmental stresses such as natural disasters or socioeconomic factors such as political and economic processes (Milton et al., 2023). They can directly affect livelihoods by damaging assets or posing health risks, thereby reducing productivity and income (Mphande, 2016). Addressing these hazards requires a comprehensive approach that considers both climatic and non-climatic hazards to effectively enhance livelihoods, security, and long-term sustainability (Nguyen et al., 2023).

Therefore, climate-related hazards included natural hazards, climate change-related hazards, and man-made/environmental degradation hazards. Non-climatic-related hazards include financial hazards, health hazards, social and cultural hazards, and policy and governance hazards. As shown in *Table 9.1* of Appendix A, a summary of the hazard's origin and its example is provided on how it impacts livelihoods. Nevertheless, hazards are crucial for the identification of sustainable livelihood strategies of which are recognized as adaptation strategies in this study in building resilience to face various challenges. Moreover, field observations of community-based risk reduction, planned adaptation strategies, and supportive policies were made during the data collection period to contribute to further understanding of what building more robust livelihood systems encompassed. These were outlined in detail in the focus group discussions, elite interviews, and semi-structured survey interviews of the results chapter of this thesis.

### 2.2.3 Climatic hazards

Climate change exerts significant impacts on Earth's biophysical and biochemical cycles, leading to heightened variability in environmental conditions, including surface temperature, oceanic chemistry, sea level, and weather patterns such as rainfall, droughts, storms, and floods (Adger, 2006; IPCC, 2022a). These impacts extend to natural ecosystems, particularly

oceans, where they induce alterations in biodiversity, ecosystem structure, and functionality (Adger, 2006), with profound repercussions for human socioeconomic systems, encompassing realms like human health, energy, transportation, and food farming systems (IPCC, 2014). The intricate interdependence among climate, natural, and human systems highlights the exacerbation of non-climatic impacts by climate change, ranging from rapid urbanization and demographic shifts to social and economic disparities, pandemics, food insecurity, and unsustainable consumption of natural resources (IPCC, 2022c). Scholarly attention has been directed towards delineating the myriad impacts of climate change variability, culminating in the design of policy frameworks geared towards prioritizing adaptation measures to mitigate direct and indirect climate-related risks in an evolving environment (Adger et al., 2009; Burton et al., 2002). In the context of SIDS, the burgeoning literature on climate change impacts has centered on livelihood developments, particularly the implications of seawater temperature fluctuations in coastal and marine environments (Badjeck et al., 2010a; ISSD, 2003) including disruptions such as sargassum influxes (Monnereau and Oxenford, 2017).

Climate variability, recognized as an inherent reality historically navigated by human societies, underscores the necessity of leveraging existing mechanisms to cultivate resilience to future changes, with developing countries being disproportionately vulnerable to the consequences of climate change (CAST, 2015). This vulnerability stems from exposure to climatic variables that can precipitate abrupt disruptions such as floods, droughts, and tropical storms, exacerbating existing environmental challenges like declining water resources and shortages (El Ouadi and Ouarda, 2023; Nguyen et al., 2023) thereby heightening the imperative of sustainable natural resource management (Alley et al., 2019).

Climatic hazards pose significant risks to human health, ecosystems, and property. They encompass extreme weather events and conditions, such as tropical cyclones, floods, droughts, heat waves, and other weather-related phenomena, which can lead to direct and indirect impacts on human health and livelihoods (Grigorieva and Revich, 2021). Although tropical cyclones are often the focus of research and literature, other non-tropical climatic hazards, such as orographic precipitation and meteorological drought, also significantly affect regions, such as the Caribbean (Gamble, 2014). The interplay between climatic hazards and socioeconomic factors, such as rapid urbanization and ecosystem changes, can influence the adoption of adaptation strategies at community-level to these events (Hung et al., 2024). This includes the development of early warning systems, public health preparedness, and policies aimed at enhancing resilience and adaptive capacity in a changing climate (Diaz et al., 2004; Grigorieva and Revich, 2021).

#### 2.2.4 Non-climatic hazards

Non-climatic hazards are risks that affect livelihoods unrelated to climate change or weather events. These include biological threats, such as invasive species, disease, and pestilence, as well as socio-economic factors, such as unemployment, market volatility, health epidemics, political instability, and technological or industrial accidents, which can disrupt livelihoods and increase vulnerability (Erundu and Anyanwu, 2011; Liu et al., 2016; Makame et al., 2023). While climatic hazards, such as floods, droughts, and storms, are often emphasized, non-climatic hazards can be equally significant. For example, unplanned urban expansion into flood-prone areas can increase flood vulnerability, which is a non-climatic factor contributing to a climatic hazard (Braun and Aßheuer, 2011; Formosa et al., 2017). Additionally, the socioeconomic impacts of tourism and the role of NGOs in livelihood security are non-climatic factors that influence livelihoods (Schipper et al., 2014). Thus, non-climatic hazards include various factors that affect livelihoods independent of climate change. It is crucial to recognize the multifaceted nature of livelihood vulnerability, which includes various non-

climatic challenges undermining individuals' and communities' ability to sustain their livelihoods (Erenstein et al., 2010; A. Singh, 2022).

#### 2.2.5 Coping mechanisms

Coping mechanisms are techniques or strategies for handling stress and adjusting to challenging circumstances. Depending on their efficacy, these processes may have favorable or unfavorable impacts (Alosaimi et al., 2015; Bondarchuk et al., 2023; Shen and Slater, 2021). Coping methods are influenced by several factors including personality traits, social support, spiritual experiences, and professional interventions (Cacaj and Melonashi, 2019; Setiawan et al., 2024a). The employment of active coping methods has been associated with resilience since it can lessen physiological reactions connected to stress (Setiawan et al., 2024b). However, maladaptive methods do not address the root causes of stress, even if they may provide momentary alleviation (Bondarchuk et al., 2024). Having coping techniques in place is crucial for maintaining mental health and managing stress.

#### 2.2.6 Adaptation versus Maladaptation

Given the range of climate change impacts and climate variability, there is a need for socioeconomic and ecological adaptation to cope with and minimize the risks associated with negative consequences on vulnerable societies such as SIDS (IPCC, 2022c; McClanahan and Cinner, 2012). The process of adapting human systems to actual and expected climate change, whether positive or negative, is referred to as adaptation (Eriksen et al., 2021; IPCC, 2014; Schipper, 2007). There are many definitions of adaptation to climate change across the literature. The IPCC (2001) describes climate change adaptation as an adjustment in ecological, social or economic systems in response to observed or expected changes in climatic stimuli coupled and their impacts occurring in two pathways of either alleviating adverse impacts of change or taking advantage of new opportunities. This is similar to others who have described adaptation as how people survive and prosper in areas of high recurrent natural hazards (Hughes, 1994; Kelman, 2020; Rougier et al., 2011). Other definitions emphasize more the process in which people adjust to climate change by seeking to reduce its adverse impacts on health and wellbeing or to take advantage of the opportunities that the climatic environment provides (Burton et al., 2000; McClanahan and Cinner, 2012). Nevertheless, it is important for SIDS to recognize and act on opportunities to develop socioeconomically while ensuring environmental sustainability and adaptation strategies for building resilience in the face of climate change (UNCTAD, 2014). It is broadly agreed that more focus needs to be placed on adaptation research and frameworks to assist vulnerable societies undergoing this paradigm shift to identify ways of reducing the risks of climate-related hazards and to take advantage of opportunities that come with environmental changes (Burton et al., 2002). Schipper (2007) posits that adaptation requires mainstreaming into development processes to reduce vulnerability directly rather than a reactive response to the observed impacts and experiences of climate change in a specific country.

Adaptation also requires processes in natural systems to adjust to actual climate and its impacts in order for the ecosystem to take advantage of the new climate (Klein et al., 2014; McClanahan and Cinner, 2012). This includes the shifting of geographical ranges and opportunistic species. The adaptation process can be facilitated through vulnerability reduction approaches especially within the context of development (Schipper, 2007). Pelling (2014) identified three pathways in adaptation development; these include,

- i.resilience – maintaining the status quo,
- ii.transition – incremental change, and
- iii.transformation – radical change

These distinctions have been highlighted previously by Pelling (2011) of which these pathways were closely aligned with the concept of the "4 Rs" (resistance, resilience, response, and realignment) within the conservation and natural resource management domain (Hansen



and Hoffman, 2011; Moser and Boykoff, 2013). There is no one pathway that necessarily leads to 'progressive' or 'more equitable' and 'efficient outcomes' than any of the others in this new paradigm of development (Pelling, 2014). In fact, the evaluation of pathways and subsequent outcomes will be a function of context and the viewpoint of individual actors in response to the same climate change associated pressure (Pelling, 2014). However, from the decision-making standpoint, according to (Moser and Boykoff, 2013) there are two primary adaptation strategies employed from an entity and from collective action. Firstly, entities such as individuals, firms, and organizations that may independently engage in adaptation actions and initiatives, thus utilizing the resources and alternatives within their reach (Eisenack and Stecker, 2012; Moser and Boykoff, 2013). This approach is inherently constrained by individual capacities and limitations (Moser and Boykoff, 2013). Secondly, collective action can be employed to alter the spectrum of available adaptation options and distribute the responsibility for adaptive responses or residual climate change impacts. This collective approach to adaptation entails coordinated endeavors across multiple scales, encompassing local, national, and international levels, as well as intermediary levels situated between these scales (Moser and Boykoff, 2013).

Besides pathways, adaptation responses take many different forms and occur via a variety of processes. This has been identified as 'autonomous' and 'planned' adaptation (Moser and Boykoff, 2013). Schipper et al. (2014) highlights that IPCC recognizes adaptation in this way as well. Planned adaptation involves proactive measures driven by deliberate policy decisions to anticipate and address anticipated climate change impacts, aiming to enhance resilience and minimize negative impacts on communities, ecosystems, and economies (Fedele et al., 2019). Although these planned adaptation efforts are in its early stages, Moser and Boykoff (2013) highlighted some key barriers in evaluating these planned adaptation initiatives such as undefined goals, criteria, and baselines, alongside difficulties in establishing causality and conducting rigorous comparisons which relate to limited resources available for comprehensive evaluations from various stakeholders' perspectives. This is the opposite to autonomous adaptation which involves actions taken in response to environmental changes without deliberate policy decisions, but rather emerge as responses to environmental changes, market forces, or other external factors (Adger et al., 2009). The autonomous nature of adaptation efforts derives from individuals, communities, or organizations who independently respond to observed or anticipated impacts of climate change based on their own resources, knowledge, and priorities (Adger et al., 2009). Smit et al. (2000) describes often refers to this type of adaptation as spontaneous, natural, passive, or automatic 'adaptations which have been widely accepted as a concept; however, unmanaged biophysical systems tend to be limited to autonomous adaptation. Mostly often, this type of adaptation is undertaken by climate-affected communities for sustaining their livelihood activities. For example, in environmental impact assessments, it primarily focuses on autonomous adaptation, while adaptation evaluations are concerned with intentionally planned adaptive policies and measures (GOB, 2014).

In this regard of responses to climate adaptation, Biswas and Rahman (2023) provided a comprehensive overview of response strategies to climate change, categorizing adaptation efforts into coping mechanisms, incremental adaptation, and transformative adaptation. Coping strategies involve resisting climate change impacts to maintain the affected social-ecological system's business-as-usual functioning without altering its characteristics, often due to limited resources or recognition of the need for change (Hossain, 2005). Examples include replanting damaged crops or seeking alternative food sources after extreme weather events (Adato and Meinzen-Dick, 2003). Moreover, incremental adaptation involves making minor adjustments to build adaptation strategies to cope with climate change impacts such as resilience such as changes in agricultural practices or land management (FAO, 2016). Transformative adaptation aims to address root causes of vulnerability by fundamentally changing systems, characterized by restructuring, innovation, and persistent efforts to shift towards sustainable trajectories (Schipper et al., 2014).

However, there is limited research on the dynamics of adaptation in decision-making processes, including the conditions that facilitate or hinder adaptation, and the influence of non-climatic factors (Klein et al., 2005; Pelling, 2014). Analyzing the on-the-ground conditions is crucial for assessing communities' adaptation strategies and associated risks (Pelling, 2014), which are essential tasks for contemporary studies aiming to advance adaptation theories. Eriksen et al. (2021) has expressed the climate adaptation process as complex and uncertain as poorly planned adaptation strategies can lead to maladaptation, exacerbating vulnerability to climate change rather than mitigating it. Therefore, identifying and addressing the drivers of vulnerability is essential to minimize the risk of maladaptation and ensure effective climate adaptation efforts (Eriksen et al., 2021; Schipper et al., 2014).

Nevertheless, adaptation to climate change involves procedures put in place to adjusting to actual or predicted climate change-related impacts and its consequences with the objective of minimizing hazards or untapping economic beneficial opportunities (Reser and Swim, 2011). Adaptation encompasses a broad range of actions and strategies undertaken by individuals, communities, organizations, and governments in response to climate impacts, including changes in precipitation patterns, temperature increases, and more frequent extreme weather events. Notably, while adaptation strategies are diverse and context-specific, they often share common elements such as the use of traditional knowledge, diversification of livelihoods, and the implementation of technological and management innovations (Galappaththi and Schlingmann, 2023). For instance, in the context of fisheries, adaptation can involve changing fishing locations or incorporating new technologies, whereas in agriculture, it may include crop diversification or the use of irrigation schemes (Chete, 2019). Furthermore, adaptation is reactive and proactive, as seen in the planning and implementation of strategies in anticipation of future climate-related challenges (Wilkins et al., 2021). In summary, climate change adaptation is a multifaceted and dynamic process essential for managing the risks associated with climate change. It is characterized by a variety of approaches tailored to specific environmental, social, and economic contexts and is critical for enhancing adaptation strategies in building resilience and ensuring sustainable livelihoods in the face of a changing climate (Dhungana et al., 2020; Mwendwa and Giliba, 2012; Reser and Swim, 2009).

The IPCC (2022a) describes maladaptation as unintended consequences from planned or autonomous adaptation actions that may lead to an increased risk of climate-related impacts or produce undesirable outcomes that further diminish human welfare or exacerbate environmental issues. Therefore, maladaptation can result in the shifting of vulnerability from one social group or place to another and/or the shifting of risk to future generations and/or to ecosystems and ecosystem services (Ayers and Forsyth, 2009). Maladaptation occurs because of poorly designed and implemented policies to cope with climate change impacts that mostly affect vulnerable areas and communities (IPCC, 2001; Schipper et al., 2020). An example of maladaptation is the establishment of new human settlements in areas where, due to the development of 'weatherproof' roads in areas that are highly exposed to climate change, impact such low lying coastal zones that are vulnerable to sea-level rise (OECD, 2009). This promotes the development in risk prone areas neglecting information on climatic variability and over-reliance on insurance mechanisms due to short-term foresights of investors and politicians (Hirsch and Hampel, 2020). Maladaptation can occur in situations where interventions intended to improve livelihoods or address specific challenges inadvertently lead to negative outcomes for ecosystems or communities (Salgueiro-Otero and Ojea, 2020). One example is the introduction of non-native species (NAS) to enhance fisheries or aquaculture production in coastal areas but instead lead to serious aquatic bio-invasions (Ju et al., 2020). While the initial intention may be to provide economic benefits, these introduced NAS can sometimes become invasive, outcompeting native species for resources or disrupting the balance of ecosystems (Bai and Cheng, 2018). Townhill et al. (2021) provided climate-smart fisheries initiatives as adaptation strategies in the Caribbean SIDS but highlighted maladaptation should precede the implementation of any adaptation measure such as stocking

mariculture species that may carry diseases, reduce the genetic pool, or impoverish the wild environment. Maladaptation must therefore be a serious consideration for decision-makers who will need the best available information to avoid this pitfall (Robinson, 2018).

Therefore, maladaptation to climate change involves actions that inadvertently increase vulnerability or have negative environmental or socioeconomic impacts, despite intending to reduce harm or exploit benefits from climate change (Enríquez-de-Salamanca et al., 2017). It can shift risks between groups, regions, or time frames, and often results from responses that do not account for changing climate conditions, leading to unsustainable solutions (Enríquez-de-Salamanca et al., 2017). The literature indicates that maladaptation frequently arises from inadequate assessments of adaptation measures, where environmental impacts are overlooked owing to a predominant focus on technical, social, and economic factors (Enríquez-de-Salamanca et al., 2017). There is also a tendency to assume that adaptation measures are inherently positive, without evaluating potential negative outcomes (Enríquez-de-Salamanca et al., 2017). This concept highlights the need for comprehensive planning and assessment of adaptation strategies, integrating environmental, social, and economic considerations to avoid unintended negative consequences and ensure genuine benefits (Enríquez-de-Salamanca et al., 2017).

#### 2.2.7 Policy measure/responses

Policy measures are actions taken by government and/or administrative organizational actions that address various hazards, challenges, or opportunities, that require intervention within the legal framework and institutional conventions (Altunyan, 2023). Policy responses include laws, subsidies, quotas, or other measures intended to address public issues such as climate change impacts. In this regard, when it comes to policy-level responses to climate change impacts and its variability, there were various policy-level interventions that have been initiated at international, regional, and local levels to manage these impacts and enhance the strength of vulnerable and marginalized populations (IPCC, 2022c). Strategies are driven by a consensus at the policy level to effectively align stakeholders, prioritize innovation, and tackle public issues. This means that fostering a culture of collective leadership, communication, resource sharing, and democracy within institutions is crucial for effective implementation (Saleh et al., 2021).

Although this thesis doesn't focus on the policy measures that tackle climate change mitigation, it does capture aspects of climate adaptation aspects such as carbon pricing, emission regulations, renewable energy investment, energy efficiency promotion, sustainable land use, low-carbon technology research, international cooperation, public education, adaptation strategies, climate-conscious urban planning, and resilience policies for vulnerable communities and ecosystems (IPCC, 2021). These are essential for mitigating global warming, reducing greenhouse gases, and transitioning to cleaner energy while meeting international climate and sustainability commitments (IPCC, 2023a). The evaluation of policy responses is determined by factors such as impact, execution, expenses, feasibility, and public acceptance, which influence decision-making in public administration (Altunyan, 2023).

### 2.3 Climate change adaptation and livelihoods

Development and climate change is a complex issue that focuses on the relationship between economic growth, environmental sustainability, and social equity (Schipper et al., 2020). Climate change poses significant risks to development, particularly in vulnerable regions, such as disrupting agricultural productivity, water resources, and infrastructure; increasing natural disaster frequency and severity; health risks; and displacement (IPCC, 2014; Res et al., 1998). Scholars debate the balance between adaptation and mitigation, with adaptation

focusing on building strategies for resilience through infrastructure, technology, and social programs and mitigation emphasizing reducing emissions through renewable energy, energy efficiency, and carbon pricing (Klein et al., 2005; Suckall et al., 2014). Climate justice and equity are central to the debate, with global inequality and intergenerational equity being the central issues (Hirsch and Hampel, 2020). Policy and governance play a major role in addressing climate change, and international agreements such as the Paris Agreement foster cooperation and commitment to climate goals (UN, 2015). National policies should integrate climate action into national development plans, considering the economic, social, and environmental dimensions (Kurecic, 2017). Economic models supporting sustainable development include green growth and advocating for environmentally sustainable and socially inclusive economic growth (Sun, 2023). Technological innovation and transfer play a crucial role in combating climate change with new technologies for renewable energy, carbon capture, and sustainable agriculture (Blanco et al., 2022). Incorporating local and indigenous knowledge into climate strategies is essential because traditional practices in sustainable land and resource management empower local communities to develop and implement adaptation strategies tailored to their specific contexts (Dorji et al., 2024). Scholarly debate on development and climate change is multifaceted and involves economic, social, and environmental dimensions (Schipper et al., 2020). While there is a consensus on the need for economic growth to evolve in response to environmental limits, there is also an acknowledgment of the complex social challenges posed by climate change (Rising et al., 2022).

The link between development and climate change is clear and has been stated by several authors addressing the interdisciplinary underlying causes and drivers of vulnerability (Adger et al., 2006; Schipper, 2007). A major issue is the disconnection between the definition of adaptation as an issue of climate change and the policy and institutional frameworks in place that are expected to address it from a sustainable development standpoint (Ayers and Dodman, 2010). Adaptation, especially in the context of vulnerable SIDS, should be viewed as an extension or part of the development agenda and should therefore be viewed as synonymous (Mitchell et al., 2008).

Moreover, unsustainable development is the underlying cause of climate change (Mitchell et al., 2008). Developmental pathways are dependent on how the design and degree to which social systems can determine the states' vulnerability to climate change (Huq et al., 2008). The type of development that is sustainable and can ensure a successful adaptation process is referred to as good adaptation in the context of livelihoods (Schipper, 2007). Good adaptation promotes learning of new skills and acquiring advanced knowledge on how to respond to different climate-related stressors for improved management decisions that can further benefit individual and household asset profiles and by extension support local livelihoods (Pelling, 2011).

### 2.3.1 Development and climate change adaptation

The impacts of climate change are expected to significantly affect regional and national development in all sectors, particularly amongst the world's poorest communities of which studies have linked climate change to development (Adger et al., 2006; OECD, 2009). The existing debate between economists and environmental practitioners regarding the definition of development, has evolved over time and is now perceived as economic progress (average income generated per individual over a period) (Apostolides and Moncada, 2013). From an economic standpoint, development is broadly characterized by 'western culture' and measured by economic data including Gross Domestic Product (GDP) and Gross National Income (GNI). This tangible measure of progress is still broadly used to determine economic growth (increase of GNI or GDP) of a country (Apostolides and Moncada, 2013; Fritz and Koch, 2016). It is important to highlight that the type of development that meets the needs of

the present without compromising the ability of future generations to meet their own needs is referred to as sustainable development (Michalos, 2014; WCED, 1987).

The type of development desired in the world is one that is sustainable. The most modern principles that guide the sustainable development recognizes the three pillars that are interconnected: the economy, society, and the environment (Al-Taai, 2021a). In environmental sustainability, it involves practices which ensure responsible resource consumption and minimizes environmental impact. Economic sustainability involves efficient resources used to generate long-term profits. Lastly, social sustainability, which focuses on maintaining societal well-being and stability over time (Al-Taai, 2021b). The United Kingdom Government established five guiding principles for sustainable development since 2005 as shown in Figure 2.1 below.



*Figure 2.1. Summary of the guiding principles in sustainable development (UK Government, 2005).*

However, there are diverse interpretations of sustainability and there is need for a set of universally applicable core principles to guide sustainable development efforts effectively (Lindsey, 2011). While the Sustainable Development Goals (SDGs) provide a framework for sustainable development efforts globally, they are not universally applicable core principles. The SDGs are a set of 17 goals and 169 targets adopted by the United Nations in 2015 to address various dimensions of sustainable development, including poverty, inequality, climate change, environmental degradation, peace, and justice (Gosling-Goldsmith et al., 2019). While the SDGs serve as a valuable guide for sustainable development efforts, interpretations of sustainability remain diverse and may extend beyond the scope of the SDGs (Ruhana et al., 2024). Additionally, other frameworks, principles, and guidelines may also be used to inform sustainability initiatives in different contexts while contributing to the SDGs.

Sustainable development is underpinned by the impacts of climate change which may become more significant in the future and thus increase the cost of development (Huq et al., 2006). Realizing sustainability means that it also includes profitability that considers all hazards, environmental neutrality to minimize ecological impacts, and social acceptability with transformational experiences (FAO, 2014, p.53). To achieve sustainability, three governance principles are proposed which are accountability, effectiveness and efficiency of government activities, and certainty (FAO, 2014, p.53). For instance, large investments are required to develop infrastructure that is strong and able to withstand the impacts of severe storms and flooding (Adger et al., 2006). This can make adaptation to climate change a costly priority to

include in national development processes and development policies to reduce hazards and exposure of existing systems for livelihoods (Schipper, 2007). According to Ayers and Dodman (2010), there are three types of adaptation that emerge from the link between climate change and the development of communities. These include.

- i. the ‘stand-alone’ adaptation, as presented under the UNFCCC.
- ii. the ‘adaptation plus development’ emerged from development community where development is ‘climate proofed’; and
- iii. the ‘adaptation as development’, where development is the basis for, and in some cases synonymous with, adaptation as observed in the case of using community-based adaptation.

In closing, the implementation of adaptation is dependent upon the capacity and effectiveness of governance and decision-making processes (Apostolides and Moncada, 2013) along with the ability to engage adaptive action from the communities (Reid et al., 2009). Boyd et al. (2009) highlighted the critical issues of adequately financing adaptation for now and in the future through effective mechanisms that promote local ownership and mainstreaming of gender and equity considerations. To approach the climate change challenge, it is recognized that there is a need to explore more integrated approaches to policy and practice (more than fossil fuels and prevailing than the economic-growth models) which would ultimately benefit development agendas at a local, regional and international scale (Boyd et al., 2009). The development of seaweed products and other climate smart innovations represents an opportunity for community and national development with climate change adaptation.

#### 2.3.2 Adaptation in SIDS compared to more developed countries

The global impact of climate change disproportionately affects smaller and least developed nations, especially those located in tropical and sub-tropical regions. Predictions of the long-term impacts of climate change suggest that SIDS will be far more affected by severe impacts compared with more developed countries located in other areas (Kalaidjian and Robinson, 2022). SIDS are therefore on the frontlines of climate change crisis based on their geographical location and socioeconomic characteristics (Kalaidjian and Robinson, 2022). Larger countries are developed states that are generally less vulnerable to climate change impacts compared to the climate zones in developing countries like SIDS (IPCC, 2022b). As a result, SIDS and the developing world are also less resilient and have less capacity to adapt compared to more developed countries that can implement systematic changes and invest in infrastructure and innovations considering climate impacts (Chinowsky et al., 2011). Many SIDS rely on larger countries and the international community for development aid, technical assistance and financial aid for adaptation (DFID, 2010; Remling & Persson, 2015; UNEP, 2021). However, accessing adaptation funds can be challenging and much time is not sufficient to meet their needs. Often the process to apply for climate finances entails a complex application process with many pitfalls due to the lack of capacity within institutions to complete the first phases of climate finance readiness (Kalaidjian and Robinson, 2022). Although larger countries have their own bureaucracy, they have higher economic resilience (Fritz and Koch, 2016) especially in adapting to climate change impacts through public investments for disaster risk reduction and adaptation projects such as river training, embankments, and barrages (A.K. et al., 2016; Chinowsky et al., 2011). SIDS therefore face serious challenges to implement and finance good adaptation and development. As such, the increased knowledge from this thesis will hopefully contribute to the body of work necessary to allow these countries to successfully achieve adaptation goals.

## 2.4 Framework Approach of PhD Thesis

The theoretical and conceptual framework approach in this thesis is the integration of sustainable livelihoods with climate adaptation approaches to provide a robust framework for

assessing and enhancing the sustainability and climate adaptation strategies of seaweed farming in SIDS. This integrated approach considers asset management, local knowledge and participation, ecosystem services, and overall sustainability. Regarding asset management, evaluating how seaweed farmers utilize and manage their assets (natural, human, social, physical, financial and cultural) to adapt to climate change (DFID, 2010; UNDP, 2017). As for local knowledge and participation, this ensures that adaptation strategies are informed by local knowledge and actively involve community members (Schipper et al., 2014). Moreover, recognizing the role of coastal ecosystems in providing essential services that support seaweed farming and enhance climate resilience (CBD, 2014; Reid and Alam, 2014). To ensure over habitats and sustainability of livelihood activity, promoting sustainable farming practices that maintain biodiversity, protect marine habitats, and support the overall health of marine ecosystems (Chambers and Conway, 1991; Singh, 2024).

Climate change adaptation approaches at a community-level include both community-based adaptation (CbA) and ecosystem-based adaptation (EbA). CbA is closely associated with rural and vulnerable communities striving to improve their livelihood against the imminent and long-term threat of climate change (A.K. et al., 2016). Like CbA, EbA considers the use of biodiversity and ecosystem services as part of an overall adaptation strategy in ensuring that the environment remains intact to help people to adapt to the adverse impacts of climate change (Giot et al., 2012). Nevertheless, the integration of approaches to CbA and EbA in the context of SLF has a lot of concepts in common to deliver an ever-elusive win-win solution for conservation, development and adaptation practitioners and planners working together with affected communities that are mostly impacted by climate change and safeguarding their livelihoods, homes and environment (Figure 2.2.). EbA has gained recognition for the way it prioritizes delivery of ecosystems services, primarily for human benefits, and therefore, ecosystem management has an essential role to play in successful people-centered adaptation (Giot et al., 2012). EbA is built on the principles of ecosystem approach and is effectively adopted through empowerment of stakeholders who benefit from provisioning of ecosystem services including ecosystem regulating, supporting and cultural services.

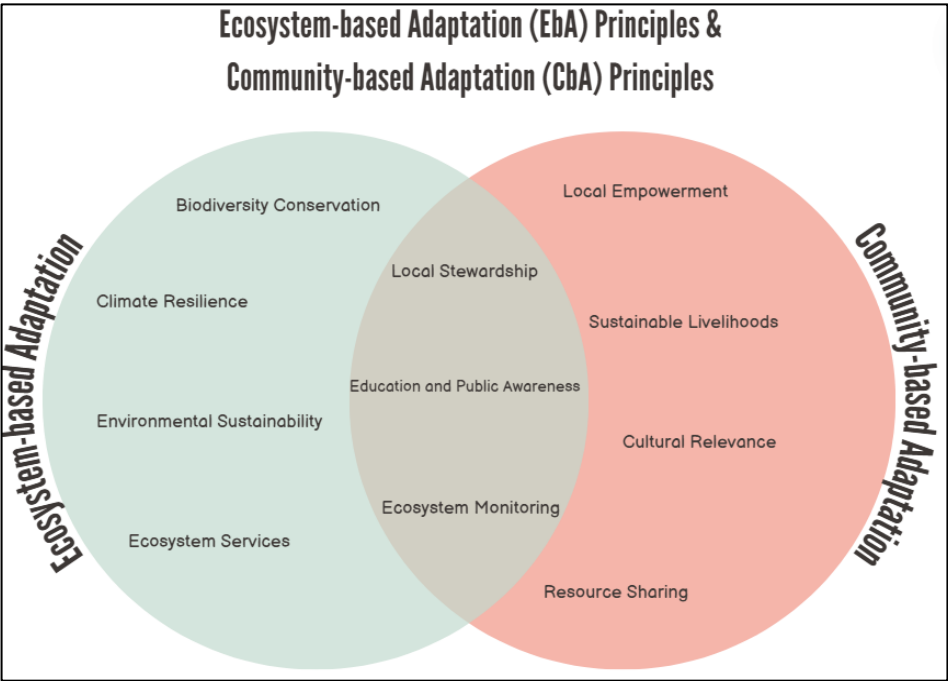


Figure 2.2. A visualization of Ecosystem-based Adaptation (EbA) and Community-based Adaptation (CbA) Principles and their overlap (Author’s own elaboration).

The EbA adopted twelve principles from the ecosystem approach, guiding the implementation of the Convention on Biological Diversity, promoting conservation and sustainable use of

natural resources, including long-term objectives, decentralization, economic gains, and balancing conservation and use (Reid et al., 2018). CbA, informed by human rights principles, is a participatory, process-oriented approach to development and natural resource management (Forsyth, 2013). It prioritizes ecosystem goods and services, creating a sustainability plan for community members to access natural resources (Nill et al., 2016).

Additionally, with increasing awareness of the blue economy framework in SIDS, it has been used to promote the sustainable use of ocean resources for economic growth, improved livelihoods, and job creation while preserving the health of marine ecosystems (Commonwealth Secretariat, 2021).

Seaweed farming fits well within the blue economy as it is a low-impact, high-yield aquaculture practice that supports economic diversification and resilience in coastal communities (Makame et al., 2021). Integrating SLF, CbA, and EbA provides a comprehensive approach to addressing the sustainability and climate resilience of seaweed farming. The concept of the Blue Economy emphasizes the sustainable use of ocean resources for economic growth, improved livelihoods, and job creation, while preserving the health of ocean ecosystems (UNCTAD, 2024). Seaweed farming, as part of the Blue Economy, offers significant potential for sustainable development in SIDS by providing economic opportunities and enhancing food security (Katsaliaki et al., 2022). By integrating SLF, CbA, and EbA, seaweed farming can contribute to achieving the goals of the Blue Economy, ensuring that economic activities are environmentally sustainable and socially inclusive (WBG and UNDESA, 2017).

If EbA is integrated with other existing mechanisms and approaches for climate change adaptation efforts while enhancing platforms for information sharing communities, locals can understand what is happening in the environment in simple terms and presentation and can adopt planned adaptation strategies to combat the impacts of climate change especially in the Caribbean SIDS (Mercer et al., 2012). Therefore, it would be ideal for this research study to integrate the approach of CbA and EbA with their interdependent roles of principles that are human rights-based and environmental sound management. This along with community-based climate screening toolkit in the context of sustainable nature-based livelihoods would lead to successfully responding to climate variability and long-term adaptation strategies that can lead to resource efficiency, environment equity and desired outcomes at farm-level. This type of conceptual framework with EbA and CbA can be applicable to all types and levels of people-centered adaptation that also seeks to empower local communities through capacity building in managing ecosystems and nature-based livelihoods under resilient governance arrangements that can provide the ecosystem services on which they depend (A.K. et al., 2016; Girot et al., 2012; Reed et al., 2013a). The theoretical framework integrating SLF, CbA, and EbA provided a comprehensive approach to understanding and enhancing the sustainability and climate adaptation strategies employed in seaweed farming in SIDS. This framework supports the development of adaptive strategies that are community-led, ecologically sustainable, and aligned with the principles of the Blue Economy. The success of these strategies depends on effective governance, community participation, and the integration of local and scientific knowledge in the adaptation process (Apostolides and Moncada, 2013; Ayers and Forsyth, 2009).

#### 2.4.1 Importance of mixed methods frameworks for community-level and policy-level climate adaptation strategies operational in local context

Climate change is happening on a global scale, but the recent development of toolkits has allowed researchers to integrate local perspectives into community-level projects planning in further understanding the link between climate-related risks, people's livelihoods and project activities at a local scale (Robledo et al., 2012). One such toolkit specially developed to understand how local livelihoods have been affected by climate change is the Community-based Risk Screening Tool-Adaptation and Livelihoods (CRiSTAL) toolkit (IISD, 2012) but



used as a hazard screening exercise in this study. This toolkit is a type of climate change vulnerability assessment that can identify the main hazards that a community faces and strengthen the ways in which locals respond to adjust, moderate or take advantage of climate-induced changes in their local setting. It must be highlighted that the CRiSTAL toolkit is built on the Sustainable Livelihoods Framework (SLF) which has been found very instrumental when it comes to sustainable livelihood projects. SLF has increased community resilience to a range of threats that also captures climate change by identifying short and long-term adaptation strategies that not only assist community members in diversifying their livelihoods and income streams but also secures the natural resource base and reduces exposure to climate hazards (Elasha et al., 2005; Javeed, 2023). The SLF developed by Department for International Development (DFID) of United Kingdom emphasizes to focus on people, their assets and their activities, rather than all the economic sectors and their performances of a country of which this manner is a conventional point of entry to policy for a people of specific areas and regions (DFID, 2010). Even though the livelihoods approach was developed disjointed to CbA and/or EbA (these two concepts are relatively new), SLF, being a mature framework in development, is offering a more comprehensive way of understanding how different people are in different places (Scoones, 1998, 2009). The literature further describes SLF in chapter 3.

Particularly, CRiSTAL aims to facilitate positive contribution to local livelihoods by improving the knowledge and skills capacities of individuals to collectively improve the communities' long-term adaptation capacities to increase their resilience and reduce vulnerability to climate change impacts. According to Robledo et al. (2012), the toolkit provides a systematic process information from the participants is gathered and organized into; (i) characterization of local climate and livelihood along with climate hazards; (ii) identification of how people cope and the resources needed to cope with climate- and non-climate stressors; (iii) enable assessment of livelihood project impact on community-level adaptive capacity (sustainable management practices of resources use can be devised); and (iv) assist participants in adjustments to improve impact of the livelihood project on adaptive capacity. In total, recommendations can be prepared to address local priorities and needs, institutional capacity, and relevant policy frameworks. Within this context, CRiSTAL tool allows synthesizing information on climate and livelihoods which will be ideal for development recommendation for planning and managing livelihood projects for adaptation such as seaweed farming livelihoods (Dovie and Pabi, 2023). CRiSTAL toolkit has been applied across the world in investigating sustainable livelihoods in rural communities such as in Africa and South America (Obonyo et al., 2013; Sarstún, 2011; Silvestre, 2010).

#### 2.4.2 Policy analysis toolkit

The PESTEL policy analysis tool, as described by Kambey et al. (2021a), is a strategic framework used to evaluate external factors that can impact policy implementation in a specific industry. PESTEL stands for Political, Economic, Social, Technological, Environmental, and Legal factors. This tool helps in systematically analyzing these external factors to understand their influence on policy outcomes (Yüksel, 2012).

In this thesis, the following factors in PESTEL are further elaborated. Political factors encompass government policies, political stability, and regulations, significantly impacting policy implementation in relation to safeguarding the seaweed aquaculture in the case study country. For instance, this is important to analyze because there may be regulatory changes or political instability that can either aid or obstruct the adoption of biosecurity measures within the mariculture industry. Economic factors, such as economic growth, exchange rates, inflation, and stability, affect the financial aspects of policy implementation. In seaweed aquaculture, economic support is crucial for farmers to adopt biosecurity measures, and a lack of resources can hinder necessary practices. Social factors include demographics and cultural

influences on policy implementation. Education levels, cultural attitudes towards farming, and community support are vital in seaweed aquaculture. Kambey et al. (2020) noted the disconnect between policy and practice due to varying biosecurity knowledge among farmers and extension officers. Technological factors involve the availability and adoption of new technologies. Modern farming techniques and equipment can improve biosecurity in seaweed aquaculture, but their adoption depends on available resources and training. Environmental factors pertain to ecological aspects like climate change, weather, and environmental regulations, directly impacting seaweed farming and pathogen spread. Effective biosecurity policies must address these environmental challenges. Legal factors include laws and regulations governing industry. The legal framework established by the government heavily influences the implementation of biosecurity policies in seaweed aquaculture. Clear, enforceable regulations are crucial for successful biosecurity measures.

The PESTEL analysis tool provides a comprehensive framework to evaluate the external factors affecting the implementation of biosecurity policies in the seaweed aquaculture industry. By analyzing these factors, stakeholders can identify potential challenges and opportunities to enhance policy effectiveness and sustainability (Kambey et al., 2021b).

## 2.5 Summary and Research Gap

Natural and human systems have learnt to cope with changes in climatic conditions throughout history, however there is increasing evidence that climate change is impacting more dangerously and severely every part of the society and the environment, with climate change adaptation gaining increasing attention within scholarly and policy community alike, and across regions (Girod et al., 2012; Klöck and Nunn, 2019; Templeton et al., 2022).

The sustainability term has evolved over time, reflecting shifts in focus from ecological adaptation to sustainable growth influenced by global economic dynamics (Ruggerio, 2021). Despite its broad usage and challenges in defining it precisely, sustainable development fundamentally seeks to meet the needs of the present without compromising the ability of future generations to meet their own needs, as famously stated in the Brundtland Report (Srivastava, 2012). Interestingly, the term's popularity and frequent use have not necessarily translated into a clear and consistent understanding among practitioners, as evidenced by the varied interpretations of Malaysian local authorities (Joseph, 2011). Moreover, the concept has been extended to specific sectors, such as public transport, where sustainability principles are redefined to foster development that aligns with environmental and societal goals (Patlins, 2017). Sustainable development is a dynamic and evolving concept that strives for the harmonious integration of economic growth, social inclusion, and environmental protection. Despite the lack of a universally accepted definition, its core principle is to safeguard the planet's resources for future generations, while addressing current societal needs. Ongoing discourse and research continue to refine its meaning and application across different contexts and industries (Ruggerio, 2021; Srivastava, 2012).

New developments are now more interested in paving the road towards sustainability through planned adaptation strategies, rather than only waiting for autonomous forms of adaptation, to achieve transformational outcomes (CCCCC, 2012; Pelling, 2014). However, there is yet a scarcity of research in the field of sustainable livelihoods and perceptions at community-level about livelihoods that are categorized as 'sustainable' and can be used as adaptation strategies in the face of shocks, especially climate-induced shocks (Schipper et al., 2014). This includes scarcity of studies in the use of CbA and EbA strategies, especially in vulnerable regions such as SIDS. Furthermore, even when these climate adaptation initiatives exist at the local level, there is still some confusion on how the effectiveness of CbA and EbA as adaptation tools were applied and measured. Based on the literature, there have been little to no studies that focused on identifying the integration of CbA and EbA in SLF using CRiSTAL toolkit in a SIDS of the Caribbean region. The few studies that look at the use of these two

approaches have limited analysis on the synergies when CbA and EbA were integrated to determine the sustainability of livelihoods, and the role they both played in climate change adaptation strategies. This research intends to contribute to the literature that investigates ways on how EbA can be integrated into livelihood projects (Mercer et al., 2012), and how EbA actions can impact marginalized people in addressing climate change adaptation in an effective manner (Woroniecki et al., 2019). Moreover, adaptation studies are conceptualized and operationalized in different ways depending on the capacity of researchers and institutions involved which may lead to diverging outcomes such as data and reporting that is subject to bias (Klöck and Nunn, 2019). Consequently, this leads to ineffectiveness and unsustainability of associated interventions that may be manifested from this, as well as from the large numbers of “failed” adaptation initiatives (Klöck and Nunn, 2019).

As the knowledge gaps of adaptation persist in agreeing on definitions and understanding of a broad range of adaptation strategies that only address certain climate change impacts and certain types of adaptation (Klöck & Nunn, 2019; Mercer et al., 2012). This is dependent on geographical and temporal scales where there is capacity for scientific research, long-term monitoring and evaluation. There is very limited research conducted on climate change adaptation in SIDS in parallel with limited understanding of the long-term effectiveness and sustainability of adaptation responses. CbA and EbA solutions to climate change are suited to the environmental, social, economic, political, and cultural context but require standardized ways of implementation and reporting to capture valuable lessons to be learnt from experiences. The use of CbA and EbA can be further integrated into the SLF to close the knowledge gap of nature-based livelihoods like in the sector of seaweed mariculture which has great potential to be used effectively as a climate change adaptations livelihoods for sustainable development in the ocean space. The use of the existing tool for livelihoods and adaptation, such as the CRiSTAL toolkit, has been shown to be very effective in operationalizing all these climate adaptation initiatives into the SLF. However, there is need to integrate both EbA and CbA into SLF to further investigate and assess coping mechanisms of rural livelihoods at a local level with the focus being farmers’ perspectives.

With communities leading their own adaptation agendas, numerous aspects of the optimization points would probably be autonomously incorporated: the wider vulnerability context and its local processes will be accounted for; local context will be underpinned, which means important priorities, resources and knowledge will be more appropriately used; and a stronger sense of local approval and ownership will be fostered. These factors, in turn, support sustainability (as the key area requiring improvement) as initiatives, being rooted in community aspirations and local context, will be self-sufficient over time. Related to this, a community-led approach may be better ‘future-proofed’ through the integration of local resources and local knowledge (for example, in terms of observed trends in local processes) that were often overlooked.

### **3. SEAWEED MARICUTLURE LIVELIHOOD AS A CLIMATE CHANGE ADAPTATION AND BLUE ECONOMY STRATEGY**

The ocean forms an integral part of the culture, food and livelihoods of the inhabitants of Small Island Developing States (SIDS), especially those involved in fishing, tourism and farming communities along the coast, who are increasingly faced threats from climate change (UNCTAD, 2014). SIDS have withstood the pressures from weather variability and climate change impacts and continue to be challenged in traditional and contemporary ways of life (Robinson, 2020). The ocean food production sector, specifically seaweed mariculture, has been identified as one of the pillars in new economic growth strategies, such as the blue economy (UNCTAD, 2024). The Blue Economy aims to promote sustainable economic growth and development through ocean-based industries, such as aquaculture, and incorporates climate change action strategies to build capacity among people for sustaining a healthy ocean environment for long-term food production and income generation (ComSec, 2021a; Hughes et al., 2016).

Addressing multiple pressures in development, sustainable livelihoods is complex therefore it is important to identify the factors that hinder the process of achieving sustainability of livelihoods for communities directly dependent on natural resources within Caribbean SIDS (Räsänen et al., 2016; Reid, 2016). These efforts in sustainable management of natural resources can lead to the betterment of communities through empowering marginalized groups to develop sustainable incomes to meet both challenges and opportunities (Ruggerio, 2021). For instance, in SIDS, communities create their enabling environment for food production to compete with a global market which requires pioneering social, economic and political aspects that bring about cultural change and indigenous knowledge of the environment that develops more permanency in a society (Maslia et al., 2024; Zulfachri et al., 2017). In parallel, locals can benefit from technological advances to improve value chains of rural commodities which are often associated with regional and global trends in market networks, trade and globalization in a changing environment (Kusumaningrum et al., 2021). Even though these expanding worldviews may seem far reaching, they increasingly influence local economies and policies by how people make a living. In further understanding how livelihoods evolve in SIDS, it is important to assess all aspects of what supports an individual or household to continue doing the livelihood they are doing including these external shocks that are non-climate related (Birkmann et al., 2023; Chambers and Conway, 1991; Robinson, 2020). Therefore, understanding the different interactions and their varying influencing factors that impact a community livelihood development can begin to explain some of the challenges and barriers faced by locals such as farmers (Pandey et al., 2017).

SIDS can build new sustainable directions for their local economies within the capacity and resources available in their territories, and among their population, to increase benefits of nature-based livelihoods and sustainable harvested produced crops such as seaweed (Colls et al., 2009; Ortiz-Carabantes, 2020). The sustainable and climate-friendly seaweed mariculture development continues to gain interest and investment within SIDS, as it has demonstrated enhanced socio-economic and ecological benefits over the past decade (Rebours et al., 2014b). This has been demonstrated through the various work conducted by non-government organizations (NGOs), specifically environmental NGO (E-NGOs) and civil society organizations (CSOs) who have been key institutional players at the level of the community in mobilizing resources and expertise in marine spatial planning (MSP) and mariculture development processes to assist in expediting the process for mariculture site selection near or around marine protected areas (MPAs) (Gutierrez-Corley et al., 2023). Using the theoretical conceptual underpinnings of Sustainable Livelihoods Framework (SLF), community-based adaptation (CbA) and ecosystem-based adaptation (EbA), takes into

account use of different factors for assessing livelihoods including indigenous and local knowledge through mapping exercises in further understanding these knowledge systems and realizing the potential of social capital for climate change adaptation in making climate resilient ocean-based industries (Girod et al., 2012; Mercer et al., 2012). Subsequently, local traditions and local knowledge in knowing how to get around fisheries, aquaculture and conservation are complemented with the new sustainable developments and advancements of innovation and science.

This chapter defines and discusses the key concepts and definitions around the blue economy, along with reviewing literature on the status of seaweed mariculture livelihoods as a specific climate change adaptation strategy with particular focus on identifying the role that seaweed aquaculture plays in the blue economy of SIDS, especially in the face of climate change and other associated challenges. Moreover, it conducts a systematic literature review investigating the role of seaweed farmers in promoting climate change adaptation in the context of SIDS.

### 3.1 Nexus Between Seaweed Mariculture, Blue Economy and Adaptation

Seaweed mariculture is promoted as both a mitigation and adaptation strategy for addressing climate change (García-Poza et al., 2020; Sudarwati et al., 2020b; UNEP, 2023b). Mitigation is a short-term intervention to reduce the negative impacts of emissions and enhance the sinks of greenhouse gasses (Bhuyan et al., 2021). Adaptation addresses the long-term responses to actual or expected climatic stimuli and their impacts facilitating adjustment of humans in the natural systems and reducing harm or exploitation of beneficial opportunities (IPCC, 2001). Documented evidence support how seaweed acts as a natural carbon sink in the ocean making it an ideal mitigation strategy but when seaweed is farmed as a livelihood while it acts as an adaptation strategy in enduring day-to-day activities with perceived improved coping mechanisms to face expected climate changes in trends, intensity and frequency of severe events at a local level (Amri and Arifin, 2016; Andriesse and Lee, 2017; Yong et al., 2022).

There are important synergies in blue economy between local seaweed mariculture livelihoods as an adaptation strategy but there are myriads of questions as pre-requisites for the industry to kick off within the perspective of sustainable development and the welfare of communities and protection of biodiversity in a changing environment. The human-centric approach to seaweed mariculture considers environmental sustenance in the context of adaptation and offers a solution to drive a more efficient, inclusive, responsive and comprehensive climate policy for ocean-based industries (van der Velden, 2022b). For developing countries like SIDS, these co-benefits with other goals of sustainable development have been recommended to be mainstreamed into national strategies that aim to integrate a circular economy for gaining blue carbon credit and incorporating adaptation aspects into sustainable development aspirations (Cai et al., 2021). The potential blue carbon from seaweed farms has been highlighted by many scholars (Duarte et al., 2022) and advocated for seaweed farmers to be economically compensated and hopefully improve income of this livelihood especially in the case that optimized practices are implemented to maximize climate benefits (Froehlich et al., 2019b).

Specifically, seaweed mariculture supports carbon capture ecosystems including sea grasses, mangroves and saltmarshes that could be a significant benefit of seaweed farming in the blue economy and potentially making a significant contribution to carbon offsets initiatives (Krause-Jensen et al., 2016; Hasselström et al., 2018). Seaweed has potential contributions to adaptation including to shoreline protection through absorption of wave energy. In the ocean, seaweed can reduce ocean acidification impacts on calcifiers by elevating daytime pH and lessening the impacts of reduced oxygen absorption at higher temperatures through oxygen release (Duarte et al., 2017). With blue economy as the championing branch of economics, there are synergies between the livelihood and ecosystem functionality of seaweed as a crop for human use and a marine species for provision of environmental services. However, studies

of this type that takes a holistic ecosystem services assessment for community-led seaweed cultivation are almost non-existent in the scientific literature apart from Hasselström et al. (2018). Therefore, investigating the true synergies between seaweed mariculture and climate adaptation in the context of blue economy requires a comprehensive analysis of community- and ecosystem-based adaptation strategies to capture this information using the SLF and participatory rural appraisals (PRAs) techniques. As the impacts of climate change are intensifying in certain parts of SIDS, it is important to assess perceived adaptation strategies practices in seaweed farming communities in the context of newly emerging blue carbon economy and revolutionary tools to combat climate change in the long-term.

Seaweed farms, as viable food production systems in the sea, play a crucial role in bioeconomy as a Biotrade commodity, linking marine livelihoods with biodiversity-based trade (Yong et al., 2022). However, it requires further investigation into how efficiently seaweed farmers are achieving this while ensuring long-term ecological benefits of their regenerative ocean practices (UNCTAD, 2024). The United Nations Conference on Trade and Development (UNCTAD) has been working towards promoting trade and investment in biodiversity-based products and services, as well as sustainable development through the Biotrade initiative (UNCTAD, 2023). UNCTAD (2023) defines Biotrade as ethical commercialization of biodiversity resources, guided by principles of sustainable management, conservation, fair trade, and community rights (UNCTAD, 2023, p.3-5). Many countries, including Belize, have already adopted Biotrade policies in an effort to improve trade and investment of biodiversity-based products and services, and these policies have been implemented with universally accepted expectations of commodities' Minimum Eligibility Requirements (MER) and Principles and Criteria (P&C) for businesses, governments, and civil society (UNCTAD, 2020b). Seaweed mariculture supports wider ecosystem functions, from carbon capture ecosystems (seagrasses, mangroves, saltmarshes) to shoreline protection, pH buffering, and oxygen cycling (Krause-Jensen et al., 2016; Duarte et al., 2017). However, holistic ecosystem services assessments of community-led seaweed farming remain scarce (Hasselström et al., 2018). Given the intensifying climate impacts across SIDS, a comprehensive analysis of both community- and ecosystem-based adaptation strategies is needed, using approaches such as SLF and PRAs.

### 3.1.1 Characterization of seaweed mariculture globally

Seaweed mariculture involves the cultivation of three primary types of marine macroalgae, brown (*Phaeophyta*), green (*Chlorophyta*), and red (*Rhodophyta*), which are autotrophic macroalgae found in both fresh and marine water bodies and classified under the Protista Kingdom (FAO, 2021; Lin, 2005). Globally, seaweed has become a cornerstone of aquaculture due to its sustainability and environmental benefits. It is fast-growing, requires relatively little input, and occupies no land space, making it an attractive option for sustainable farming practices (Cai et al., 2021; UNCTAD and FAO, 2021).

The global appeal of seaweed is largely due to its multidimensional benefits, which have positioned it as a leader in aquaculture (Cai et al., 2021). Seaweed cultivation is conducted at both small and large scales using environmentally friendly methods, helping to mitigate the unsustainable harvesting of wild seaweed stocks (van Oirschot et al., 2017). One of the most significant environmental contributions of seaweed is its role in combating ocean acidification by acting as a carbon dioxide sink. It is estimated that seaweed sequester approximately 200 million tonnes of CO<sub>2</sub> each year, with the potential to store this carbon in the deep ocean for thousands of years, offering a pathway for climate change mitigation (Duarte et al., 2017, 2022). However, the current scale of seaweed cultivation, both farmed and wild, remains insufficient to support a global role in climate mitigation (Krause-Jensen and Duarte, 2016).

Beyond carbon sequestration, seaweed contributes to marine biodiversity by providing habitats for finfish and shellfish, thus enhancing habitat complexity and supporting marine

diversity (Cabral et al., 2016; Hasselström et al., 2018). Seaweed's ability to absorb nutrients such as nitrogen and phosphorus from seawater helps reduce eutrophication, prevent harmful algal blooms, and offers natural bioremediation services (Kraan, 2020). These properties also make seaweed valuable for wastewater treatment, where it can absorb pollutants, including heavy metals, from the environment (Farghali et al., 2023).

Seaweed can serve as a biological indicator to measure the extent of contamination along coastlines, providing critical data for environmental monitoring (Morrison et al., 2008). However, it is important to recognize that seaweed grown for environmental purposes should not be harvested for human or animal consumption (Duarte et al., 2017; FAO, 2022a). Despite the many positive impacts of seaweed aquaculture, some concerns have been raised, particularly regarding the aesthetic and cultural impacts of seaweed farms on local communities. For instance, in Sweden, seaweed cultivation has been noted to have minimal environmental impacts but can affect recreational values and the cultural landscape (Hasselström et al., 2018).

### 3.1.2 Overview of blue economy

There is not a universal definition for the blue economy as it varies within geographic regions and developmental contexts, nonetheless it is generally aimed at achieving social, economic and ecological objectives with the development of ocean and marine resources at its center (Smith-Godfrey, 2016). It often refers to the sustainable development of ocean-based industries and resources that, among others, allow for opportunities for sustainable, clean, and equitable growth in traditional and emerging ocean-related sectors (WB and UNDESA, 2017). Blue Economy has become a widely used term and is usually defined according to the priorities of a country's economy as well as cultural and societal needs (Smith-Godfrey, 2016). This developmental approach has been adopted as a global strategy by many islands, including SIDS, and coastal nations as a mechanism to realize sustainable growth and to develop local communities (Roberts, 2015). The blue economy paradigm also advances other modern developmental principles such as the circular economy and prioritizes the health of marine ecosystems and coastal resources for the sustainable development of aquaculture, fisheries, tourism, maritime transport, marine biotechnology, seabed mining, and renewable energy sectors (WBG and UNDESA, 2017).

The concept of the "Blue Economy" (BE) emerged from the Rio+20 United Nations Conference on Sustainable Development (UNCSD) in 2012. It is grounded in the Institutional Framework for Sustainable Development and the "Green Economy" idea, which were outlined in "The Future We Want" (UN Sustainable Development Knowledge Platform, 2013). The "Blue Economy" has been described by various sources, with the World Bank characterizing it as the sustainable exploitation of ocean resources for economic growth, enhanced livelihoods, and employment opportunities, while preserving the health of ocean ecosystems (WB, 2022). On the other hand, the European Commission defines it as embracing all economic activities related to oceans, seas, and coasts (UNCTAD, 2024). The Center for the Blue Economy further categorizes it into three interconnected meanings: the overall contribution of the oceans to economies, the need to address the environmental and ecological sustainability of the oceans, and the ocean economy as a growth opportunity for both developed and developing nations (Smith-Godfrey, 2016).

BE recognizes and respects the ecological limits which determine the safe operating space for economic activities and the minimum social standards that a fair economic model should address and is a unique reflection of a country's economic development needs and its natural and human wealth (Cassin, 2021). The Blue Economy is an evolving paradigm with a myriad of definitions (Cassin, 2021), but in which the maintenance of coastal, environmental and ecosystems health, and nature-based solutions (NbS) are indispensable requirements to achieve blue growth and a robust ocean economy (Bridgewater, 2018; Hughes, 2021). Marine and coastal ecosystems are the source of natural capital needed for the development of a series

of blue industries and economic sectors that offer a diversity of services which make up the ocean economy (O'Hogain and McCarton, 2018; Patil et al., 2016).

This shift towards environmentally sound investments in the blue economy is referred to as 'blue growth' and 'blue revolution' (Choi, 2017). The blue growth strategy targets marine resource efficiency, exploring carbon neutral opportunities and promoting socially inclusive measures to stimulate economic stability, facilitating job creation, providing a clean and healthy environment that helps conserve resources (EIU, 2015). The Food and Agriculture Organization (FAO) developed four main components for development as part of the blue growth initiative that is relevant to SIDS (FAO, 2020) including.

- marine coastal and inland capture fisheries.
- sustainable aquaculture.
- sustainable livelihoods and food systems; and
- sustainable economic growth from ecosystem services

The development of seaweed mariculture and product development covers all four components and represents a great opportunity for developing economies and resilience against short and long term environmental and economic shocks. These components also can help to redesign the ocean and natural resources governance framework through which investments and sustainable utilization towards blue growth can be achieved (Choi, 2017). However, Hughes (2021) pointed out that aquaculture activities, if planned and operated within specific criteria, can qualify as NbS within the BE. Additionally, blue growth can be further facilitated through proactive collaborations and partnerships between government and private sectors involved in areas operating in the open sea including ports and shipping, offshore oil and mining, offshore renewable energy, tourism, fisheries and aquaculture (EIU, 2015; FAO, 2017a).

#### 3.1.2.1 Blue economy and SIDS

Many SIDS throughout the tropical and subtropical Pacific Ocean, Indian Ocean and the Caribbean are rich in ocean space, marine resources and biodiversity (ComSec, 2021). The Blue Economy and Blue Growth concepts present several opportunities to develop marine-based goods and services in the areas of tourism, fisheries, aquaculture livelihoods, and others that support food security, livelihoods and general sustainable development (ComSec, 2022). In the Caribbean, the blue economy is focused on contributing towards the conservation and/or the enhancement of natural capital initiatives that prioritize marine spatial planning and marine protection (e.g. the 30X30 target movement) that impulses other economic activities based on the ocean (Roberts, 2015). Blue economy strategies safeguard socioeconomic benefits by ensuring that sustainable development goals are embedded into policies and actions that contribute towards food security, livelihood opportunities, income, poverty alleviation, health, safety, equity, and political stability (Ahmed and Thompson, 2019). For example, in the Caribbean SIDS, they have jurisdiction over significant ocean areas which in many cases, far exceed the land area of the countries themselves (Roberts, 2015). This can be observed with comparing the exclusive economic zone (EEZ) to land mass such as in the case of St Vincent and the Grenadines that have an estimate of 13,900 square miles EEZ which is over 90 times its actual land area and the same applies to other SIDS that are surrounded by ocean. This is an untapped resource of which the blue economy is the main policy driver of not only ocean-based economic and trade activities but also drives the expansion of marine protected areas (MPAs) for conservation and sustainable use and management of marine biodiversity.

The blue economy also supports sustainable livelihoods and food systems, like mariculture, for artisanal, small-scale fisheries and aquaculture operations in rural island and coastal communities. In most cases, these operations are unable to provide full-time employment but aid in diversifying the income earned by households (Agar et al., 2019; Msuya, 2011). Mariculture can be a major part of this income diversification offering the opportunity to



develop wholesome and high-quality local products for the domestic and international markets to help reduce pressure on fish stocks, reliance of traditional enterprises, and build resilience within coastal communities (Hughes et al., 2016). Many rural communities have adopted blue economy policies and principles in developing sustainable livelihoods while promoting a healthy functioning environment (Das, 2023; Narwal et al., 2024).

SIDS are now also exploring carbon markets for trading carbon credits and blue carbon to offset emissions from other countries (Froehlich et al., 2019b). Seaweed along with seagrass meadows and mangrove ecosystems can naturally sequester carbon from the ocean environment and atmosphere, sometimes at faster rates than terrestrial trees (Yong et al., 2022). These carbon markets have the potential for substantial economic earnings. However, proper valuation of environmental services and these ecosystems are needed to establish fair market prices for resources (CDB, 2018). For example, the mariculture of filter feeders (i.e. mollusks and pearls) supports environmental services like bioremediation of coastal waters (Kraan, 2020). It also has the potential of developing marine biomolecules from the fouling algae around the farms and other new opportunities may rise from viable fishery products and restaurant trade for the invasive alien species of lionfish that may be introduced due to climatic environmental conditions (Del Rio-Portilla et al., 1992; Pouvreau et al., 2000).

Some caution needs to be exercised in adopting the blue economy agenda as it relates to avoiding or minimizing stakeholder conflicts. The crowding coastal and ocean spaces risk the marginalization of smaller scale activities in favor of larger-scale ones such as tourism within coastal zones (Cingano, 2014). The development of marine spatial plans will be invaluable in this regard and will need to be formally incorporated into national and regional policies and laws to be effective (Choi, 2017). There is also the risk of introducing invasive mariculture species to the marine environment that may compete with native species and threaten local marine biodiversity, natural marine habits and/or cause economic damage (Kambey et al., 2021a, 2021b; Reis et al., 2009). Macroalgae has often been subjected to invasive spread through aquaculture activities (Lyons and Scheibling, 2009). It is important to develop guidelines for the control of invasive species to respond in a timely manner and at the early stages of invasion (Giakoumi et al., 2019). Failing this, it may be very difficult to control the dispersal of species, risking the formation of toxic algae blooms that can negatively affect blue economic activities and marine ecosystems (Bourgougnon et al., 2021). This has been observed with rapid proliferating seaweed biomass like sea lettuce, *Ulva* spp. has been commonly linked to the formation of “green tides” (Sarkar, 2018). If seaweed mariculture is approached from the extractivism viewpoint, these may have untended and irreversible consequences as it relates to overharvesting of native seaweed species from the natural reef system either used for direct consumption referred to as ‘wild collection’ and/or used as a source for ‘seeds’ in propagation farming (Hayashi et al., 2014). Other risks involve breaching biosecurity measures of introducing new commercial seaweed strains for higher production (Kambey et al., 2020). Therefore, approaching seaweed mariculture from this extractivism point of view (with not environmental awareness) there is risk of replicating the mistakes made with other models of development which only involves the use and extraction of living resources from nature with no consideration of environmental sustainability. However, there has been limited examination between blue food and blue economy narratives specifically regarding seaweed mariculture production and consumption (Farmery et al., 2021).

### 3.1.2.2 Blue economy and Caribbean SIDS

The blue economy is becoming increasingly popular in the Caribbean and North Brazil Shelf Large Marine Ecosystems (CLME+) region (Debels et al., 2017). However, its full potential remains untapped mainly because it hasn't been officially acknowledged as a significant economic driver (Nurein, 2022). The CLME+ region's prospects for sustainable blue growth are increasingly threatened by habitat degradation, unsustainable fishing practices, and pollution (Debels et al., 2017). Recognizing the blue economy as a strategic development opportunity for the Caribbean, multilateral institutions such as the Caribbean Development Bank, the InterAmerican Development Bank, and the World Bank have taken note. Various

regional and national strategies and initiatives are centered on the ideas of the Green Economy, Blue Economy, Green Growth, Green Jobs, and Sustainable Consumption and Production. Notable examples include the Regional Strategy for Sustainable Consumption and Production along with its Action Plan (2015-2016), the OECS Eastern Caribbean Regional Ocean Policy (ECROP) and its Strategic Action Plan (2013), Grenada's Blue Growth Coastal Master Plan, and the planned outcomes of Guyana's Green State Development Strategy initiative (Acosta et al., 2020). These frameworks are integral in setting the policy environment to ensure that blue economy activities thrive.

Blue economy activities involve various sectors, including fisheries, aquaculture, tourism, marine biotechnology, and renewable energy (ComSec, 2016; Hughes et al., 2016). Each of these sectors holds significant potential for contributing to the economic development of Caribbean countries while ensuring environmental sustainability. Fisheries and aquaculture are pivotal to the Caribbean blue economy, providing food security, employment, and income. According to the Caribbean Regional Fisheries Mechanism (CRFM), in 2019, around 118,053 individuals were employed in direct production within the commercial marine capture fisheries and aquaculture sub-sectors in the region. This figure includes full-time and part-time fishers, harvesters, and farmers involved in both artisanal/subsistence and commercial activities (CRFM, 2020). Sustainable fisheries management practices are essential to prevent overfishing and ensure the long-term viability of fish stocks. For example, CRFM works towards sustainable fisheries management across member states. Initiatives like the Eastern Caribbean Flying Fish Initiative aim to develop a regional management plan for flying fish, a key species for several Caribbean nations (IDB, 2020).

Tourism is a major economic driver in the Caribbean, with coastal and marine tourism being particularly significant (Renaud, 2020). The region's pristine beaches, coral reefs, and marine biodiversity attract millions of visitors annually (Morozova, 2016). Sustainable tourism practices are crucial to preserving these natural assets and ensuring the long-term viability of the tourism industry (BTB and MBECA, 2011; Horwich and Lyon, 1998). The Blue Flag program is an example of an initiative promoting sustainable tourism in the Caribbean (Prats and Merino, 2024). Beaches and marinas that meet stringent environmental, educational, and safety standards are awarded the Blue Flag, signaling their commitment to sustainability. Barbados, for instance, has several Blue Flag beaches, enhancing its reputation as a sustainable tourism destination (Merino and Prats, 2020).

Marine biotechnology offers opportunities for innovation and economic growth by utilizing marine organisms and their by-products. This sector includes pharmaceuticals, nutraceuticals, and cosmetics derived from marine resources. The Caribbean's rich marine biodiversity provides a valuable resource for biotechnological research and development. Jamaica's University of the West Indies (UWI) has been at the forefront of marine biotechnology research in the region (Lam and Lee, 2012). The university's Biotechnology Centre conducts research on marine natural products, exploring their potential for developing new drugs and other products (World Bank, 2022).

The Caribbean has significant potential for renewable energy development, particularly from ocean resources such as wave, tidal, and offshore wind energy (Ferdinand, 2020). Transitioning to renewable energy can reduce the region's dependence on imported fossil fuels and contribute to climate change mitigation. The Caribbean Community (CARICOM) has recognized the importance of renewable energy in its Regional Energy Policy (CCCCC, 2012). Projects like the Caribbean Renewable Energy Development Programme (CREDP) aim to promote renewable energy technologies and increase their adoption across the region. For example, the installation of ocean thermal energy conversion (OTEC) plants is being explored in countries like The Bahamas and Puerto Rico (CDB, 2018).

Nevertheless, the Blue Economy's status differs significantly among Caribbean SIDS, influenced by geographical location, size, and economic priorities (IDB, 2020). Proximity to

major shipping lanes, as seen in Jamaica and Trinidad and Tobago, may prioritize port infrastructure and maritime services (Recinos and Blue, 2019; Smith-Godfrey, 2016). Larger islands such as Cuba and the Dominican Republic invest in offshore renewable energy and aquaculture, while smaller ones like Grenada and Saint Lucia emphasize boutique tourism and artisanal fishing (Patil et al., 2016). Tourism-centric economies like Barbados adopt strategies for sustainable tourism, while resource-dependent islands like Saint Kitts and Nevis prioritize fisheries management (Morozova, 2016; Nalau and Becken, 2018). Vulnerabilities to climate change and natural disasters, seen in Dominica, Haiti, and others, drive resilience-building efforts in infrastructure and disaster preparedness (Kelman, 2020; Seara et al., 2016). Overall, tailored Blue Economy approaches are vital for maximizing benefits while ensuring sustainability and building adaptation strategies for resilience in Caribbean SIDS (ComSec, 2022; Monsanto et al., 2023).

The region's commitment to a sustainable blue economy can be showcased through the Unleashing the Blue Economy of the Caribbean (UBEC) Program which is set to unfold over a fifteen-year span, structured into Series of Projects (SOP), each lasting five years (WB, 2022). These initiatives aim to bolster the Blue Economy in the Caribbean, enhancing climate resilience and fostering economic recovery post-COVID. Phase 1, slated for implementation between fiscal years 2022 and 2028, targets Grenada, Saint Lucia, Saint Vincent and the Grenadines, and the OECS Commission, concentrating on tourism, fisheries, and waste management. With a total financial backing of US\$56 million in International Development Association (IDA) credits and grants, along with US\$4 million from the PROBLUE trust fund, Phase 1 sets the groundwork for subsequent phases. Phase 2, slated to commence in fiscal year 2023, will expand to include more Organization of Eastern Caribbean States (OECS) and Caribbean nations, drawing on an additional US\$3 million from the PROBLUE Multi-Donor Trust Fund to facilitate their integration (PROBLUE, 2023). The UBEC SOP serves as an overarching blueprint, aligning interventions across sectors to achieve regional developmental objectives while offering flexibility for countries to join at their own pace (WB, 2022).

### 3.1.3 Characterization of seaweed mariculture in SIDS

In SIDS, seaweed mariculture is primarily focused on the cultivation of red seaweed species, which are particularly well-suited to the warm marine environments of these regions (FAO, 2021; Lin, 2005). Red seaweed has become a significant player in global aquaculture due to its wide range of benefits, providing a sustainable livelihood opportunity for coastal communities in SIDS, who are often vulnerable to the impacts of overfishing and climate change (Monnereau et al., 2015; Monnereau and Oxenford, 2017; Townhill et al., 2021). SIDS that practices red seaweed cultivation near shore specialize in farming species like *Kappaphycus alvarezii* ('cottonii'), *Eucheuma isiforme* ('Irish moss'), and *Gracilaria crassissima* ('Irish moss') using small- and large-scale methods to combat unsustainable harvesting from wild collections (van Oirschot et al., 2017).

The cultivation methods commonly employed in SIDS include off-bottom farming and floating raft farming, both of which are variations of the long-line (or line farming) method to suit the requirements of the farming site (Hayashi et al., 2014). In addition to these methods, SIDS have adopted specific techniques such as the tie-tie (twist) method for environments with higher wave action while the raffia method is commonly used in calm waters to secure seaweed to the cultivation lines (McKoy and Dubon, 2021). The tie-tie method, also known as the twist method, involves un-braiding the ropes and placing a propagated piece of red seaweed thallus in the opening of the rope at intervals of 1 to 1.5 feet (McKoy and Dubon, 2021). This technique ensures the secure attachment of seaweed, promoting healthy growth. The raffia method, introduced from South America, involves creating an eye in the raffia to tie the propagated seaweed, which is then hung from the cultivation rope at intervals of 0.5 to 1 foot (de Góes and Reis, 2011). These methods have been integrated into both off-bottom and floating raft farming to optimize the cultivation process (TNC, 2017, 2021, 2024b).

In this context, off-bottom farming involves the use of submerged lines anchored to the seabed at depths of approximately 6 to 10 feet where sunlight is still sufficient for healthy growth. This method ensures that seaweed crop remain submerged and stable, which is particularly suitable for species like *Eucheuma isiforme*, *Kappaphycus alvarezii*, and *Gracilaria crassissima* that thrive in such high wave conditions (Lucas and Southgate, 2012).

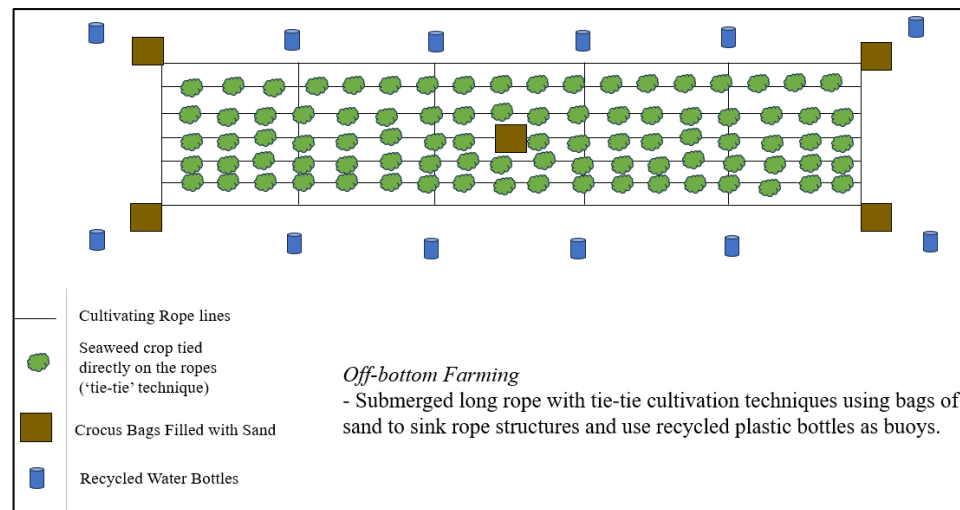


Figure 3.1. Off-Bottom Seaweed Farming: Utilizing Submerged Long Rope Techniques with Recycled Buoys and Sand Anchors (Author's own elaboration).

The off-bottom farming technique uses a submerged plot (each 15 feet by 15 feet square referred to as a 'farm cell') of long rope method with tie-tie cultivation as shown above in Figure 3.1. The ropes are submerged underwater and anchored to the seabed using crocus bags filled with sand. The seaweed crop is attached to the ropes using the tie-tie technique, which involves unbraiding sections, placing a propagated piece of seaweed thallus, and twisting the rope back. Crocus bags with sand act as anchors, and recycled water bottles are used as buoys to maintain the structure's horizontal position (St. Lucian seaweed farmer, personal communication, June 20, 2023).

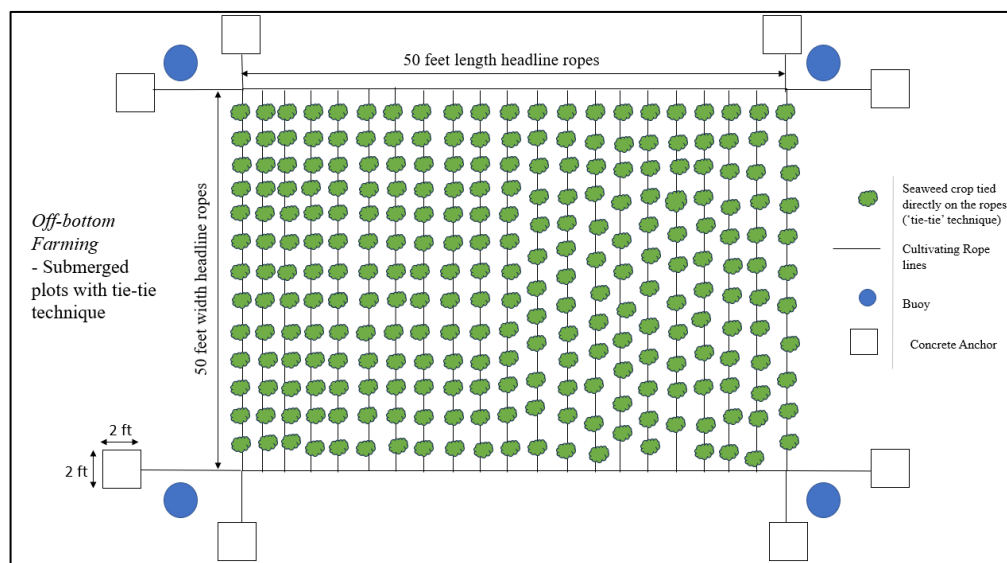


Figure 3.2. Submerged Plot Seaweed Cultivation: Utilizing the Tie-Tie Technique with Anchored Ropes and Buoys (Author's own elaboration).

The off-bottom farming technique uses a submerged long rope method with tie-tie cultivation as shown above in Figure 3.2. The ropes are submerged underwater and anchored to the

seabed using concrete anchors with a piece of steel that act as a handle for tying the anchor ropes to hold the submerged farms. The seaweed crop is attached to the ropes using the tie-tie technique, which involves unbraiding sections, placing a propagated piece of seaweed thallus, and twisting the rope back. Cement blocks are used in the event that more support is needed to anchor the farm, and recycled buoys are used as buoys to maintain the structure's horizontal position.

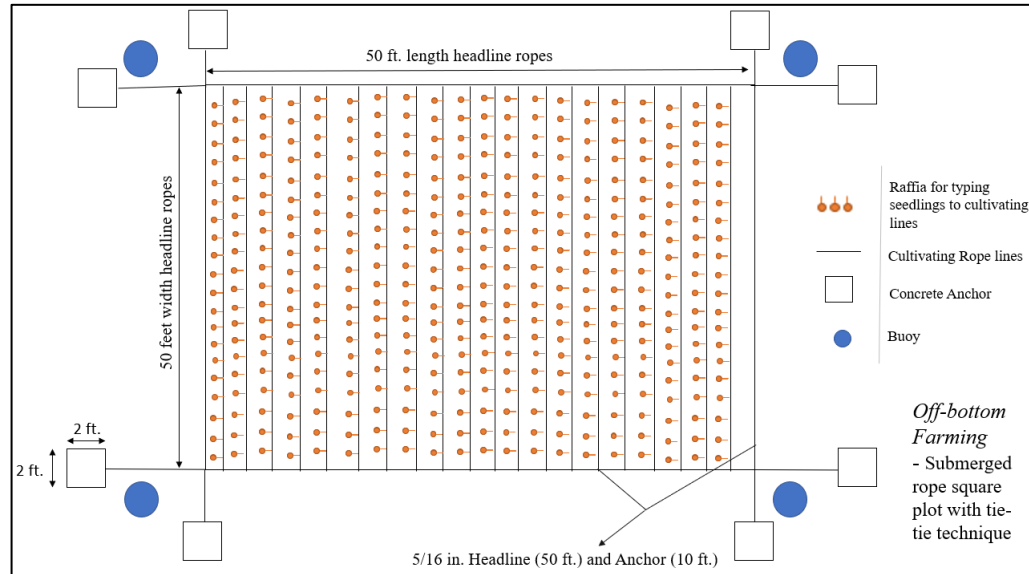


Figure 3.3. Submerged Square Plot Seaweed Cultivation: Raffia-Tied Seedlings Anchored with Ropes and Buoys (Author's own elaboration).

The off-bottom farming method, commonly used in the Caribbean for seaweed cultivation, involves a submerged rope square plot with raffia technique (McKoy and Dubon, 2021) as shown above in Figure 3.3. The ropes are arranged in a grid pattern, typically 6 to 10 feet deep, and spaced evenly across the area. Raffia, a type of tying technique that resembles a hanging circle (referred to as the 'eye'), is used to tie seaweed seedlings to the ropes, ensuring sufficient space for growth. Concrete anchors secure the ropes to the seafloor, and buoys keep them suspended in the water column. This method promotes even seaweed growth, making it ideal for large-scale operations.

On the other hand, floating raft farming also employs long-line cultivation techniques but with the cultivation lines positioned just 1 to 3 feet below the sea surface. This method allows for easier access and management of seaweed crops and is particularly advantageous in areas with varying tidal conditions. Floating rafts are widely used across SIDS for cultivating species like *Gracilaria* sp., *Eucheuma* sp. and *Kappaphycus* sp., providing flexibility and scalability for large-scale operations (TNC, 2020).

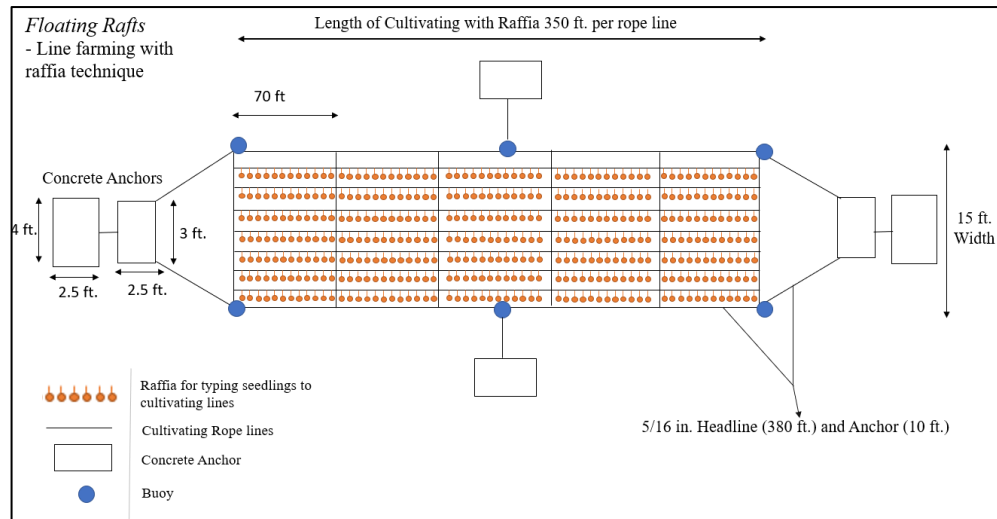


Figure 3.4. Floating Raft Seaweed Cultivation: Raffia-Tied Seedlings on Anchored Long Lines (Author's own elaboration).

The floating rafts method is a line farming technique used for seaweed cultivation in shallow water depths as shown above in Figure 3.4. It consists of a 70-foot raft with 350-foot cultivating rope lines, raffia-tied seaweed seedlings, concrete anchors for stability, and buoys to maintain the raft's submerged position. The raffia technique ensures secure attachment and easy harvesting seaweed. The raft is stabilized with concrete anchors to prevent drifting and maintain optimal growth. This method is ideal for calm water conditions and offers flexibility in site selection and management.

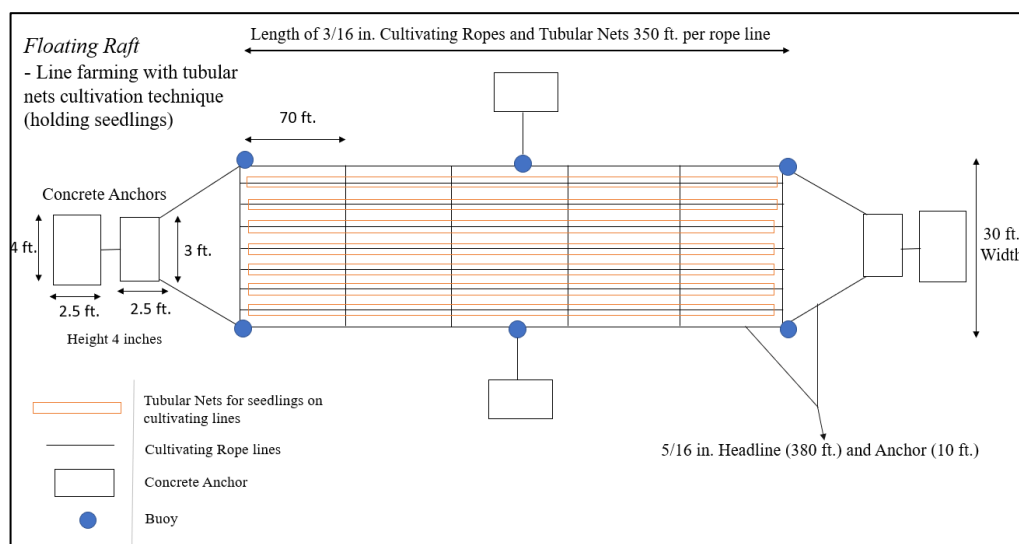


Figure 3.5. Floating Raft Seaweed Cultivation: Tubular Nets for Seedling Propagation on Anchored Long Lines (Author's own elaboration).

The floating raft method is a seaweed farming technique that uses a floating raft with tubular nets to securely hold seaweed seedlings as shown above in Figure 3.5. The raft measures 70 feet in length and 30 feet in width, with 350 feet per line of cultivating ropes. Tubular nets are attached to the ropes, providing a secure enclosure and ensuring the seedlings remain evenly spaced and submerged. Concrete anchors stabilize the raft, and buoys keep it afloat. This method is particularly beneficial in environments with strong currents and waves, as it reduces the risk of dislodgment and ensures consistent growth.

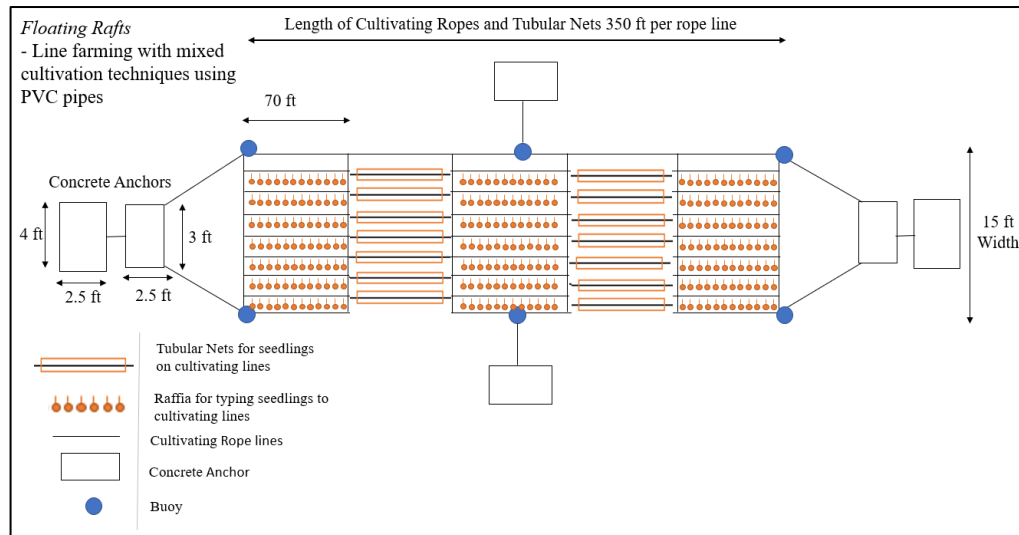


Figure 3.6. Floating Raft Seaweed Cultivation: Mixed Techniques Using Raffia and Tubular Nets on Anchored Long Lines (Author's own elaboration).

The floating raft method is a seaweed farming technique that uses a combination of line farming, tubular nets, and raffia as shown in Figure 3.6. The main components include 350-foot-long cultivating rope lines, which are anchored to a 70-foot-long floating raft. Tubular nets secure seedlings, protecting them from strong currents and predators. The raffia method allows for flexible seedling placement and uniform growth. Concrete anchors stabilize the raft, especially in dynamic marine environments. PVC pipes provide additional structural support and facilitate seedling distribution. Buoys are strategically placed to maintain the raft afloat and maintain the cultivation lines at the right depth, ideal for species like *Kappaphycus* sp. and *Eucheuma* sp. This method offers adaptability and productivity, making it suitable for diverse marine environments.

After a growth period of about two to three months in the sea, the seaweed is typically harvested, sun-dried on racks or tarps, and then processed at home, including both pre- and post-packaging stages (McKoy and Dubon, 2021). The local and international markets for seaweed products in SIDS are supported by government and civil society initiatives, which help farmers access and expand markets through platforms like Export St. Lucia, Export Belize, and other government-led trade programs (ID and M, 2021; Rebours et al., 2014b; TNC, 2017).

#### 3.1.4 Seaweed mariculture production and blue economy

There is growing demand for seaweed as a highly nutritious food, source of agar, carrageenan, and bioactive substances such as dietary fibers, proteins, minerals (iron, calcium, iodine, potassium, selenium), vitamins (particularly A, C and B-12), prebiotics, antioxidants, anti-inflammatory, phytochemicals, low caloric polyunsaturated fatty acids and natural omega-3 long-chain fatty acids properties (FAO, 2022b; Ramu Ganesan et al., 2020). These seaweeds have been consumed directly in beverages (mainly seamoss, *Eucheuma* sp.), sushi wraps (mainly nori, *Porphyra* sp.), salads (mainly wakame, *Undaria pinnatifida*) and snacks (mainly nori, *Pyropia* sp.). In industry, hydrocolloids products such as carrageenan, agar or alginates are extracted for use in cosmetics, nutraceuticals, pharmaceuticals, textiles fibers, bio-compostable packaging, wastewater treatment/bioremediation, carbon capture/sequestration, etc. (Fleurence et al., 1999; Yong et al., 2022). It is used in feed as an additive (mainly the red seaweed, *Asparagopsis taxiformis*) and in aquaculture hatcheries in feeds (mainly the sea lettuce, *Ulva lactuca*) and as a biostimulant/biofertilizer (mainly *Laminaria* sp., *Ascophyllum* sp., *Fucus* sp. and *Sargassum* sp.) (Hansen et al., 2003; Hu et al., 2008).



The global demand for seaweed continues to grow, with world seaweed production reaching approximately 22.5 million tonnes in 2022, contributed by 47 countries/territories including SIDS (refer to Figure 3.9. for further details). Of this cultivated production, 97% is accounted for by countries in Asia. In Figure 3.7. below, it highlights the steady increase in global seaweed cultivation over the past two decades, with red seaweed consistently dominating the market, followed by brown and green seaweed. Red seaweed, which includes species such as *Eucheuma* sp., *Gracilaria* sp., and Elkhorn Sea Moss (refers to *Kappaphycus* sp.) has been the most extensively cultivated category, reflecting its widespread application in food, industry, and pharmaceuticals. Brown seaweed cultivation has also grown significantly, though it has experienced more volatility compared to red seaweed, particularly in the mid-2010s. Green seaweed remains the smallest category by cultivation volume, with stable but limited growth. In 2019, the global seaweed market was valued at around USD 5.6 billion, with the majority of the production directed toward human consumption in both freshwater and marine environments (FAO, 2020). The data illustrates the dynamic and expanding nature of the seaweed industry, driven by its increasing importance in global aquaculture and sustainable development.

Specifically, the figures below show the farmed seaweeds (cultivation) in Figure 3.7. and wild harvested (wild collections) in Figure 3.8. as documented by the FAO for the Global Fishery and Aquaculture Production Statistics which is made available on the FishStatJ software (Author's own elaboration; Cai 2021, FishStatJ, 2022). Figure 3.7. illustrates the production trends of the three major seaweed groups cultivated worldwide: red seaweeds (increasing from approximately 2 million tonnes to over 20 million tonnes), brown seaweeds (rising from around 2.8 million tonnes to over 2 million tonnes), and green seaweeds (remaining relatively stable with slight fluctuations, ranging between 20,000 to 30,000 tonnes). In 2019, world seaweed production show that China, Indonesia and South Korea were the three top producing countries (Figure 3.7.) and in 2022, China and Indonesia continued being top producers followed up with Philippines. However, there is growing demand in Europe and North America (FAO, 2022). Figure 3.8. shows the three seaweed groups harvested from the wild; seaweed wild collections (i.e. brown seaweeds (decreasing from 792 000 tonnes to 676 000 tonnes), red seaweeds (decreasing from 349 000 tonnes to 190 000 tonnes); and green seaweeds (decreasing from 53 000 tonnes to 16 000 tonnes) for the period 1950 to 2019) based on FishStatJ of March 2021 (Cai, 2021).

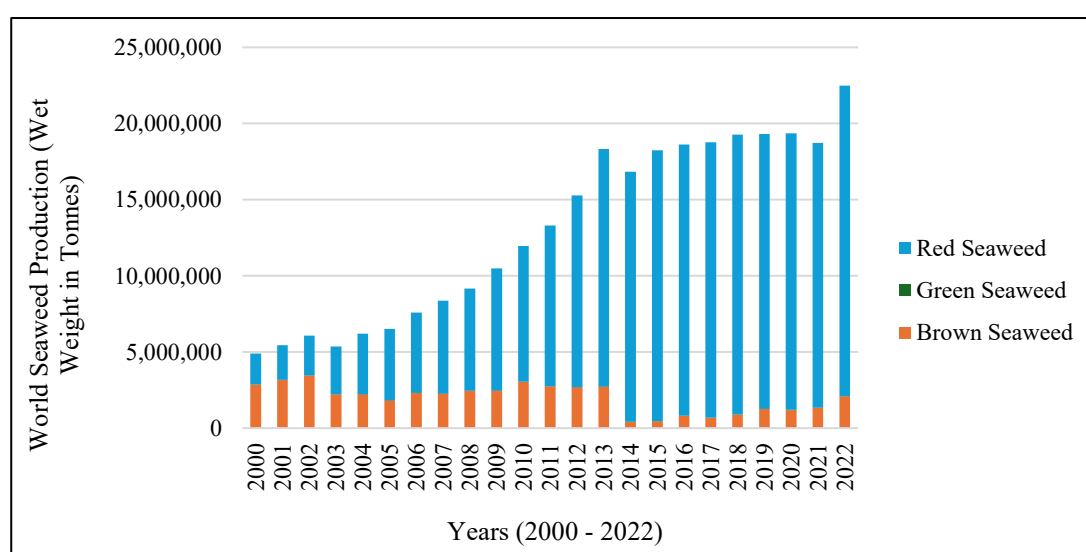


Figure 3.7. Global Cultivated Seaweed Production by seaweed species in wet weight from 2000-2022 (Author's own elaboration based on FishStatJ dataset; 2024).



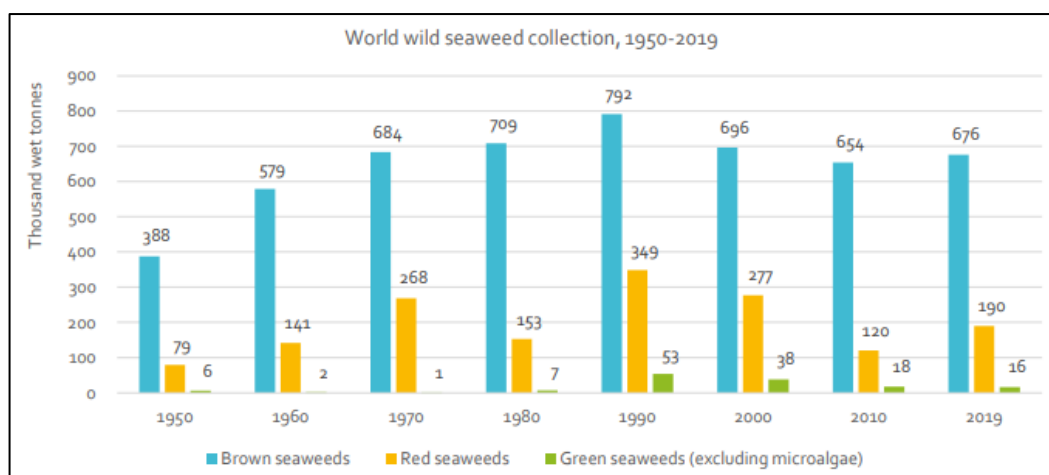


Figure 3.8. Trends in Global Wild Seaweed Harvesting by Type (1950–2019) based on FishStatJ; March 2021 (Cai, 2021).

Furthermore, the highest producing countries/territories of seaweed cultivation (world production: 22,494,326 tonnes (wet weight) in the year 2022 (Author's own elaboration based on FishStatJ dataset; 2024) highlights the contributions of major producers, with China leading at 10,338,470 tonnes, followed by Indonesia at 9,219,276.03 tonnes, and the Philippines at 1,544,959.87 tonnes (Cai, 2021). The combined production of all Small Island Developing States (SIDS) is 13,497.60 tonnes, while other significant producers, represented by 'Rest of the World' which include the Republic of Korea, Malaysia, Japan, and Tanzania. The reflects the dominance of Asian countries in global seaweed production (Author's own elaboration based on FishStatJ dataset; 2024).

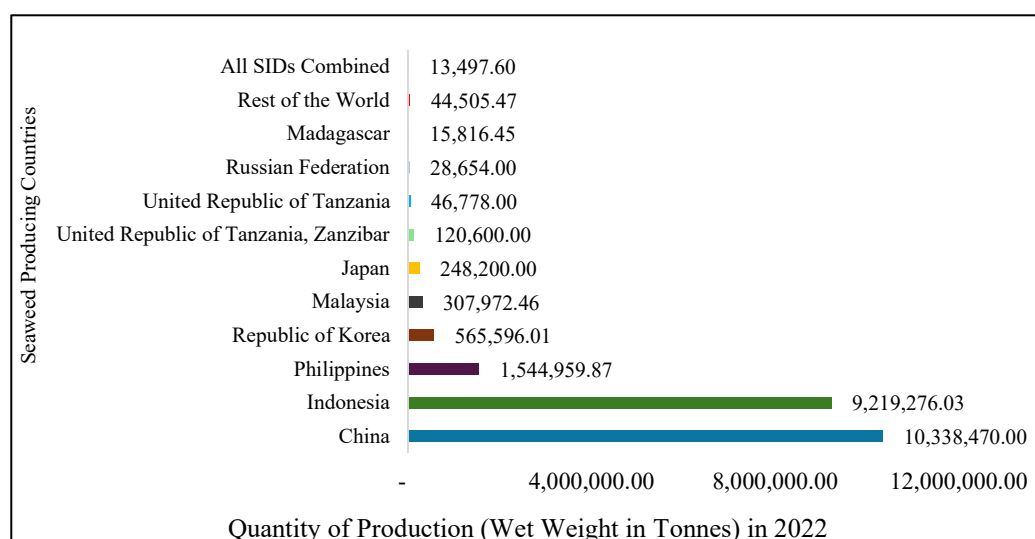


Figure 3.9. Global Seaweed Production by Country in 2022 (Wet Weight in Tonnes) (Author's own elaboration based on FishStatJ, 2024).

In addition, the economic benefits of red seaweed mariculture in Caribbean SIDS extend beyond direct revenue generation (Hayashi et al., 2014). Seaweed farming provides an alternative source of income for coastal communities, particularly in areas where traditional livelihoods such as fishing are under threat (UNCTAD and FAO, 2021). Moreover, red seaweed cultivation offers ecosystem services such as nutrient uptake, carbon sequestration, and habitat creation, contributing to coastal communities local economy and biodiversity conservation (Cottier-Cook et al., 2021; PROBLUE, 2023). The Caribbean SIDS currently account for a small fraction of this market, there is growing recognition of the region's

potential to become a significant player in the global seaweed industry (Author's own elaboration based on FishStatJ; 2024).

### 3.1.5 Belize seaweed mariculture production

The development of seaweed mariculture in Belize has evolved significantly since its inception in the late 1970s. Initially, seaweed farming in Belize began with wild harvesting by local fishers, focusing on low-input monoculture line cultivation methods, primarily involving red seaweed species (*Rhodophyta*) (Ortiz-Carabantes, 2020). These efforts were followed by key initiatives in the 1980s and 1990s, such as the Princess Diane Project and a USAID Grant that facilitated habitat surveys conducted by local E-NGOs, laying the groundwork for more structured farming activities. In 2005, the introduction of formal seaweed farming training by Allan H. Smith from CANARI, in collaboration with the Government of Belize and World Wildlife Fund (WWF), marked a turning point, leading to the organized cultivation of species like *Gracilaria crassissima*, *Eucheuma isiforme*, and *Kappaphycus alvarezii* (Wilbur Dubon, personal communication, January 22, 2022). Significant milestones were achieved in the late 2000s and 2010s, including the issuance of the first UNEP/COMPACT grant to a fisherman cooperative in 2009 and the implementation of the Lobster Shade Project in 2010, which integrated seaweed farming with marine conservation efforts. By 2014, private sector partnerships and exchange fishers initiatives promoted knowledge sharing of which led to the development of a seaweed farming trainers curriculum and training in cultivation for the public (TNC, 2017). To further the development across the region, Compete Caribbean Partnership Facility in partnership with Inter-American Development Bank (IDB) have issued out grant awards to seaweed farming initiatives across the Caribbean including central and southern areas of Belize. The industry saw a notable shift in 2016, when *Eucheuma isiforme* replaced *Gracilaria crassissima* as Belize's primary farmed seaweed species, particularly following the impacts of Hurricane Richard.

From 2020 to 2024, the seaweed mariculture industry in Belize witnessed increased institutional support, highlighted by the establishment of seedbanks, a research institute focused on seaweed, and the organization of Belize's first Seaweed Aquaculture Symposium in 2024 (TNC, 2024b). The industry's expansion was also marked by the formation of women's seaweed farming groups in Southern Belize, reflecting significant progress in gender inclusion and community-based farming (UK Grant Awards Grant). The roadmap of Belize's seaweed mariculture industry is outlined in detail in Figure 3.10. below from its inception stages intertwined with conservation efforts protecting marine areas with its rich biodiversity including wild seaweed beds in the Belize Barrier Reef Reserve System (BBRRS).

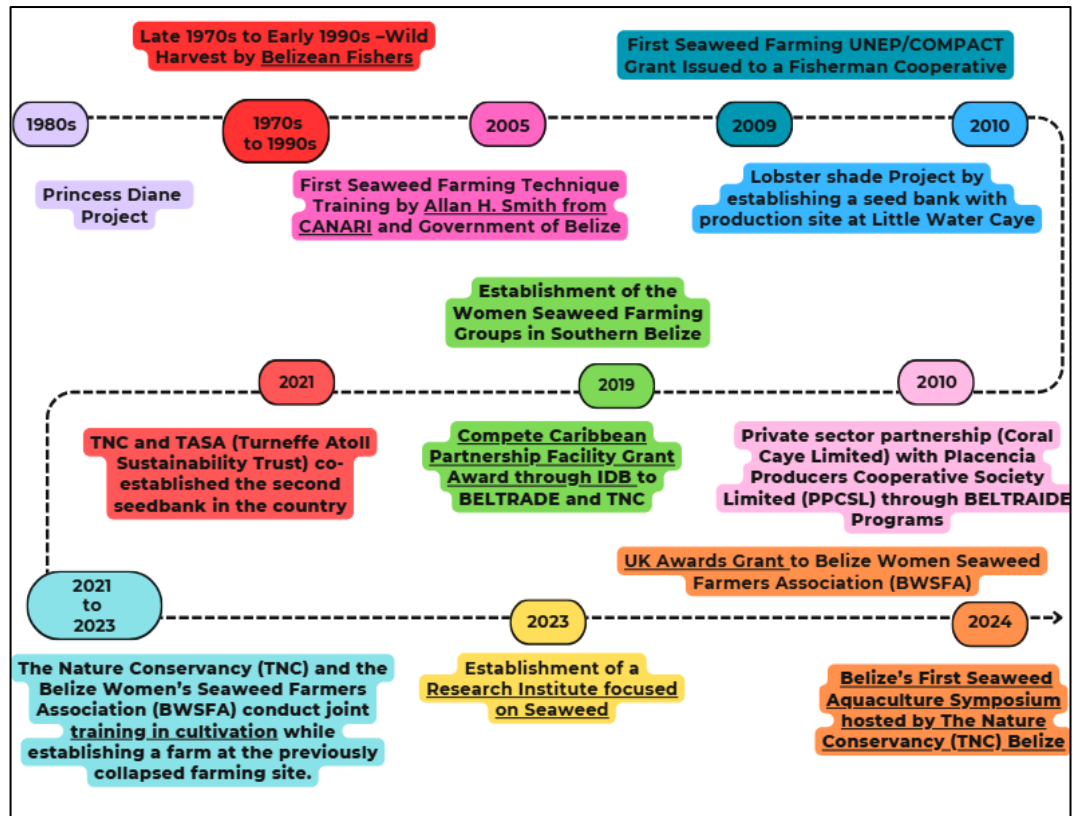


Figure 3.10. Key Milestones in the Development of Seaweed Mariculture in Belize (1970s-2024) (Author's own elaboration).

The timeline above in Figure 3.10 highlights the importance of *Seamoss* (locally referred to as 'seaweed') in Belize's economy, both as a raw commodity and in its processed forms for local and niche markets (Ortiz-Carabantes, 2020; TNC, 2024b). However, it also highlights the need for improved data collection to support the industry's sustainable growth (Cai, 2021). These developments collectively demonstrate the growing institutional support, international cooperation, and overall resilience that have driven the expansion and sustainability of seaweed mariculture in Belize.

Seaweed is the low-lying fruit in the blue economy as it requires low initial capital costs, short harvest periods, and relatively accessible technology involved (Ortiz-Carabantes, 2020), allowing profitable returns if farmed under an environment with suitable farming conditions (van Oirschot et al., 2017). However, the status of seaweed farms in the Caribbean SIDS is generally underreported from farm-level and it is unknown what methods seaweed farmers are employing on the ground to supply high quality seaweed to the market (Hayashi et al., 2014, 2020).

In Belize, seaweed mariculture activities are primarily overseen by the National Mariculture Policy approved in 2022 (TNC, 2024), which is part of the broader Belize Maritime Economy Plan (BMEP). This policy aims to develop sustainable mariculture practices and enhance the quality and competitiveness of Belize's seaweed products. The Ministry of Blue Economy and Civil Aviation (MBECA), along with the Belize Fisheries Department (BFD), plays a crucial role in regulating and supporting these activities. They ensure compliance with best practices

and facilitate capacity building, market access, and certification for seaweed farmers (IDB Blog) (Sanchiz, 2024)<sup>2</sup>.

Additionally, the development and implementation of the Belize Sustainable Ocean Plan (BSOP) are integral to these efforts since 2022. The BSOP includes initiatives to designate up to 30% of Belize's ocean as Biodiversity Protection Zones, which support sustainable seaweed farming among other activities. This plan aligns with the Blue Economy goals of fostering sustainable growth, improving climate resilience, and ensuring equitable access to marine resources (BSOP, 2022). These legislative frameworks and strategic plans highlight Belize's commitment to developing a sustainable and competitive seaweed mariculture industry that benefits local communities and contributes to the national economy.

Table 3.1. below presents a summary of the global seaweed industry in 2022, showcasing the production volumes, economic value, and average unit prices across different regions. Belize, despite its burgeoning seaweed industry, produced a modest 10 tons (wet/live weight referred to as LTW hereinafter) with a notable unit price of \$3,850 per LTW, highlighting the premium value of its seaweed, potentially due to niche market positioning or specialized cultivation techniques. In contrast, SIDS collectively contributed 13,484 tons to global production, with a total market value of approximately \$3.1 million. The average unit price in SIDS, however, was significantly lower at \$230 per LTW, possibly reflecting a broader market approach with less specialized products. The rest of the world dominated the industry with an astonishing production volume of over 20 million tons, valued at more than \$9 billion, and an average unit price of \$442 per LTW, indicating a large-scale, industrialized approach to seaweed farming. Altogether, global seaweed production reached over 20.3 million tons in 2022, generating a staggering \$9 billion in value, highlighting the growing importance and economic potential of seaweed as a global commodity.

| Location          | 2022 Production in Wet Weight (Tonnes) | 2022 Value             | 2022 Unit Price |
|-------------------|----------------------------------------|------------------------|-----------------|
| Belize            | 10                                     | \$38,500               | \$3,850         |
| SIDS              | 13,484                                 | \$3,096,390            | \$230           |
| Rest of the World | 20,382,212                             | \$9,007,274,920        | \$442           |
| <b>Total</b>      | <b>20,395,706</b>                      | <b>\$9,010,409,810</b> | <b>\$442</b>    |

*Table 3.1. Global Seaweed Industry Dynamics in 2022: A Comparative Analysis of Production, Value, and Pricing Across Regions (Author's own elaboration based on FishStatJ; 2024).*

### 3.2 Contextualizing The Theoretical and Conceptual Underpinnings of Thesis

There are different terms, concepts and strategies that have been employed at community-level (commonly referred to as grassroots-level) that deal with sustainable development, the ocean environment, and the protection of biodiversity in the context of climate change adaptation. The coastal communities within SIDS have a high dependence on natural resources for livelihoods (Breachin and Salas, 2011; Cherian, 2007). This socio-ecological system (SES) operates within a context that is defined by:

- i. biophysical, demographic, cultural, technological, political and market-related factors.

<sup>2</sup> Sanchiz, A. (2024, February 7). *Awakening a dormant blue economy industry: Seaweed mariculture in Belize*. IDB Blog. <https://blogs.iadb.org/innovacion/en/awakening-a-blue-economy-dormant-industry-seaweed-mariculture-in-belize/>

- ii. the nature of state agencies, policies and strategies.
- iii. the legal and institutional environment.
- iv. historical processes; and
- v. the involvement of various external actors and groups (non-governmental organizations (NGOs) and governments) in the development landscape (Olsson et al., 2015).

The way internal households operate also shapes how different people construct their livelihoods and utilize environmental resources (Scoones, 1998). As for nature-based livelihoods, they are dependent on the ecosystem goods and services of which can only be provided in healthy coastal and marine systems (Cassin, 2021). A livelihood entails assets (i.e. natural, physical, human, financial, social and sometimes even cultural in environmental economics), activities and the process of accessing these assets (mostly mediated by institutions, policy and processes) and gained from carrying out that livelihood over a period (Angelsen et al., 2011).

Within the context of sustainable livelihood in SIDS, the blue economy paradigm has endorsed the three pillars of sustainability to address the need in ensuring sustainable development (Smith-Godfrey, 2016). These three main pillars or capitals are the economic (produced/physical capital linked to financial capital), ecological (natural capital linked to biodiversity protection) and societal (networks and associations) capitals. However, there are aspects of the blue economy that do not comprehensively assess the realities on ground with ocean-based livelihoods, such as seaweed mariculture, and require the use of other approaches. For this purpose, community-led initiatives using the sustainable livelihood and ecological approach will be studied in identifying climate change adaptation short- and long-term strategies employed by seaweed farmers in a SIDS which will be the theoretical conceptual underpinnings of this research.

At a community development level, the best practices and lessons learnt in managing livelihood resources, strategies and institutional processes and organizational structures are better captured by considering the use of sustainable livelihoods and ecosystem approaches (EIU, 2015). These approaches complement initiatives implemented by community-based organizations to aid rural communities in learning how to collectively respond to changes in climate and ways they can safeguard their livelihood through prioritizing their local needs, knowledge and capacities. According to the Department for International Development (DFID) of the United Kingdom (DFID, 2010), the livelihood approach puts forward a broad framework, sustainable livelihood framework (SLF), for analyzing all these components that support an individual or household livelihood by evaluating their assets and higher scale factors that are principal components in livelihood definition and their interactions (i.e. local market, environment, institutions, political system and so on). Providing this context to livelihoods, it goes on and considers the result of employing livelihood strategies by the individual or household and any other associated livelihood outcomes that influences livelihood security such as income stability, household income, seasonality and degree of risks (Allison and Ellis, 2001; Scoones, 2009).

The sustainable livelihood approach encompasses more than the three pillars of blue economy and provides a holistic approach to assessing livelihoods through the guiding principles of sustainable development. This allows for the analysis of vulnerabilities in nature-based businesses, even in the face of significant disturbances/hazards or stressors (Adger, 2006; Räsänen et al., 2016). Within this thesis, the SLF is adapted to encompass six livelihood capitals, representing the full spectrum of assets and resources that impacts seaweed farming livelihoods in Belize:

- i. natural (fish stocks, seaweed wild stock, ocean spaces, land, etc.)
- ii. physical (possession instruments, materials, equipment, etc., that facilitates labor),
- iii. human (people, education, health, etc.),
- iv. social (kinship networks and associations),

- v. financial (savings, credit, etc.), and
- vi. cultural (religion, spirituality, environmental culture, creativity, sports, recreation).

Therefore, this inclusion of cultural capital in this research is deliberate and theoretically grounded. Literature on livelihoods and development in SIDS increasing highlights that cultural identity, traditional knowledge and spiritual practices play pivotal roles in shaping adaptive behaviors, environmental stewardship, and social cohesion (Boswell et al., 2022; Makame et al., 2021; Narayan & Pritchett, 1999; Recinos & Blue, 2019). Therefore, this research incorporates cultural capital as a sixth pillar within the SLF to capture these intangibles yet influential dimensions of livelihood resilience. Cultural aspects are also captured in environmental economics literature (Angelsen et al., 2011; Moncada, 2016). Although the cultural pillar is scarcely added to the SLF, Moncada (2016) incorporated cultural capital into the SLF to capture the significant role of religious practices and cultural activities in enhancing adaptation strategies and well-being of communities, thereby providing a more comprehensive and contextually relevant understanding of livelihoods and informing more effective and culturally sensitive development interventions in communities. Additionally, the training improved self-assessed physical health, attitudes towards air quality, and reduced periods without food, as well as reducing fear of crime and violence in the community (Moncada, 2016). However, there were some unintended outcomes, such as an increase in firewood consumption, which could potentially delay the achievement of targets set by the authorities for improved health standards and carbon emission reductions (Moncada, 2016; Obonyo et al., 2013). The methodological framework adopted from Moncada (2016) was used to assess adaptation strategies at community-level in evaluating the impacts of climate-related and non-climatic hazards and local response capacity. Having six (6) pillars of SLF is ideal, as recommended by Moncada (2016), to include it in this study especially in coastal communities of SIDS where the ocean plays a very important role like the Caribbean SIDS (Hong, 2013; Ode et al., 2015). This livelihood platform provides the context for understanding the state of livelihoods' vulnerability and resilience (Levine, 2014) although this thesis is not using those terms specifically in this research. SLF goes further to developing a list of resources between the domains of economics, politics (local, national and regional) and its application works more effectively when policy analysis is combined to it to assess the legislative frameworks and intervention which includes policies, institutions and processes (PIPs) (Ingle et al., 2018). The SLF identifies interventions conducted by locals that may harness negative or positive impacts on key livelihood resources and how locals survive during difficult times of year which may be sustainable short-term coping strategies (Angelsen et al., 2011; Birkmann et al., 2023). New policies are created to foster an enabling environment to incentivize new investment in nature-based livelihoods which are contingent on the integrity of natural resources (UNDP, 2021; UNEP, 2023a).

The use of SLF provides a foundation for assessing ocean-based livelihoods, like seaweed mariculture, which has been widely used by many environmental and development practitioners, as well as scholars in academia and supranational organizations (Krantz, 2001). The SLF naturally captures the existing risks and conflicts within nature-based livelihoods including concerns with the sustainability of ecosystems or socio-ecological systems (Allison and Ellis, 2001). In the blue economy, this kind of information is collected in marine spatial mapping exercises targeted to resolve conflicts arising from competing to access ocean spaces (Lee et al., 2021). The complex interactions that occur between local communities can be analyzed by bringing together the different kinds of forces and their interactions on assets such as shocks, trends and seasonality (Levine, 2014). Figure 3.11 illustrates how the theoretical and conceptual underpinnings were contextualized in this dissertation as described above.

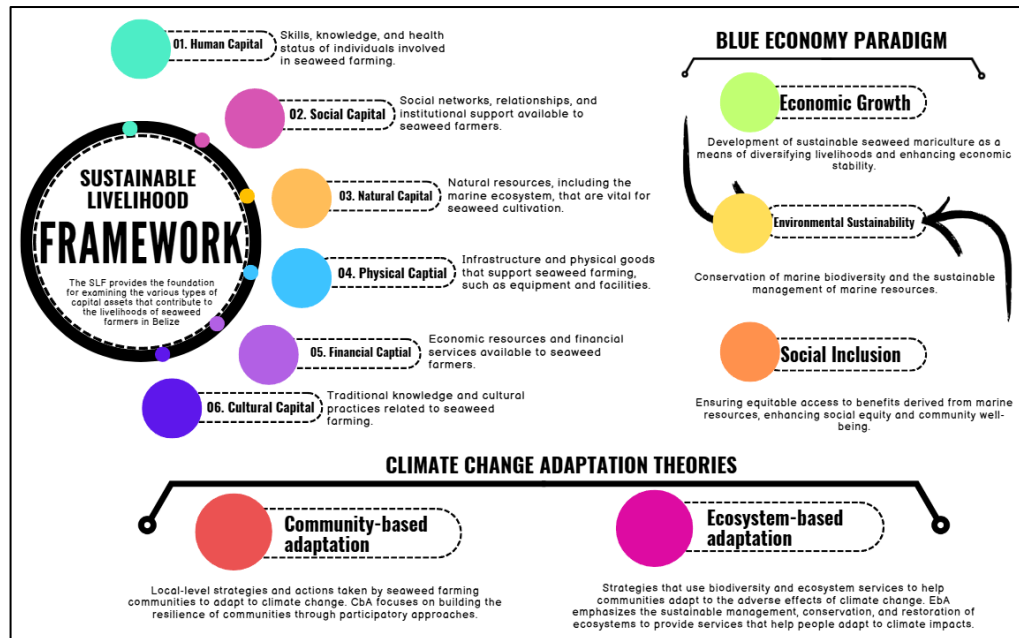


Figure 3.11. The Theoretical and Conceptual Framework of this Study's Case Study using The Lens of Sustainable Livelihood Framework in Seaweed Mariculture through the Integration Blue Economy Paradigm and Climate Change Adaptation Theories (Author's own elaboration).

### 3.2.1 Context to SIDS, with a focus on Belize

Belize, renowned for its rich biodiversity and extensive natural resources, is facing significant challenges from climate change and environmental degradation (Luis Martín-Ortega et al., 2021; MAFFES, 2016). This case study delves into the community-based and ecosystem-based adaptation strategies employed in Belize, analyzed within the frameworks of sustainable livelihoods and climate adaptation concepts. Belize's biodiversity includes approximately 7,046 biological species, with over 1,014 native vertebrates and about 3,408 native plant species thriving in ecosystems such as broadleaf forests, pine forests, savannahs, mangroves, wetlands, coral reefs, and seagrass beds (Mitchell et al., 2017; Rivera and Pratt, 2005). To protect these ecosystems, Belize has adopted an integrated approach to environmental adaptation, effectively utilizing community involvement and ecosystem management within the SLF and climate adaptation frameworks.

Community-based adaptation (CbA) involves local communities in developing and implementing strategies to manage and adapt to environmental changes (TNC et al., 2014). In Belize, CbA is evident through initiatives like the co-management of protected areas, local education and awareness programs, and fisheries management (Gutierrez-Corley et al., 2023; Young and Horwich, 2007). The Forest Department has developed a co-management system for 24 protected areas, promoting sustainable practices and involving local communities in conservation efforts. Education and awareness programs in schools and community groups enhance environmental stewardship by educating the public about biodiversity, pollution, and deforestation. Local fishermen are regulated to harvest only mature marine produce seasonally, preventing overfishing and ensuring long-term sustainability of marine resources.

Ecosystem-based adaptation (EbA) leverages biodiversity and ecosystem services to help people adapt to adverse impacts of climate change (Spiegelhalder et al., 2022). Belize's EbA strategies include mangrove protection, marine protected areas (MPAs), and riparian forest conservation. Mangroves, covering 3.4% of the land area, provide essential functions such as coastline protection and pollutant filtration (Cherrington et al., 2010). The Ecosystems Management Unit oversees marine reserves and regulates activities within these protected

areas, ensuring the protection and renewal of marine habitats (Wade et al., 2019). Riparian forests are preserved to prevent soil erosion, filter pollutants, and provide habitats for various species, playing a crucial role in maintaining water quality and mitigating flood damage (Nath et al., 2023).

The SLF focuses on enhancing capabilities, assets, and activities required for a means of living (Scoones, 1998; UNDP, 2017). Belize's integration of SLF in environmental strategies is evident through economic benefits from biodiversity, community empowerment, and sustainable harvesting practices. Eco-tourism, fisheries, and forestry support livelihoods while preserving the environment through sustainable management practices. By involving communities in co-management and education initiatives, Belize empowers its citizens, enhancing their livelihoods and resilience to climate change. Seasonal harvesting regulations and habitat protection enable local communities to rely on natural resources without compromising health of ecosystems.

Climate adaptation concepts emphasize proactive strategies to cope with climate change impacts. Belize's interventions on adaptation strategies at a community-level acclaims to align their practices with the theoretical concepts through the legislative frameworks along with its institutional support, continuous research and monitoring, and integrated ecosystem management. For example, national laws like the Wildlife Protection Act and the Forest Act provide a legal framework for terrestrial biodiversity conservation and sustainable resource use. Continuous monitoring of marine and forest ecosystems allows Belize to adapt management practices based on scientific data, ensuring effective responses to changing climatic conditions. An integrated approach to ecosystem management has proven to address multiple environmental issues, enhancing the resilience of both natural and human systems.

The same is hoped to be replicated in the protection, conservation and sustainable use of the marine biodiversity in Belize through the national Fisheries Resource Act and Marine Protect Areas Act and national project initiatives related to the Blue Economy. These accumulated interventions leverage its extensive marine resources management practices and governance not only to marine fauna but also to the marine flora, including those in the Belize Barrier Reef as part of the Meso-American Barrier Reef System (MBRS). Key aspects of these interventions include sustainable fisheries management, eco-tourism, conservation of the Blue Hole, and coral reef restoration projects. Emerging and innovative approaches like seaweed mariculture offer economic and environmental benefits, while climate resilience initiatives address vulnerabilities to climate change. Marine renewable energy exploration and strong community involvement are integral to these efforts, reflecting continuous progress in the Blue Economy sector. Belize's adaptation strategies, rooted in community and ecosystem-based approaches, illustrate a comprehensive effort to address environmental challenges while promoting sustainable livelihoods. Through legal frameworks, community involvement, and continuous research, Belize sets a precedent for integrating SLF and climate adaptation theory in environmental management. Legislative measures such as the Fisheries Resource Act, Marine Protected Areas Act, Offshore Oil Moratorium, and Marine Spatial Planning highlight Belize's commitment to sustainable marine resource management and protection.

Figure 3.12 illustrates the theoretical and conceptual framework used in this dissertation. This integrated model links CbA and EbA as complementary pathways toward achieving sustainable livelihoods in seaweed aquaculture within the context of climate change and the Blue Economy. It emphasizes that effective adaptation and livelihood resilience emerge when community participation, traditional knowledge, and social organization (CbA) are harmonized with ecosystem conservation, ecological integrity, and marine resource management (EbA). Positioned within multi-scalar policy and governance frameworks, from national to global levels, the model highlights the role of climate change adaptation strategies and scientific understanding of seaweed biology as critical foundations supporting both approaches. Ultimately, it demonstrates that the convergence of CbA and EbA can transform



external hazards, whether climatic or non-climatic, into opportunities for building resilient, diversified, and sustainable livelihoods for seaweed farming communities in SIDS.

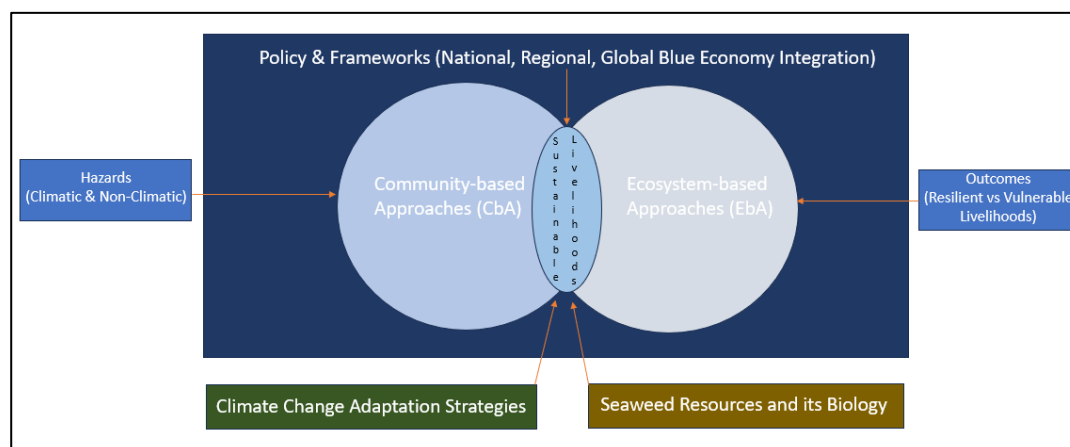


Figure 3.12. Theoretical and conceptual framework of this PhD Study highlighting the integration of community-based and ecosystem-based approaches for sustainable livelihoods in seaweed aquaculture management and science (Author's own elaboration).

### 3.2.2 Importance of community participation in sustainable seaweed mariculture development

Seaweed farmers in SIDS are at the forefront of exposure to current and future climate-related and environmental risks, with little to no intervention from their governments (Buschmann et al., 2017; Monnereau et al., 2015; Nurse et al., 2015). Establishing seaweed farms along the coast has been predominantly driven by individual seaweed farming communities operating autonomously (Makame et al., 2021; Msuya, 2012). Due to this lack of formal guidance and support, the seaweed mariculture industry has struggled to scale up from small-scale operations to commercial-level production, as highlighted by Ortiz Carabantes (2020) and frequently reported by the FAO (2022). Despite these challenges, the seaweed industry in SIDS has proactively adapted to climate change (Duarte et al., 2017) to provide income, both full-time and supplementary to households in coastal communities (Msuya, 2011). The industry benefits from a relatively low cost of entry and minimal technological barriers, making it accessible to many coastal residents. To further develop this industry sustainably, it is crucial to identify and highlight farm-level adaptation strategies and best practices. Active community participation is the key driver for the sustainable development of seaweed-based regenerative ocean farming initiatives. These initiatives are environmentally friendly and represent a viable bioeconomy option for coastal nations (FAO, 2022; Klöck et al., 2019; Krishnan et al., 2013).

Seaweed farming is an emerging livelihood option that has the potential to contribute towards reducing poverty and food security under climate change (Duarte et al., 2017; Hassan and Othman, 2019). However, at this point it is difficult to differentiate whether past and current seaweed farming practices are autonomous or planned adaptation strategies at community-level. There is a juxtaposed relationship between planned and autonomous adaptation (Aguilar, 2001) as actions that are autonomous occur naturally by private actors that take place without direct intervention of a public agency and actions that are planned receive more public investment (Moench and Dixit, 2007). Adaptation responses to climate-related risks and trends have been distinguished in the literature as 'autonomous or spontaneous' adaptation occurring at the individual, household or farm level (private actors) while 'planned adaptation' usually occurs at the national level, (public interventions) mostly government-led initiatives (Wright et al., 2014). These two types of adaptation can be further distinguished but leading to the same desirable outcome of integrating communities into climate change adaptation initiatives. Autonomous adaptation as being 'bottom up' approaches

demonstrating adaptive behavior by the users themselves that may be in the form of community-based and ecosystem-based adaptation projects targeted to build climate-resilient sectors cost effectively. Planned adaptation, as ‘top-down’ approaches, refers to government-led programs designed to improve productivity and benefit a wide range of farmers. These programs are like those observed in agricultural planning and investment processes in regions facing similar changes (Wright et al., 2014).

Nevertheless, it is vital to understand the coping mechanisms and long-term adaptation strategies employed by farmers at micro-scale seaweed farming especially if SIDS have not gone into commercial seaweed aquaculture (Mateo et al., 2021; Ndawala et al., 2021). This will help to inform planned adaptation in the future by designing effective and sustainable adaptation strategies of oceanic-based economies and enhancement of seaweed farming communities’ adaptive capacities which will require a holistic understanding of such sustainable livelihoods in its localized socio-ecological and cultural system (Jagtap and Meena, 2021). Therefore, it is expected that successfully mainstreaming climate change issues into the seaweed mariculture sector will be slow and tedious at local level, but it will ensure sustainable development and harness many synergies (Birkmann et al., 2023). Mainstreaming implies that awareness of climate impacts and associated measures to address these impacts are integrated into existing and future development policies and plans of SIDS, as well as multilateral institutions, donor agencies and non-governmental organization (NGOs) (Calow et al., 2011). However, when it comes to successful mainstreaming through community participation, it is key to gain political will for attaining support in effective institutional and policy coordination to benefit affected community stakeholders which will allow prioritization of adaptation options that could even be included in future budget planning process as well.

Seaweed farmers are at the forefront exposed to current and future climate-related and environmental risk with little to no intervention from the Government (Buschmann et al., 2017; Monnereau et al., 2015; Nurse et al., 2015). Establishing seaweed farms along the coast has been led by individual seaweed farming communities with autonomous guidance (Aslan et al., 2018; Darmi et al., 2018), and as a result the seaweed mariculture industry has struggled to move from small-scale farming to commercial level as seen in the study by Ortiz Carabantes (2020) and reported frequently by FAO (2022). The seaweed industry in SIDS appears to have taken a proactive approach to climate adaptation (Duarte et al., 2017) to provide income as a full time and supplementary income to households in coastal communities (Shal et al., 2014; Terauds and Zhuawu, 2021). The cost of entry into this industry is relatively low with minimal technological barriers. If planned adaptation was occurring at farm-level, it would be important to identify those strategies and highlight best practices. Active community participation is the key driver for further sustainable development in seaweed-based regenerative ocean farming initiatives that are environmentally friendly and a viable bioeconomy option for coastal nations (FAO, 2022; FAO, 2014; Keller, 2009; Klöck et al., 2019; Krishnan et al., 2013; Nunn and Kumar, 2018; Yong et al., 2022).

### 3.2.3 Community participation in adaptation and seaweed mariculture in SIDS

The benefits of seaweed culture have not been fully appreciated by many sections of society yet including environmental practitioners, academics, entrepreneurs, coastal/island residents and government entities (Vincent et al., 2020). To address this and uncover some of the salient issues, a systematic literature review was conducted to identify gaps regarding the link between climate change and community participation in adaptation through seaweed mariculture development initiatives in SIDS. Only peer-reviewed articles and book chapters were included in this proposal research review (non-peer-reviewed sources or “gray literature” was considered). This study followed the formal systematic review process for transparency and reproducibility as delineated in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Page et al., 2021). This PRISMA protocol

followed the main points from the 27 checklists established and widely used methods in systematic reviews (Page et al., 2021). The systematic literature review was conducted to identify gaps regarding the link between climate change and community participation in adaptation through seaweed mariculture development initiatives in SIDS. Only peer-reviewed articles and book chapters were included in this proposal research review (non-peer-reviewed sources or “gray literature” was considered).

#### 3.2.4 Key trends in systematic literature review

These sustainable seaweed production systems have been more inclined to environmental approach as a diversification strategy to the fisheries industry with limited findings to the economic and social dimensions of sustainability of what seaweed farmers face on the ground and their adaptation mechanisms to climate change impacts. The broad affinities found across the literature reviewed include; (i) perceptions on increased climate variability and extreme events, (ii) other risk and shocks such as diseases and genetic pools (iii) socio-economic characteristics and viability, (iv) farm characteristics and decrease productivity, (v) limited technical support, (vi) behavioral anomalies amongst seaweed farmers and increased political infighting and (vii) others such as gender dimensions and increased interest to use ecosystem-based and community-based approaches in seaweed farming projects. It is further elaborated below.

*Increasing climate change threats:* Only a few studies have been conducted to investigate the socio-economic aspects of seaweed mariculture livelihoods and the perceptions on climate change impacts and adaptation strategies for safeguarding livelihoods and resilience coastal communities (Alemañ et al., 2019; Msuya et al., 2022; Sultana et al., 2023). The perceptions of seaweed farming as a diversification strategy are that it has not reduced the vulnerabilities to climate and non-climate related factor (Hassan and Othman, 2019). Instead, climate variability is predicted to impact global mariculture industries and is the greatest constraint for commercial mariculture in coastal communities in the coming decades (Del Valle et al., 2022; Oyinola et al., 2020). Changes in ocean conditions due to climate change may occur in the loss of suitable seaweed farming sites causing reduced production output, diseases, loss of markets, sea level rise causing coastal ecosystem changes among others (Oyinola et al., 2020; Del Valle et al., 2022).

*Seaweed farming as a diversification strategy has not addressed vulnerabilities:* Recent studies have shown that there are climate-resilient seaweed strains such as *Eucheuma denticulatum* with favorable growth rates and local market acceptability (Adel et al., 2020) which can lead to selective breeding in the future as adaptation strategies (Naylor et al., 2021). Species diversification in seaweed culture may be a good adaptation strategy to avoid some of the socio-economic losses linked to climate change, especially in SIDS areas (Oyinola et al. 2020). However, Halling et al. (2012) highlighted the issue of narrowing genetic variation through species selection for promoting productivity and lead to unintended consequences such as losses in resilience capacity to eco-physiological stressors in environmental conditions. For instance, in seaweed farming, vegetative propagation was mostly practiced avoiding depletion of natural seaweed banks and in turn does not hamper seaweed habitats that may be home of commercially valued juvenile marine organisms such as shrimps, conch and lobsters (Pereira et al., 2020).

Due to major losses in seaweed farming, Indonesian communities diversified the set of mariculture species through integrated multi-trophic aquaculture (IMTA) at small-scale and included the culture of pearl oysters, mixed fin-fish species, abalone, sea cucumber and lobster into one farming system (Ode et al. 2015). Adopting an ecosystem services approach to mariculture development can have economic, social, environmental and cultural value for multiple beneficiaries in the marine space to ensure industry sustainability (Ode et al. 2015). The IMTA approach has been implemented in China at the commercial level but can have complex environmental impacts as highlighted by Del Valle et al. (2022) in a spatial temporal

study. Del Valle et al. (2022) also showed trends of future growth within the mariculture sector that will likely be constrained by the availability of suitable farming sites, and the opportunity cost of sea areas may likely be increased soon.

*Increased autonomous adaptation response in the face of decreased seaweed production:* In the face of climate change and the need to adapt, many developing seaweed industries, including the Philippines, also face a lack of government support, weak institutions, and poor legislation which can contribute to unstable incomes in addition to the environmental pressures (Andriesse and Lee (2017). This has led seaweed farmers to become marginalized and isolated within the seaweed value chain and heavily relying on the international civil society for support to advance this livelihood (Andriesse and Lee, 2017). Small-scale farming often needs to be creative in adapting to sustain their livelihoods but require more government intervention and support (Andriesse and Lee, 2017; Ode et al., 2015). This same issue was also faced in Zanzibar, Tanzania (Hashim 2015; Hassan and Othman 2019).

Moreover, Hassan and Othman (2019) noted that seaweed farming was becoming unattractive business in Tanzania and those who were involved had no alternative reliable income sources. This led to other coping mechanisms after harvesting seaweed such as harvesting wild seaweed species, developing seaweed-based value-added products, constructing shelters for drying and storing raw seaweed and even engaging in other economic activities to diversify their household income. Therefore, the decreasing trend of seaweed production and quality was due to mainly weather and climatic variables such as increasing seawater temperatures, wind speed, sea waves, irregular rainfall patterns and salinity. This has reduced the quality of seaweed, decreased crop yield, and washed away seaweed seedlings during strong wind, storms and flooding events. Seaweed species like *Eucheuma cottonii* was once very profitable but with increase seawater surface temperature, it has been impacted by *ice-ice* disease, epiphytism and fouling in areas it uses to grow (Mmochi et al., 2005; Msuya, 2007; Msuya, 2012 cited in Hassan and Othamn, 2019).

An earlier study by Hashim (2015) in Tanzania linked global climate change and climatic variables to the inability of seaweed to survive in coastal areas due increased seawater temperature. Consequently, changes in water temperature have induced an outbreak of heat-loving invasive plants or epiphytes that have caused increased events of *ice-ice* seaweed disease leading to dying-off of large volumes of seaweed. Also, Hashim (2015) revealed autonomous interventions by seaweed farmers using their wealth of indigenous knowledge in developing coping mechanisms to reduce damage to crops due to environmental stressors. Coping mechanisms to combat the impacts of climate change included; using heavy stones and poles to fix seaweed; planting tolerant seaweed species, improving equipment for regular planting and tending operations, while adaptation measures included; planting seaweed in deeper waters where it is cooler; relocating seaweed farms in areas that are protected by mangroves and enclosed areas to reduce the exposure and impacts of strong winds (Hassan and Othman, 2019; Hashim, 2015).

*Increased gender dimensions and increased efforts of international civil society:* An increasing trend on the gender dimensions of seaweed farming has appreciated the role of women in the farming operations making seaweed livelihood a household business (Sunadji et al., 2021) and a family economic survival strategy (Subair and Haris, 2019). This was also aligned with the study presented by Hassan and Othman (2019) that seaweed farming activity was a family-owned business that acts as an adaptation strategy to climate change. Despite the household economy improving when the family is fully engaged, Sunadji et al. (2021) revealed this livelihood is very weather dependent as some periods of the year it would rain heavily and there is need to diversify the household income. With the increased efforts in CbA and EbA initiatives, literature remains disconnected from economics and social dynamics but there is further needed to conduct interdisciplinary research analyzing the synergies that are beneficial for smaller economies to undergo transformational adaptation rather than

incremental adaptation as climate change impacts increase (Thomas et al., 2020). There is a need for further research in adaptation strategies for the improvement of local economy and enhance capacities of community-led environmental restoration initiatives for long-term climate resilience.

Interestingly, there was a comprehensive field-based study conducted in Brazil by Pereira et al. (2020) that proved the sustainability of farming a native and local seaweed species, *Hypnea pseudomusciformis*. This was an initiative that was supported by the international civil society as a mechanism in investigating the viability of seaweed ecosystem goods and service which was measured using environmental indicators in ways seaweed farming contributes to the protection of biodiversity and genetic conservation. Although the field study reported the cost of production for the startup of a seaweed farm, it didn't conclude whether it was a profitable endeavor for locals. The economic and social dimensions of this industry were a concern as seaweed wasn't a food ingredient traditionally used by locals but was certainly consumed by tourists (Pereira et al., 2020). This affected the sustainability of the startup seaweed industry in Brazil and required educational awareness in promoting the benefits of including seaweed in daily diet.

### 3.3 Summary and Research Gaps

As the literature on seaweed mariculture continues to be fragmented, this systematic review showed the lack of research in SIDS as it pertains to seaweed mariculture developments. There was no literature on the Caribbean SIDS. It was unclear whether seaweed farming was an ideal and profitable livelihood as a climate change adaptation strategy. In practice, there seems to be a continuum of CbA and EbA approaches applied in the field with substantial overlaps at the core of these community-driven initiatives. Although EbA practices have been considered for developing seaweed mariculture, it has not fully embraced ecosystem services and functionality and continues to operate with strategies used in natural resource management at community-level. However, future developments of seaweed mariculture in the open sea must incorporate an EbA and CbA approaches into SLF with a focus on reducing risks to the social-ecological and cultural systems. There is a need to incorporate culture capital into the SLF along with the EbA and CbA to further investigate and assess coping mechanisms and other adaptation strategies that may be non-climate related from a farmers' perspective. This includes the culture of its social and political landscape that has a strong impact on the productivity of a striving ocean-based industry. Overall, the research questions in this study remain unanswered and efforts in this research will seek to address the gaps to better understand the perceptions of seaweed farmers in their ability to cope and adapt to current and future climate change impacts along with human driven stressors and changes. The following research gaps were highlighted in the systematic literature review as described below.

*Lack of research from SIDS:* Consistent with other parts of the world, very little information was found on seaweed mariculture as an adaptation strategy in Caribbean SIDS. Among the few reports found, there was little consideration of the perceptions of seaweed farmers, and they did not differentiate the perceived short-term coping and long-term adaptation strategies and little evidence of how scientific knowledge and innovation can be transferred and scaled up to seaweed farmers. In general, there was poor field-based research on identifying ways to build resilience in the seaweed mariculture particularly under climate change such as diversification of cultured seaweed species and development of technological innovations to improve resource efficiency and profitability of this sector. There is a need for more rigorous research to develop the understanding of climate change impacts, adaptation barriers and risks.

*Lack of short- and long-term adaptation strategies employed by seaweed farmers:* There was contradictory evidence in the literature reviewed purporting seaweed farming as an economically viable industry (Ode et al., 2015). Others noted that the industry was becoming increasingly unattractive and was only being practiced by marginalized and most vulnerable groups in coastal communities (Hassan and Othman, 2019). There were consequences of planned and autonomous adaptation approaches observed throughout the literature which required further investigation to identify the ability of communities to access financial services, including insurance, to reduce risks. Financial, infrastructural and institutional support of seaweed farmers is crucial to improving the resilience of ocean-based farms against the risks inherent to mariculture operations (Del Valle et al. 2022). These risks include climate and non-climate related factors such as unfavorable weather conditions, pest and disease outbreaks, personal injuries, variable market conditions and resources efficiency (ie. fuel consumption, time demands, and overall logistics requirements for seaweed mariculture operations). For example, with increased flooding events and *ice-ice* seaweed disease outbreaks in the twentieth century, it required planned adaptation rather than autonomous. However, it wasn't revealed what seaweed farmers were doing on the ground.

The improvement of monitoring, planning, and policies and strategy development for improving the livelihoods of seaweed farmers will need to consider more explicitly the changing environmental conditions (Ode et al. (2015).) Changes in the marine environment will significantly impact on mariculture activities, extreme events and their likelihood of increasing severity and frequency will also need to be given due consideration (Oyinlola et al., 2020). There are some key underexplored areas that are both sensitive to environmental change but also crucial to understanding its implications for food security and adaptation strategies; scenarios specifically designed to investigate the wider issues that underpin food security, and the environmental consequences of different adaptation options are lacking. Few efforts have focused on the aspects of adaptation measures implemented at the drying stage of seaweed and at biosecurity level especially in dealing with disease incidences and its treatment due to limited knowledge and adaptive capacity (Hassan and Othman, 2019).

*Lack of evidence in scientific knowledge transferred to seaweed farmers:* There is a need for further research to understand the causes and drivers of vulnerability along with identifying ways of building adaptive capacity within the seaweed mariculture sector. Such adaptation strategies suggested by Oyinlola et al., (2020) includes revision of marine aquaculture zoning and site selection factoring in climate change to reduce uncertainties and minimize impacts on production and dependent socioeconomics. There is increased interest in farming different strains of native seaweed species in the tropics to maintain high species richness and withstand future losses. However, information on genetic variation among seaweed is yet limited. The hybridization and the development of new strains from native species have been reported as a way to improve survival rates but should consider potential negative ecological impacts (Halling et al. 2012). This kind of research and access to improved strains could help to improve seaweed yield and economic return if farmers enable them to choose seed stocks better suited for specific farming locations and seasons (Halling et al., 2012). However, there was no evidence of how this recommendation can be mobilized to benefit seaweed farmers.

*Poor field-based research in building resilience in mariculture particularly under climate change:* Further investigation is required on the socio-economic and governance factors determining seaweed mariculture productivity in the face of climate change, a gap which this study proposes to address. This would include investigating the sustainability of the future expansion of aquaculture linked to the effectiveness of conservation and governance measures. For planned adaptation, policymakers will be required to set clear objectives for the industry and ensure the rule of law and due processes are followed. Concerns of spatiotemporal dynamics for commercial seaweed production was mainly focused on

improving the efficiency in the production process by increasing farming density through optimized design of the structures in which seaweed is farmed (Del Valle et al., 2022). It was unclear how this could be implemented onsite where seaweed farms may be in remote areas. However, there were no details provided on strategies that can be employed to achieve scaling up of seaweed production. Studies in the future will need to focus on seaweed aquaculture development projections at the regional and national scale and use downscaled climate data and other relevant data sets at resolutions relevant to such analyses. It would be important to incorporate the socio-economic and governance aspects in projection studies as it will aid in adapting to the impacts of climate change on the future suitability of ocean sites for farming aquatic organisms for food production. Hassan and Othman (2019) call for new research to develop new adaptation technologies that will help farmers to counteract the effect of desiccation and associated diseases aggravated by climatic variables in the field.

## 4. METHODOLOGY

This chapter outlines the methodological framework used to investigate the sustainability of seaweed mariculture in Belize, with a particular focus on its role as a livelihood activity and climate adaptation strategy in the context of Small Island Developing States (SIDS). A mixed-methods design was employed to address the five research questions guiding this study, integrating qualitative and quantitative approaches to ensure methodological triangulation and enhance the robustness of findings. The chapter is structured as follows: Section 4.1 introduces the mixed-methods approach, Section 4.2 outlines the research timeline, Sections 4.3–4.5 detail the qualitative and quantitative assessments, Section 4.6 discusses ethics and data protection, and Section 4.7 provides a summary of the methodology.

### 4.1 Overview of Mixed Methods Approach

This study employed a mixed method approach integrating qualitative and quantitative tools to investigate the status of seaweed mariculture and its implications for climate adaptation and livelihoods in the SIDS of Belize (outlined in Table 4.1 and illustrated in Figure 4.1). The research design was structured to capture the multidimensional nature of seaweed aquaculture, which simultaneously represents a livelihood activity, an adaptation strategy, and a sector embedded within broader Blue Economy and policy frameworks. Five research questions guided the study, each addressed through specific qualitative and quantitative methods (Table 4.1). This design enabled methodological triangulation by drawing on multiple sources of evidence, thereby enhancing the validity of findings. Data collection combined participatory focus group workshops, semi-structured household surveys (N=18, representing all active farmers in Belize at the time of research), elite interviews and a systematic policy review. These primary data were complemented with secondary information available from the national databases and grey literature.

The overarching aim was to investigate adaptation response strategies to climatic and non-climatic hazards and identify the key components of the Sustainable Livelihood Framework (SLF), human, social, natural, physical, financial, and cultural capitals, that shape household well-being and economic stability for seaweed farmers. Since existing adaptation mechanisms of seaweed farmers were poorly documented, the study also sought to establish a baseline understanding of farmer perceptions, strategies and institutional support mechanisms. This was undertaken within the conceptual frame of community-based adaptations (CbA) and ecosystem-based adaptations (EbA) (Reed et al., 2013a) both of which emphasize the sustainability of nature-based livelihoods in vulnerable coastal contexts (Dhar and Khirfan, 2016; Reid, 2016c).

The qualitative phase began with a systematic literature review guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), to synthesize evidence on seaweed mariculture, adaptation strategies and policy frameworks and design the research approach to inform this study. This was supplemented by a scoping review of grey literature to capture applied and practice-based knowledge often excluded from peer-reviewed sources. At the field level, participatory techniques were facilitated and analyzed using the Community-Based Risk Screening Tool - Adaptation and Livelihoods (CRiSTAL) toolkit to identify local hazards, coping mechanisms and adaptation strategies. Semi-structured household surveys (N=18, representing all active farmers in Belize at the time of study) were conducted to collect data on socio-demographic characteristics, perceptions of climate change impacts, and the sustainability of seaweed farming practices. In addition, elite interviews with key national and regional state and non-state actors provided insights into policy measures addressing climatic and non-climatic hazards impacting the emerging seaweed farming sector. To complement these, a PESTEL framework (Political, Economic, Social, Technological,



Environmental, and Legal Factors) was used to systematically review the effectiveness of existing policy measures and governance mechanisms in supporting seaweed farming in Belize.

In the quantitative phase, structured surveys and statistical analysis were employed to identify and measure the impacts of key factors, based on the SLF capitals, on the sustainability of seaweed mariculture livelihoods. Using Statistical Package for the Social Sciences (SPSS), the data were analyzed using Pearson chi-square tests and linear regression models to examine relationships between socio-demographics variables and production outcomes. Additional tests included independent *t*-test, cross tabulation and factorial analysis (Creswell, 2011). To validate regression assumptions, the normality of residuals was assessed through graphical methods (histograms and normal P–P plot) (Appendix C, Figure 9.6.). The residuals approximated a normal distribution, supporting use of Pearson’s correlation and regression in this analysis.

| <b>Research Question</b>                                                                                     | <b>Research Approach</b>                                                                                                                     | <b>Data Sources</b>                                                                                                                                                          | <b>Analysis Tool or Methods Used</b>                                                                                                                                                                                   |
|--------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. What are the key characteristics of seaweed aquaculture in the context of SIDS?                           | Community-based (CbA) and ecosystem-based adaptation (EbA) concepts in the context of sustainable livelihoods frameworks and blue economies. | Peer-reviewed articles, reports, policy documents on climate adaptation theory.                                                                                              | The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol was used for the systematic literature review.                                                                                |
| 2. What are the main opportunities and challenges faced by seaweed mariculture in SIDS?                      | Utilized qualitative participatory Rural Appraisal (PRA) approach combined with qualitative and quantitative techniques.                     | Seaweed farming community workshops, surveys, and elite interviews followed up with quantitative household surveys with the seaweed farmer participant as head of household. | Focus group discussions (FGDs) employed the Community-based Risk Screening Tool-Adaptation and Livelihoods (CRiSTAL) toolkit to investigate existing adaptation strategies.                                            |
| 3. What are the main climatic and non-climatic hazards impacting the livelihoods of seaweed farmers in SIDS? |                                                                                                                                              |                                                                                                                                                                              | Administered household semi-structured interview surveys to capture socio-demographics and variables of interest.                                                                                                      |
| 4. What are the existing responses, practices, and strategies being implemented by seaweed                   |                                                                                                                                              |                                                                                                                                                                              | Conducted elite interviews with regulatory agencies, civil society, and regional entities involved in overseeing seaweed farming operations and projects in Belize.<br><br>Conducted reflexive thematic analysis using |

|                                                                                                                                                                           |                                                                                                                                                                                                                              |                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| farmers to cope with and adapt to climate- and non-climatic hazards in SIDS?                                                                                              |                                                                                                                                                                                                                              |                                                                                          | NVivo for qualitative data, and descriptive and inferential statistical analysis using SPSS statistical software for quantitative assessment.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 5. To what extent, if at all, are the policy measures in place in the SIDS of Belize capable of tackling climate and non-climatic hazards in relation to seaweed farming? | The PESTEL (political, economic, social, technological, environmental, and legal) approach was used to conduct policy analysis on the existing policy measures tackling climate and non-climatic hazards in seaweed farming. | National laws, policies, and open-source databases on aquaculture and marine governance. | <p>Conducted a keyword search of national law(s) or policies in relation to the governance of seaweed farming operations.</p> <p>Performed a policy analysis to systematically evaluate the political, economic, social, technological, environmental, and legal (PESTEL) factors affecting Belize's policy measures and legal frameworks for tackling climate and non-climatic hazards in seaweed farming.</p> <p>A content thematic analysis was conducted using binding and non-binding legislation frameworks in relation to Belize's aquaculture (ie. mariculture) development sector using NVivo software.</p> <p>Conducted descriptive and inferential analysis (Crosstabs correlations, Factorial analysis, Pearson Chi-square and regression statistical test) using SPSS software for the ranking/prioritization of perceived climate adaptation options in relation to seaweed farming activities.</p> |

*Table 4.1. Overview of research design and methods for the mixed methodological approach to answer the thesis research questions (section 1.7) (Author's own elaboration).*

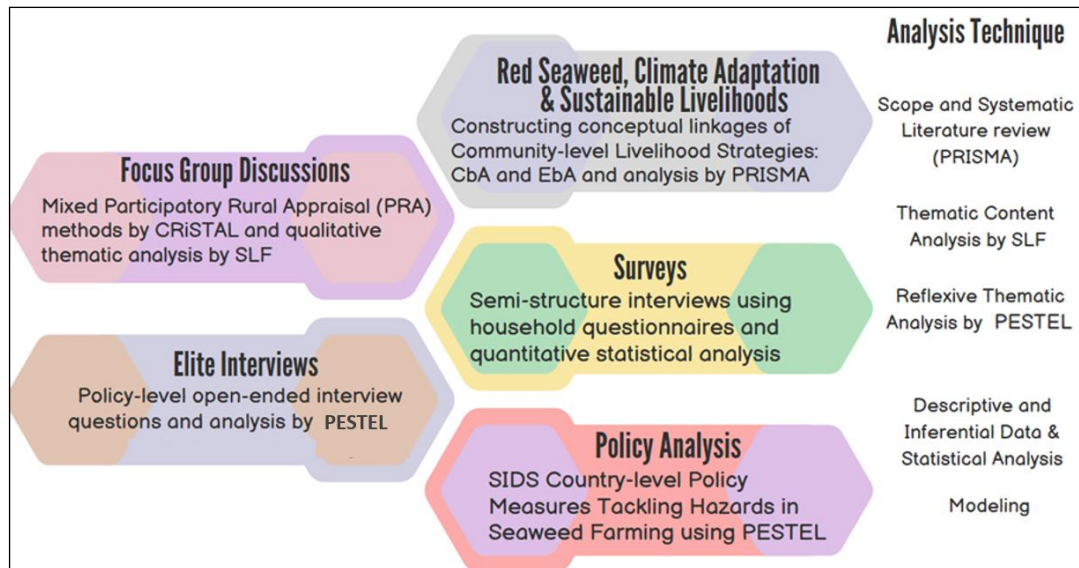


Figure 4.1. Summary of mixed methodological framework used in this thesis for analyzing red seaweed, climate change adaptation, and sustainable livelihoods in Belize (Author's own elaboration).

## 4.2 Research Timeline and Roadmap

The doctoral research was conducted over the course of three years (Figure 4.2.). The stages comprised of:

- a comprehensive review of the existing literature,
- the collection of both qualitative and quantitative data,
- the analysis of the data, and
- the Communication, reporting, and of the findings.

The research began with an extensive literature review during the first year, which included scoping and systematic analysis to identify key research gaps and develop a robust theoretical framework based on the SLF and the blue economy paradigm. This phase also involved the development of research tools and securing necessary approvals, ensuring that the groundwork was done before fieldwork commenced. In the second year, qualitative and quantitative data collection was done, where surveys, interviews, and focus group discussions were conducted with local stakeholders, including seaweed farmers, processors, and Marine Protected Area (MPA) co-managers. The data gathered provided insights into the livelihoods, climate-related hazards, and adaptation strategies within the seaweed aquaculture sector. The final year was dedicated to data analysis, where both qualitative and quantitative methods were employed to analyze the collected data. After which the interpreted findings and discussion were reported and presented on various platforms which is further elaborated in Appendix H (Conferences, Workshops, Professional Development Activities and Peer-Reviewed Publications (2021–2025)).

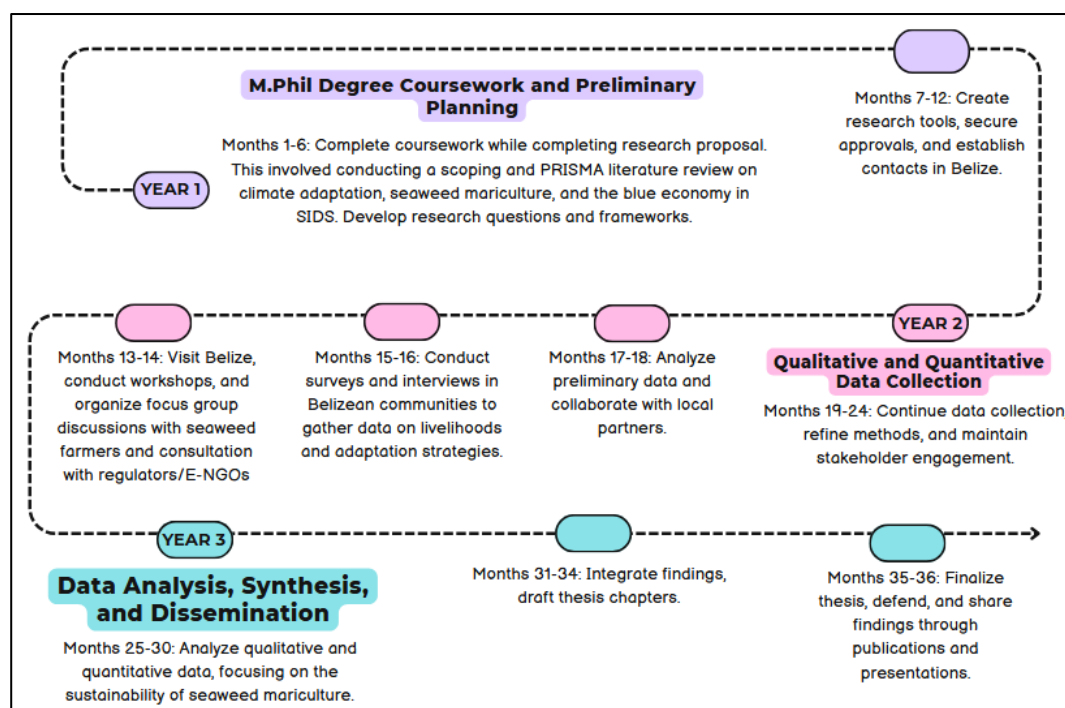


Figure 4.2. PhD Phased Research Timeline for the Investigation of Climate Adaptation Strategies in Seaweed Aquaculture within Caribbean SIDS (Author's own elaboration).

### 4.3 Data Collection

The sample size for the surveys was determined as the entire population of active seaweed farmers in Belize, based on a list provided by relevant regulatory agencies. Thus,  $N$  = all active seaweed farmers at the time of research. This census-style approach ensured a 95% confidence level with a 5% margin of error.

Quantitative data was collected through questionnaires with both closed- and open-ended questions, while qualitative data was collected through focus group dialogues. Data collection followed several phases: (i) a systematic literature review guided by PRISMA (ii) participatory focus groups guided by the CRiSTAL toolkit, (iii) household surveys administered to seaweed farmers, (iv) elite interviews with state and non-state stakeholders, and (v) a policy review using the PESTEL tool.

The survey data provided the basis for developing a quantitative model was developed to measure variables in the SLF capitals. This facilitated the identification of factors impacting the socio-economic benefits of seaweed cultivation and the determinants for improving the livelihoods of seaweed producers. Variables included production indicators (eg. the amount of seaweed harvested and its value) and socio-demographic and household variables (eg. education, age, recent overall physical health, approaches to seaweed farming, and even farm cluster structure) (Putri Maslia et al., 2024).

All data were systematically organized and cleaned prior to analysis. For qualitative data, this involved transcribing interviews, coding responses, and categorizing themes. For quantitative data, survey responses were entered into spreadsheets, cross-checked for accuracy and completeness before entering it into SPSS statistical software. Descriptive statistics were used to summarize the key variables and identify main trends, while inferential statistics were conducted to make generalizations about seaweed farmers population based on the census-style dataset.

## 4.4 Qualitative Assessment

### 4.4.1 Systematic literature review

A systematic literature review was undertaken, using PRISMA protocol complemented by a scoping review to synthesize evidence on seaweed farmers' perceptions of short- and long-term climate change adaptation in SIDS. The PRISMA protocol was adopted to ensure the replicability and transparency of the study (Page et al., 2021). The review was structured in three stages according to the methodology suggested by (Yigitcanlar, (2021) and (Regona et al., (2022)). The central research question was: "What are the current perceptions of seaweed farmers in response to short- and long-term climate change adaptation in SIDS?".

The PRISMA review queried Web of Science, Scopus, and SpringerLink for peer-reviewed journal articles and book chapters published 2000–2023 (English only). Searches were first run 1 June 2022 and updated 14 February 2023. This is reflected in chapter 3 section 3.2.4. The scoping review complemented this by capturing grey literature and applied reports not indexed in the three databases, ensuring that policy, programme, and practice evidence relevant to seaweed mariculture and adaptation in SIDS was included. This is reflected throughout chapters 1,2, 3 and 4.

Search strings combined terms for seaweed farming ("seaweed mariculture/aquaculture/cultivation/farming; marine aquaculture"), climate change/adaptation, and SIDS/small islands using Boolean operators and field tags (e.g., TITLE-ABS-KEY/TS). Full strings are provided in the supplementary material. Inclusion criteria targeted studies addressing seaweed farmers' perceptions and/or adaptation in island and small-state contexts. The refined database search yielded 1,012 records; after duplicate removal, 254 remained. 145 records underwent abstract screening; 15 proceeded to full-text assessment. One chapter lacked retrievable full text, producing a final set of 14 peer-reviewed publications. The selection workflow is summarized in Figure 4.3 (PRISMA flow diagram).

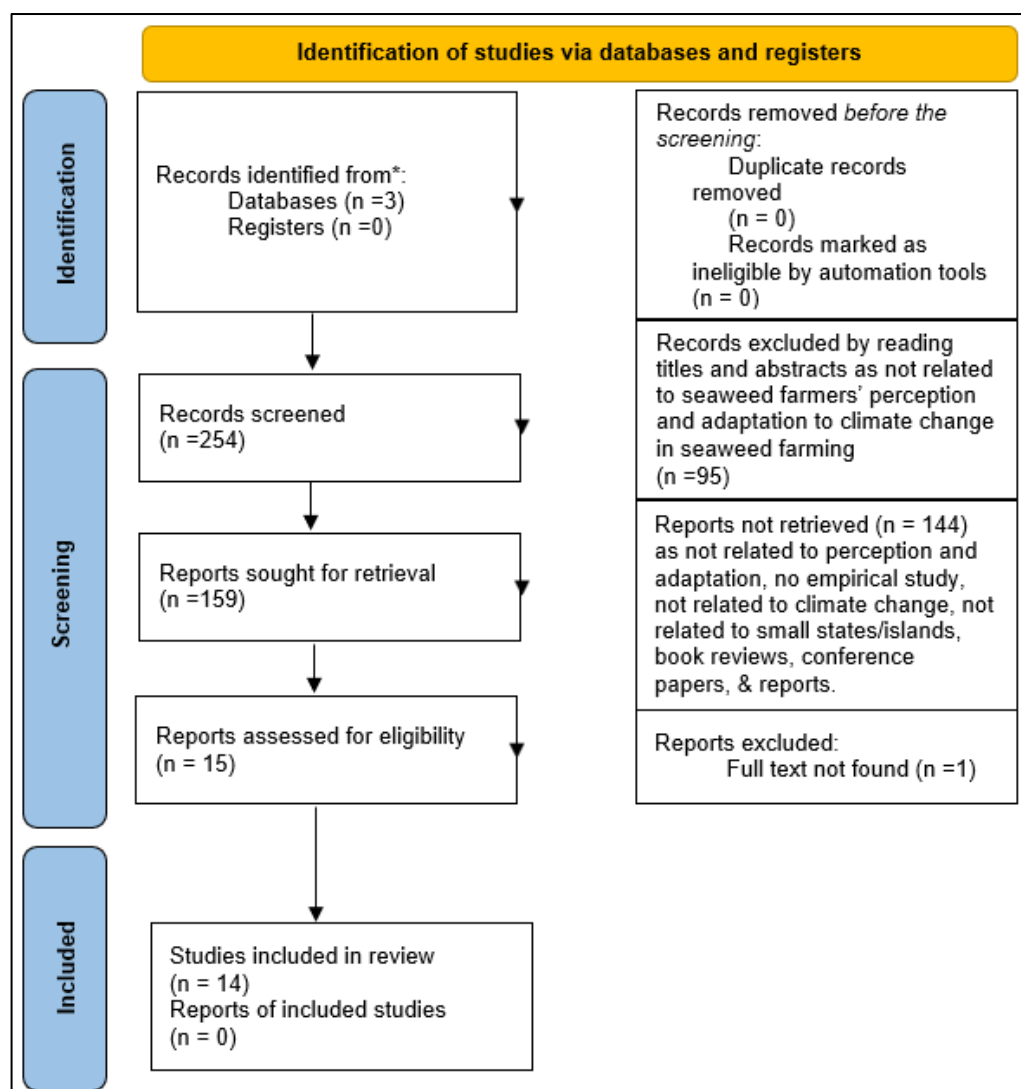


Figure 4.3. PRISMA flow chart showing the selection procedures of the studies (Author's own elaboration adopted from Page et al. (2021)).

#### 4.4.2 Participatory focus groups and the CRiSTAL tool

Participatory focus group discussions (FGDs) were facilitated using the CRiSTAL toolkit (IISD 2012). The CRiSTAL toolkit was applied as a decision-support tool for hazard screening and climate change adaptation into community-level planning, enabling seaweed farmers to identify hazards, evaluate adaptation responses and prioritize feasible adaptation strategies.

Complementary PRA tools including historical timelines, institutional mapping, seasonal calendars and livelihood charts, were used to capture perceptions, beliefs, and adaptation mechanisms. The FDGs provided rich insights into coping strategies, hazard management and ways in which community knowledge informs climate change adaptation decision-making at the community-level.

##### 4.4.2.1 Thematic Content Analysis using SLF

Thematic analysis of FDGs and field observations was conducted following Mohamed et al. (2020), with data transcribed, entered in Microsoft Excel and coded for analysis. Analysis was guided by the SLF as operationalized in the CRiSTAL toolkit.

The SLF approach emphasizes five capitals: natural, physical, financial, human, and social resources (Camarra, 1998; IISD, 2012; Obonyo et al., 2013). To capture the artisanal and cultural dynamics of Belize's seaweed mariculture, a sixth category, cultural capital or assets, added reflecting traditional knowledge, community cohesion (Angelsen, Larsen, et al., 2011) and shared values (Makame et al., 2021; Recinos and Blue, 2019). Through this framework, SLF was used to link the interplay between various livelihood assets and the community's capacity to adapt to climate change including tangible and intangible assets (de la Torre-Castro et al., 2022; Jones et al., 2011b).

Utilizing the CRiSTAL toolkit as a guide in the discussions, drawing maps and developing an understanding of seasonal ocean weather-related events with details of farming activities that took place in the years of farming experience. This included the types of seaweed, species cultured, and the main challenges experienced with aspects to climate change. This provided information on the spatiotemporal vulnerability of farmers and when adaptation strategies could be employed. It also provided information on how farmers coped with some risks.

To understand seaweed livelihood adaptation strategies implemented by seaweed farmers in Belize, the CRiSTAL toolkit was used to identify assets, hazards, perceived risks associated with and unrelated to climate change, as well as their short- and long-term coping mechanisms while providing a platform for team building and knowledge-exchange. Additional outputs from the CRiSTAL toolkit included: (i) an evaluation of seaweed farmers' ability to adapt to climate variability and change; (ii) suggestions for interventions and adaptation strategies to strengthen the resilience of seaweed farmers' livelihoods; and (iii) an order of importance for actions based on risk and implementation feasibility. However, for the toolkit to be implemented successfully within the unique socio-economic, socio-legal, and socio-ecological constraints of the seaweed farming community, cooperation, understanding, and access to resources were required.

The main assumptions of the CRiSTAL toolkit in this process included:

- (i) that seaweed farmers would be sufficiently knowledgeable about climate change to participate in the toolkit's activities;
- (ii) that seaweed farmers would cooperate and participate appropriately in the process of gathering and analyzing data;
- (iii) that the toolkit's recommendations would be feasible and contextually appropriate for implementation within the unique socioeconomic and environmental conditions of the seaweed farming communities; and
- (iv) that seaweed farmers would have access to the necessary networks, and support for the implementation of adaptation measures identified through the toolkit process.

For analysis purposes, the following assets and hazards were categorized in the following structure according to SLF:

#### *Livelihood Assets Categorization*

In the SLF, six key types of assets were identified (Table 4.2.), enabling respondents to achieve their sustainable livelihood activities (Scoones, 1998; DFID, 1999). Although the assets were interrelated and worked together to support the diverse strategies respondents used to secure their well-being, the key type of asset was selected based on the context in which the response was given.

| Type of Asset | Definition                                                                                                                                                                                                                                                                                                                                                          | Example                                                                                                       | Reference                   |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|-----------------------------|
| Human         | Refers to the knowledge, skills, health, and capacities that individuals possess. Human capital is crucial for individuals to engage in productive activities and pursue various livelihood strategies.                                                                                                                                                             | Education, training, health status, and the ability to adapt to changing circumstances.                       | (DFID, 2010; Scoones, 1998) |
| Natural       | Refers to the natural resources and environmental assets that individuals rely on for their livelihoods. Sustainable use and management of natural capital are essential for long-term livelihood security.                                                                                                                                                         | Land, water, biodiversity, and ecosystem services.                                                            | (DFID, 2010; Scoones, 1998) |
| Physical      | Comprises the tangible assets necessary for livelihood activities. Access to and maintenance of physical assets are crucial for carrying out livelihood strategies effectively.                                                                                                                                                                                     | Infrastructure, tools, equipment, farming practices and other physical resources.                             | (DFID, 2010; Scoones, 1998) |
| Financial     | Involves the economic resources and assets individuals have at their disposal. Financial capital is essential for purchasing goods and services, responding to emergencies, and investing in livelihood-enhancing activities.                                                                                                                                       | Income, savings, credit, and investments.                                                                     | (DFID, 2010; Scoones, 1998) |
| Social        | Encompasses the social relationships, networks, and institutions that individuals or communities can rely on. Strong social capital enhances cooperation, facilitates resource-sharing, and contributes to the overall resilience of livelihoods.                                                                                                                   | Community connections, social support, and collective action.                                                 | (DFID, 2010; Scoones, 1998) |
| Cultural      | Influences how individuals or communities collaborate (community cohesion), share resources and practices (traditional knowledge), and engage in collective action (intangible assets). Cultural capital influences the social dynamics that shape livelihood strategies, strengthen social networks, and foster cooperation and mutual support within communities. | Shared beliefs, shared customs, shared values, and shared traditions, cultural ties, social norms, trust, and | (Engle, 2011)               |

*Table 4.2. Key Types of Assets in the Sustainable Livelihoods Framework.*

*Livelihood Hazards Categorization:* Hazards were defined as disruptions or stresses, occurring as sudden spikes in pressure (e.g., hurricanes, economic crises) or gradual, increasing pressures (e.g., soil degradation) (Reed et al., 2013b; Thompson, 2022). Moreover, hazards in livelihoods were described as various risks and threats that had the potential to cause harm, damage, or adverse impacts on individuals and communities' income-generating activities, property and the environment (Dewan, 2013; María et al., 2024). These hazards may have diverse origins and impacts, of which may arise from within or outside the system



of study (Reed et al., 2013b) posing challenges to people's economic activities and its long-term sustainability. Understanding and addressing these hazards was crucial for developing adaptation options within livelihood activity. Categorization of hazards according to literature has been further captured in appendix A, *Table 9.1*.

*Livelihoods Community-level Responses Categorization:* The SLF was used to analyze community-level responses to natural disasters. The responses identified were categorized into six categories: Human Capital, Social Capital, Natural Capital, Physical Capital, Financial Capital and Cultural Capital. Human Capital involves strategies related to knowledge, skills, education, and health, such as training programs for seaweed farming techniques or health interventions (Zhang & Fang, 2020). Social Capital involves social networks, community organizations, and collective action, such as cooperatives and community-based resource management (Abenakyo et al., 2008). Natural Capital involves approaches that utilize or conserve natural resources, such as diversifying crop production or implementing sustainable harvesting practices. Physical capital involves investments in infrastructure to mitigate risks, while financial capital involves economic strategies like savings and income diversification (Natarajan et al., 2022). Cultural Capital refers to traditional knowledge and practices embedded in the community, such as indigenous knowledge systems for weather prediction or ritual practices promoting communal resilience (Moncada, 2016).

#### 4.4.3 Qualitative surveys

Surveys were conducted in the form of questionnaires using semi-structured interviews to collect data with all active seaweed farmers based on a contact list provided by regulatory agencies and E-NGOs (see survey instrument in appendix C section 9.3.1). Respondents also included fishers with dual livelihoods who had harvested wild seaweed. Interviews were arranged through in-person visits, phone calls, Zoom, or WhatsApp, ensuring flexibility and full participation.

For qualitative questions regarding household assets in the survey, the Likert scale was used (Batterton et al., 2017). The Likert scale is a useful way to measure or rate responses in qualitative surveys, as suggested by Wuensch (2005). It shows whether there were direct linkages to seaweed farm households or clusters to the productivity of seaweed farming activities in each of the study sites. In addition to the structured questions in the questionnaire, a mix of closed- and open-ended and checklist questions were administered to generate detailed and contextual discussions on the adaptation strategies to climate change variability. Data were collected using a number of variables as guided by Worku et al. (2014) including household characteristics, livelihood strategies, household asset and income composition, expenditure, preference for seaweed cultivation farming systems in the open ocean, seaweed collected/farmed, climate and non-climate factors affecting seaweed-derived income dependence, climate change impacts trend and the consequent vulnerability, and ex-ante risk and ex-post coping strategies of seaweed farming in the marine environment.

Informed consent (see consent form in appendix D, Figure 9.11.) and information sheets (see information sheet in appendix D, Figure 9.10.) were provided to all participants.

#### 4.4.4 Elite interviews

Elite interviews were conducted with key stakeholders, including government officials, policymakers, environmental experts, and representatives from private organizations, directly engaged in seaweed governance, project implementation, or advocacy (elaborated in appendix F section 9.6.1 including transcriptions). A structured interview protocol was developed, encompassing topics such as regulatory frameworks, environmental regulation, blue growth measures, and community engagement. The elite interviews were conducted via in-person meetings, Zoom calls, or written responses, with participants' consent to record the sessions.

The collected data were subsequently transcribed, organized, and coded to identify common themes and insights related to the socio-legal and socio-ecological challenges affecting seaweed farming (see elite interviews codebook in appendix F section 9.6.2).

The elite interviews were designed to engage stakeholders deeply involved in the governance, implementation, advocacy of seaweed farming practices as well as stewardship. The objective was to gain a comprehensive understanding of the regulatory, environmental, and socio-economic dimensions that impact the sector.

The interview participants comprised of two primary groups:

*Regulatory Authorities:* This group comprised individuals involved in the governance and regulation of seaweed farming at both national and regional levels. These interviews aimed to explore the existing legal and policy frameworks, challenges related to regulatory compliance, and the strategic direction of seaweed farming initiatives. The focus was on understanding how governmental policies address the development, sustainability, and scaling of seaweed farming practices.

*Environmental Non-Governmental Organizations (E-NGOs):* Participants from this group were selected to provide insights into the environmental and socio-economic implications of seaweed farming. The interviews with E-NGO representatives focused on issues such as environmental conservation, sustainable development practices, and community-based approaches. This group also offered perspectives on the integration of global environmental standards and best practices into local seaweed farming operations.

#### 4.4.5 Thematic content and reflexive analysis by PESTEL

Elite interviews were analyzed thematically using the PESTEL framework (Political, Economic, Social, Technological, Environmental, and Legal factors) to provide structured insights into the policy-level opportunities and constraints shaping seaweed mariculture in Belize. The elite interviews included seven questions covering themes such as integration of seaweed farming into the national BE strategy, the role of blue bonds in scaling up mariculture, the contribution of seaweed livelihoods, and climate adaptation and the policy and regulatory frameworks supporting nature-based solutions and sustainable livelihoods. These interview questions included:

1. Is there a Blue Economy Strategy Plan in Belize, and if yes can you describe blue growth strategies currently employed?
2. Do you think that there is a link between seaweed farming and climate change adaptation for blue growth?
3. Is there any legislative framework in place for safeguarding nature-based solutions (such as seaweed farming) in Belize's Blue Economy Plan?
4. To what extent are seaweed mariculture activities captured in the Belize Blue Economy Strategy Plan in relation to the rollout of the Belize Blue Bond?
5. How does the blue bond capture the scaling up of seaweed farming activities in Belize through blue growth financial mechanisms/instruments? If not, is there any plan to do so?
6. Do you think that seaweed farming, in this current status, is beneficial to sustain the livelihoods of those who work in it? If not yet, what do you think is needed in steps towards it?

7. What space and scale of development do you think seaweed aquaculture can have in Belize (how do you envision this type of sustainable development to benefit Belize's socio-economic and environmental wellbeing), and more general in the Caribbean region?

Qualitative data were transcribed, imported into Excel, and coded in NVivo to identify recurring patterns and themes (Cavendish, 2002). Thematic coding under PESTEL enabled systematic categorization of responses, ensuring consistency, validity, and comparability across participants at a policy-level.

*Thematic analysis:* The key themes derived from the elite interviews were systematically categorized using PESTEL as a framework in analyzing the qualitative data as shown in Table 4.3. Therefore, the following categories structured the analysis:

| Category          | Key Themes                                                            | Description                                                                                                                         |
|-------------------|-----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Political (P)     | National Blue Economy Strategy, Blue Bond, Institutional Coordination | Themes related to government priorities, international commitments, and institutional arrangements shaping seaweed governance.      |
| Economic (E)      | Market Opportunities, Access to Finance, Investment Mechanisms        | Themes focusing on revenue generation, funding opportunities, trade markets, and blue growth financial instruments.                 |
| Social (S)        | Community Participation, Equity, Livelihood Benefits                  | Themes addressing social inclusion, trust, cooperative norms, and livelihood benefits for seaweed farmers.                          |
| Technological (T) | Farming Innovations, Value-added Processing, Research & Monitoring    | Themes covering innovations in mariculture practices, availability of technology, and technical capacity for scaling up production. |
| Environmental (E) | Climate Change Risks, Biodiversity Conservation, Ecosystem Services   | Themes capturing ecological sustainability, climate resilience, and the role of ecosystem-based adaptation.                         |
| Legal (L)         | Regulatory Frameworks, Licensing, Compliance Mechanisms               | Themes related to national legislation, policy frameworks, and enforcement of fisheries and aquaculture governance.                 |

*Table 4.3. Key categories according to the PESTEL tool.*

It was important to analyze the elite interviews and focus groups on a complementary manner to ensure triangulation and reliability across data sources. While focus group discussions with seaweed farmers were analyzed using the SLF to capture household and community-level adaptation strategies, elite interviews with regulators and policymakers were examined using the PESTEL framework to evaluate broader governance, policy, and institutional drivers. This dual-framework approach allowed validation by comparing community-level priorities with policy-level perspectives, thereby strengthening the credibility and comprehensiveness of the findings.

The coding process for both datasets involved multiple readings to ensure familiarity with the material, followed by the development of a codebook with definitions and examples for each category (see Appendix F, Section 9.6.2). Codes were refined iteratively to ensure consistency in their application. Findings were further validated by cross-referencing existing literature, regulatory documents, and community perspectives, producing a holistic understanding of the socio-ecological and governance dynamics influencing seaweed mariculture in Belize.

#### 4.4.6 Policy analysis by PESTEL

The PESTEL framework was used to conduct policy analysis of the legislative framework supporting seaweed mariculture livelihoods. PESTEL captured both direct and indirect external factors impacting the sector such as the macroeconomic variables of trade, health, and environment, thereby providing a holistic understanding of the socio-economic and socio-legal dynamics that shape seaweed farming

Legislative frameworks governing various seaweed were categorized into binding and non-binding instruments, each serving distinct purposes in policy implementation and governance. Binding frameworks (e.g., statutes, regulations, and acts) established enforceable rules and regulations that ensure compliance with national and international standards, non-binding instruments (e.g., strategies, guidelines, and policies) provide strategic guidelines or policy recommendations supporting the development by offering direction and best practices without the enforceability of law. Together, these instruments reflect the policy environment within which seaweed farming operates.

Thematic content analysis was conducted on sixty-six binding and non-binding laws and policies for answer research question 5: ‘to what extent, if at all, are the policy measures in place in the SIDS of Belize capable of tackling climate and non-climatic hazards in relation to seaweed farming?’. Three components of the regulatory framework were examined using NVivo including (i) the Fisheries Resources Act No. 7 of 2020, (ii) Belize Blue Economy Development Policy, Strategy, and Implementation Plan (2022-2027) and (iii) Belize National Mariculture Policy. These three documents along with field data used to investigate whether seaweed farmers' perceptions of challenges to climate change adaptation had been addressed in the legal framework of the country. Data and information were gathered and analyzed using keywords in content analysis via NVivo software, in parallel with linking them to findings using the CRiSTAL toolkit (5.0) and household semi-structured interview surveys.

The study involved collecting and familiarizing with legislative frameworks, categorizing them into binding, non-binding, and international agreements, and reviewing their content, scope, and relevance to seaweed farming and associated hazards. The data was then coded according to the six PESTEL dimensions: Political, Economic, Social, Technological, Environmental, and Legal. Key themes and sub-themes related to these dimensions were identified, such as government support and regulations under the "Political" theme, and economic incentives and financial strategies under the "Economic" theme. Relevant information was extracted from each framework, focusing on their inclusion of seaweed farming, the type of information used, the level of precaution, and the use of CbA, EbA, or hybrid approaches (see further details of legislative frameworks in appendix G section 9.7.1).

For each PESTEL category, patterns and correlations were identified, such as how political support translated into legal frameworks and whether economic policies supported technological innovation. Thematic themes and sub-themes were identified within each PESTEL category, such as government commitment and policy coherence under the Political dimension and sustainability and climate adaptation under the Environmental dimension (see codebook in appendix G section 9.7.2).

The findings were subsequently compared with existing literature on seaweed farming and climate adaptation to situate the results within the broader discourse of sustainable

development and climate adaptation strategies in Belize. This allowed for the identification of strengths and weaknesses in Belize's current governance system, highlighting both areas of progress and gaps that may undermine the viability of seaweed mariculture as a climate adaptation pathway.

## 4.5 Quantitative Assessment

The quantitative assessment based on empirical data was conducted using IBM SPSS Statistics Version 29.0.0.0 (241). The dependent variable was defined as the amount of seaweed harvested monthly, measured in pounds (wet weight). This measure was selected instead of using income generated from seaweed sales as it is a direct indicator of farming productivity in terms of actual output rather than economic returns, avoiding distortions introduced by market variability, price fluctuations, or irregular sales (Aslan et al., 2018; Putri Maslia et al., 2024; Rubekie & Bwathondi, 2022). By focusing on wet weight, the analysis captured a more accurate and stable measure of seaweed farming performance.

Independent variables consisted of socio-demographic and livelihood characteristics, structured according to the SLF (Charles-Toussaint & Moore, 2024; Ruiz-Fernández et al., 2020). Given that much of the survey data were non-normally distributed, both nonparametric correlations (Spearman's rho,  $r_s$ ) and parametric (Pearson's correlation,  $r$ ) tests were employed. Spearman's rho was particularly suited for ordinal and non-normally distributed data, while Pearson's correlation was used for continuous, normally distributed variables. To interpret results consistently, correlation strengths were classified as follows: low (0.10–0.29), moderate (0.30–0.49), and high (0.50–1.0), following Cohen's (1988) guidelines.

The following quantitative techniques were used in their respective order:

### 4.5.1 Correlations for hazards and responses associations

To examine the relationships between hazards and coping responses in the research questions, a series of correlation and association tests were conducted. Correlations included the associations between variables were identified using nonparametric Spearman's rho ( $r_s$ ) correlations (for ordinal/non-normal variables) and parametric Pearson's ( $r$ ) correlations (for continuous variables). For the hazards and responses quantitative analysis, the following correlations and associations were conducted: Cross tabulation and Chi-square Tests of Association (to examine the associations between categorical variables), Likelihood Ratio and Fisher-Freeman-Halton exact (applied when cell counts were small, to improve robustness of associations), Linear-by-linear association (to detect monotonic trends in ordinal data) and factorial analysis (to reduce multiple hazard and response variables into latent factors guided by SLF). Sampling adequacy was assessed using Kaiser-Meyer-Olkin (KMO) statistics, Bartlett's Test of Sphericity, Communalities and Total Variance Explained. Through this multi-method approach, the analysis identified significant associations between hazards and farmer responses, and clarified which livelihood capitals were most relevant to adaptation strategies. The following correlation analysis was conducted depending on the type of data analyzed within their statistical assumptions (continuous or categorical datasets):

Spearman's rho ( $r_s$ ) was chosen because it handles non-normal distributions effectively, as often encountered in survey data from seaweed farmers. This approach ensured accurate and reliable measurement despite the challenges posed by the survey data. This test was the preferred method in testing correlations between variables in the survey data following this test of identifying key independent variables.

Pearson's correlation coefficient ( $r$ ) is a measure used to evaluate the strength and direction of linear relationships between two continuous variables. It ranges from -1 to 1, with +1 indicating a perfect positive linear relationship and -1 indicating a perfect negative linear

relationship. Pearson's correlation is appropriate when both variables are continuous and have a normal distribution. In this study, Pearson's correlation was applied to scenarios like seaweed harvest and income, age and income, and health and productivity. The objective was to measure the strength and direction of linear relationships between continuous variables, providing insights into factors impacting productivity and socio-economic outcomes in seaweed farming. For variables not meeting these assumptions, Spearman's rho ( $r_s$ ) or other nonparametric methods were used. The study considered the correlations of key variables for the model of which the independent variable was identified.

*Likelihood Ratio:* In the study, this test was employed alongside the Pearson Chi-Square test to assess the association between hazard categories and response categories. The Likelihood Ratio test is utilized to evaluate the relationship between two categorical variables by comparing the likelihood of the observed data under the null hypothesis (that the variables are independent) with the likelihood of the data under the alternative hypothesis (that the variables are associated). The Likelihood Ratio is often preferred in cases where the assumptions of the Pearson Chi-Square test (e.g., large sample size) may not be applicable, offering an alternative view on the association between variables. This test provided outputs such as statistics and a  $p$ -value, which indicated whether to reject the null hypothesis of no association. A significant  $p$ -value implied a relationship between the two categorical variables. The degrees of freedom in this test match those of the Pearson Chi-Square, which ensured comparability between the two.

*Fisher-Freeman-Halton Exact:* This exact test is an extension of Fisher's Exact Test, suited for larger contingency tables with small, expected cell counts. It is specifically designed to evaluate associations between categorical variables when the sample size is small or when many cells have expected counts of fewer than 5, making the Pearson Chi-Square test less reliable. Given that a large proportion of cells in the dataset may have low expected counts, this test was used to provide a more robust evaluation of the relationship between hazards and responses. The Fisher-Freeman-Halton Exact test calculates an exact  $p$ -value without relying on asymptotic assumptions, making it especially useful for small datasets or sparse contingency tables. This test produced an exact significance level, which helped to determine whether there was a significant association between hazard and response variables in this study. It is particularly applicable when assumptions required for other tests, such as the Pearson Chi-Square, are not met.

*Linear-by-Linear Association:* The Linear-by-Linear Association test is designed to detect a linear relationship between two ordinal variables. It assesses whether there is a consistent trend (either increasing or decreasing) in the relationship between the variables, which is especially relevant when dealing with ordinal data or when a monotonic relationship is expected. This test was applied to analyze whether the categories of hazards and responses follow a linear trend, as opposed to simply being associated. It complements the general association tests like Pearson Chi-Square by focusing on linearity in the relationship. This test calculated a statistic based on the linear relationship between ordinal variables. If the test yields a significant  $p$ -value, which would indicate that the relationship between the two variables is linear. Otherwise, it suggests the lack of a monotonic trend between the variables.

*Factorial analysis:* Factorial analysis was used to understand the structure of relationships between multiple variables by reducing a large set of variables into a smaller set of factors or components. This reduction is achieved by identifying groups of variables that are highly correlated with each other, which can then be interpreted as underlying "factors." Factorial analysis is commonly applied in exploratory research where the goal is to uncover latent structures in the data. The variables were ordinal, and it was ensured that the selected variables were according to the SLF capitals and suitable for dimension reduction. A larger sample size was recommended for factorial analysis of which each category consisted of at least 5 to 10

cases per variable as hazards and responses reported were aggregated and then categorized into four main themes.

Before performing factorial analysis, two key tests were used to assess whether the data was appropriate for this method which included KMO Measure of Sampling Adequacy. This statistic assessed the proportion of variance in the variables that might be caused by underlying factors. KMO values range from 0 to 1 and Bartlett's Test of Sphericity.

*Symmetric measures:* Symmetric measures are statistical metrics used to evaluate the strength and direction of associations between two categorical or ordinal variables. They include Pearson's  $r$  and Spearman's rank correlation, which measure linear or monotonic relationships between variables. These measures range from -1 to 1, with values closer to 1 or -1 indicating stronger positive or negative associations. In the context of seaweed farming livelihoods, symmetric measures helped to understand the strength and direction of relationships between hazards and responses, enabling the correlation of changes in one category with changes in another.

*Covariance matrix:* The Co-variance matrix was used to measure the change in two variables together, capturing the degree of covariation between them. It includes the variances of each variable on the diagonal and the covariances between each pair of variables on the off-diagonal elements. In factorial analysis, it helped to understand the interrelationships between variables. Positive covariances indicate that variables tend to increase together, while negative covariances suggest one variable increases as the other decreases. In the context of seaweed farming livelihoods, a covariance matrix helped to assess the degree of co-variation between different hazards and response variables.

*Communalities:* Communalities indicate the proportion of a variable's variance explained by retained factors, ranging from 0 to 1. Close to 1 indicated well-explained variables, while close to 0 indicated poorly explained ones. Factors were interpreted based on the variables that load heavily on them, with each factor labeled based on its conceptual meaning.

*Total Variance Explained:* The "Total Variance Explained" table summarized how much of the total variance in the dataset were accounted for by the factors extracted during factor analysis. Factor analysis reduced the number of observed variables into underlying factors, with each factor explaining a portion of the variance in the original dataset. The "Total Variance Explained" table showed the percentage of variance explained by each factor, which included both the Initial Eigenvalues (before rotation) and Extraction Sums of Squared Loadings (after rotation). The goal was to retain enough factors to explain a significant portion of the total variance, usually aiming for a cumulative variance of at least 60%. For analyzing seaweed farming livelihood data, the Total Variance Explained table showed how much of the variability in the hazard and response categories was captured by the underlying factors identified through factor analysis.

The study used multiple tests to analyze the relationships between hazard and response categories in seaweed farming livelihoods. These tests assessed various aspects of the relationship, including general associations, Fisher-Freeman-Halton Exact Test, and Linear-by-Linear Association Test. For example, covariance matrix, total variance explained, and symmetric measures are a set of statistical tools that form the backbone of understanding and interpreting the relationships between variables in a complex dataset, such as those involving hazards and responses in seaweed farming. This multi-faceted approach strengthened the analysis by accounting for different types of relationships between variables.

#### 4.5.2 Model for measuring livelihood capitals

To further examine which livelihood capitals that strongly impact seaweed farming sustainability, multi-linear regression models were employed. Continuous variables such as age, household income, savings, and income from seaweed farming were tested as independent predictors of seaweed harvest (wet weight). Regression assumptions were validated through residual normality checks, supporting the robustness of the models. It assumes a linear relationship between dependent and independent variables; however, it may fail to uncover a relationship that is non-linear (Angelsen, Larsen, et al., 2011).

While existing studies often rely on qualitative measures of livelihoods, this study applied quantitative modelling to identify statistically significant relationships between socio-demographic factors and seaweed farming outputs. Logistic regression has been used elsewhere in aquaculture studies (Rubekie et al., 2022), but the use of linear regression here provides a novel contribution by quantifying the direct impact of livelihood capitals on production outcomes in the Belizean context. Other research studies also used this analytical approach as models to explore the degree and direction of the relationship between dependent and independent variable(Comoé and Siegrist, 2015).

*Data and Variable Selection:* The key capitals that have a direct impact on seaweed farming were selected and categorized by variables according to the SLF in order to model their impact on the sustainability of this blue livelihood. The quantitative surveys included only closed-ended questions to obtain continuous variables and categorical variables related to household profiles, socio-economic conditions, and general livelihood conditions. The variables included in the regression models were based on Zamroni et al. (2020) who used the SLF framework and financial analysis methods. These variables included age, gender, ethnicity, education level, nationality, number of adults and children in the household, and residential status (see Appendix 9.2.2 for further details on all the variables).

To explore how various livelihood capitals impact seaweed farming productivity, a multiple linear regression analysis was conducted. The key research question was framed as: *"Which livelihood capital directly impacts the production of seaweed harvested (wet weight in pounds)?"* The dependent variable or predictor in this analysis was wet seaweed production (in pounds), while independent variables were selected from the SL capitals (human, social, natural, physical, financial, and cultural).

To address this gap in the literature, the study employed multiple linear regression analysis on continuous variables to assess the impact of livelihood capitals on seaweed farming productivity. The independent variables were categorized as shown in Table 4.4



| Capital   | Examples                                                          | References                                        |
|-----------|-------------------------------------------------------------------|---------------------------------------------------|
| Human     | Education level, experience in seaweed farming, health            | (Mphande, 2016; Scoones, 2009)                    |
| Social    | Gender, community engagement, support from government             | (Salayo et al., 2014; Woolcock and Narayan, 2000) |
| Natural   | Farming approaches (EbA, CbA, Integrated), access to marine space | (Marino et al., 2022; Osman-Elasha et al., 2005)  |
| Physical  | Boats and engines, farming infrastructure, processing facilities  | (Rakodi, 1999; Mastrotillo et al., 2016)          |
| Financial | Household income, savings, remittances, access to credit          | (Rebours et al., 2014; Abebe et al., 2021)        |
| Cultural  | Traditional knowledge, family practices                           | (Castillo Loeza et al., 2023; Throsby, 2001)      |

*Table 4.4. Independent variables categorized according to the Sustainable Livelihoods Framework (SLF).*

The primary dependent variable was defined as the amount of seaweed harvested monthly, rather than the income generated from the seaweed. This allowed the analysis to directly focus on productivity outcomes.

*Data Preparation:* Various treatments were done to the datasets including variable transformations. Several independent variables required transformation to meet assumptions of normality and linearity. These transformations were handled using SPSS’s “recoded into different variables” function, particularly for variables showing skewed distributions or non-linear relationships with the dependent variable. Specifically:

- Seaweed farming approaches (i.e. EbA, CbA, Integrated) were transformed into new dummy variables (e.g. Approach\_CbA, Approach\_EbA, Approach\_Integration\_of\_CbA\_and\_EbA).
- Variables related to financial and farming measures, such as household income, remittances, seaweed income, and farm size, were transformed using either logarithmic or square root functions to handle skewness, resulting in variables like log\_householdincome, sqrt\_Remittance, log\_FarmSize, etc.
- Experience in seaweed farming and other similar continuous variables were square root transformed to address non-normality, giving rise to variables like sqrt\_Experience.

*Handling Categorical Variables:* Dummy variables were created for categorical predictors such as gender and value-added products. This recoding allowed the inclusion of these nominal variables in the regression model.

**Outlier Handling:** Outliers were identified through graphical analysis and statistical measures. Decisions to retain or exclude these outliers were made based on their potential influence on the regression results.

*Model Specification:* Addressing the research questions involved specifying the regression model and testing its assumptions for robustness. The regression model examined how various independent variables (transformed as necessary) impacted the dependent variable of seaweed production. These variables, which represented different livelihood capitals, were entered into the model using the Enter method to evaluate their individual and combined impacts. This method was selected to ensure that all variables of theoretical significance were included, as identified through the SLF.

The model underwent diagnostic checks to ensure the assumptions of multiple linear regression were met:

- Linearity was confirmed using scatterplots and residuals analysis.
- Multicollinearity was checked using the Variance Inflation Factor (VIF) and Tolerance statistics, and no severe multicollinearity was observed among the independent variables.
- Normality of residuals was assessed using histograms and normal probability plots (P-P plots). Minor deviations from normality were observed but were within acceptable limits.
- Homoscedasticity was confirmed through residuals versus fitted value plots, and no significant heteroscedasticity was detected.

*Model Fit and Interpretation:* The model fits, and interpretation further address the research questions by identifying which livelihood capitals significantly impact seaweed farming productivity. The regression model's explanatory power was assessed by utilizing  $R^2$  and Adjusted  $R^2$  values to assess its fit. The coefficients offered a perspective on the magnitude and direction of each variable's impact on seaweed cultivation productivity, and significant predictors were identified based on their respective  $p$ -values.

The subsequent chapter emphasized the substantial impacts of specific livelihood capitals on seaweed production, as demonstrated by the main findings. The most significant coefficients were attributable to factors such as formal training, aquacultural methods, and household income, which could account for the variability in seaweed production. Nevertheless, the results section presents these findings, and tables showcase the exhaustive details of the regression output, enabling a clear understanding of the relationships between seaweed productivity and livelihood capitals.

## 4.6 Ethics and Data Protection

This section outlines the ethical and data protection protocols followed in the study, ensuring compliance with both University of Malta and Belizean regulatory requirements. This doctoral research adhered to strict ethical and data protection protocols in order to comply with international and local standards.

### 4.6.1 University of Malta Research Ethics Committee (UREC) approval

The ethical approval process for this study involved submitting a comprehensive application to the University of Malta's Research Ethics Committee (UREC). The application provided a detailed description of the research aims, methodologies, recruitment strategies, consent forms, survey questionnaires, and data management procedures. Given that the study involved

the collection of data through both interviews and survey questionnaires from human participants, the ethics application placed significant emphasis on the protection of participants' rights. This included ensuring that participants provided informed consent and that their confidentiality was maintained throughout the research process. Participants were fully informed about the research's purpose, the voluntary nature of their participation, and their right to withdraw from the study at any time. The survey questionnaires were carefully designed to avoid sensitive questions, further ensuring participant comfort and security. Data protection measures were meticulously planned and aligned with the General Data Protection Regulation (GDPR) and national legislation. These measures included protocols for securely handling and storing survey data, restricting access to authorized personnel only, and anonymizing participants' responses to maintain their privacy. After a thorough review of the application by UREC, feedback was provided to ensure that all ethical considerations were comprehensively addressed. Following the necessary revisions, the research proposal, including the survey component, was approved, confirming that the study adhered to the ethical standards of the University of Malta. A final declaration was signed by the researcher, affirming compliance with these ethical guidelines and consenting to the processing of personal data by the ethics committee as part of the evaluation process.

#### 4.6.2 Approval from the Belize ethics committee

Conducting research in the case study Caribbean SIDS, Belize, also required obtaining ethical clearance from local authorities, particularly due to the inclusion of survey questionnaires in the data collection process. This clearance was secured through a social research permit from the Institute for Social and Cultural Research (ISCR), under the National Institute of Culture and History (NICH) of Belize. The permit, granted in accordance with the NICH Act, authorized the researcher to conduct the study, including the distribution of survey questionnaires, among human subjects in Belize. The permit was valid from April 1, 2023, to April 1, 2024, and included conditions ensuring that the study, particularly the use of survey questionnaires, was conducted in a responsible and ethical manner. Participants were provided with detailed information about the study, including the purpose of the survey, the voluntary nature of participation, and their right to withdraw at any time. Consent forms accompanied the survey questionnaires, ensuring that participants' informed consent was documented before they completed the surveys. Confidentiality of the survey data was strictly maintained, with personal data being anonymized and access to this data limited to authorized personnel only. The survey data management practices were compliant with both GDPR and Belizean regulations, ensuring that participants' privacy was protected throughout the research process.

Nevertheless, the research was conducted with a strong commitment to ethical principles, respecting the cultural sensitivities of the Belizean participants and ensuring that the survey process did not cause any harm. The dual approvals from both the University of Malta's Research Ethics Committee and the Belizean authorities, which covered all aspects of the research including the use of survey questionnaires, demonstrated the researcher's commitment to ethical standards and participant protection. This dual compliance was crucial in ensuring the responsible conduct of the research, maintaining the integrity of the study, and safeguarding the well-being of all participants involved. Throughout the research, a commitment to ethical conduct was maintained, taking into account the cultural sensitivities of the Belizean participants and ensuring that the research did not cause harm. Furthermore, the study aimed to positively impact the local communities by addressing the challenges faced by seaweed producers. The dual approvals from the University of Malta's Research Ethics Committee and Belizean authorities demonstrated the researcher's dedication to upholding the highest ethical standards. This dual compliance not only ensured the responsible conduct of

the research but also safeguarded the integrity of the study and the well-being of all participants involved.

#### 4.7 Summary

This chapter presented the methodology employed to investigate the sustainability of seaweed mariculture in the SIDS of Belize. A mixed-methods design, rooted in pragmatism, was adopted to capture both qualitative and quantitative dimensions of seaweed farming industry as a livelihood and adaptation strategy to climate change. The research followed an explanatory sequential approach, beginning with qualitative methods to explore local perceptions and practices, and followed by quantitative analysis to test relationships between livelihood capitals and production outcomes. The qualitative phase combined a systematic literature review participatory focus groups using the CRiSTAL toolkit, semi-structured household surveys, elite interviews, and a PESTEL policy review. The quantitative phase applied structured surveys and statistical modelling (correlation and regression analyses) to identify the socio-demographic and livelihood factors influencing seaweed production. Ethical clearance was secured from the University of Malta and relevant Belizean authorities, ensuring participant rights and data protection.

Together, these methods provided a triangulated evidence base for addressing the five research questions, enabling the study to assess the contributions of different livelihood capitals and the adequacy of policy frameworks. The next chapter presents the results of this analysis.

## 5. RESULTS

This chapter presents the results of the mixed-methods approach outlined in Chapter 4. The findings are organized into three main parts. Section 5.1 reports quantitative analysis, including survey descriptions and hypothesis testing using regression models. Section 5.2 presents qualitative results, drawing on focus group discussions, qualitative surveys, elite interviews, and policy analysis. Section 5.3 synthesizes the overall findings, emphasizing community-level and policy-level integration in the governance of sustainable seaweed mariculture in Belize.

### 5.1 Quantitative Assessment

#### 5.1.1 Quantitative surveys

A structured survey instrument was designed to capture various aspects of seaweed farming livelihoods in Belize, including demographic and socio-economic information, with emphasis on variables linked to Sustainable Livelihoods Framework (SLF) capitals. A purposive sampling strategy was employed and identified 18 active seaweed farmers across Belize. A list of seaweed farmers was received from environmental non-governmental organizations (E-NGOs) who have previously worked with seaweed farmers on supporting the execution of cultivation training programmes in collaboration with Belize Fisheries Department (BFD) of the Government of Belize. Seaweed farmers signed consent forms (Figure 9.11.) and received the information sheets (Figure 9.10.) about this doctoral research as observed in Appendix D. After conducting semi-structured interviews, responses were recorded in a coded format and entered into a spreadsheet. The data were recoded into numeric values for analysis, cleaned to correct inconsistencies, and prepared for statistical analysis in Statistical Package for the Social Sciences (SPSS). Descriptive statistics were generated to summarize the sample characteristics, ultimately contributing to a robust understanding of livelihoods in the context of climate change adaptation. These seaweed farmers were connected via their respective leader in their organization of which they were formally invited to take part in a focus group discussion and requested to participate in the one-to-one quantitative survey. Seaweed farmers were asked to take part in the survey at their convenience and in their home spaces. For this reason, the high attrition rate was consistent with similar studies that used participatory rural appraisals (PRAs) (Asakura et al., 2022). The participants were initially contacted via mobile phone and email, where they were informed about the purpose of the research and invited to participate in the study. Each farmer was requested to dedicate approximately one hour of their time for a semi-structured interview to contribute to this doctoral research. Upon agreeing, the farmers participated in interviews during which the researcher recorded their responses directly into the survey instrument.

To ensure confidentiality, all personal identifying information was anonymized, and each participant's survey was assigned a unique code. The coding system employed the word "File" followed by the acronym for Belize (BZ) and a corresponding number (e.g., File/BZ1) to differentiate between individual respondents. After collecting the data on physical (hard copy) survey forms, the responses were systematically entered into both Microsoft Excel and Microsoft Word for further data management and analysis. This ensured the accurate organization and storage of the survey data, facilitating subsequent statistical analysis and interpretation.

The surveys captured information on demographics, farming practices, economics, and perceptions of climate change impacts. The surveys were administered over a 2-month period from June to August 2023. They captured aspects of seaweed farming operations in the last 12 months such as climatic and non-climate hazards and responses.

No data sets were removed from the study but if there was no response received from a question in the survey, it was recorded as ‘no data’ but if the answer was not in the options provided in the multiple choices it was recorded as ‘other’.

This may lead to quantitative analysis being oversimplified with unrealistic assumptions of the model (Sun, 2023). The descriptive analysis of the quantitative data provides an understanding of the characteristics of all active seaweed farmers in Belize (N=18) and overview of the livelihood assets within the community. Key variables were selected to depict the seaweed farming industry and were used to test research hypothesis for identifying factors impacting the sustainability of seaweed farming sector. The following descriptive data was used to provide a profile of the seaweed farming community in Belize based on the qualitative survey responses:

### 5.1.2 Description of participants

The 18 participants were from several coastal areas in Belize, representing important sites where seaweed farming is practiced. Of this number, 14 respondents or 78% of the total were from Stann Creek District, while the remaining 4 respondents or 22% were from Belize District. The survey captured respondents from at least two districts, with only one location in the Belize District, that is: Belize City. Most respondents were from four locations in the Stann Creek District: Dangriga Town, Placencia Village, Independence Village, and Riversdale Village (Figure 5.1).

Placencia Village had the greatest number of individuals involved in seaweed farming s in the country with a total of 7 participants. There was a comparatively greater proportion of individuals from Placencia (39%) in comparison to other locations. Both Belize City and Independence Village had an equal number of respondents with each area representing 22% of the sample. Riversdale Village has a lower percentage (17%) of individuals involved in seaweed farming activities compared to other locations, 3 individuals.

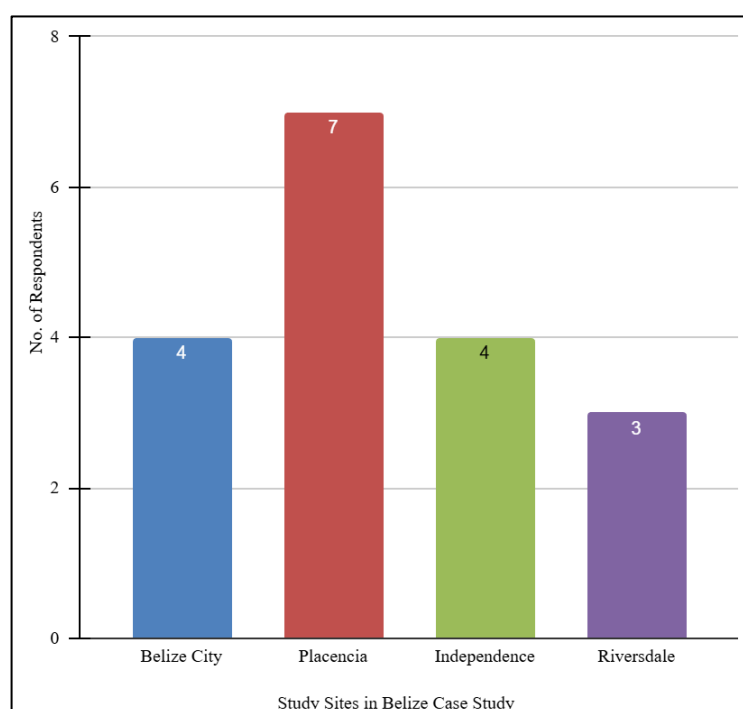


*Figure 5.1. Geographical diversity in seaweed farming livelihood encompassing individuals from several coastal regions of Belize (Author's own elaboration).*

The respondents' main occupations encompassed a diverse range of economic sectors. Tourism and fishing were the dominant economic sectors with six (33%) individuals. There were participants involved in several other economic domains such as fisheries, aquaculture (ie. seaweed farming), tourism and hospitality, real estate (rental of property for tourism purposes), maritime transportation (boat captain services for tourism purposes), service sector (ie. construction), and project management administration in cooperatives/associations (Figure 5.2). Although the participation of these sectors was smaller in comparison to tourism and fishing, they made a valuable contribution to the overall economic variety of the town.

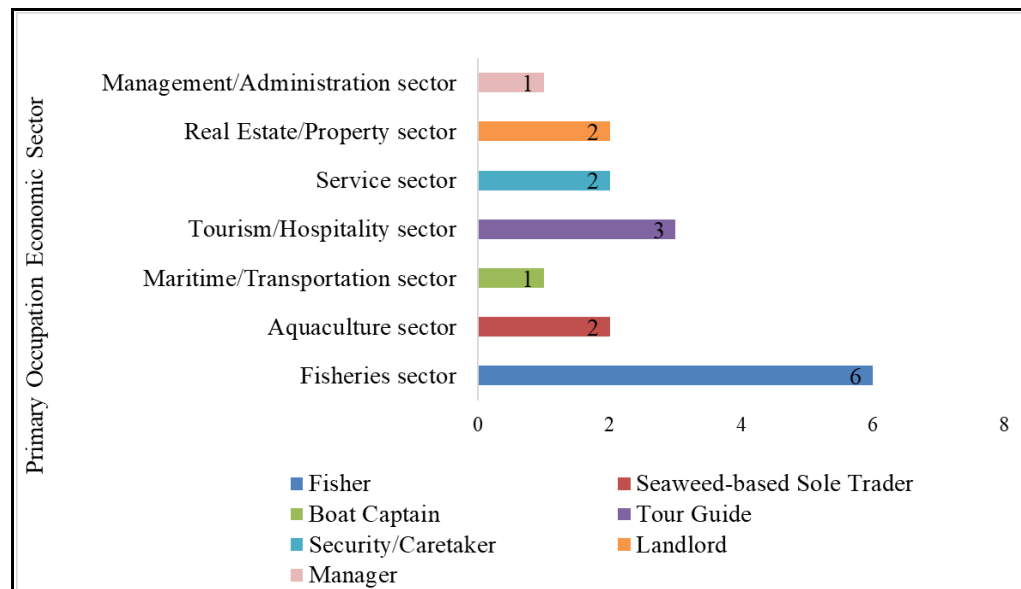


Figure 5.2. Primary occupation and economic sector of head of household respondent (Author's own elaboration).

Seaweed-based sole traders in the aquaculture sector cultivate and harvest seaweed for various purposes, contributing to the growth and development of the industry. A boat captain in the maritime/transportation sector operates vessels for various purposes, such as fishing, tourism, or transportation. Tour guides in the tourism/hospitality sector showcase the area's natural or cultural attractions to visitors, contributing to the local economy's tourism sector. Security/caretakers in the service sector ensure the safety and maintenance of properties, facilities, or communities, contributing to the overall well-being and security of the area. Landlords in the real estate/property sector lease residential or commercial properties, providing housing or business spaces to tenants and generating rental income. A manager in the management/administration sector oversees operations, coordinates resources, and makes strategic decisions to ensure the efficient functioning of an organization or business entity, contributing to its overall success and productivity.

Regarding gender distribution, the number of respondents captured in the surveys was relatively balanced. Males made up a slightly larger proportion of the sampled population (56%) compared to females (44%). Figure 5.3 presents a relatively balanced gender distribution of seaweed farmers in Belize.

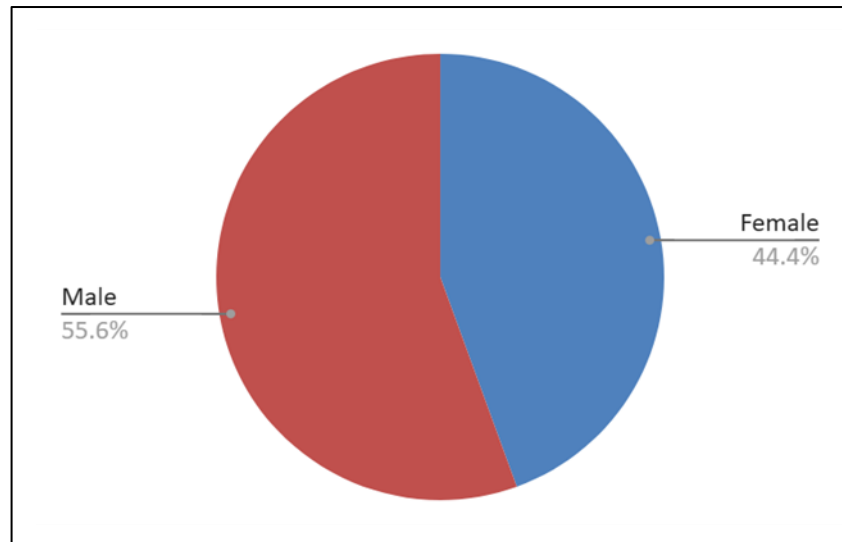


Figure 5.3. Gender percentage number of all respondents in the study (Author's own elaboration).

Figure 5.4 presents the head of household respondents' educational attainment which ranged from incomplete primary education to post-secondary/university. In primary level education, one (1.6%) had some education, while three (3.17%) completed it. Secondary level education was completed by three (3.17%) and seven (7.39%). There was one (1.6%) with higher education qualifications and three (3.17%) with technical/vocational training in the construction trade.

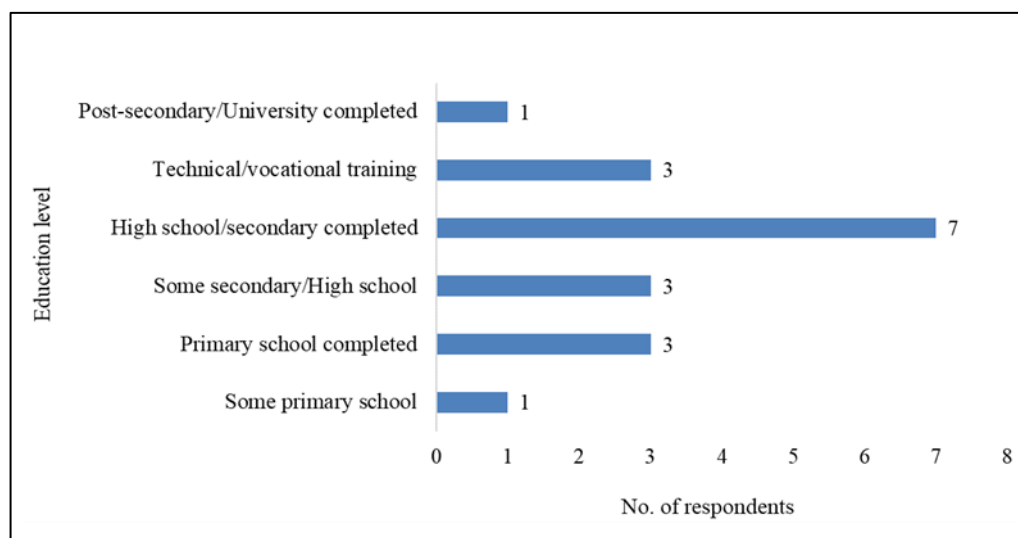


Figure 5.4. Education levels of respondents from incomplete primary education to post-secondary/university completion in the seaweed farming community (Author's own elaboration).

### 5.1.3 Comparison of household surveys to national statistics Belize SIDS

In the comparison of household surveys in this research study to the national statistical data of Belize, the Caribbean SIDS case study. Variables in comparison include key demographic data, household income, remittance, savings, life satisfaction, and essentials amongst others. Therefore, Table 5.1 below shows the averages/means of the variables identified for



comparison. shows the following demographics which include household size, household members, ethnicity, age, and house tenure comparisons.

| Description                    | Survey Total | Survey Mean or % | Belize 2010 Census Total | Belize Census Mean or % |
|--------------------------------|--------------|------------------|--------------------------|-------------------------|
| No. of Household               | 18           |                  | 79,492                   |                         |
| No. of Household Members       | 75           | 4.170            | 322,453                  | 4.100                   |
| Gender                         |              |                  |                          |                         |
| Female                         | 8            | 5.250            | 161,226                  | 50%                     |
| Male                           | 10           | 3.300            | 161,227                  | 50%                     |
| Ethnicity                      |              |                  |                          |                         |
| Creole                         | 13           | 72.200%          | 83,460                   | 25.880%                 |
| Mestizo/Hispanic               | 4            | 22.200%          | 170,446                  | 52.870%                 |
| Other: East Indian             | 1            | 5.600%           | 12,452                   | 3.860%                  |
| Age                            |              |                  |                          |                         |
| 25-34                          | 8            | 44.400%          | 28,840                   | 8.940%                  |
| 35-44                          | 4            | 22.200%          | 12,589                   | 3.910%                  |
| 45-54                          | 3            | 16.700%          | 8,891                    | 2.760%                  |
| 55-64                          | 1            | 5.600%           | 4,654                    | 1.440%                  |
| 65+                            | 2            | 11.100%          | 13,587                   | 1.960%                  |
| Housing Characteristics        |              |                  |                          |                         |
| Tenure: Owned with Mortgage    | 0            | 0%               | 11,049                   | 13.90%                  |
| Tenure: Owned without Mortgage | 12           | 66.700%          | 40,056                   | 50.400%                 |
| Tenure: Renting                | 3            | 16.700%          | 17,732                   | 22.300%                 |
| Tenure: Rent-free              | 2            | 11.100%          | 8,824                    | 11.100%                 |
| Tenure: Other (ie. Lease)      | 1            | 5.600%           | 1,668                    | 2.100%                  |
| Tenure: Not Reported           | 0            | 0.000%           | 238                      | 0.300%                  |

*Table 5.1. Comparison of this study household surveys to the national statistical data of Belize, the Caribbean SIDS case study (Author's own elaboration).*

*Contextualizing this study and Belize Census Data of 2010:* Based on Table 5.1, the average household size in the survey and Belize Census was similar, with the survey slightly higher at 4.17 compared to 4.1. The gender distribution was balanced, with a slightly higher mean for females. The survey sample had a higher proportion of Creole respondents (72.200%) compared to the national average (25.880%) and a lower proportion of Mestizo/Hispanic respondents (22.200%) compared to the national average (52.870%). The survey sample had a higher proportion of individuals in the 25-34 and 35-44 age ranges compared to the national percentages, and the older age groups (55-64 and 65+) were also more represented in the survey than in the national census.

There was a difference in housing tenure, with a higher percentage of survey respondents owning their homes without a mortgage (66.700%) compared to the national average (50.400%). None of the survey respondents reported owning their homes with a mortgage, unlike the national percentage (13.900%). The survey highlights the distinct demographic and socio-economic characteristics of seaweed farming households in Belize, as captured in the

survey, against the broader national context. These differences may reflect the unique nature of the communities engaged in seaweed farming compared to the general population.

#### 5.1.4 Hazards and responses in seaweed farming

*Descriptive statistics of hazards and responses:* The descriptive statistics in Table 5.2 provides a summary of the main features of the data for the variables, hazards and responses. The sample size for both hazards and responses was 54. This means that there were 54 valid observations where respondents provided a hazard that occurred and their response to it as a coping mechanism.

The descriptive statistics for both variables implied that the data for hazards and responses were comparable in terms of central tendency and variability. The minimum value for both Hazards and Responses was 0. The maximum value for both hazards and responses was 4. The mean (average) value for both hazards and responses was 2.070 which was categorized from 0 to 4. The standard deviation for hazards was 1.040, and for responses it was 1.060. A standard deviation close to 1 indicated that the data points are spread out around the mean, but not excessively. The equal means and similar standard deviations showed the distributions of hazards and responses were symmetric about the mean.

| Descriptive Statistics |    |     |     |       |                |
|------------------------|----|-----|-----|-------|----------------|
| Category               | N  | Min | Max | Mean  | Std. Deviation |
| Hazards                | 54 | 0   | 4   | 2.070 | 1.040          |
| Responses              | 54 | 0   | 4   | 2.070 | 1.060          |
| Valid N (listwise)     | 54 |     |     |       |                |

Table 5.2. Descriptive statistics of hazards and responses data showing the general characteristics of the quantitative survey dataset (Author's own elaboration).

*Frequency:* The frequency of hazards (Table 5.3) and responses (Table 5.4) were further elaborated to highlight key variables used in the correlations (Author's own elaboration).

| Hazard Category |                                                           | Frequency | Percent  | Valid Percent | Cumulative Percent |
|-----------------|-----------------------------------------------------------|-----------|----------|---------------|--------------------|
| Valid           | 0.No Data                                                 | 1         | 1.900%   | 1.900%        | 1.900%             |
|                 | 1.Limitation of Human, Financial and Production Resources | 17        | 31.500%  | 31.500%       | 33.300%            |
|                 | 2.Environmental and Climatic Issues                       | 20        | 37.000%  | 37.00%        | 70.400%            |
|                 | 3.Regulatory and Bureaucratic Complexity                  | 9         | 16.700%  | 16.700%       | 87.000%            |
|                 | 4.Personal and Societal Safety Issues                     | 7         | 13.000%  | 13.000%       | 100.000%           |
|                 | Total                                                     | 54        | 100.000% | 100.000%      |                    |

*Table 5.3. Hazards in seaweed farming (Author's own elaboration).*

Table 5.3 presented the distribution of hazards identified in seaweed farming, categorized into four distinct groups. The data reflects the frequency and percentage of responses related to various hazards encountered by seaweed farmers. The most frequently reported hazard was "Environmental and Climatic Issues," with 20 respondents (37.000%), followed closely by "Limitation of Human, Financial and Production Resources," which accounted for 17 respondents (31.500%). "Regulatory and Bureaucratic Complexity" and "Personal and Societal Safety Issues" were reported by 9 (16.700%) and 7 (13.000%) respondents, respectively. The data indicated that a significant portion of respondents experienced environmental and climatic challenges, emphasizing the pressing need for adaptive strategies in seaweed farming.

| Response Category |                                                 | Frequency | Percent  | Valid Percent | Cumulative Percent |
|-------------------|-------------------------------------------------|-----------|----------|---------------|--------------------|
| Valid             | 0.No Data                                       | 1         | 1.900%   | 1.900%        | 1.900%             |
|                   | 1.Ecosystem-based Approaches                    | 19        | 35.200%  | 35.200%       | 37.000%            |
|                   | 2.Community-based Approaches and Social Capital | 15        | 27.800%  | 27.800%       | 64.800%            |
|                   | 3.Infrastructure and Financial Capital          | 13        | 24.100%  | 24.100%       | 88.900%            |
|                   | 4.Government and External Support               | 6         | 11.100%  | 11.100%       | 100.000%           |
|                   | Total                                           | 54        | 100.000% | 100.000%      |                    |

*Table 5.4. Responses in seaweed farming (Author's own elaboration).*

Table 5.4 outlined the various response strategies employed by seaweed farmers to address the hazards identified in Table 5.3. The responses are categorized into four groups, with "Ecosystem-based Approaches" being the most commonly reported strategy, selected by 19 respondents (35.200%). "Community-based Approaches and Social Capital" was noted by 15 respondents (27.800%), while "Infrastructure and Financial Capital" garnered 13 responses (24.100%). Lastly, "Government and External Support" was identified by 6 respondents (11.100%). This distribution highlights the multifaceted approaches taken by seaweed farmers, underscoring the importance of both community engagement and external assistance in mitigating challenges faced in the sector.

*Crosstabulation:* Table 5.5 presents the crosstabulation analysis provided a summary of the frequency of hazard categories across different response categories. Ecosystem-based approaches were the most common with 19 occurrences primarily driven by environmental and climatic issues. Responses for limited human, financial, and production resources were evenly distributed, with a preference for community-based approaches and social capital. Government and external support were the least common response strategies. There was only one instance of "No Data" for both hazard and response categories, suggesting that the dataset is mostly complete with minimal missing information.

| Crosstabulation |                                                         |                   |     |                        |                                      |                                 |       |
|-----------------|---------------------------------------------------------|-------------------|-----|------------------------|--------------------------------------|---------------------------------|-------|
|                 |                                                         | Response Category |     |                        |                                      |                                 | Total |
|                 |                                                         | No Data           | EbA | CbA and Social Capital | Infrastructure and Financial Capital | Government and External Support |       |
| Hazard Category | No Data                                                 | 1                 | 0   | 0                      | 0                                    | 0                               | 1     |
|                 | Limitation of Human, Financial and Production Resources | 0                 | 2   | 6                      | 5                                    | 4                               | 17    |
|                 | Environmental and Climatic Issues                       | 0                 | 13  | 2                      | 5                                    | 0                               | 20    |
|                 | Regulatory and Bureaucratic Complexity                  | 0                 | 2   | 4                      | 1                                    | 2                               | 9     |
|                 | Personal and Societal Safety Issues                     | 0                 | 2   | 3                      | 2                                    | 0                               | 7     |
| Total           |                                                         | 1                 | 19  | 15                     | 13                                   | 6                               | 54    |

*Table 5.5. The crosstabulation table showed the frequency distribution of hazard categories across response categories (Author's own elaboration).*

Table 5.5 presents the responses for other hazard categories that were more evenly distributed across the different response strategies, with "Government and External Support" being the least common. This analysis helped identify the prevalent response strategies for different types of hazards and highlighted areas where certain responses were underutilized.

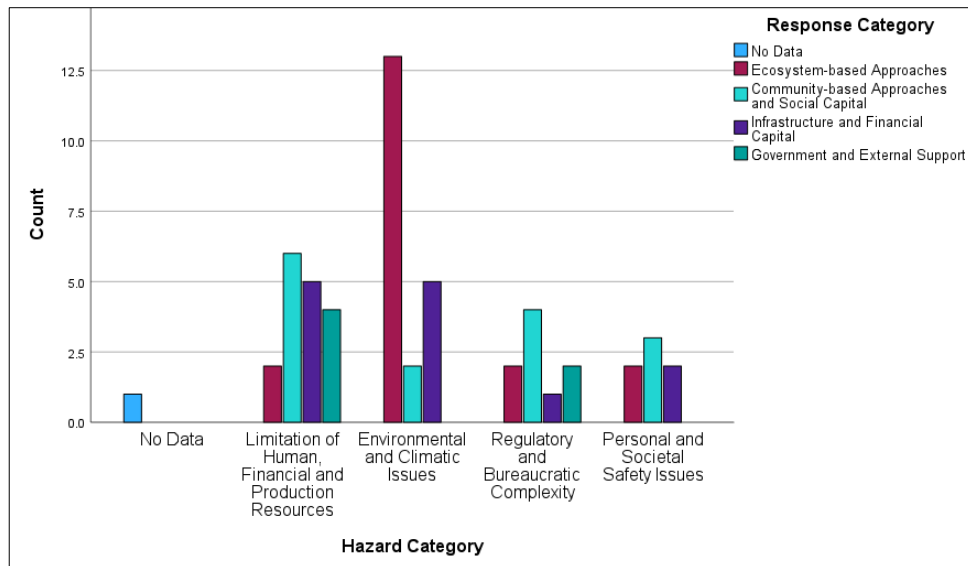


Figure 5.5. The distribution of responses across different hazard categories, highlighting the response strategies commonly associated with each type of hazard (Author's own elaboration).

Figure 5.5 revealed that "Ecosystem-based Approaches" were particularly prevalent for environmental and climatic hazards, indicating an association between this hazard type and this response strategy. Other responses, such as "Community-based Approaches and Social Capital," were more evenly distributed across different hazard categories. "Government and External Support" was identified as the least common response strategy overall, highlighting that this approach might be underutilized. The analysis revealed that "Ecosystem-based Approaches" were particularly prevalent for environmental and climatic hazards, indicating a strong association between this hazard type and this response strategy. Other responses, such as "Community-based Approaches and Social Capital," were more evenly distributed across different hazard categories. "Government and External Support" was identified as the least common response strategy overall, highlighting that this approach might be underutilized.

*Inferential statistics of hazards and responses:* The associations between the key variables related to hazards and responses were analyzed using both nonparametric Spearman's rho ( $r_s$ ) and parametric Pearson's ( $r$ ) correlations. These statistical tests were employed to examine the relationships between the quantity of harvested seaweed and various demographic and socioeconomic factors. Spearman's rho and Pearson's correlations revealed the strength and direction of relationships between seaweed production and these factors.

In addition, cross-tabulation and chi-square tests of association were conducted to explore trends between the types of hazards (such as climatic and non-climatic shocks) and the coping mechanisms (responses) employed by seaweed farmers. These tests were crucial in determining whether particular hazards were associated with specific response patterns.

The following hypothesis was tested:

- Null Hypothesis ( $H_0$ ): There is no association between the quantity of cultivated seaweed and all the key variables in livelihood resources and hazards. The variables are independent.
- Alternative Hypothesis ( $H_1$ ): There is an association between the quantity of cultivated seaweed and the other variables in livelihood resources and hazards. The variables are not independent.

The study used various statistical tests to evaluate the relationship between seaweed farmers' responses and specific hazards.

Spearman's rho correlation analysis revealed weak correlations between hazards and seaweed production factors, with most correlations being statistically insignificant ( $p$ -values above 0.05) and many coefficients close to zero, indicating weak or no relationship between the variables. Each climatic and non-climatic variable were tested was further outlined in Table 9.5 in section 9.3.2.1 of appendix C. This indicated that the correlation between hazards and seaweed production was not strong. The variables retrieved from the primary data, based on the survey instrument, there was an association between seaweed production, the frequency of climatic and non-climatic hazards, and their perceived impacts, along with the corresponding correlation coefficients. This indicated the need to conduct more robust associations requiring more focused investigations on specific factor/themes according to SLF.

Table 5.6. Chi-square, Likelihood Ratio, Fisher-Freeman-Halton Exact, and Linear-by-Linear Association tests of hazards and responses in the seaweed farming community (Author's own elaboration). presents the results of the hazards and responses based on the Pearson Chi-Square, Likelihood Ratio, and Fisher-Freeman-Halton Exact Test. This analysis conducted via SPSS was employed to determine whether a significant relationship exists between the variables, while the Linear-by-Linear Association test was used to assess the potential for a linear trend. Therefore, the results in Table 5.6. Chi-square, Likelihood Ratio, Fisher-Freeman-Halton Exact, and Linear-by-Linear Association tests of hazards and responses in the seaweed farming community (Author's own elaboration). below revealed the degrees of freedom ( $df$ ) and significance levels for each test, with particular attention to the adequacy of expected cell counts. These tests helped to evaluate whether seaweed farmers' responses are associated with specific hazards, providing key insights into the dynamics of hazard-response relationships.

| <b>Chi-Square Tests</b>                                                                 | <b>Value</b>        | <b><math>df</math></b> | <b>Asymptotic Significance (2-sided)</b> | <b>Exact Sig. (2-sided)</b> | <b>Exact Sig. (1-sided)</b> | <b>Point Probability</b> |
|-----------------------------------------------------------------------------------------|---------------------|------------------------|------------------------------------------|-----------------------------|-----------------------------|--------------------------|
| Pearson Chi-Square                                                                      | 73.550 <sup>a</sup> | 16                     | <.001                                    | <.001                       |                             |                          |
| Likelihood Ratio                                                                        | 32.325              | 16                     | .009                                     | .003                        |                             |                          |
| Fisher-Freeman-Halton Exact Test                                                        | 29.994              |                        |                                          | .003                        |                             |                          |
| Linear-by-Linear Association                                                            | .284 <sup>b</sup>   | 1                      | .594                                     | .624                        | .322                        | .043                     |
| N of Valid Cases                                                                        | 54                  |                        |                                          |                             |                             |                          |
| a. 22 cells (88.0%) have expected count less than 5. The minimum expected count is .02. |                     |                        |                                          |                             |                             |                          |
| b. The standardized statistic is -.533.                                                 |                     |                        |                                          |                             |                             |                          |

Table 5.6. *Chi-square, Likelihood Ratio, Fisher-Freeman-Halton Exact, and Linear-by-Linear Association tests of hazards and responses in the seaweed farming community (Author's own elaboration).*

Key significance: The analysis included 54 valid cases, which indicated the sample size used for the tests. However, the Chi-Square test relied on expected counts of at least 5 for validity. A large proportion of cells with low expected counts may affect the reliability of the test results. Therefore, there were 22 cells (88.0%) that had less than 5 expected counts, with the minimum expected count being 0.020.

The Pearson Chi-Square test statistic is 73.550 with 16 degrees of freedom, and the  $p$ -value was less than 0.001. This indicated a significant association between the hazard and the response categories. Therefore, this led to the rejection of the null hypothesis of no association.

The Likelihood Ratio Chi-Square test statistic was 32.325 with 16 degrees of freedom, and the  $p$ -value was 0.009 (asymptotic) and 0.003 (exact). Both  $p$ -values indicated a significant association between the variables tested. Thus, this led to rejecting the null hypothesis.

The Fisher-Freeman-Halton Exact Test provides a  $p$ -value of 0.003, which was also significant. This test was especially useful when expected frequencies were low, further confirming the significant association.

The Linear-by-Linear Association test statistic was 0.284 with 1 degree of freedom, and the  $p$ -values (0.594, 0.624, and 0.322) were not significant. This revealed that there was no significant linear trend between the variables.

The Pearson Chi-Square and Likelihood Ratio tests both show a significant association between the hazard categories and the response categories ( $p < 0.001$  and  $p = 0.009$ , respectively). The Linear-by-Linear Association test did not show a significant linear trend ( $p = 0.594$ ). The high proportion of cells with expected counts less than 5 which indicated that caution should be used when interpreting the results, as this may affect the validity of the Chi-Square test.

#### *Symmetric Measures*

Table 5.7 presents the symmetric measures that measure the strength and direction of the relationship between the two variables, hazards and responses, using Pearson's  $r$  and Spearman's correlation.

| Symmetric Measures         |                         | Value  | Asymptotic<br>Standard<br>Error <sup>a</sup> | Approximate<br>$T^b$ | Approximate<br>Significance | Exact<br>Significance |
|----------------------------|-------------------------|--------|----------------------------------------------|----------------------|-----------------------------|-----------------------|
| Interval<br>by<br>Interval | Pearson's $r$           | -0.073 | 0.141                                        | -0.529               | 0.599 <sup>c</sup>          | 0.624                 |
| Ordinal<br>by<br>Ordinal   | Spearman<br>Correlation | -0.119 | 0.142                                        | -0.866               | 0.390 <sup>c</sup>          | . <sup>d</sup>        |
| N of Valid Cases           |                         | 54     |                                              |                      |                             |                       |

|                                                                      |
|----------------------------------------------------------------------|
| a. Not assuming the null hypothesis.                                 |
| b. Using the asymptotic standard error assuming the null hypothesis. |
| c. Based on normal approximation.                                    |
| d. Cannot be computed because there is insufficient memory.          |

*Table 5.7. Hazards and responses correlations using Pearson's  $r$  and Spearman's to identify strength and direction relationships.*

Key significant relationship: The Pearson's  $r$  and Spearman's correlation coefficients indicate a very weak negative linear relationship between two variables, hazards and responses. The  $p$ -values for the Pearson  $r$  coefficient are both greater than 0.05, indicating that the relationship is not statistically significant. The exact significance is also greater than 0.05, confirming the non-significance. The null hypothesis that the correlation coefficient is zero was rejected, and the exact significance cannot be computed due to insufficient memory.

Overall, based on the correlation analysis and chi-square tests, the findings indicated that the null hypothesis could not be fully rejected for most of the hazard-response variables. In Spearman's rho correlation analysis, the relationships between seaweed production and various hazards showed weak and statistically insignificant correlations, implying that no strong association exists between these variables. Therefore, in this context, the null hypothesis, which assumes no association between the quantity of cultivated seaweed and key variables in hazards and responses, is retained.

However, when using chi-square and exact tests (e.g., Pearson Chi-Square, Likelihood Ratio, and Fisher-Freeman-Halton Exact Test), significant associations were identified between hazard and response categories, particularly regarding the types of hazards and corresponding coping mechanisms. These significant chi-square results allowed for the rejection of the null hypothesis, indicating that there is a meaningful relationship between specific hazard types and the response strategies employed by seaweed farmers. Therefore, while correlations with seaweed production were weak, significant associations were found in the context of hazard-response patterns. The association of Hazards and Responses are further elaborated in appendix C section 9.3.2.1.

#### 5.1.5 Hypothesis testing using linear regression models

This multiple regression analysis investigates how various livelihood capitals, classified under the SLF, impact seaweed farming productivity, measured by seaweed harvested in pounds (wet weight). Each capital, Human, Social, Natural, Physical, Financial, and Cultural, was represented by several independent variables, and the relationship between these variables and seaweed production was examined.

*Key variables selection:* Table 5.8 summarizes the variables that were observed during the semi-structured interviews with seaweed farmers. These variables are aligned with the SLF and represent different livelihood capitals (human, social, natural, physical, financial, and cultural) that impact seaweed farming productivity. Note that only certain socio-economic factors were included in the quantitative model. Only variables that theoretically align with these livelihood capitals, such as education, health, household size, income, and experience, were included to ensure that the model accurately reflects the framework and research questions (see further details in appendix C section 9.3.2.2). Variables that have been consistently shown in previous literature to significantly impact productivity or livelihoods tend to be prioritized in quantitative models. For these reasons, the decision to include only



certain socio-economic factors in the quantitative model reflects a combination of theoretical relevance, empirical evidence, data quality, multicollinearity considerations, and the need for model parsimony.

| <b>Survey Question</b>                                                                      | <b>Variable</b>                                        | <b>Purpose</b>                                                                                                                                         |
|---------------------------------------------------------------------------------------------|--------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| Q82 With no hazards, how much seaweed do you normally harvest monthly (estimate in pounds)? | Seaweed Production (Dependent Variable)                | To assess the monthly seaweed production (wet weight) as the dependent variable for evaluating the impact of different livelihood capitals.            |
| What is your Age?                                                                           | Socio-demographics (Human Capital)                     | To gather the respondent's age, which helps understand the demographic profile and its impact on seaweed farming productivity and sustainability.      |
| What is your Gender?                                                                        | Socio-demographics (Social Capital)                    | To determine the gender distribution among seaweed farmers and analyze any gender-specific differences in farming practices or productivity.           |
| What is your Highest level of Education?                                                    | Education (Human Capital)                              | To assess the education level of respondents and its correlation with the adoption of seaweed farming techniques and overall productivity.             |
| What is your Household Size?                                                                | Household Size (Social Capital)                        | To determine the number of household members and assess whether household size provides additional labor for seaweed farming or increases consumption. |
| What is your Seaweed Farming Experience (in years)?                                         | Experience (Human Capital)                             | To capture the number of years spent in seaweed farming, reflecting the accumulated skills and knowledge that might positively impact productivity.    |
| How much seaweed is lost due to climate/non-climatic events?                                | Seaweed Loss (Natural Capital)                         | To measure the extent of seaweed loss, evaluating its impact on productivity and the sustainability of farming practices.                              |
| Do you own a seaweed farm?                                                                  | Farm Ownership (Physical - Infrastructure Capital)     | To assess whether farm ownership provides secure access to marine space, which could impact productivity and long-term investments in farming.         |
| Do you use boats and engines for farming?                                                   | Boats and Engines (Physical - Infrastructure Capital)  | To capture access to physical capital (boats and engines) essential for maintaining seaweed farms, especially in marine environments.                  |
| What is your monthly household income?                                                      | Household Income (Financial Capital)                   | To assess the financial stability of the household and its impact on the ability to invest in seaweed farming operations or handle losses.             |
| Have you received formal training in seaweed farming?                                       | Training (Human Capital)                               | To evaluate whether farmers who have received formal training have higher productivity due to better technical skills and practices.                   |
| Do you engage in value-adding activities (e.g., bio-products)?                              | Value-Adding Products (Physical - Product Development) | To assess the role of value-adding products in diversifying income streams and enhancing livelihood adaptation strategies.                             |

|                                                                                 |                                                             |                                                                                                                                                |
|---------------------------------------------------------------------------------|-------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| What farming approach do you follow (CbA, EbA, Integrated, learning as you go)? | Farming Approach (Natural Capitals - Adaptation Strategies) | To determine whether farmers using specific farming approaches (CbA, EbA, Integrated, or Learning as you go) have varying productivity levels. |
| What Traditional Knowledge do you use in seaweed farming?                       | Traditional Knowledge (Family Tradition - Cultural Capital) | To evaluate the role of traditional knowledge passed down through family practices and its impact on farming productivity.                     |

Table 5.8. Key variables selected for measuring seaweed farming livelihoods (Author's own elaboration).

*Descriptive statistics:* Table 5.8 summarizes the key variables tested in the quantitative model that were theoretically aligned with the SLF capitals that impact seaweed farming productivity. Table 9.5 in Appendix C presents all the variables considered to measure each livelihood capitals, such as education, health, household size, income, and experience, were included to ensure that the model accurately reflects the framework and research questions. Variables that have been consistently shown in previous literature to significantly impact productivity or livelihoods tend to be prioritized in quantitative models. For these reasons, the decision to include only certain socio-economic factors in the quantitative model reflects a combination of theoretical relevance, empirical evidence, data quality, multicollinearity considerations, and the need for model parsimony.

Table 5.9 summarizes the descriptive statistics for the key variables representing the livelihood capitals included in the multiple linear regression model. The means and standard deviations provided insights into the central tendency and variability of each variable, categorized under their respective livelihood capital, based on Table 5.8. Other socio-demographic and farm-specific variables were also not included in the model but were further elaborated in Table 9.7. in Appendix C. (section 9.3.2.3) reveals key variables measured in each capital. This encompassed seaweed farm description, current farming system, species farmed, distance to the seaweed farming site, harvesting depth, impact of climate change on seaweed crops, biological factors affecting seaweed farms, and sources of funding through network and cluster formation initiatives revealed in the literature.

| Livelihood Capital | Variable                                                                                              | Mean   | Std. Deviation (SD) |
|--------------------|-------------------------------------------------------------------------------------------------------|--------|---------------------|
| Human Capital      | Education                                                                                             | 1.205  | 0.443               |
|                    | Health                                                                                                | 16.388 | 2.659               |
|                    | Formal training                                                                                       | 0.666  | 0.485               |
|                    | Age                                                                                                   | 0.593  | 0.609               |
|                    | Experience                                                                                            | 1.474  | 0.411               |
| Social Capital     | Household size                                                                                        | 1.303  | 0.565               |
|                    | Gender                                                                                                | 0.444  | 0.511               |
|                    | Farm ownership                                                                                        | 0.722  | 0.460               |
| Natural Capital    | Seaweed loss                                                                                          | 1.598  | 0.484               |
|                    | Farming Approach – Learning (learning in the field as seaweed farmers progress/no specified approach) | 0.388  | 0.504               |
|                    | Approach - CbA                                                                                        | 0.166  | 0.383               |
|                    | Approach - EbA                                                                                        | 0.055  | 0.235               |

|                   |                                       |        |       |
|-------------------|---------------------------------------|--------|-------|
|                   | Approach – Integration of CbA and EbA | 0.388  | 0.501 |
| Physical Capital  | Farm size                             | 0.757  | 0.397 |
|                   | Boat equipment                        | 0.555  | 0.511 |
|                   | Value added products (infrastructure) | 0.500  | 0.511 |
| Financial Capital | Value adding Income                   | 0.614  | 0.694 |
|                   | Seaweed Income                        | 0.901  | 0.702 |
|                   | Household income                      | 1.67   | 0.308 |
|                   | Savings                               | 0.467  | 0.447 |
|                   | Remittance                            | -0.111 | 0.323 |
| Cultural Capital  | Traditional knowledge                 | 0.500  | 0.514 |

*Table 5.9. Descriptive statistics of key variables in the livelihood capitals measured in the multiple linear regression model.*

*Key insights:* The descriptive statistics provided insights into the key livelihood capitals and their associated variables, offering a detailed overview of the seaweed farmers' characteristics

In terms of human capital, the average education level was relatively low, with a mean of 1.2055 (SD = 0.443), suggesting that most respondents had attained only primary to some secondary education. Respondents rated their health relatively high, with a mean score of 16.3889 (SD = 2.659), indicating positive health conditions but with moderate variability. Two-thirds of the farmers (mean = 0.666, SD = 0.485) had received formal training in seaweed farming, while the average age score was 0.593 (SD = 0.609), reflecting a sample of mostly middle-aged individuals. The experience of the farmers in seaweed farming was moderate, with an average of 1.474 (SD = 0.411), suggesting that many farmers had between 1 and 5 years of farming experience.

For social capital, the average household size was 1.303 (SD = 0.565), representing small to moderately sized households, which could affect labor availability for farming. The gender distribution indicated a slight predominance of male respondents (mean = 0.444, SD = 0.511). Regarding farm ownership, the mean score of 0.722 (SD = 0.460) indicated that the majority of respondents owned their seaweed farms, reflecting secure access to marine resources.

In the realm of natural capital, the reported seaweed loss was moderate (mean = 1.598, SD = 0.484), which likely pointed to shared environmental challenges affecting production. Regarding farming approaches, 39% of respondents employed the “learning as you go” method (mean = 0.388, SD = 0.504), while the use of Community-Based Adaptation (CbA) and Ecosystem-Based Adaptation (EbA) approaches was low, with mean scores of 0.166 (SD = 0.383) and 0.055 (SD = 0.235), respectively. However, 38.890% of respondents adopted integrated approaches combining CbA and EbA (mean = 0.388, SD = 0.501).

Regarding physical capital, the average farm size was moderate (mean = 0.757, SD = 0.397), while access to boat equipment was reported by over half of the farmers (mean = 0.5556, SD = 0.511). Half of the respondents (mean = 0.5, SD = 0.511) were engaged in value-adding activities such as processing seaweed into bio-products.

For Financial Capital, the average value-adding income was moderate (mean = 0.614, SD = 0.694), with significant variability among respondents. The seaweed income was also moderate (mean = 0.901, SD = 0.702), while the household income was relatively stable (mean = 1.673, SD = 0.308). Nearly half of the respondents managed to save some of their earnings (mean = 0.467, SD = 0.447), though the levels of savings varied widely. Remittance was minimal, with a negative mean (-0.111, SD = 0.323), indicating that most respondents did not receive financial support from family members abroad.

In terms of cultural capital, approximately half of the respondents utilized traditional knowledge in their seaweed farming practices (mean = 0.5, SD = 0.514), often passed down through family traditions.

The descriptive data highlighted that the seaweed farmers had moderate levels of experience and education, along with access to key physical and financial resources. However, there were notable variations in income levels, farm sizes, and the use of farming approaches. Farm ownership and access to boat equipment were critical physical assets for the majority of the farmers, and traditional knowledge continued to play a crucial role in their farming practices.

*Modelling Strategy:* In the multiple regression analysis, the Enter method was initially used as the primary approach for selecting variables in the multiple regression model, followed by the Backward elimination method to refine the model.

In the first step, the Enter method included all predictor variables simultaneously without selection or elimination. These variables encompassed key factors representing the livelihood capitals, such as human, social, natural, physical, financial, and cultural capitals. The Enter method allowed the inclusion of these variables based on theoretical assumptions, ensuring that no variable was excluded from the model, regardless of its statistical significance.

Following the Enter method, the Backward elimination method was applied to systematically refine the model. This iterative process removed variables that did not meet the F-statistic criterion for inclusion. Variables that had the least impact or statistical significance were removed one at a time in subsequent models. For example, Education (Log\_Education), Health (Average of physical, mental and overall life satisfaction), and savings (sqft\_Savings) were among the first variables eliminated based on their lack of significance in relation to the dependent variable (seaweed production).

This elimination process continued, removing non-significant variables, until the final model (Model 13) retained only those variables that met the established criteria for inclusion. This allowed the analysis to focus on the most significant predictors contributing to seaweed farming productivity.

The combination of the Enter and Backward elimination methods was used to ensure that the model was both comprehensive (reflecting theoretical assumptions) and refined (eliminating non-significant variables). This approach allowed the study to maintain theoretical rigor while improving the model's efficiency and predictive power.

*Model Findings:* Full regression outputs (coefficients  $\beta$ , standard errors, 95% CIs, standardized betas where meaningful, model-level  $R^2$ /adjusted  $R^2$ , F-test, diagnostics) of the effects of each independent variables on the dependent variable (seaweed harvested) are provided in Table 9.12. of Appendix C section 9.3.2.4. Below Table 5.10 summarizes key variables with  $p < 0.05$  in the final model and note those without evidence of impact. The outcomes of the best fit model are based on Model 13 compared to the other models elaborated in appendix C section 9.3.2.4 to 9.3.2.6 showing how significant factors impact seaweed productivity and the corresponding null hypotheses. Overall, the models indicated a good fit with the data as presented in the residuals' statistics behavior in the multiple linear regression model be found in in the Appendix C section 9.3.2.3

| <b>Livelihood Capital</b> | <b>Variable</b>            | <b>R<sup>2</sup></b> | <b>F Statistic</b> | <b>p-Value</b> | <b>Null Hypothesis</b> |
|---------------------------|----------------------------|----------------------|--------------------|----------------|------------------------|
| Human Capital             | Education                  | 0.461                | 3.342              | 0.086          | Accept                 |
|                           | Health                     | 0.866                | 2.622              | 0.125          | Accept                 |
|                           | Formal Training            | 0.053                | 0.892              | 0.359          | Accept                 |
|                           | Experience                 | 0.597                | 4.726              | 0.045**        | Reject                 |
| Social Capital            | Gender                     | 0.228                | 4.726              | 0.045**        | Reject                 |
|                           | Household Size             | 0.519                | 3.254              | 0.090          | Accept                 |
|                           | Approach CbA               | 0.462                | 2.190              | 0.034**        | Reject                 |
|                           | Integration of CbA and EbA | 0.012                | 1.533              | 0.221          | Accept                 |
| Natural Capital           | Seaweed Loss               | 0.667                | 2.622              | 0.044**        | Reject                 |
|                           | EbA Approach               | 0.462                | 2.533              | 0.034**        | Reject                 |
| Physical Capital          | Farm Size                  | 0.157                | 1.137              | 0.397          | Accept                 |
|                           | Boat Equipment             | 0.266                | 0.892              | 0.130          | Accept                 |
|                           | Value-Added Products       | -0.444               | 0.556              | 0.360          | Accept                 |
| Financial Capital         | Household Income           | 0.643                | 2.622              | 0.045**        | Reject                 |
|                           | Seaweed Income             | 0.643                | 2.622              | 0.045**        | Reject                 |
|                           | Remittance                 | 0.111                | 1.123              | 0.300          | Accept                 |
|                           | Savings                    | 0.467                | 1.732              | 0.245          | Accept                 |
| Cultural Capital          | Traditional Knowledge      | 0.500                | 2.500              | 0.046**        | Reject                 |

*Table 5.10. Summary of correlation and regression model output for livelihood factors based on Model 13 using the backward method (Author's own elaboration).*

*Key significance:*

Human Capital: Education showed a moderate  $R^2$  value of 0.461 and an F-statistic of 3.342, with a  $p$ -value of 0.086, leading to the acceptance of the null hypothesis. This suggests that education did not have a significant impact on seaweed productivity in this sample. Health had the highest  $R^2$  (0.866), but its  $p$ -value (0.125) indicated no significant relationship with seaweed production. Thus, the null hypothesis was approved. Formal Training ( $R^2 = 0.053$ ) did not substantially influence productivity ( $p = 0.359$ ), and the null hypothesis was accepted. Experience was a significant factor ( $R^2 = 0.597$ ,  $p = 0.045^{**}$ ), leading to the rejection of the null hypothesis, indicating experience had a positive impact on seaweed cultivation productivity.

Social Capital: Gender was found to substantially impact productivity ( $R^2 = 0.228$ ,  $p = 0.045^{**}$ ), and the null hypothesis was rejected. Household Size showed no significant impact ( $R^2 = 0.519$ ,  $p = 0.090$ ), with the null hypothesis being adopted. Approach\_CbA (Community-based Adaptation) significantly influenced productivity ( $R^2 = 0.462$ ,  $p = 0.034^{**}$ ), refuting the null hypothesis. Integration of CbA and EbA (Ecosystem-based Adaptation) did not exhibit a significant effect on production ( $R^2 = 0.012$ ,  $p = 0.221$ ), leading to the adoption of the null hypothesis.

Natural Capital: Seaweed Loss had a significant impact on productivity ( $R^2 = 0.667$ ,  $p = 0.044^{**}$ ), with the null hypothesis rejected. EbA Approach (Ecosystem-based Adaptation) also showed significant results ( $R^2 = 0.462$ ,  $p = 0.034^{**}$ ), refuting the null hypothesis.

Physical Capital: The null hypothesis was accepted, as farm size did not substantially influence seaweed production ( $R^2 = 0.157$ ,  $p = 0.397$ ). The null hypothesis was adopted, as Boat Equipment did not have a significant effect ( $R^2 = 0.266$ ,  $p = 0.130$ ). The null hypothesis was accepted, as Value-Added Products did not exhibit a significant impact, as evidenced by a negative  $R^2$  value (-0.444) and a  $p$ -value of 0.360.

Financial Capital: The null hypothesis was rejected as a result of the substantial impact of household income on seaweed production ( $R^2 = 0.643$ ,  $p = 0.045^{**}$ ). The null hypothesis was denied, as seaweed income also had a significant effect ( $R^2 = 0.643$ ,  $p = 0.045^{**}$ ). The null hypothesis was adopted, as remittance did not have a significant impact on seaweed production ( $R^2 = 0.111$ ,  $p = 0.300$ ). The null hypothesis was adopted, as savings did not have a substantial impact on productivity ( $R^2 = 0.467$ ,  $p = 0.245$ ).

Cultural Capital: The null hypothesis was rejected, and the significance of cultural practices in seaweed cultivation was underscored by the significant influence of Traditional Knowledge on productivity ( $R^2=0.5$ ,  $p=0.046^{**}$ ).

However, the results indicated that the productivity of seaweed farming was significantly impacted by specific variables, including Human Capital (Experience), Social Capital (Gender, Approach\_CbA), Natural Capital (Seaweed Loss, EbA Approach), Financial Capital (Household Income, Seaweed Income), and Cultural Capital (Traditional Knowledge), in this study. The analysis emphasizes the intricacy of the factors that contribute to the success of seaweed cultivation and identifies areas for targeted interventions to improve productivity and adaptation in the SIDS of Belize.

### 5.1.6 Summary of quantitative assessment using linear regression model

The final regression model (Model 13) provided insights into the livelihood capitals that impact seaweed farming productivity in Belize. The results highlight the importance of practice-based, knowledge-based, and financial variables, while indicating that asset-related factors were not statistically significant. The following implications of the quantitative assessments are summarized below:

**Adaptation Approaches:** The model confirmed that the adoption of EbA practices ( $p = 0.034$ ) and CbA practices ( $p = 0.034$ ) had significant positive impacts on productivity. This finding indicated that aligning farming practices with ecological conditions and embedding them within community structures enhances yields.

**Human and cultural capital:** Experience ( $p = 0.045$ ) and traditional knowledge ( $p = 0.046$ ) were both significant predictors of productivity. This demonstrated that practical know-how accumulated through farming and the transmission of locally grounded knowledge continues to play central roles in sustaining seaweed mariculture. Formal education and training, by contrast, did not show significant impacts.

**Financial capital:** Both household income and seaweed income showed significant positive impacts on productivity ( $p = 0.045$ ). This evidenced that financial stability provided farmers with the means to sustain and potentially expand production. By contrast, remittances and savings were not significant.

**Social Capital:** Gender was a significant factor ( $p = 0.045$ ), which indicated differences in productivity outcomes across male and female farmers. Other social variables, such as household size and the integration of CbA and EbA into a combined strategy, were not significant in the final model.

Overall, the quantitative assessment revealed that the sustainability of seaweed farming in Belize is strongly linked to the adoption of community- and ecosystem-based adaptation practices, the utilization of experience and traditional knowledge, and the presence of stable household and farming income. By comparison, physical expansion and external financial inflows, such as remittances, were not shown to have significant impacts. These results provided a clear indication that intangible and practice-based capitals may be more critical than physical scale in shaping seaweed farming productivity in the Belizean context.

## 5.2 Qualitative Assessment

### 5.2.1 Focus group discussions

There was a total of four (4) focus group discussions in the central (Belize City) and south central (Placencia and Riversdale) parts of Belize along the coast, (Figure 5.6.). A total of nineteen (19) participants consisting of 10 males and 9 females, discussions were conducted collectively and separated by gender from seaweed farming communities in Belize City, Riversdale Village, and Placencia Village, as indicated by the red circle on the map in Figure 5.6.



Figure 5.6. The location of seaweed farming communities in Belize highlighting Belize City and Placencia where data collection activities occurred (adapted from WorldAtlas, 2023).

The aggregated results of the four (4) focus group discussions conducted in various parts of Belize as shown in Figure 1, involving nineteen (19) participants, are presented below.

*Livelihood capitals and resources:* The livelihood resources, as categorized by the SLF, included human, social, natural, physical, financial, and cultural resources, were identified according to priority, how they supported the day-to-day farming activities and their contribution to sustaining their seaweed farming livelihoods (Table 5.11).

| Livelihood Categories               | Livelihood Resources                                                                                                                                                                                                                                                                                                |
|-------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Human</b>                        | <ul style="list-style-type: none"> <li>• Health and balanced diet</li> <li>• Practical skills in swimming, diving, CPR, and sea navigation</li> <li>• Knowledge and skills in seaweed farming</li> </ul>                                                                                                            |
| <b>Social (including political)</b> | <ul style="list-style-type: none"> <li>• Family and community support (including tour operators and university students)</li> <li>• Training programs in sustainable farming practices, disease prevention and seeds</li> <li>• Knowledge and skills exchange through focus groups and training sessions</li> </ul> |
| <b>Natural</b>                      | <ul style="list-style-type: none"> <li>• Access to marine environments seaweed resources, seagrass beds, mangroves, reef waters</li> <li>• Availability of wild seaweed patches for seed collection</li> <li>• Good ocean weather and nutrient-rich waters</li> </ul>                                               |



|                  |                                                                                                                                                                                                                                                                   |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Physical</b>  | <ul style="list-style-type: none"> <li>• Boats, engines, ropes, and farming infrastructure</li> <li>• Drying and packaging facilities</li> <li>• Freshwater access for rinsing seaweed</li> <li>• Tools and machines for seaweed processing</li> </ul>            |
| <b>Financial</b> | <ul style="list-style-type: none"> <li>• Grants from NGOs and government</li> <li>• Personal savings and investments</li> <li>• Access to credit and microfinance</li> <li>• Local and small international markets</li> </ul>                                     |
| <b>Cultural</b>  | <ul style="list-style-type: none"> <li>• Traditional knowledge of seaweed uses (e.g., food, medicine)</li> <li>• Community bonding activities around seaweed farming</li> <li>• Potential for cultural festivals and events to promote seaweed farming</li> </ul> |

*Table 5.11. Aggregated Key Livelihood Resources identified from all 4 Focus Group Discussions (Author's own elaboration).*

The following key points emerged in the discussion amongst all the participants, about their livelihood resources:

Seaweed farmers in Belize prioritized maintaining good health and a balanced diet, recognizing these as essential for their physically demanding work. Farmers possessed critical practical skills, including swimming, diving, cardiopulmonary resuscitation (CPR), and sea navigation, which were fundamental for the safe and effective management of their seaweed farms. The farmers' knowledge and skills in seaweed farming were extensive, having been developed through years of experience and supplemented by training programs focused on sustainable farming practices. These programs, often facilitated by environmental non-governmental organizations (E-NGOs) and government agencies, provided farmers with the necessary expertise to enhance their farming techniques and prevent diseases.

The support from family members and the broader community, including local tour operators and university students, was important for the seaweed farmers. These formal and informal networks provided both practical help and emotional support, which was crucial for the farmers' sustaining their operations and mitigating hazards. Various training programs covered sustainable farming practices, disease prevention, and seed management, benefiting the farmers significantly. These training programs were frequently organized by E-NGOs of which were endorsed by government entities. Furthermore, focus groups and training sessions offered platforms for knowledge and skills exchange, enhancing the overall capacity of the seaweed farming community.

The natural resources available to seaweed farmers in Belize were abundant and varied. Farmers had access to rich marine environments, including seagrass beds, mangroves, and reef waters, which were conducive to seaweed cultivation. Wild seaweed patches provided a crucial source of seeds for cultivation, ensuring the sustainability of farming operations. Additionally, favorable ocean conditions and nutrient-rich waters have supported healthy seaweed growth, perceived to provide a stable environment for their crops.

The physical infrastructure supporting seaweed farming was robust and well-developed. Essential equipment such as boats, engines, ropes, and farming tools was critical for daily operations. These tools enabled farmers to manage their farms efficiently, from planting and maintenance to harvesting. Drying and packaging facilities were necessary for processing

seaweed before it was sold, ensuring the seaweed was prepared to meet market standards. Access to freshwater was crucial for rinsing seaweed, especially before drying, and various tools and machines for processing enhanced efficiency and product quality.

Financial support was a cornerstone of the sustainability and growth of seaweed farming in Belize. Grants attained from E-NGOs in collaboration with community-based organizations, associations and cooperatives and government entities (often referred to as a ‘cluster’ in a project grant) provided significant capital for operations and expansion, enabling farmers to invest in new equipment, improve infrastructure, and explore new markets. Many farmers relied on personal savings and investments to fund their activities, which allowed them to make decisions that best suited their operations. Although access to credit and microfinance was limited, it was crucial for managing cash flow and making necessary investments. Selling products in local and small international markets ensured a steady income and economic sustainability for the farmers.

The cultural heritage associated with seaweed farming in Belize was rich and deeply embedded in the communities. Traditional knowledge of seaweed uses, passed down through generations, encompassed its applications in food, medicine, and other areas, adding value to the seaweed products and strengthening community ties. Seaweed farming activities served as opportunities for community bonding and mutual support, fostering a sense of belonging and shared purpose. The potential for cultural festivals and events centered around seaweed farming was significant, as such events could promote industry, attract tourists, and enhance community engagement, showcasing the cultural and economic importance of seaweed farming.

In summary, the four focus group discussions highlighted various livelihood resources and key hazards impacting seaweed farming in Belize. Human resources, including practical skills attained on their own experience and training programs, were essential for sustainable farming practices. Social support from family, community, and E-NGOs played a significant role in facilitating seaweed farming activities. Natural resources, such as healthy marine environments and wild seaweed patches, provided the necessary conditions for seaweed growth. Physical resources, including boats and processing facilities, were vital for farming operations. Financial resources mainly came from grants, personal savings, and limited market access. Cultural aspects, including traditional knowledge and community bonding, were integral to the seaweed farming community.

*Hazards, impacts and coping mechanisms:* The focus group discussions identified multiple hazards affecting seaweed farming in Belize (Table 5.12), defined by their frequency, duration, intensity, and impacts on farming resources and activities.

| <b>Hazards</b>     | <b>Frequency</b> | <b>Duration</b> | <b>Intensity</b> | <b>Description of Direct/indirect impacts on Seaweed farms</b>          |
|--------------------|------------------|-----------------|------------------|-------------------------------------------------------------------------|
| Theft and Security | 3-5 times/year   | 1 day/event     | High             | (↑) Loss of crops and equipment<br>(↓) Reduced motivation among farmers |

|                                                                   |                  |                     |                |                                                                                                                                    |
|-------------------------------------------------------------------|------------------|---------------------|----------------|------------------------------------------------------------------------------------------------------------------------------------|
| Cultivated Seaweed Die-offs/Breakoffs                             | 4-6 times/year   | Throughout the year | High           | (↑) Income loss<br>(↓) Reduced productivity<br>(↑) Increased disease outbreaks                                                     |
| Extreme Weather Events (including hurricanes, storms, and floods) | 3times/year      | June-November       | Medium to High | (↑) Damage to infrastructure<br>(↑) Loss of seaweed crops<br>(↑) Inability to work                                                 |
| Sea Temperature Increase                                          | Increasing trend | Continuous          | High           | (↑) Disease outbreaks in seaweed<br>(↓) Reduced harvest quality                                                                    |
| Extended Droughts                                                 | Seasonal         | Dry season          | High           | (↑) Increased salinity in final product<br>(↓) Reduced seaweed quality due to difficulty in rinsing seaweed<br>(↑) Loss of seaweed |

*Table 5.12. Key climatic hazards and resources identified by participants that impact seaweed livelihoods group discussions (Author's own elaboration).*

The following key points emerged from the discussions with participants regarding the hazards impacting their livelihoods:

Based on Table 5.12, theft of seaweed and equipment was reported multiple times per year, occurring approximately 3 to 5 times. Each theft event typically lasted a single day but had a high intensity of impact. Directly, theft resulted in the loss of seaweed crops and essential farming equipment, which directly diminished farmers' incomes, operational capacities, and responses to other hazards. Indirectly, theft increased stress levels and reduced motivation among the farmers, potentially leading to decreased productivity and overall morale.

Die-offs and breakoffs occurred frequently, requiring replanting and raising costs. These types of hazards were reported to occur 4 to 6 times per year, spread throughout the year. These events had a high intensity, leading to reductions in yield and immediate income loss. The direct impact of these die-offs necessitated more frequent replanting efforts, increasing labor and operational costs. Indirectly, these events made the seaweed more vulnerable to disease outbreaks, compounding the challenges faced by the farmers.

Extreme weather events, particularly hurricanes, storms, and floods, were identified as another major hazard. These events were reported to occur about three times per year, primarily during the hurricane season from June to November, with durations ranging from a few hours to several days. The intensity of these events causes physical damage to farming infrastructure, such as broken ropes and displaced seaweed beds, resulting in the loss of seaweed crops and contributing to marine pollution. Indirect impacts included prolonged

periods of inactivity due to damaged farms, leading to income instability and potential financial distress.

Increasing sea temperature was identified as posing a high-intensity hazard. Rising sea temperatures directly contributed to increased disease outbreaks in seaweed, which reduces both the quality and quantity of the harvestable seaweed. Indirectly, long-term shifts in seaweed growth patterns necessitated the relocation of farms or changes in farming practices, requiring additional resources and adaptation efforts.

Extended droughts, typically occurring during the dry season and lasting several months, presented a high-intensity hazard. The lack of rainfall increased salinity levels in the water, negatively affecting seaweed quality as the seaweed crop would thrive under shallow conditions near the islands and experience stunted growth. Moreover, there was revealed too that there is difficulty in accessing sufficient freshwater for rinsing seaweed further impacted processing quality as seaweed is not grown near mainland but around islands about 5 to 15 miles from the mainland. Indirectly, participants believed that not rinsing the seaweed crop with freshwater reduced the product quality which meant that their produce attained a lower market price. Therefore, this reduced income for farmers is not ideal and has led these farmers to venture into new ways of post-harvesting practices such as dehydrating the seaweed crop and using its own water to clean itself once stored properly in a plastic bag on the ground. Others would transport freshwater into VAT/water tanks in order to secure freshwater, but this increased operational costs.

*Coping strategies against identified hazards:* Farmers also reported a range of coping strategies below (Table 5.13), combining short-term measures and longer-term approaches designed to mitigate hazards and support the sustainability of seaweed farming livelihoods.

| Hazards                               | Current Responses                                            | Long-term Responses                                                      |
|---------------------------------------|--------------------------------------------------------------|--------------------------------------------------------------------------|
| Theft and Security                    | Regular site visits, community monitoring                    | Hiring security, stronger policy enforcement                             |
| Cultivated Seaweed Die-offs/Breakoffs | Regular monitoring, use of resilient seaweed species         | Continuous research and development, adapting farming techniques         |
| Hurricanes/Storms/Floods              | Short-term relocation of farms, installation of buoy systems | Submerged farming techniques, improved anchor systems                    |
| Sea Temperature Increase              | Adjusting farm depths, monitoring sea temperatures           | Permanent relocation to cooler areas, breeding resilient seaweed species |

|                   |                                                           |                                                                                         |
|-------------------|-----------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Extended Droughts | Use of rainwater catchment systems, short-term relocation | Development of drought-resistant farming practices, continuous environmental monitoring |
|-------------------|-----------------------------------------------------------|-----------------------------------------------------------------------------------------|

*Table 5.13. Main short and long-term responses coping strategies against identified hazards from focus group discussions (Author's own elaboration).*

The following key points emerged from the discussions with participants regarding their coping mechanisms:

Based on Table 5.13, seaweed farmers in Belize reported a range of coping strategies to address key hazards, balancing immediate autonomous responses with longer-term measures. Theft and security were identified as one of the hazards impacting participants' seaweed farms. To address the frequent and high-intensity hazard of theft, participants adopted several coping strategies. In the short term, they conducted regular site visits and established community monitoring systems to deter potential thieves. These immediate measures were crucial in reducing the occurrence of theft and safeguarding their crops and equipment. In the long term, participants planned to hire security personnel and advocated for stronger enforcement of policies related to marine resource protection. These long-term strategies aim to provide a more permanent solution to the threat of theft and ensure the security of their farming operations.

In response to the recurrent die-offs and breakoffs of cultivated seaweed, participants implemented both immediate and enduring strategies. Short-term responses included regular monitoring of seaweed health and the use of resilient seaweed species less susceptible to disease and environmental stressors. These measures helped to mitigate immediate losses and maintain crop health. For the long term, participants focused on continuous research and development to improve farming techniques and develop more robust seaweed varieties. Adapting farming practices based on ongoing research was essential for sustaining productivity and minimizing the impact of die-offs and breakoffs.

To cope with the destructive impacts of hurricanes, storms, and floods, farmers employed various strategies. Short-term responses involved relocating seaweed farms to safer areas and installing buoy systems to protect seaweed beds from being damaged or washed away during storms. These measures provided immediate protection and minimized damage. In the long term, participants aimed to implement submerged farming techniques and improve anchor systems to withstand severe weather conditions. These long-term strategies were designed to enhance the adaptation of their farming infrastructure and reduce the vulnerability of seaweed crops to extreme weather events.

The increasing trend in sea temperatures necessitated adaptive strategies to ensure the continued viability of seaweed farming. In the short term, participants adjusted the depths at which they cultivated seaweed and closely monitored sea temperatures to mitigate the immediate impacts on crop health. These adjustments helped to reduce the stress on seaweed caused by higher temperatures. For the long term, participants planned to relocate farms to cooler areas and focus on breeding seaweed species that were more resilient to temperature changes. These strategies aimed to adapt farming practices to the changing environmental conditions and ensure sustainable production.

Extended droughts posed a significant challenge to seaweed farming, requiring both short-term and long-term coping strategies. In the short term, participants used rainwater catchment systems to supplement their freshwater needs and temporarily relocated farms to areas with better water availability. These measures helped to address the immediate scarcity of

freshwater for rinsing seaweed. In the long term, participants aimed to develop drought-resistant farming practices and implement continuous environmental monitoring to better manage water resources.

Collectively, these strategies highlight the autonomous adaptation responses of farmers and their efforts to sustain livelihoods under climatic and non-climatic pressures

In summary, the focus group discussions identified key livelihood resources (human, social, natural, physical, financial, and cultural), as well as the major hazards impacting seaweed farming in Belize, namely theft, seaweed die-offs, extreme weather, rising sea temperatures, and drought. Farmers described a range of coping strategies, combining short-term measures such as monitoring, adjusting farm depths, and relocating farms with longer-term strategies such as security arrangements, breeding resilient seaweed varieties, and adopting submerged farming techniques. These results provide an evidence base for further analysis in relation to SLF and are explored in greater depth in the Discussion chapter.

### 5.2.2 Qualitative surveys

This section reports qualitative survey results addressing research questions: RQ1 (key characteristics of seaweed aquaculture in SIDS, with Belize as case), RQ2 (main opportunities and challenges), RQ3 (climatic and non-climatic hazards impacting livelihoods), and RQ4 (existing responses, practices, and strategies used by farmers to cope/adapt).

The following results of the qualitative surveys are further elaborated depicting direct narratives of seaweed farmers:

- Livelihood resources characteristics (respondents' profile; production practices; work schedules; income; organizational support/ motivation;
- Farmers' awareness and perceptions of climate change impact on community and seaweed crops;
- Opportunities and challenges in seaweed farming;
- Farmer's perceptions of blue economy and farmer-reported recommendations to strengthen implementation farming

#### *Livelihood characteristics and practices (RQ1):*

Respondents' profile: Table 5.14 summarized the socio-demographic profile of the seaweed farmers surveyed at the time of data collection in 2023. The sample was diverse by age, gender, ethnicity, education, and household size. Most respondents (44%) were aged between 25-34 years, indicated that seaweed farming attracted a relatively younger demographic. Following this, 22% of the respondents were aged between 35-44 years, and 17% were in the 45-54 age group. A smaller percentage of respondents were older, with 6% aged 55-64 years and 11% aged 65 and above.

The gender distribution among respondents showed a slight male dominance, with 56% of the participants being male and 44% female. This suggested a relatively balanced gender representation in seaweed farming activities, albeit with a slightly higher participation of males. The majority of the respondents (72%) identified as Creole, indicating that this ethnic group was predominant in the seaweed farming community. Mestizo/Hispanic respondents accounted for 22%, while a small percentage (6%) identified as East Indian. This ethnic composition highlighted the cultural diversity within the seaweed farming sector.

In terms of education, many respondents (39%) had completed secondary education, suggesting a relatively educated group of farmers. Additionally, 17% of respondents had received technical or vocational formal training, which likely contributed to their skills in

seaweed farming. Another 17% completed primary education, while 6% had post-secondary or university education. However, there was still a portion of the population with incomplete primary (6%) and secondary education (17%), indicating varying levels of educational attainment among the farmers. The analysis of household size revealed that 44% of the respondents lived in medium-sized households, consisting of 4-5 individuals.

Small households (1-3 individuals) were reported to be 39% of the respondents, and 17% of the respondents lived in large households of 6 or more individuals. This data suggested that most seaweed farmers came from medium to small households, which could have implications for household labor availability and the reliance on seaweed farming as a primary income source. These socio-demographic characteristics provided a comprehensive overview of the seaweed farming community, indicating a relatively young, predominantly male population with varied educational backgrounds and diverse household sizes. This diversity likely played a role in the different approaches and strategies employed in seaweed farming practices.

| <b>Respondents Characteristics (%)</b> |              |                   |
|----------------------------------------|--------------|-------------------|
| <b>Variable</b>                        | <b>Count</b> | <b>Percentage</b> |
| <b>Age</b>                             |              |                   |
| 25-34                                  | 8            | 44%               |
| 35-44                                  | 4            | 22%               |
| 45-54                                  | 3            | 17%               |
| 55-64                                  | 1            | 6%                |
| 65+                                    | 2            | 11%               |
| <b>Gender</b>                          |              |                   |
| Female                                 | 8            | 44%               |
| Male                                   | 10           | 56%               |
| <b>Ethnicity</b>                       |              |                   |
| Creole                                 | 13           | 72%               |
| Mestizo/Hispanic                       | 4            | 22%               |
| East Indian                            | 1            | 6%                |
| <b>Education Level</b>                 |              |                   |
| Incomplete Primary Education           | 1            | 6%                |
| Primary Education Completion           | 3            | 17%               |
| Incomplete Secondary Education         | 3            | 17%               |
| Secondary Education Completion         | 7            | 39%               |
| Technical/Vocational Formal Training   | 3            | 17%               |
| Post-secondary/University Completion   | 1            | 6%                |
| <b>Household Size</b>                  |              |                   |
| Small Households (1-3 individuals)     | 7            | 39%               |
| 1 adult and 0 children (2 households)  |              |                   |
| 1 adult and 2 children (3 households)  |              |                   |
| 2 adults and 1 child (2 households)    |              |                   |
| Medium Households (4-5 individuals)    | 8            | 44%               |
| 2 adults and 2 children (4 households) |              |                   |
| 3 adults and 1 child (1 household)     |              |                   |
| 5 adults and 1 child (3 households)    |              |                   |
| Large Households (6+ individuals)      | 3            | 17%               |
| 3 adults and 5 children (1 household)  |              |                   |
| 4 adults and 2 children (1 household)  |              |                   |
| 6 adults and 2 children (1 household)  |              |                   |

Table 5.14. Socio-Demographic Profile of Seaweed Farmers: Age, Gender, Ethnicity, Education, and Household Composition (Author's own elaboration).

*Farming characteristics (RQ1):*

Table 5.15 revealed a diverse set of practices and experiences of surveyed seaweed farmers. Majority of the farmers (56%) reported owning their seaweed farms, while 39% did not, and 6% had other forms of access or ownership arrangements. Regarding the types of seaweed cultivated, *Kappaphycus alvarezii* was the most farmed species, cultivated by 53% of the respondents. *Eucheuma isiforme* and *Gracilaria crassissima* were also farmed, with 34% and 13% of the respondents growing these species, respectively.

The predominant farming technique used was the submerged plots method, known locally as the tie-tie method, employed by 94% of the farmers. Only 6% of the respondents utilized a mixed technique that combined submerged plots and rafts. In terms of farming systems, 61% of the farmers practiced multiple commercial seaweed species farming, while 39% engaged in monofarming, focusing on *Kappaphycus alvarezii* exclusively. The distance to seaweed farms varied significantly among the respondents. A substantial 67% of the farmers operated farms located more than 10 miles away from their residences, 28% had farms between 4 to 9 miles away, and a small fraction (6%) managed farms within 0 to 3 miles from their homes. Experience in seaweed farming was also varied; 33% of the respondents had been farming for 1-2 years, 28% had 3-5 years of experience, 11% had farmed for 5-9 years, and 28% had been involved in seaweed farming for more than 10 years.

The establishment timeline of the seaweed farms indicated that a significant number of farms (72%) were established between 2020-2022, followed by 22% that were established between 2000-2019, and a small portion (6%) established in 2023. Regarding the perceived best farming depth for seaweed, opinions were split among the respondents. A significant portion, 50%, favored a mixed approach, utilizing both shallow and deep water with midrange buoys. Another 33% preferred shallow water or shallow intertidal water (~3 ft - 5 ft), while a smaller group of 6% opted for deep water (~6 ft - 8 ft). Additionally, 11% of the respondents admitted they had not noticed or kept track of the best farming depth, as they did not maintain farm records.

| <b>Seaweed Farming Characteristics (%)</b>                                                       |              |                   |
|--------------------------------------------------------------------------------------------------|--------------|-------------------|
| <b>Variable</b>                                                                                  | <b>Count</b> | <b>Percentage</b> |
| <b>Ownership of Seaweed Farms</b>                                                                |              |                   |
| Yes                                                                                              | 10           | 56%               |
| No                                                                                               | 7            | 39%               |
| Other                                                                                            | 1            | 6%                |
| <b>Cultivated Seaweed Species</b>                                                                |              |                   |
| <i>Kappaphycus alvarezii</i>                                                                     | 17           | 53%               |
| <i>Eucheuma isiforme</i>                                                                         | 11           | 34%               |
| <i>Gracilaria crassissima</i>                                                                    | 4            | 13%               |
| <b>Seaweed Farming Technique</b>                                                                 |              |                   |
| Submerged Plots (tie-tie method)                                                                 | 17           | 94%               |
| Mixed technique (submerged plots & rafts)                                                        | 1            | 6%                |
| <b>Farming System</b>                                                                            |              |                   |
| Monofarming ( <i>Kappaphycus</i> sp.)                                                            | 7            | 39%               |
| Multiple commercial seaweed species ( <i>Kappaphycus</i> , <i>Eucheuma</i> & <i>Gracilaria</i> ) | 11           | 61%               |



| <b>Distance to seaweed farms</b>      |    |     |
|---------------------------------------|----|-----|
| 0 – 3 miles                           | 1  | 6%  |
| 4 – 9 miles                           | 5  | 28% |
| More than 10 miles                    | 12 | 67% |
| <b>Years in Seaweed Farming</b>       |    |     |
| 1-2 years                             | 6  | 33% |
| 3-5 years                             | 5  | 28% |
| 5-9 years                             | 2  | 11% |
| More than 10 years                    | 5  | 28% |
| <b>Establishment of Seaweed Farms</b> |    |     |
| 2000-2019                             | 4  | 22% |
| 2020-2022                             | 13 | 72% |
| 2023                                  | 1  | 6%  |

*Table 5.15. Seaweed Farming Practices and Characteristics: Ownership, Techniques, and Species Cultivated (Author's own elaboration).*

*Income characteristics:* Table 5.16 highlighted a range of income streams possessed by seaweed farmers which were categorized as primary, secondary, and tertiary occupations. Notably, none of the respondents reported seaweed farming as their primary occupation. Instead, 33% identified as fishers, 11% as seaweed-based sole traders, and 6% each as boat captains, tour guides, security/caretakers, builders, landlords, and managers.

However, when it came to secondary occupations, a significant majority (72%) reported seaweed farming as their secondary income source. Other secondary occupations included fishing (6%), seaweed-based sole trading (11%), community research (6%), and tour guiding (6%).

As a third occupation, 28% of respondents indicated they engaged in seaweed farming. Additionally, 17% reported freelancing, 11% each were involved in seaweed-based sole trading and tour guiding, and 6% each worked as fishers, boat captains, community researchers, seafood sole traders, and food caterers.

Regarding their work arrangements on the farms, 44% of the respondents were involved in casual employment, while 28% worked full-time (40 hours per week) and 17% part-time (less than 35 hours per week). Only 6% were employed on a fixed-term or contract basis, and another 6% indicated they did not work on farms regularly.

The farming schedule also varied among the respondents. The majority (39%) reported working on the farms once a month, while 28% worked every two weeks. Other work schedules included visiting more than twice a week (11%), twice a month (6%), and once every two months (11%).

| <b>Income Generating Activities Characteristics</b> |                   |
|-----------------------------------------------------|-------------------|
| <b>Variable</b>                                     | <b>Percentage</b> |
| <b>Primary Occupation</b>                           |                   |
| Seaweed Farmer                                      | 0%                |
| Fisher                                              | 33%               |
| Seaweed-based Sole Trader                           | 11%               |
| Boat Captain                                        | 6%                |
| Tour Guide                                          | 17%               |
| Security/Caretaker                                  | 11%               |
| Builder                                             | 6%                |
| Landlord                                            | 11%               |
| Manager                                             | 6%                |
| <b>Secondary Occupation</b>                         |                   |
| Seaweed Farmer                                      | 72%               |
| Seaweed-based Sole Trader                           | 11%               |
| Fisher                                              | 6%                |
| Community Researcher                                | 6%                |
| Tour Guide                                          | 6%                |
| <b>Third Occupation</b>                             |                   |
| Seaweed Farmer                                      | 28%               |
| Seaweed-based Sole Trader                           | 11%               |
| Fisher                                              | 6%                |
| Boat Captain                                        | 6%                |
| Tour Guide                                          | 11%               |
| Community Researcher                                | 6%                |
| Freelancer                                          | 17%               |
| Seafood Sole Trader                                 | 11%               |
| Food Catering                                       | 6%                |
| <b>Work Arrangement on the farms</b>                |                   |
| Full-time (40 hours hrs/wk)                         | 28%               |
| Part-time (< 35 hrs/wk)                             | 17%               |
| Fixed Term and/or Contract Basis                    | 6%                |
| Casual Employment                                   | 44%               |
| Other (ie. not working on farms )                   | 6%                |
| <b>Farming Schedule</b>                             |                   |
| Only Visit                                          | 11%               |
| More than 2 Times/week                              | 6%                |
| Every 2 weeks                                       | 28%               |
| Once a month                                        | 39%               |
| Twice in a month                                    | 6%                |
| Once Every Two Months                               | 11%               |

*Table 5.16. Diversified Livelihoods and Work Patterns Among Seaweed Farmers: Characteristics of Income Generating Activities (Author's own elaboration).*

*Organizational support and motivation:* Table 5.17 summarized the drivers and support systems reported by farmers, with 100% of the respondents indicating their intention to continue working as seaweed farmers. The motivations for engaging in seaweed farming were diverse. A significant portion of the farmers, 44%, were motivated by family tradition, while another 44% cited the good market price for raw seaweed as a driving factor. High local and international market demand also played a critical role, motivating 44% of the farmers. Additionally, 39% of the respondents pursued seaweed farming as an alternative livelihood to fishing, and 17% considered it an alternative to tourism. Other factors that motivated the farmers included high returns from value-added products (22%), environmental health (17%), mental and physical health benefits (17%), and the provision of a seed bank for local farmers (6%).

The organizational structure supporting these farmers was also varied. Half of the respondents (50%) were part of associations, while 28% were members of cooperatives. Community-based organizations supported 17% of the farmers, and 6% were entrepreneurs operating independently. Training was a crucial component of their success, with 61% of the farmers receiving cooperative or association grant training. Private training from family and friends was the second most common source of knowledge, cited by 22% of the respondents. Additionally, 17% of the farmers had been trained through E-NGO grants with government support, and 6% learned through trial and error. The use of cultivated seaweed was primarily directed towards direct human food consumption, as reported by 72% of the farmers. Cosmetics represented another significant use at 33%, while 28% of respondents indicated other uses, including research and development or promotion rather than selling.

Respondents showed strong intent to remain in the mariculture sector, reliance on organizational structures, and community- and ecosystem-oriented practices which indicated strong foundations for durable livelihoods provided governance and technical support are strengthened.

Beyond the quantitative summaries of support and motivation, the qualitative surveys also highlighted farmers' voices. These narratives illustrate respondents' optimism for the future of seaweed farming, their reliance on diverse organizational structures, and their approaches to farming. The detailed analysis of these findings provided a comprehensive understanding of the factors driving the seaweed farming industry, as well as the challenges and opportunities faced by the farming communities. Through the lens of optimism and commitment, the surveys illuminated the farmers' belief in the potential of seaweed as a valuable commodity, while also highlighting the importance of robust organizational support and adaptation strategies in ensuring the sustainability of their livelihoods.

*Optimism and commitment driving the seaweed farming industry:* Respondents frequently expressed confidence in seaweed's future market potential and stated intentions to continue farming. There were strong optimism and commitment towards the future of seaweed farming as a key economic activity. Across the responses, there was a consistent belief in the potential of seaweed as a valuable commodity, with one respondent confidently stating, "*Seaweed is one of the most valuable products in Belize. Seaweed will become the richest commodity in the next five years*" (Files 01 BZ). This statement encapsulated the widespread anticipation among farmers that seaweed farming would play a significant role in Belize's economic development.

Furthermore, Table 5.17 revealed respondents responses when they were asked if they have intent to continue working in seaweed farming, of all respondents (100%) said “yes” with no hesitation. This highlights the sector's perceived stability and growth potential. For many farmers, the decision to persist in seaweed farming was not just about economic prospects but also about long-term personal and professional plans. For instance, one farmer mentioned their *"retirement plan to farm seaweed full-time"* (Files 10 BZ), indicating that seaweed farming was viewed as a sustainable livelihood that could support them well into the future.

In addition to this optimism, some farmers highlighted the importance of research and development in advancing the seaweed industry. One respondent mentioned *"research and development in seaweed"* suggesting that ongoing innovation and scientific inquiry were seen as essential for maximizing the industry's potential (Files 03 BZ). This focus on research pointed to a forward-thinking attitude among farmers, who recognized the need for continuous improvement and adaptation to ensure the industry's success.

The uniformity in responses, with nearly every participant affirming their commitment to seaweed farming with a simple "Yes" (Files 02 BZ, 04 BZ, 05 BZ, etc.), indicated a collective confidence in the viability of the industry. This widespread agreement suggested that seaweed farming had garnered strong support within the community, with farmers willing to invest their time and resources into this burgeoning sector.

The findings revealed a community of seaweed farmers in Belize who were not only optimistic about the future of seaweed as a valuable commodity but also deeply committed to the industry's growth and sustainability. The consistent affirmations of intent to continue farming, coupled with a recognition of the importance of research and development, painted a picture of a resilient and forward-looking industry poised for significant expansion in the coming years. The following explains each key finding of the seaweed farming livelihood's characteristics of the SIDS of Belize. Collectively, responses indicated high stated commitment to remain in the sector across participants.

| <b>Sources of Support and Motivation for Seaweed Farmers</b>                                        |                   |
|-----------------------------------------------------------------------------------------------------|-------------------|
| <b>Variable</b>                                                                                     | <b>Percentage</b> |
| <b>Whether will continue to be a seaweed farmer</b>                                                 |                   |
| Yes                                                                                                 | 100%              |
| No                                                                                                  | 0%                |
| <b>Motivation for Seaweed Farming</b>                                                               |                   |
| Family tradition                                                                                    | 44%               |
| Good labor wages                                                                                    | 6%                |
| Alternative livelihood (fishing)                                                                    | 39%               |
| Alternative livelihood (tourism)                                                                    | 17%               |
| Good market price for raw seaweed                                                                   | 44%               |
| High local market demand                                                                            | 44%               |
| High international market demand                                                                    | 44%               |
| High returns from value-added products                                                              | 22%               |
| Environmental health                                                                                | 17%               |
| Mental and physical health                                                                          | 17%               |
| Seed bank provision for local farmers                                                               | 6%                |
| <b>Cluster Structure</b>                                                                            |                   |
| Association                                                                                         | 50%               |
| Cooperative                                                                                         | 28%               |
| Community-based Organization                                                                        | 17%               |
| Entrepreneur                                                                                        | 6%                |
| <b>Training Source</b>                                                                              |                   |
| Cooperative/Association grant training                                                              | 61%               |
| Private training from family/friends                                                                | 22%               |
| E-NGO grant training with government support                                                        | 17%               |
| Trial & error basis (experimental)                                                                  | 6%                |
| <b>Use of Cultivated Seaweed</b>                                                                    |                   |
| Cosmetics                                                                                           | 33%               |
| Direct human food consumption (eg. promoting in local market for its use in shakes, porridges, etc) | 72%               |
| Other (ie. not selling/only R&D or for promotion)                                                   | 28%               |

*Table 5.17. Drivers and Support Systems in Seaweed Farming: A Comprehensive Overview of Farmer Motivation and Resources (Author's own elaboration).*

*Strong organizational structures and support:* The analysis revealed a strong reliance on community-based organizations, associations, and informal communication networks. A significant number of respondents indicated that they were part of community-based organizations, which played a central role in their seaweed farming activities. This pattern suggested that collective action and mutual support were critical components of their approach to seaweed farming.

For instance, in several cases, farmers mentioned being affiliated with community-based organizations, emphasizing the importance of these local groups in providing a support network and facilitating collaboration. One farmer stated simply, "*community-based organization*" highlighting the organizational structure that underpinned their farming activities (Files 01 BZ). This sentiment was echoed by others who also identified community-based organizations as their primary organizational affiliation (Files 04 BZ, 07 BZ, 08 BZ).

In addition to community-based organizations, some farmers operated through informal or unofficial networks, where communication amongst farmers was a key element of their collaborative efforts. These informal structures allowed for flexibility and responsiveness, as farmers could easily share information and resources without the constraints of formal organizational rules. One respondent described this as "*unofficial (with communication amongst farmers)*," illustrating the grassroots nature of their collaboration (Files 02 BZ, 06 BZ).

Moreover, the presence of cooperatives was also noted, particularly in areas where seaweed farming had a more established presence. For example, the Placencia seaweed farmers were described as "*a group of independent producers collaborating with Placencia Coop*" indicating a hybrid model where individual entrepreneurship was combined with cooperative support (Files 03 BZ). This blend of independence and cooperation allowed farmers to benefit from collective bargaining and shared resources while maintaining a degree of autonomy.

A smaller number of farmers identified themselves as operating within entrepreneurial structures, where the focus was more on individual business ventures rather than collective or community-based approaches. These farmers highlighted the entrepreneurial spirit driving some seaweed farming activities, which contrasted with the more commonly reported community-based or cooperative models. For example, one farmer simply noted, "*entrepreneurial*" reflecting a more individualistic approach to seaweed farming (Files 05 BZ, 09 BZ).

Associations also played a role in the organizational landscape, though they were less frequently mentioned compared to community-based organizations and cooperatives. Some farmers indicated their affiliation with associations, which provided a structured framework for collaboration and advocacy but perhaps lacked the grassroots engagement seen in community-based organizations. The dual mention of "*association*" alongside community-based organization by some respondents suggested that these structures often worked in tandem, supporting different aspects of the farmers' operations (Files 08 BZ, 14 BZ).

Overall, the results in livelihood characteristics and practices (RQ1) highlighted the diversity of organizational structures within the seaweed farming community in Belize. While community-based organizations were predominant, providing a strong foundation for collective action and mutual support, other models such as informal networks, cooperatives, and entrepreneurial ventures also played significant roles.

*Use of community-based and ecosystem-based approaches:* The findings showed that seaweed farmers in Belize employed diverse approaches to implementing community-based and ecosystem-based practices in their farming activities. A significant number of farmers reported using mixed approaches that integrated elements of both community-based adaptation and ecosystem-based adaptation, tailored to their specific local conditions.

Many farmers expressed a strong commitment to working in harmony with the environment, reflecting an ecosystem-based adaptation approach. For instance, one farmer emphasized that they practiced "*farming in harmony with the environment and educational awareness of health benefits*" highlighting the dual focus on ecological sustainability and community education (Files 05 BZ). Another farmer noted that they integrated environmental considerations into their farming practices by ensuring that "*fish get to eat and live*" within their seaweed farms, which suggested an intentional effort to maintain the ecological balance and contribute to marine biodiversity (Files 06 BZ).

Some farmers described their adaptation practices as being closely tied to the community. For example, one respondent mentioned the collaborative aspect of their approach, stating that

their seaweed farm received "*support from the cooperative*" highlighting the importance of social capital and community engagement in their operations (Files 06 BZ). Another farmer discussed how they practiced "*sharing information amongst each other and lobby*" reflecting a community-based approach where knowledge exchange and collective advocacy were key components of their strategy (Files 18 BZ).

In contrast, a few farmers admitted to a more trial-and-error approach, which they described as "*learning as you go*". This method, while not formally structured, reflected the adaptive nature of their farming practices as they responded to challenges and opportunities in real-time (Files 07 BZ, 08 BZ, 09 BZ). This approach indicated that while formal knowledge of ecosystem or community-based adaptation might have been limited, farmers still engaged in adaptive practices that contributed to the resilience of their livelihoods.

Despite these efforts, some farmers acknowledged gaps in their practices, with one respondent candidly stating, "*I don't know any of these terms*" reflecting a need for more targeted education and capacity-building initiatives to enhance their understanding and application of these concepts (Files 16 BZ). Another farmer noted the lack of formal monitoring, admitting that ecosystem and community adaptation were "*mentioned but not practiced*" indicating a gap between awareness and implementation (Files 12 BZ).

Overall, while many seaweed farmers in Belize intuitively engaged in practices that aligned with community-based and ecosystem-based adaptation, there was variability in their understanding and application of these approaches. The mixed approaches they employed, whether through formal strategies or learning as they went, reflected on their adaptability to seaweed farming in a changing environment. The narratives highlighted adaptability as a strength but also revealed the need for structured capacity-building to ensure all farmers could benefit from these strategies.

#### *Farmers' Awareness and Perceptions of Climate Change Impact on Community and Seaweed Crops:*

Table 5.18 provided valuable insights into the perceptions of seaweed farmers regarding the impacts of climate change on their farming practices. The data revealed that all respondents were fully aware of climate change, as indicated by the unanimous response of 100% affirming its existence. This consistent awareness across the surveyed population implied that climate change has become a widely recognized issue within the seaweed farming community, likely due to its perceived or observed impacts on their environment and livelihoods.

In addition to their awareness, every respondent also recognized the impact of climate change on their broader community, again with a 100% affirmative response. This uniform perception indicated that climate change was seen as a significant factor affecting the socio-economic and environmental conditions in their region, underscoring the community's collective acknowledgment of its broader implications.

However, respondents revealed varied responses to the perceived impact of climate change on their seaweed crops. Majority of the farmers (61%) reported that they perceived climate change to have a direct effect on their seaweed crops, advising that many farmers had observed changes in crop health, growth, or yield that they attributed to climate-related factors. In contrast, 22% of the respondents did not perceive any impact of climate change on their seaweed crops, indicating a divergence in experiences or observations among the farmers. Additionally, 17% of the respondents were uncertain, stating that they did not know whether climate change had affected their crops.

This variation in responses regarding the impact on seaweed crops pointed to a complex and nuanced understanding of climate change among the farmers. While the general awareness of climate change was uniformly high, the specific recognition of its impacts on seaweed farming varied, possibly due to differences in local environmental conditions, farming practices, or the subtlety of climate impacts that might not be immediately apparent to all farmers.

These findings highlighted the need for further research and education to better understand and address the specific ways in which climate change is impacting seaweed farming. By deepening the understanding of these impacts, farmers could be better equipped to adapt their practices to mitigate potential negative impacts and enhance the strength of their farming operations in the face of a changing climate.

| Variables                                                  | Percentage |
|------------------------------------------------------------|------------|
| <b>Awareness of climate change</b>                         |            |
| Yes                                                        | 100%       |
| No                                                         | 0%         |
| <b>Perceived climate change impact in the community</b>    |            |
| Yes                                                        | 100%       |
| No                                                         |            |
| <b>Perceived climate change impact on the seaweed crop</b> |            |
| No                                                         | 22%        |
| Yes                                                        | 61%        |
| Don't know                                                 | 17%        |
| <b>Perceived Best Farming Depth</b>                        |            |
| Shallow water / shallow intertidal water (3 ft - 5 ft)     | 33%        |
| Deep water (6ft - 8ft)                                     | 6%         |
| Mixed shallow and deep (Midrange with buoys)               | 50%        |
| I haven't noticed or kept track (no farm record)           | 11%        |

*Table 5.18. Seaweed Farmers' Perception of Climate Change and Its Impacts on Communities and Crops (Author's own elaboration).*

*Views on the opportunities (positive) and challenges (negative) in seaweed mariculture livelihoods (RQ2):*

This subsection addresses RQ2: What are the main opportunities and challenges faced by seaweed mariculture in SIDS? The findings were drawn on structured survey prompts, thematic coding, correlation patterns, and farmers' own narratives. Both opportunities and challenges were analyzed in relation to the SLF capitals in shaping the prospects and obstacles within the seaweed farming industry. Opportunities most often reflect strong community practices, economic diversification, and the health benefits of seaweed products. challenges were predominantly rooted in financial constraints, environmental pressures, and the erosion of traditional practices.

Table 5.4 summarizes the survey prompts and response options used to elicit farmers' perspectives on opportunities and challenges. These responses were subsequently examined using reflexive thematic analysis (Table 5.21 and Table 5.22), Pearson's correlation patterns among coded responses (Table 5.20), and word frequency outputs (Figure 5.7 and Figure 5.8). Farmers' direct quotes are included to illustrate key themes.



| Category      | Question Content                                                                                                                                                                                                                         | Response Options                                                                                                                                                                                                                                                                             |
|---------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Opportunities | Q53. What was your main reason for venturing into producing this seaweed commodity?                                                                                                                                                      | <ul style="list-style-type: none"> <li>- Family tradition</li> <li>- Good labor wages</li> <li>- Alternative livelihood (fishing/tourism)</li> <li>- Good market price</li> <li>- High local/international demand</li> <li>- High returns from value-added products</li> </ul>               |
|               | Q57. What do you think your seaweed is used for when you supply the market?                                                                                                                                                              | <ul style="list-style-type: none"> <li>- Cosmetics</li> <li>- Direct human food consumption</li> <li>- Pharmaceutical/nutraceuticals</li> <li>- Bioenergy/fuel</li> <li>- Bio-liquid fertilizer/composting</li> <li>- Seaweed biotechnology</li> <li>- Livestock food supplements</li> </ul> |
|               | Q58. If you have ventured into making seaweed value-added products, what were your reasons when you started?                                                                                                                             | <ul style="list-style-type: none"> <li>- Low barriers to enter market</li> <li>- Profitable (high revenue)</li> <li>- Environmentally-friendly</li> <li>- Attractive for tourism</li> <li>- Health and Wellness</li> </ul>                                                                   |
|               | Q59. What value-added products do you make from the following seaweed species?                                                                                                                                                           | Respondents specify the products they create from various seaweed species                                                                                                                                                                                                                    |
| Challenges    | Q60. What are the challenges you are facing in expanding your seaweed business?                                                                                                                                                          | <ul style="list-style-type: none"> <li>- Finance</li> <li>- A consistent market</li> <li>- Infrastructure for processing seaweed</li> <li>- Limited access to resources</li> </ul>                                                                                                           |
|               | Q92. In regard to the sustainable growth of your seaweed business, which dimensions of sustainability (economy, market, society, government, policy and laws, and environment) concern you the most? Rank from highest to least concern. | Respondents rank their concerns related to different sustainability dimensions from highest to lowest.                                                                                                                                                                                       |

*Table 5.19. Key Opportunities and Challenges in Seaweed Farming: Community-level Perspectives in Survey Question Prompts and Response Options (Author's own elaboration).*

This qualitative analysis combines Pearson correlation coefficients, word-frequency outputs, and in-depth open responses. Correlation strength categories (low, moderate, high) follow the definitions specified in Section 4.5 (Cohen, 1988), and statistical results are reported consistently as  $r$  or  $rs$  with exact  $p$ -values (e.g.,  $r = 0.41$ ,  $p = 0.028$ ). The results showed significant relationships among respondents, with high correlations in the same community, particularly in regions like Placencia and Riversdale Village (see Figure 5.1 to view location proximities of study sites in the case study of Belize). The following correlations were observed:

Moderate correlations were observed across various communities, indicating shared influences but also notable differences. Word frequency analysis highlighted key themes such

as governance, specific seaweed species, environmental conditions, and socio-economic factors. The survey also revealed a diverse demographic profile among farmers, with varying ages, genders, ethnicities, and educational backgrounds. Opportunities include economic diversification, market demand, and health benefits of seaweed products, while challenges include high operational costs, lack of technical support, environmental pressures, and erosion of traditional practices.

The analysis of the Pearson correlation coefficients among the seaweed farmers, who were anonymized with respondent numbers and a country code (BZ) for confidentiality, provided valuable insights into the patterns within the data. The correlations between pairs of respondents across different communities revealed significant relationships that help understand the similarities and differences in seaweed farming practices across various regions in Belize. The following sections further elaborate on the key findings of the Pearson correlation and word frequencies analysis based on the qualitative aspects of the survey.

| Correlation Strength                         | Number of Respondent Pairs | Key Observations                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------------------------------------------|----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| High Correlations ( $r > 0.7$ )              | 34 pairs                   | <ul style="list-style-type: none"> <li>- Strong correlations were predominantly found among respondents from Placencia and Independence.</li> <li>- The highest correlation (<math>r = 0.988</math>) was between Respondent 15 (Belize City) and Respondent 17 (Belize City), indicating a strong similarity in responses from these urban seaweed farmers.</li> <li>- Significant cross-community correlations were also observed between respondents from Placencia and Independence, suggesting shared practices or environmental conditions across these communities.</li> </ul> |
| Moderate Correlations ( $0.3 < r \leq 0.7$ ) | 66 pairs                   | <ul style="list-style-type: none"> <li>- Moderate correlations were observed both within and across communities, including Placencia, Independence, Riversdale, and Belize City.</li> <li>- Respondents from Riversdale showed moderate correlations with those from other communities, reflecting moderate similarities in farming practices or environmental conditions.</li> </ul>                                                                                                                                                                                                |
| Low Correlations ( $r \leq 0.3$ )            | 64 pairs                   | <ul style="list-style-type: none"> <li>- Low correlations were largely observed among respondents from different communities, particularly between Belize City and other areas like Placencia and Riversdale.</li> <li>- The lowest correlation was between Respondent 03 (Independence) and Respondent 10 (Independence), with <math>r = 0.935935</math>, indicating minimal commonality in their responses, even within the same community.</li> </ul>                                                                                                                             |

*Table 5.20. Summary of the Pearson Correlation Coefficients Among Seaweed Farmers by Communities in the case study country, Belize (Author's own elaboration).*

**Correlations:** High correlations were most prominent among respondents from the same community, particularly within Placencia and Independence. This implied a high degree of correlation in seaweed farming practices, environmental conditions, or socio-economic factors within these regions. Moderate correlations, which were observed across various



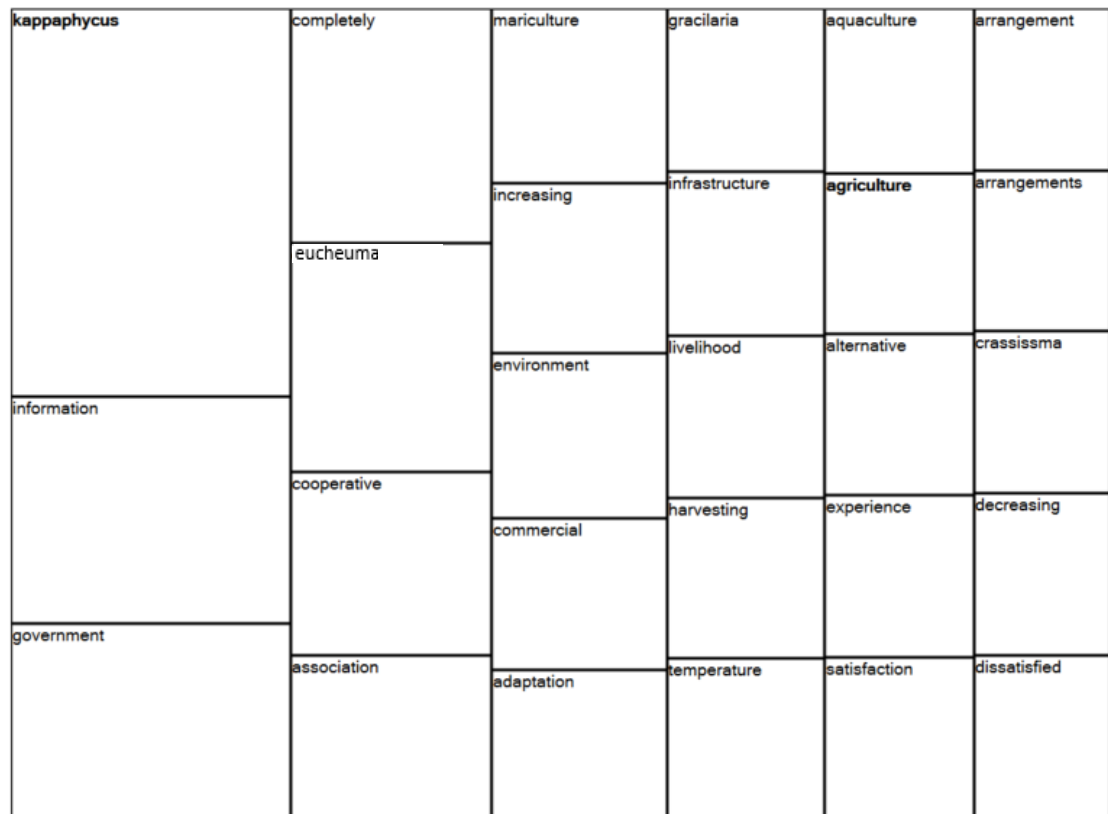


Figure 5.8. Tree map visualization depicted the frequency of key terms extracted from the analyzed dataset (Author's own elaboration).

Figure 5.8 shows the most prominent terms in the tree map were "*Kappaphycus*," "government," "information," and "cooperative," indicating that these topics were central in the discussions and texts analyzed. These terms suggested a strong focus on specific seaweed species (*Kappaphycus* sp.), governance structures, the dissemination of information, and cooperative frameworks within the seaweed mariculture context.

Additional significant terms included "*Eucheuma* sp.," "environment," "commercial," and "temperature," which further pointed to the importance of environmental conditions, commercial aspects, and the specific species involved in seaweed farming. These words were represented by medium-sized rectangles, indicating their substantial but slightly lesser frequency compared to the most prominent terms. The visualization also featured numerous smaller rectangles representing less frequent but still relevant terms such as "satisfaction," "aquaculture," "infrastructure," "harvesting," and "livelihood." These words reflected broader socio-economic concerns, the technical aspects of aquaculture, and the practical elements of seaweed farming, including infrastructure and community impacts. Overall, the tree map provided a comprehensive visual summary of the major themes and topics that were prevalent in the dataset, with a clear emphasis on governance, specific seaweed species, environmental factors, and the economic dimensions of seaweed mariculture. This visualization effectively highlighted the multifaceted nature of the discussions, illustrating the various elements that contributed to the sustainability and growth of seaweed farming livelihoods.

*Reflexive Thematic Analysis by SLF:* The reflexive thematic analysis of the qualitative surveys identified both opportunities (Table 5.21) and challenges (Table 5.22) in seaweed mariculture livelihoods, categorized according to the SLF. This approach provided a nuanced

understanding of how human, social, natural, physical, financial, and cultural capitals shaped both the potential and the obstacles facing farmers in Belize.

| <b>Capitals</b>               | <b>Main Theme</b>                                            | <b>Files<br/>[Survey<br/>Transcripts]</b> | <b>Codes</b> | <b>Correlation<br/>Strength</b> |
|-------------------------------|--------------------------------------------------------------|-------------------------------------------|--------------|---------------------------------|
| Human and Social Capital      | Seaweed farming as a family tradition and community practice | 12                                        | 38           | High                            |
| Human and Financial Capital   | Economic diversification and alternative livelihoods         | 14                                        | 46           | High                            |
| Natural and Financial Capital | High returns from value-added products                       | 13                                        | 40           | High                            |
| Human and Natural Capital     | Health and wellness benefits of seaweed products             | 11                                        | 30           | Moderate                        |
| Cultural and Social Capital   | Preservation of cultural practices through seaweed farming   | 8                                         | 22           | Moderate                        |
| Social and Financial Capital  | Strong market demand and profitability                       | 10                                        | 35           | High                            |

*Table 5.21. Prevalence of Main Themes Identified in Qualitative Survey on Seaweed Farming Opportunities (Author's own elaboration).*

*Opportunities analysis:* The qualitative surveys revealed opportunities in seaweed farming which were illustrated according to the SLF capitals. Further information is outlined below according to the capitals with high correlations.

**Human and Social Capital:** Seaweed farming was widely described as both a family tradition and a community practice. Farmers reported that the activity strengthened local bonds and sustained intergenerational knowledge transfer, thereby reinforcing community resilience.

**Human and Financial Capital:** Farmers consistently highlighted seaweed farming as an important means of economic diversification. It provided an alternative to fishing and tourism, generating supplementary income streams that reduced dependence on single livelihood activities.

**Natural and Financial Capital:** Several farmers emphasized the potential of value-added products (e.g., drinks, gels, and cosmetics) to deliver high returns. These activities increased profitability and connected seaweed farming to expanding domestic and international markets.

Human and Natural Capital: Seaweed products were associated with health and wellness benefits, including nutritional value and medicinal uses. These qualities added to the cultural and market appeal of seaweed-based goods.

Cultural and Social Capital: Seaweed farming was also described as preserving cultural practices, particularly in coastal villages where it was tied to identity and traditional knowledge systems.

Social and Financial Capital: Farmers noted strong local and international market demand for seaweed and its by-products. This demand was seen as a critical driver of future profitability and industry growth.

Overall, the opportunities revealed in the analysis illustrated how seaweed farming could contribute simultaneously to economic diversification, cultural preservation, and community resilience.

| Capitals                     | Main Theme                                              | Files [Survey Transcripts] | Codes | Correlation Strength |
|------------------------------|---------------------------------------------------------|----------------------------|-------|----------------------|
| Human and Social Capital     | Lack of technical knowledge and support                 | 6                          | 18    | High                 |
| Human and Financial Capital  | High operational costs and limited financial access     | 7                          | 22    | High                 |
| Natural and Physical Capital | Environmental challenges and infrastructure limitations | 8                          | 26    | High                 |
| Cultural and Social Capital  | Traditional practices due to modern pressures           | 4                          | 10    | Moderate             |
| Social and Financial Capital | Ineffective policy support and financial barriers       | 6                          | 21    | High                 |

*Table 5.22. Prevalence of Main Themes Identified in Qualitative Survey on Seaweed Farming Challenges (Author's own elaboration).*

*Challenges analysis:* Table 5.22 shows the analysis of challenges in seaweed farming, categorized according to the SLF, revealed several critical obstacles that stakeholders have encountered. These challenges reflected the complexities of maintaining and expanding seaweed farming as a sustainable livelihood.

Human and Social Capital: A significant challenge identified was the lack of technical knowledge and support, which was consistently highlighted in 6 qualitative surveys with 18 codes, demonstrating a high correlation strength. The findings suggested that many seaweed farmers struggled with insufficient training and access to technical expertise, which hampered their ability to optimize farming practices and respond effectively to emerging issues, such as disease outbreaks or environmental changes. This gap in knowledge and support posed a considerable barrier to the sustainable development of seaweed farming, as farmers were often left to navigate complex challenges without adequate guidance.

Human and Financial Capital: The high operational costs and limited access to financial resources were also prominent challenges, as evidenced by 22 codes across 7 qualitative surveys, indicating a high correlation strength. Respondents noted that the costs associated with seaweed farming, such as purchasing equipment, maintaining infrastructure, and

covering transportation, were prohibitively high for many small-scale farmers. Additionally, limited access to credit and financial services exacerbated these difficulties, making it challenging for farmers to invest in their operations or expand their farms. This financial strain threatened the viability of seaweed farming as a sustainable livelihood, particularly for those without sufficient capital to absorb these costs.

**Natural and Physical Capital:** Environmental challenges and infrastructure limitations were frequently mentioned, with 26 codes in 8 qualitative surveys reflecting a high correlation strength. Farmers reported various environmental issues, such as the impact of climate change, seasonal variability, and the presence of invasive species, which negatively affected seaweed growth and farm productivity. In addition, the physical infrastructure needed to support seaweed farming, such as ropes, nets, and boats, were reported damaged after a severe climatic-related issue. However, these infrastructures were often inadequate or deteriorated quickly due to harsh marine conditions when necessary. These combined factors created a difficult operating environment, where maintaining and expanding seaweed farms required significant effort and resources that were not always available.

**Cultural and Social Capital:** The erosion of traditional practices due to modern pressures was another challenge, though with moderate correlation strength, as was mentioned in 4 qualitative surveys with 10 codes. The findings indicated that the pressures of commercialization and the need to adapt to modern market demands were leading to the gradual loss of traditional seaweed farming practices. This erosion of cultural practices not only threatened the cultural heritage of the communities involved but also undermined the social cohesion that had historically supported seaweed farming as a communal activity. The shift towards more modern, profit-driven approaches was seen as potentially detrimental to the long-term sustainability of the practice, as it could lead to the abandonment of time-tested methods that had ensured the resilience of seaweed farming over generations.

**Social and Financial Capital:** Ineffective policy support and financial barriers were highlighted as significant challenges in 6 qualitative surveys, with 21 codes indicating a high correlation strength. The data revealed widespread frustration among seaweed farmers regarding the lack of effective governmental support and the bureaucratic hurdles associated with accessing financial assistance. Many respondents cited the difficulty of navigating complex regulatory frameworks, obtaining necessary permits, and securing funding as major impediments to their operations. These barriers not only limited the growth potential of seaweed farming but also discouraged new entrants from joining the industry, thereby stifling innovation and expansion within the sector.

In summary, challenges were substantial and multifaceted, spanning technical, financial, environmental, and governance-related barriers. Addressing these constraints would require coordinated interventions that improved training and technical support, reduced financial obstacles, enhanced infrastructure, and safeguarded cultural practices.

#### *Perceptions of Blue Economy and Recommendations (RQ4):*

This subsection addressed RQ4 (existing responses, practices, and strategies) by reporting farmers' perceptions of the blue economy and their recommendations for improving enabling conditions. Findings were mixed: some respondents perceived opportunities for inclusive growth and conservation, while many expressed skepticisms about governance, regulation, and implementation capacity. These results were consistent with the literature calling for inclusive, transparent, and community-anchored policy design (e.g., Geggs & Wells, 2019; Bhuyan et al., 2021).

*Awareness of seaweed farming legislation:* Farmers reported uneven awareness of laws or regulations governing the seaweed mariculture sector. Several affirmed that some regulations existed (“Yes”; Files 01 BZ, 03 BZ, 04 BZ, 05 BZ, 06 BZ). However, a more substantial number of farmers expressed uncertainty or outright denial of the existence of such regulations (“*There are none*”; “*There is none as yet*”; Files 07 BZ, 08 BZ) or were uncertain (“*I don’t know*”; Files 12 BZ, 14 BZ), with multiple explicit “No” responses (Files 09 BZ, 11 BZ, 13 BZ, 15 BZ, 16 BZ, 17 BZ, 18 BZ). This ambiguity suggested a governance gap, limited visibility, communication, or consolidation of rules, which likely constrained compliance, investment, and scaling. The recurring mention of the lack of regulations or uncertainty about their existence points to a critical gap in the governance and guidance of the seaweed farming sector. This ambiguity in regulatory presence likely contributes to the broader challenges faced by the seaweed farming community in Belize, including issues related to compliance, growth, and sustainability. Addressing this regulatory gap could be a crucial step toward establishing a more structured and supportive environment for seaweed farmers.

*Perceived Blue Economy Definitions:* The perceptions of blue economy varied, reflecting both optimism and skepticism. Some farmers saw potential benefits, associating the blue economy with economic growth and empowerment, particularly for specific groups such as female entrepreneurs. One farmer commented, “*Good job with female entrepreneurs... [there's a] strong economy in ocean farming*” (Files 01 BZ). Another articulated a more comprehensive understanding, stating that the blue economy is “the use of our aquatic resources, mainly the sea, for economic development, social upliftment, but in an environmentally sustainable manner” (Files 03 BZ).

However, many farmers expressed skepticism and concern. For some, the blue economy was seen as yet another instance of government speculation. As one farmer noted, it was “*another government speculation... politically driven*” (Files 02 BZ, 07 BZ). Another echoed this sentiment, describing it as a “government structure to come with policies, rules, and regulations to chain down locals leading to poor room for growth” (Files 05 BZ). This perspective was further reinforced by another farmer who observed that “Blue Economy is not serving its purpose or creating livelihood with fisher’s folks and tourism” (Files 10 BZ).

Several respondents highlighted the lack of clarity and perceived disconnect between the blue economy's intentions and its impact on local communities. One farmer candidly admitted, “*Don’t understand what is the purpose... Bank loan/paying interest... Give out sea space, give up rights to the ocean for a period of time*” (Files 12 BZ). Another expressed frustration with the new regulations, stating that the blue economy was “only thinking about themselves” (Files 08 BZ).

On the other hand, a few farmers recognized the potential for environmental benefits, particularly in terms of conservation. One farmer suggested that the blue economy could “benefit marine creatures” and support “*community-based adaptation to new livelihoods/alternatives through hardship*” (Files 14 BZ). Another saw it as a “fair exchange between government and civil community to manage the ocean health and resources” (Files 17 BZ).

In summary, while some seaweed farmers viewed the blue economy as an opportunity for sustainable development and empowerment, many were skeptical, viewing it as a government-driven initiative that lacked transparency and adequate community involvement. The diverse perspectives highlight the need for greater engagement with local communities to ensure that the blue economy meets their needs and contributes to both economic and environmental sustainability.



*Feedback of Past Blue Economy Interventions:* The feedback gathered from respondents in Belize painted a picture of varied experiences within the current seaweed farming landscape. Many farmers voiced their dissatisfaction and pointed out specific challenges that hindered their progress.

A significant source of frustration stemmed from the perceived lack of support and slow progress in the sector. As one farmer noted, they had been "*promised outreach for the past six years, but only recently has there been renewed interest in the sector*" (Files 01 BZ). Another farmer expressed discontent with the Belize Blue Economy Programme, stating, "We haven't benefited at all from any blue economy programme. The Belize Blue Economy Ministry, in partnership with TNC, dictates how the entire blue economy works, leaving us without any tangible benefits. The Fisheries Administrator allows us to continue because they know we aren't harming the environment" (Files 03 BZ).

Challenges related to permits and regulatory processes were also highlighted. One farmer mentioned the difficulties in navigating the permit process, saying, "*Supporting individual farms... Make permits easier to understand as the current requirements are too complicated for individual farms to qualify*" (Files 05 BZ).

The feedback further revealed a lack of support and resources available to farmers. One respondent starkly stated, "Nothing is in place for seaweed farms" (Files 06 BZ). Another emphasized the lack of engagement and support, noting that, despite efforts such as exchange programs with Jamaica and Colombia and attempts to gain social media exposure, they "received no support" (Files 10 BZ).

Minimal or no engagement was a recurring theme among several farmers, with many simply responding "None" when asked about their experiences with support or engagement from relevant authorities or organizations (Files 02 BZ, 07 BZ, 11 BZ, 15 BZ, 16 BZ, 17 BZ, 18 BZ).

Overall, these accounts underscored the frustrations and unmet needs of seaweed farmers in Belize, particularly in areas of support, regulatory complexities, and engagement from key stakeholders.

*Farmer-Reported Recommendations:* The feedback from respondents in Belize revealed several critical recommendations aimed at improving the seaweed farming landscape within the blue economy framework. These recommendations reflected the farmers' experiences and concerns, emphasizing the need for better support, clearer regulations, and more effective community engagement.

One of the primary concerns was the complexity and costliness of the licensing process, especially for pharmaceutical applications. Farmers highlighted the need for financial assistance to cover the high expenses associated with obtaining these licenses, with one farmer noting, "We need help with the pharmaceutical license: it's expensive, over \$1,000.00 BZD" (Files 01 BZ). This underscores the financial burden that regulatory compliance imposes on small-scale seaweed farmers.

Farmers also expressed a desire for a comprehensive study of all seaweed varieties in Belize, coupled with increased involvement of local fishermen in the decision-making processes. One recommendation was to "allow fishermen to patrol with boats" and involve them in governance by placing them "on boards of directors" (Files 02 BZ). This reflects a broader concern for empowering local stakeholders in the management of marine resources.

The lack of engagement with grassroots communities was another significant issue. Farmers voiced frustration with the Belize Fisheries Department, noting that "years have passed, and we haven't had a proper meeting... because TNC [The Nature Conservancy] threw money at projects without engaging us" (Files 03 BZ). They called for stronger partnerships between grassroots organizations, the government, and international entities like the ProBlue and International Climate Initiative (IKI) grants, seeing these as untapped opportunities to meet local needs and strengthen community resilience.

To make seaweed farming more accessible, farmers recommended simplifying the permit application process and providing material support for farm construction and value-added production. They also proposed integrating seaweed into school food programs, with one farmer suggesting that "*seaweed should be a key ingredient in school meals*" to boost local consumption and market demand (Files 05 BZ).

The concerns about the implementation of the blue economy were prevalent, with some farmers expressing skepticism about its benefits. As one farmer described it as "another government speculation... [that is] politically driven" (Files 02 BZ), while another criticized the initiative for creating "*rules and regulations to chain down locals*" and leaving "*poor room for growth*" (Files 05 BZ). This highlighted the strong call for cross-government cooperation to address environmental challenges and protect local waters from illegal activities by foreign entities, in order to deliver a more integrated and cooperative approach in improving seaweed farms productivity (Files 08 BZ, 09 BZ).

Financial support was a recurring theme, with farmers emphasizing the need for loans, grants, and better access to financial resources. One farmer pointed out the necessity for "*finance loans*" and support for accessing funds like the Blue Bond, noting that "lack of organizational support" was a significant barrier (Files 11 BZ, 13 BZ). They also stressed the importance of capacity building, calling for training programs that would help them navigate regulatory requirements and improve their farming practices.

Finally, farmers emphasized the need for better access to market information, investment opportunities, and technical support. One recommendation was to "*make information more readily available for market penetration opportunities*" and to provide briefings on regulations and investment prospects in the seaweed industry (Files 15 BZ). This reflects a broader need for transparency and support in helping farmers understand and access the opportunities available within the blue economy framework.

The following recommendations, reinforced by direct quotes from farmers, depict vividly the obstacles that they confront and the assistance they require. Tackling these issues could substantially strengthen the seaweed farming industry's resilience and sustainability in Belize, making the blue economy a more efficient means for fostering sustainable livelihoods and economic growth in coastal regions. The recommendations provided by seaweed farmers in Belize reflect a comprehensive understanding of the various capitals within the Sustainable Livelihoods Framework. Implementing these recommendations could lead to more robust livelihoods for seaweed farmers, contributing to the overall well-being and economic stability of their communities.

### 5.2.3 Summary of focus group discussions and qualitative surveys at community-level

This subsection addressed RQ5: To what extent, if at all, are the policy measures in place in the SIDS of Belize capable of tackling climate and non-climatic hazards in relation to seaweed farming? The qualitative survey findings indicated that existing policy measures were perceived as fragmented, inconsistently applied, and often insufficient to address the complex

range of hazards confronting farmers. These implications can be interpreted through the lens of the SLF, which highlights how institutional support shapes different forms of capital.

*Human Capital:* The study reveals that the skills, knowledge, and health of individuals involved in seaweed farming are fundamental to the industry's success. Training programs and capacity-building initiatives have empowered local communities, enhancing their ability to adopt resilient farming practices. For instance, the adoption of resilient seaweed species like *Eucheuma* and *Kappaphycus*, which thrive under conditions of increased ocean temperature and acidity, reflects the community's capacity to adapt to environmental changes (Ndobe et al., 2020). However, farmers reported limited access to formal training or extension services that could help them respond to hazards such as warming seas and *ice-ice* seaweed disease (often referred to die-offs). One respondent explained, “*We need training on how to manage when the water gets too hot; right now, we just guess and hope the seaweed survives*” (File 06 BZ). Policy interventions had not established systematic capacity-building programs, leaving farmers dependent on informal knowledge-sharing and experience.

*Social Capital:* The formation of cooperatives and associations, such as the Placencia Producers Cooperative Society Limited (PPCSL) and Belize Women Seaweed Farmers Association (BWSFA) in Belize, has been crucial in addressing market volatility, regulatory barriers, and socio-economic inequalities. These organizations in collaboration with E-NGOs and regulatory entities have enhanced collective bargaining power, improved market access, and provide critical training and capacity-building opportunities, which were recorded as being essential for sustaining the industry in the face of external hazards (Hossain et al., 2021). However, respondents consistently emphasized the lack of engagement by government agencies and weak consultation processes. As one farmer noted, “*We don't hear from the government until it is time for rules and regulations, not when we need real support*” (File 11 BZ). Cooperative groups provided some solidarity, but farmers perceived state-led Blue Economy initiatives as disconnected from their realities and overly top-down in nature.

*Financial Capital:* Institutional financial support was viewed as extremely limited. Farmers described high costs for permits, lack of access to affordable loans, and the complete absence of insurance schemes. One farmer complained, “*The license for pharmaceuticals is more than a thousand dollars. Small farmers can't pay that, so we stay out of the market*” (File 01 BZ). Another explained, “*We hear about Blue Bond and climate finance, but none of it reaches us*” (File 13 BZ). Without accessible credit or financial inclusion, policy frameworks did little to reduce vulnerability or enable investment in adaptive strategies. Other seaweed producing countries have developed financial models to support long-term ecological sustainability while aligned with community needs was crucial for the industry's resilience (Jagtap et al., 2022; Geggs and Wells, 2019).

*Physical Capital:* The physical infrastructure required for seaweed farming, included access to suitable farming locations and necessary equipment, were vital for the industry's sustainability. The study found that improvements in farming techniques, such as the adoption of floating/submerged rope lines and submerged tubular nets, has enabled communities to maintain productivity despite environmental pressures. These physical assets were essential for ensuring that seaweed farming can continue to thrive in the face of climatic challenges. However, seaweed farmers repeatedly identified damage to farms and infrastructure during storms as a major hazard. Yet no government schemes existed to provide insurance or recovery support. As one farmer observed, “*When a storm destroys the ropes and the poles, we are on our own to rebuild. There is no policy for helping us get back on our feet*” (File 07 BZ). The lack of investment in shared infrastructure, such as processing plants and drying racks, further constrained adaptation.

*Natural Capital:* The natural environment, including the marine ecosystems where seaweed was cultivated, were both a resource and a beneficiary of sustainable mariculture practices. The integration of traditional ecological knowledge with scientific innovations has allowed communities to manage these natural resources sustainably. However, farmers highlighted the susceptibility of *Gracilaria crassissima* and *Eucheuma isiforme* to disease and heat stress. *Kappaphycus alvarezii* was reported as the most cultivated strain due to its robustness, higher growth rate and adaptability properties to environmental conditions. They expressed frustration that no institutional research programs were addressing strained resilience. A farmer commented, “*When the ice-ice comes, nobody helps us. We just lose the crop and start over*” (File 03 BZ). The absence of targeted policies to safeguard species and ecosystem health left farmers highly exposed to climate-related risks. Other seaweed farming countries like Tanzania have already adopted resilient seaweed species and improved farming techniques which has allowed farmers to maintain productivity despite increasing climate pressures (Rubekie et al., 2022).

*Cultural Capital:* Cultural capital played a crucial role in both the adaptation to and the mitigation of climatic and non-climatic challenges. The traditional knowledge of local communities, included indigenous methods of farming, ecological management, and resource use, formed the foundation upon which modern seaweed farming practices were built on. This integration of traditional knowledge with contemporary scientific innovations has been pivotal in developing adaptive management practices that are responsive to environmental changes. Moreover, cultural practices related to seaweed use, such as its incorporation into local diets, traditional medicine, and ceremonial practices, helped to maintain and strengthen the cultural identity of these communities. The preservation of cultural practices and the transmission of this knowledge to younger generations ensured that seaweed mariculture continued to thrive as a sustainable livelihood option, even in the face of external pressures such as climate change (Radulovich et al., 2015). However, farmers also worried about the erosion of traditional practices in the absence of institutional recognition. One respondent remarked, “*Our grandparents taught us seaweed farming, but the government does not respect that knowledge. They only look at foreign experts*” (File 08 BZ). The lack of policy support for intergenerational knowledge transfer and community-based practices threatened both cultural identity and long-term resilience.

Overall, the qualitative survey findings at a community-level suggested that the policy measures in Belize were perceived by seaweed farmers as limited in their ability to address climatic and non-climatic hazards. Farmers recognized the risks they faced, but they did not view institutional frameworks such as providing the training, financial services, infrastructure, or cultural recognition necessary to reduce their vulnerability. The perceived disconnect between policy intent and on-the-ground realities undermined trust and constrained farmers’ capacity to adapt. As one farmer summarized, “*We want to make seaweed stronger for the future, but without real government support, it feels like we are left alone to fight the climate*” (File 12 BZ).

#### 5.2.4 Elite interviews

*Overview:* A total of six (6) participants were conducted with policymakers and institutional representatives from Belize and the wider Caribbean. These individuals were purposively selected because of their expertise in policy, governance, and regional fisheries management relevant to seaweed farming and climate change adaptation. The participants were from four of Belize’s government offices (Government of Belize Blue Bond and Finance Permanence (BBFP) Unit, Government of Belize Economic Development Council, Ministry of Blue Economy, Belize Fisheries Department, and Belize Fund for a Sustainable Future) and one

regional partner Caribbean Regional Fisheries Mechanism (CRFM). Table 5.23 below shows the demographic information and institutional affiliation of the interviewees in this study:

| <b>Respondents</b> | <b>Age</b> | <b>Gender</b> | <b>Institutional Affiliation</b> |
|--------------------|------------|---------------|----------------------------------|
| 1                  | 25 - 34    | Female        | Government                       |
| 2                  | 45 - 54    | Male          | Government                       |
| 3                  | 45 - 54    | Female        | Regional Partner                 |
| 4                  | 45 - 54    | Female        | Non-profit Partner               |
| 5                  | 35 - 44    | Male          | International E-NGO Partner      |
| 6                  | 35 - 44    | Male          | Government                       |

*Table 5.23. Elite interviews demographic information and institutional affiliation of the interviewees in this study (Author's own elaboration).*

#### *Elite Interview Findings:*

Thematic analysis by PESTEL: PESTEL framework (Political, Economic, Social, Technological, Environmental and Legal) was used to code and analyze providing a structured lens on the enabling and constraining environment for seaweed farming in Belize.

Four broad, data-driven clusters dominated the discussions and map directly onto PESTEL dimensions: (i) regulatory and policy frameworks (Legal/Political), (ii) ecosystem-based and innovative approaches (Environmental/Technological), (iii) socio-economic and community-based approaches (Social), and (iv) financial and investment mechanisms (Economic). Summary of elite interview transcription can be found in Appendix F section 9.6.2. Table 5.24 shows the prevalence and importance of the themes covered during the elite interviews.

| <b>Main Theme</b>                                                            | <b>Files [Transcripts]</b> | <b>Codes</b> | <b>Correlation strengthens</b> |
|------------------------------------------------------------------------------|----------------------------|--------------|--------------------------------|
| Regulatory and policy frameworks                                             | 6                          | 317          | High                           |
| Ecosystem-based and innovative approaches                                    | 6                          | 227          | High                           |
| Socio-economic and community-based approaches (including cultural practices) | 6                          | 171          | Moderate                       |
| Financial and investment mechanisms (including cultural practices)           | 6                          | 67           | Low                            |

*Table 5.24. Prevalence of main themes identified in elite interviews (Author's own elaboration).*

Note on prevalence of language. “High/Moderate/Low” refers to relative coded reference counts across themes in NVivo. Exact thresholds are reported in Appendix F section 9.6.2 (coding protocol), and prevalence should be interpreted comparatively within this dataset rather than as population parameters.

*Key significance:* The main themes identified in elite interviews, focusing on regulatory and policy frameworks, ecosystem-based and innovative approaches, socio-economic and community-based approaches, and financial and investment mechanisms. The high prevalence of regulatory and policy frameworks was attributed to their critical importance in

the governance and operational aspects of seaweed farming. These frameworks included discussions on legal frameworks, compliance issues, and policy development.

Ecosystem-based and innovative approaches were also discussed, emphasizing the integration of sustainable practices and innovation in seaweed farming. Topics such as biodiversity protection, climate adaptation, and advanced cultivation methods were prominent, indicating the importance of these approaches for the long-term viability and ecological balance of seaweed farming.

Socio-economic and community-based approaches, including cultural practices, were moderately discussed, highlighting the role of socio-economic factors and community involvement in seaweed farming. This included community engagement, cultural perceptions, livelihood challenges, and social equity. The integration of cultural practices suggested an awareness of the need to respect and incorporate local traditions and community dynamics in the development of seaweed farming initiatives.

Financial and investment mechanisms were less frequently discussed, suggesting that they were not the primary focus of the interviews. This theme included traditional financial considerations, funding and investment strategies, and the influence of cultural practices on financial decisions. The lower prevalence suggested that financial mechanisms might have been a challenging area within seaweed farming, potentially reflecting difficulties in securing investment or the need for more robust financial strategies that align with both economic and cultural contexts.

*Reflexive thematic analysis by Research Questions:*

To link thematic evidence to the study's research questions, Table 5.25 presents various themes identified in the elite interviews along with the number of files (interviews) and references (instances where the theme was mentioned) around issue-focused themes that cut across PESTEL. Table 5.25 shows the categories (e.g., "enabling environment" spans Legal/Political/Economic; "investment barriers" spans Economic/Legal).

| Main Theme                                               | Files<br>[Transcripts] | Codes | Correlation<br>strengthens |
|----------------------------------------------------------|------------------------|-------|----------------------------|
| Characteristics of Seaweed Farming in Belize             | 6                      | 118   | Moderate                   |
| Support in Enabling a Seaweed Farming Environment        | 6                      | 160   | High                       |
| Factors Limiting Investments in Seaweed Farming          | 6                      | 311   | High                       |
| Adaptation Strategies in Emerging Business Opportunities | 6                      | 82    | Low                        |
| Adaptation Opportunities Prioritized in Seaweed Farming  | 6                      | 111   | Moderate                   |
| Total                                                    |                        | 782   |                            |

*Table 5.25. Main thematic coding across six elite interviews indicating the prevalence and focus areas discussed according to transcription files uploaded in NVivo software (Author's own elaboration).*

*Key significance:* Table 5.25 revealed that the high reference themes were found in the category under 'Factors Limiting Investments in Seaweed Farming'. This theme has the highest number of references (311), indicating that it is a major concern or area of discussion among the respondents. This indicates that the various barriers to investment are significant and widely acknowledged. Another high reference theme identified was the theme 'Support in Enabling a Seaweed Farming Environment'. With 160 references, this theme also stands out, highlighting the importance of creating a supportive environment for seaweed farming. This includes discussions on policy, infrastructure, and community support.

Moderate reference themes include awareness of the characteristics of seaweed farming in Belize and priorities to scale-up. The theme, 'Characteristics of Seaweed Farming in Belize' theme has 118 references, reflecting a focus on the specific attributes, challenges, and opportunities of seaweed farming within the Belize context. This encompasses local species cultivated, farming techniques, and regional market conditions. The other moderate reference was to the theme 'Adaptation Opportunities Prioritized in Seaweed Farming'. With 111 references, this theme indicates discussions around key adaptation strategies to improve or expand seaweed farming practices. This involves technological innovations, new business opportunities and models, and environmental adjustments.

In low reference themes, only one theme was identified as the least referenced in the in the discussions was 'Adaptation Strategies in Emerging Business Opportunities'. This theme has 82 references, suggesting it is less prominent compared to others but still relevant. It points to how seaweed farming can integrate with and benefit from new and emerging business opportunities.

In summary, the thematic analysis across the six elite interviews reveals significant insights into the priorities and challenges in the seaweed farming sector. Themes with higher reference counts like "Factors Limiting Investments in Seaweed Farming" and "Support in Enabling a Seaweed Farming Environment" indicate major areas of concern and interest among stakeholders. Understanding these themes is key to providing scientific evidence to guide policymaking, investment decisions, and strategic planning to support the growth and sustainability of seaweed farming.

*Correlation analysis (code co-occurrence):*

The correlation analysis of co-occurrence patterns among thematic codes using Pearson correlation coefficients on code frequency vectors (Table 5.26). The correlations measured the strength and direction of the relationships between key themes, such as regulatory and policy frameworks, socio-economic and community-based approaches, ecosystem-based and innovative approaches, and financial and investment mechanisms. This is an exploratory descriptive statistic to indicate which themes tended to be discussed together of which correlations were categorized as high, moderate, or low, indicating varying degrees of association between the themes discussed.

| A                                             | B                                             | Pearson Correlation Coefficient | Correlation Strength |
|-----------------------------------------------|-----------------------------------------------|---------------------------------|----------------------|
| Regulatory and policy frameworks              | Socio-economic and community-based approaches | 0.851                           | High                 |
| Regulatory and policy frameworks              | Ecosystem-based and innovative approaches     | 0.780                           | Moderate             |
| Ecosystem-based and innovative approaches     | Socio-economic and community-based approaches | 0.735                           | Moderate             |
| Regulatory and policy frameworks              | Financial and investment mechanisms           | 0.721                           | Moderate             |
| Socio-economic and community-based approaches | Financial and investment mechanisms           | 0.721                           | Moderate             |
| Ecosystem-based and innovative approaches     | Financial and investment mechanisms           | 0.537                           | Low                  |

*Table 5.26. Correlation analysis of theoretical themes from elite interviews (Author's own elaboration).*

*Key correlation significance:* Table 5.26 revealed the analysis of the Pearson correlation coefficients between various theoretical codes from the elite interviews revealed several key relationships. The strongest correlation was found between Regulatory and policy frameworks and Socio-economic and community-based approaches, with a coefficient of 0.851. This indicated a high degree of association between discussions on regulatory frameworks and community-based approaches, implying that these themes were closely interlinked in the interviews.

Moderate correlations were observed between Regulatory and policy frameworks and Ecosystem-based and innovative approaches (0.780), as well as between Ecosystem-based and innovative approaches and Socio-economic and community-based approaches (0.735). These findings suggested that while these themes were related, their connection was less strong compared to the relationship between regulatory frameworks and community-based approaches.

Additionally, the relationships between Regulatory and policy frameworks and Financial and investment mechanisms (0.721), as well as between Socio-economic and community-based approaches and Financial and investment mechanisms (0.721), were also moderately strong. This indicated that financial mechanisms were moderately associated with both regulatory and community-based discussions, though not as strongly as other pairs of themes.

The weakest correlation was between Ecosystem-based and innovative approaches and Financial and investment mechanisms, with a coefficient of 0.537. This lower correlation suggested that while there was some relationship between these themes, they were not as



pronounced, indicating that discussions of financial mechanisms were somewhat independent of ecosystem-based and innovative approaches in the context of these interviews.

*Correlations by thematic similarity amongst interviewees:*

Table 5.27 shows the Pearson correlation coefficients between these pairs of files, indicating the level of similarity in the themes or topics discussed by the respondents in their respective interviews. File "A" and "B" represent pairs of interview transcriptions from the elite interviews conducted. Each file corresponds to a specific respondent from the elite interview series. Therefore, the results indicate varying degrees of thematic similarity between different pairs of interviewees, highlighting both commonalities and divergences in their perspectives on seaweed farming and related issues.

| <b>A</b>     | <b>B</b>     | <b>Pearson correlation coefficient</b> | <b>Correlations strength</b> |
|--------------|--------------|----------------------------------------|------------------------------|
| Respondent 3 | Respondent 5 | 0.872                                  | High                         |
| Respondent 3 | Respondent 4 | 0.866                                  | High                         |
| Respondent 3 | Respondent 1 | 0.849                                  | High                         |
| Respondent 5 | Respondent 4 | 0.842                                  | High                         |
| Respondent 1 | Respondent 5 | 0.839                                  | High                         |
| Respondent 1 | Respondent 4 | 0.794                                  | Moderate                     |
| Respondent 2 | Respondent 1 | 0.778                                  | Moderate                     |
| Respondent 2 | Respondent 5 | 0.757                                  | Moderate                     |
| Respondent 3 | Respondent 2 | 0.755                                  | Moderate                     |
| Respondent 2 | Respondent 4 | 0.692                                  | Moderate                     |
| Respondent 4 | Respondent 6 | 0.232                                  | Low                          |
| Respondent 5 | Respondent 6 | 0.227                                  | Low                          |
| Respondent 3 | Respondent 6 | 0.225                                  | Low                          |
| Respondent 2 | Respondent 6 | 0.191                                  | Low                          |
| Respondent 1 | Respondent 6 | 0.142                                  | Low                          |

*Table 5.27. Pairwise Similarity (Pearson correlation coefficient) interviewees' code profiles (Author's own elaboration).*

*Key correlation significance:* The Pearson correlation coefficients between pairs of elite interview respondents in Table 5.27, indicating the degree of similarity in the themes discussed during their interviews. The findings reveal several key insights into the thematic overlap and divergence among the respondents.

The highest Pearson correlation coefficient (0.872) is observed between Respondent 3 (Deputy Executive Director, Regional Partner) and Respondent 5 (Senior Officer, International E-NGO Partner). This suggests a substantial overlap in the themes or topics discussed by these two respondents, reflecting their roles in similar or related fields and their shared perspectives on issues related to seaweed farming. Other notable high correlations include; (i) Respondent 3 (Deputy Executive Director, Regional Partner) and Respondent 4 (Executive Director, Non-profit Partner) with a coefficient of 0.866, Respondent 3 (Deputy Executive Director, Regional Partner) and Respondent 1 (Director, Government) with a coefficient of 0.849, Respondent 5 (Senior Officer, International E-NGO Partner) and Respondent 4 (Executive Director, Non-profit Partner) with a coefficient of 0.842, and Respondent 1 (Director, Government) and Respondent 5 (Senior Officer, International E-NGO Partner) with a coefficient of 0.839. These high correlations indicate that these pairs of respondents shared similar views or extensively discussed similar topics, potentially due to their positions and experiences within their respective organizations.

Moderate correlations are observed between several pairs, indicating a moderate level of thematic similarity; Respondent 1 (Director, Government) and Respondent 4 (Executive Director, Non-profit Partner) with a coefficient of 0.794, Respondent 2 (Senior Officer, Government) and Respondent 1 (Director, Government) with a coefficient of 0.778, Respondent 2 (Senior Officer, Government) and Respondent 5 (Senior Officer, International E-NGO Partner) with a coefficient of 0.757, Respondent 3 (Deputy Executive Director, Regional Partner) and Respondent 2 (Senior Officer, Government) with a coefficient of 0.755, and Respondent 2 (Senior Officer, Government) and Respondent 4 (Executive Director, Non-profit Partner) with a coefficient of 0.692. These moderate correlations indicate that while there is some overlap in the themes discussed, these respondents also brought unique perspectives to the interviews.

Conversely, the lowest Pearson correlation coefficient (0.142) is observed between Respondent 1 (Director, Government) and Respondent 6 (Executive Director, Government), indicating significant differences in the themes or topics discussed by these two respondents. This may be attributed to their distinct roles or perspectives within the government sector.

Other low correlations include; Respondent 2 (Senior Officer, Government) and Respondent 6 (Executive Director, Government) with a coefficient of 0.191, Respondent 3 (Deputy Executive Director, Regional Partner) and Respondent 6 (Executive Director, Government) with a coefficient of 0.225, Respondent 5 (Senior Officer, International E-NGO Partner) and Respondent 6 (Executive Director, Government) with a coefficient of 0.227, Respondent 4 (Executive Director, Non-profit Partner) and Respondent 6 (Executive Director, Government) with a coefficient of 0.232. These lower correlations indicate that these pairs of respondents had less overlap in the themes or topics they discussed, possibly due to differences in their institutional affiliations, responsibilities, or personal viewpoints.

The results indicated varying degrees of thematic similarity between different pairs of respondents, highlighting both commonalities and divergences in their perspectives on seaweed farming and related issues. High correlations suggest shared views and extensive discussion of similar topics, while low correlations point to distinct perspectives and thematic divergence. These insights are valuable for understanding the range of opinions and experiences among key stakeholders in the field.

*Thematic Synthesis by PESTEL:*

Key Characteristics of Seaweed Mariculture: Drawing on the six elite interviews, this subsection synthesizes how stakeholders characterize the current status and prospects of seaweed mariculture in Belize. Analysis was organized using the PESTEL framework to foreground the enabling and constraining environment shaping sector performance.

| Capitals      | Key Characteristics                                                                                                                                                                                                                          |
|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Political     | High-level support under the Blue Economy agenda; need for cross-ministerial coordination; risk of short political cycles and shifting priorities; importance of embedding farmers' expertise in policy processes.                           |
| Economic      | Investment constraints (limited affordable finance, donor dependency), uneven access to working capital, infrastructure and logistics gaps, price volatility and niche market dependence; need for targeted incentives and export readiness. |
| Social        | Community participation critical for legitimacy; gender equity and inclusion gaps; producer organization capacity varies; importance of trust, transparency, and sustained stakeholder engagement.                                           |
| Technological | Uneven adoption of improved cultivation systems; training and extension capacity gaps; quality assurance and post-harvest handling need strengthening; demand for coordinated R&D and knowledge transfer.                                    |
| Environmental | Rising sea temperatures, seasonal hydrodynamics, disease (e.g., “ice-ice”), and sargassum influx as salient risks; potential ecosystem services of seaweed (water quality, habitat); emphasis on smart siting and environmental screening.   |
| Legal         | Centrality of clear licensing, tenure, compliance, and enforcement; fragmentation across agencies; need for mariculture-specific provisions to provide investor and farmer certainty.                                                        |

*Table 5.28. Overview of the key characteristics of seaweed farming by PESTEL Dimension (Author's own elaboration).*

*Narrative synthesis:* Table 5.28 revealed that stakeholders consistently linked sector performance to policy and regulatory clarity (Legal/Political), investment readiness and market access (Economic), and capability to adopt and diffuse improved technologies (Technological). Social and Environmental dimensions framed equity, legitimacy, and ecological resilience as necessary conditions for credible scaling.

*Climatic and Non-climatic Hazards and Responses:*

Interviewees distinguished climatic stressors that directly affect biophysical production from non-climatic stressors rooted in institutions, markets, technology, and operations. Both sets of factors shape risk profiles and feasible responses. The categorization of themes into climatic and non-climatic factors helped to differentiate between those directly related to environmental and climate conditions and those influenced by social, economic, cultural, policy, and operational considerations. Climate change issues, such as dry season challenges, increased sea temperature, ‘ice-ice’ seaweed disease, sedimentation and filtering functions of mangroves, and the capacity of seaweed to absorb excessive nutrients, are considered climatic factors.

Non-climatic factors include policy and governance, such as aligning national programs with Blue Economy policies, legislative framework status and policy development, regulation compliance and competence capacity, and regulatory compliance and licensing issues. These

factors can also impact the implementation and governance of blue economy initiatives, such as cluster formations funding benefits and challenges, stakeholder management and transparency, and the power of financial resources.

Economic and financial factors include financial sustainability issues, working capital availability constraints, alternative income sources and fisheries management strategies, accessibility for women, business management and engagement strategies, the Belize Blue Economy Approach, market viability, pricing issues, and recommendations in blue economy development. Foreign investors influence factors, and viable livelihood challenges arise from Micro, Small and Medium Enterprises (MSME) development and Sustainable Development Goals (SDGs)-oriented climate action opportunities.

Social and cultural factors include cultural perceptions and accountability, awareness of seaweed disease and climate adaptation, personal empowerment and professional identity, family support, advisory and partnership dynamics, partnership and collaboration opportunities, reluctance in cluster formation, community-based ecosystem cultivation approaches by marine E-NGOs, non-legal business practices, training and endorsement, research and development limitations, limitations in insurance schemes and risks management, and limitations in stakeholder consultation in regulation framework formulation.

Operational factors include selective harvesting techniques, seaweed production reporting challenges, pre-harvest cleaning techniques, proximity to shore, aquaculture operator's license provision, and harvested seaweed yield. Seaweed farming is a key action in international commitments, and it provides a habitat and nursery.

Enforcement of regulations, installation of physical barriers, traditional ways and transition challenges, theft and security measures, removal of mangroves, dry season challenges, smart siting and environmental considerations, export regulation and compliance, regulatory compliance and licensing issues, scaling up operations, and viable livelihood challenges are all important considerations in seaweed farming and related Blue Economy activities.

Table 5.29 below categorizes and characterizes the climatic factors in the seaweed farming industry, including their rationale and significance ranked by order of perceived severity.

| <b>Climate-related Factor</b>                   | <b>Rationale</b>                                                                                                                                                                                                                             |
|-------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Climate Change Issue (overarching driver)    | Climate change is a broad, overarching factor that influences many other climatic conditions. Addressing climate change is critical to ensuring the long-term viability of seaweed farming.                                                  |
| 2. Increase Sea Temperature                     | Rising sea temperatures can directly affect seaweed growth, species resilience, and overall farm productivity. This factor is closely tied to climate change and requires immediate attention.                                               |
| 3. <i>Ice-ice</i> seaweed disease Issue         | The " <i>ice-ice</i> " issue, which involves seaweed disease linked to environmental stress, particularly temperature fluctuations, is a significant concern for seaweed farmers. It directly impacts the health and yield of seaweed crops. |
| 4. Sargassum Influx Delay Crop Cycle Activities | The influx of Sargassum can disrupt seaweed farming cycles, leading to delays and reduced productivity. This factor needs to be managed effectively to prevent large-scale disruptions.                                                      |

|                                                                             |                                                                                                                                                                                                                                     |
|-----------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 5. Sedimentation and Filtering Function of Mangroves                        | Mangroves play a crucial role in filtering sediments and maintaining water quality, which are vital for healthy seaweed growth. Protecting and restoring mangroves can help mitigate some of the negative impacts of sedimentation. |
| 6. Dry Season Challenge with Temperature, Water Flow, and Nutrient Exchange | Seasonal changes, particularly during the dry season, can create challenging conditions for seaweed farming. Ensuring proper water flow and nutrient exchange is essential to maintain productivity during these periods.           |
| 7. Seaweed Varietal Resilience                                              | Developing and promoting resilient seaweed varieties can help mitigate the impacts of climatic changes. This factor is key to sustaining seaweed farming under varying environmental conditions.                                    |
| 8. Seaweed Absorb Excessive Nutrients                                       | Seaweed's ability to absorb excess nutrients helps improve water quality, which is crucial for maintaining a balanced marine ecosystem. This function can also mitigate the impacts of nutrient pollution.                          |
| 9. Expanding Biodiversity Protection Zones to Cover 20.5% of Ocean Space    | Expanding biodiversity protection zones helps safeguard critical habitats and supports overall marine ecosystem health, which in turn benefits seaweed farming.                                                                     |
| 10. Provisional Ecosystem Services of Shade and Cool Waters by Mangroves    | Mangroves provide shade and help cool water temperatures, which can be beneficial for seaweed farming, especially in areas prone to higher temperatures.                                                                            |
| 11. Seaweed Capacity in Ecological Resilience                               | Enhancing the ecological resilience of seaweed can help farms withstand environmental stressors, making this a priority for long-term sustainability.                                                                               |
| 12. Seaweed Improve Water Quality                                           | Seaweed's ability to improve water quality by absorbing nutrients and filtering the water is important for the overall health of the marine environment, which indirectly supports seaweed farming.                                 |
| 13. Seaweed as an Indicator for Monitoring Environmental Impacts            | Using seaweed as an indicator species for monitoring environmental changes is important for early detection of negative impacts and for informing adaptive management strategies.                                                   |
| 14. Smart Siting and Environmental Considerations                           | Proper siting of seaweed farms considering environmental factors is crucial to minimizing negative impacts and optimizing conditions for growth.                                                                                    |
| 15. Carbon-Offsetting                                                       | While important, carbon-offsetting is a longer-term strategy that can complement other more immediate measures to address climate-related challenges.                                                                               |
| 16. Carbon-Sequestering                                                     | Similar to carbon-offsetting, carbon-sequestering is a valuable long-term strategy for mitigating climate change but may not have immediate benefits for seaweed farming.                                                           |
| 17. Habitat Preservation Considerations During Harvest                      | While habitat preservation is essential, it is more of a best practice to be integrated into routine operations rather than an immediate priority compared to other climatic factors.                                               |

*Table 5.29. The climatic factors according to their significance and the rationale behind their prioritization in the sustainability of seaweed farming operations (Author's own elaboration).*

Table 5.30 below organizes the non-climatic factors characterizing the seaweed farming industry, prioritized based on their importance and urgency, along with the rationale for each ranked by order of perceived severity.

| <b>Non-Climatic Factor</b>                             | <b>Rationale</b>                                                                                                                                                                                                                                                                               |
|--------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Legislative Framework Status and Policy Development | Establishing and refining legislative frameworks is crucial for providing a stable and supportive regulatory environment for seaweed farming. Effective policy development is essential for ensuring compliance, promoting sustainable practices, and facilitating growth within the industry. |
| 2. Regulatory Compliance and Licensing Issue           | Ensuring that seaweed farming operations comply with regulations and have the necessary licenses is fundamental to the legitimacy and sustainability of the industry. Addressing these issues can prevent legal challenges and foster industry growth.                                         |
| 3. Stakeholder Management and Transparency Challenges  | Effective stakeholder management and transparency are key to building trust and collaboration among all parties involved in seaweed farming. Addressing these challenges can improve governance, facilitate cooperation, and enhance the overall success of projects.                          |
| 4. Financial Sustainability Issue                      | Financial sustainability is critical for the long-term viability of seaweed farming operations. Prioritizing financial stability ensures that farms can continue to operate, expand, and invest in necessary resources and technologies.                                                       |
| 5. Market Viability                                    | Ensuring market viability is essential for the economic success of seaweed farming. This includes access to markets, fair pricing, and the ability to compete with other producers. A viable market ensures that seaweed products can be sold at profitable rates, driving industry growth.    |
| 6. Business Management and Engagement Strategy         | Strong business management and engagement strategies are necessary for the effective operation of seaweed farms. This includes everything from day-to-day operations to long-term planning and stakeholder engagement.                                                                         |
| 7. Export Regulation and Compliance                    | Compliance with export regulations is vital for accessing international markets. Addressing these issues ensures that seaweed products meet the required standards and can be successfully exported, expanding the industry's market reach.                                                    |
| 8. Access to Working Capital                           | Working capital is necessary for the daily operations of seaweed farms, including paying for labor, materials, and other immediate expenses. Ensuring access to working capital helps maintain smooth operations and enables growth.                                                           |
| 9. Legal and Policy Framework Development Issues       | Addressing legal and policy framework issues is crucial for creating an enabling environment for seaweed farming. This includes clarifying regulations, simplifying procedures, and ensuring that policies support sustainable practices.                                                      |
| 10. Blue Business Innovation Funding Opportunities     | Innovation funding opportunities are important for developing new technologies, practices, and business models in seaweed farming. Prioritizing these opportunities can drive industry innovation and sustainability.                                                                          |
| 11. Pricing Issues                                     | Addressing pricing issues is essential for ensuring that seaweed farmers receive fair compensation for their products. This includes tackling market distortions and ensuring that pricing reflects the true value of the product.                                                             |
| 12. Stakeholder Consultation and Authority Dynamics    | Effective consultation with stakeholders and managing authority dynamics are important for ensuring that decisions reflect the interests of all parties involved. This can lead to more effective and equitable outcomes in seaweed farming projects.                                          |

|                                                                    |                                                                                                                                                                                                                                                                                        |
|--------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13. Viable Livelihood Challenges                                   | Ensuring that seaweed farming provides viable livelihoods for those involved is crucial for the social sustainability of the industry. Addressing these challenges can help retain and attract labor, fostering long-term growth.                                                      |
| 14. Accessibility for Women                                        | Ensuring that women have equal access to opportunities in seaweed farming is important for gender equity and social inclusion. This factor contributes to a more diverse and resilient workforce.                                                                                      |
| 15. Knowledge Transfer and International Collaboration Opportunity | Facilitating knowledge transfer and international collaboration can enhance the technical and operational capabilities of seaweed farmers. Prioritizing this factor helps bring in best practices and innovations from around the world.                                               |
| 16. Research Permit Compliance and Capacity Assessment             | Compliance with research permits and capacity assessments ensures that seaweed farming operations are conducted responsibly and sustainably. Addressing these factors is essential for maintaining environmental and legal standards.                                                  |
| 17. Cluster Formations Funding Benefits and Challenges             | Funding and managing cluster formations can create economies of scale and enhance collaboration among seaweed farmers. Addressing the challenges associated with these clusters can improve efficiency and market competitiveness.                                                     |
| 18. Striving for Quality and Standards                             | Maintaining high quality and standards is crucial for ensuring the competitiveness of seaweed products in both domestic and international markets. This factor helps build a reputation for excellence and supports market access.                                                     |
| 19. Limitations in Human Capacity in R&D                           | Addressing limitations in human capacity for research and development is essential for driving innovation and improving practices in seaweed farming. Building capacity ensures that the industry can continue to evolve and meet future challenges.                                   |
| 20. Cultural Perceptions and Accountability                        | Understanding and addressing cultural perceptions and accountability issues is important for ensuring that seaweed farming practices are socially acceptable and aligned with local values. This factor is crucial for community buy-in and long-term sustainability.                  |
| 21. Operational Challenges                                         | Addressing various operational challenges, such as selective harvesting techniques, pre-harvest cleaning, and proximity to shore, is necessary for optimizing efficiency and productivity in seaweed farming. These factors ensure that daily operations run smoothly and sustainably. |
| 22. Legislative Framework Status and Policy Development            | This factor is placed lower in the non-climatic category because while it is essential, its impact is more long-term compared to immediate operational or financial challenges.                                                                                                        |
| 23. Economic Viability Characteristics                             | Addressing economic viability characteristics is crucial for the sustainability of seaweed farming operations. This includes ensuring that farms are financially sound and able to sustain themselves over time.                                                                       |

*Table 5.30. The non-climatic factors were based on their prioritization in ensuring sustainability of the seaweed farming sector (Author's own elaboration).*

#### *Challenges and Opportunities in Seaweed Mariculture Livelihoods by PESTEL:*

Synthesis and Links to the Research Questions: Analyzed through the PESTEL lens, interviewees described a tightly coupled problem structure in which legal/political clarity, economic viability, technological capability, social participation, and Environmental risk

collectively shape prospects for seaweed mariculture in Belize. Addressing constraints and leveraging opportunities therefore requires an integrated approach that combines legislative reform and policy implementation, targeted financing and market development, capability-building for technological adoption, community engagement and equity measures, and robust environmental safeguards.

**Constraint profile:** Respondents highlighted complex and fragmented regulatory frameworks (licensing, compliance, tenure) and inconsistent enforcement (Legal/Political). Climate-related stressors (warming waters, seasonal hydrodynamics, disease, sargassum) and local environmental pressures were recurrent (Environmental). Financing gaps, price volatility, export conformity costs, and infrastructure deficits constrained scale and investment readiness (Economic). Social barriers included uneven organizational capacity, participation quality, and gendered access to assets (Social). Finally, limited extension/research and development (R&D), uneven adoption of improved systems, and operational bottlenecks (reporting, post-harvest handling) were noted (Technological/Operational).

**Opportunity space:** Interviewees identified credible pathways: mariculture-specific legislative instruments and clearer tenure (Legal/Political); blended finance, concessional credit, and incentive mechanisms (Economic); coordinated R&D and knowledge transfer to diffuse improved cultivation and processing systems (Technological); structured stakeholder engagement with attention to gender equity and producer-group development (Social); and smart siting with environmental screening to manage exposure and safeguard ecosystems (Environmental).

Table 5.31 provides a summary of elite interview thematic areas identified and categorized by the opportunities and challenges in Belize's seaweed mariculture livelihoods.

| <b>Thematic Area</b>                                                         | <b>Opportunities</b>                                                                                                                                                                                                                | <b>Challenges</b>                                                                                                                                                                                                                                             |
|------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Legal/ Political<br>(Regulatory and Policy Frameworks)                       | <ul style="list-style-type: none"> <li>- Supportive regulatory frameworks (streamlined regulations, clearer tenure rights)</li> <li>- Recommendations in Blue Economy development</li> <li>- Enhanced government support</li> </ul> | <ul style="list-style-type: none"> <li>- Complex and inconsistent regulations</li> <li>- High costs of compliance</li> <li>- Land and sea tenure issues (unclear/insecure tenure rights)</li> </ul>                                                           |
| Environmental / Technological<br>(Ecosystem-based and Innovative Approaches) | <ul style="list-style-type: none"> <li>- Carbon sequestration and ecosystem services</li> <li>- Climate adaptation strategies</li> <li>- Smart siting and environmental considerations</li> </ul>                                   | <ul style="list-style-type: none"> <li>- Impact of climate change (e.g., rising sea temperatures, "Ice Ice" seaweed disease syndrome)</li> <li>- Seasonal variability and environmental stressors</li> <li>- Marine pollution and invasive species</li> </ul> |
| Social (Socio-economic and Community-based Approaches)                       | <ul style="list-style-type: none"> <li>- Empowerment and gender equity</li> <li>- Cultural heritage and community engagement</li> <li>- Personal empowerment and professional identity</li> </ul>                                   | <ul style="list-style-type: none"> <li>- Gender inequality (limited access to resources, training, decision-making)</li> <li>- Community conflicts and competition</li> <li>- Stakeholder management and transparency challenges</li> </ul>                   |
| Economics (Financial and Investment Mechanisms)                              | <ul style="list-style-type: none"> <li>- Market diversification and value addition</li> <li>- Innovative financial solutions (microcredit,</li> </ul>                                                                               | <ul style="list-style-type: none"> <li>- Market viability and access issues (fluctuating prices, competition)</li> <li>- Limited access to finance</li> </ul>                                                                                                 |



|                                                                 |                                                                                                                                                                 |                                                                                                               |
|-----------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
|                                                                 | insurance, mobile banking)<br>- Blue business innovation funding                                                                                                | and investment<br>- Lack of financial incentives and subsidies                                                |
| Technological / Operational (Operational and Technical Aspects) | - Adoption of new technologies (automated harvesting, improved farming systems)<br>- Collaborative innovation (knowledge transfer, international collaboration) | - Skill gaps and training needs<br>- Disease and pest management (e.g., "Ice Ice" syndrome, invasive species) |

*Table 5.31. Summary of the key opportunities and challenges identified in the elite interviews across the different thematic areas, identified as factors impacting seaweed mariculture livelihoods (Author's own elaboration).*

**Key findings:** The findings in Table 5.31 from the elite interviews revealed a complex landscape of challenges and opportunities in seaweed farming. While regulation, economic viability, and environmental challenges posed significant barriers, there were also substantial opportunities to create a more enabling environment through dedicated legislation, stakeholder collaboration, and sustainable practices. In Belize, the diversity of resources and the strategic management of species and infrastructure were critical to the success of seaweed farming. Prioritizing adaptation opportunities, such as financing, marine spatial planning, and knowledge sharing, was identified as essential for building resilience in the sector. Additionally, integrating conservation efforts with business management and sustainability strategies offered a promising pathway for the future of seaweed mariculture.

**Research questions:** To make the contribution of the elite interviews to the study's research questions explicit, the coded were grouped into five cross-cutting themes that aggregate relevant PESTEL categories. The table below provides a summary of the challenges and opportunities that emerged from the elite interview discussion in the context of characterization of the seaweed farming industry in response to the research questions.

| Main Theme                                               | Key Subthemes                                                           |
|----------------------------------------------------------|-------------------------------------------------------------------------|
| Factors limiting investments in seaweed farming          | Regulation limitations, viable livelihood challenges, export issues     |
| Support in enabling a seaweed farming environment        | Dedicated legislation, Stakeholder collaboration, Sustainable practices |
| Characteristics of seaweed farming in Belize             | Resource diversity, Species management, infrastructure                  |
| Adaptation opportunities prioritized in seaweed farming  | Adaptation financing, marine spatial planning, knowledge sharing        |
| Adaptation strategies in emerging business opportunities | Conservation integration, business management, sustainability           |

*Table 5.32. Summary of the main themes and their key subthemes (Author's own elaboration).*

**Key findings:** Table 5.32 summarizes the key themes and subthemes revealed in the elite interviews that highlighted the common challenges and opportunities identified at a policy level. Elite interviewees reported that the industry faces significant barriers, including

regulatory limitations, a lack of expertise, and delayed reporting, all of which limit investments. These challenges contributed to issues such as theft, limited financial support, and export difficulties. Some participants shared that in order to address these challenges, there is a need for dedicated legislation for this industry, such as advancing the Blue Economy, improving Fisheries Resource Management, and enhancing stakeholder collaboration. These points are further elaborated below:

**Factors Limiting Investments in Seaweed Farming:** The interviewees highlighted several critical barriers that restricted investment in seaweed farming, including complex and inconsistent regulatory frameworks, viable livelihood challenges, and export issues. Regulation limitations, such as burdensome administrative requirements, unclear tenure rights, and high compliance costs, discouraged both local and foreign investments. Additionally, the uncertainty surrounding the economic viability of seaweed farming, driven by fluctuating market prices and competition, further limited investment. Export issues, including barriers to accessing international markets and the additional costs associated with compliance, also reduced the attractiveness of the sector to investors.

**Support in Enabling a Seaweed Farming Environment:** The findings pointed to the need for more focused and supportive legislation, stakeholder collaboration, and the adoption of sustainable practices to create a more conducive environment for seaweed farming. Dedicated legislation was identified as crucial, with a focus on streamlining regulatory processes, securing tenure rights, and promoting sustainable practices. Effective stakeholder collaboration among government agencies, E-NGOs, local communities, and investors was deemed essential for resource sharing and integrated support. The promotion of sustainable farming practices, including environmentally sound techniques and conservation efforts, was seen as vital for long-term success.

**Characteristics of Seaweed Farming in Belize:** The interviewees described specific characteristics of seaweed farming in Belize, focusing on resource diversity, species management, and infrastructure. Belize's marine environment offered a variety of seaweed species and habitats that could be leveraged for different products and applications. Effective species management, including the cultivation of native and non-invasive species, was critical to avoiding negative impacts on local ecosystems. The importance of infrastructure was also highlighted, encompassing both physical facilities and support systems necessary for maintaining quality and sustainability.

**Adaptation Opportunities Prioritized in Seaweed Farming:** The interviewees emphasized the prioritization of adaptation opportunities, such as adaptation financing, marine spatial planning, and knowledge sharing, to enhance the resilience of seaweed farming in the face of climate change. Securing financing for adaptation was identified as crucial for infrastructure improvements, developing resilient farming techniques, and adopting innovative practices to mitigate environmental risks. Marine spatial planning was identified as key to optimizing marine resource use and protecting critical habitats. Knowledge sharing, through training programs and awareness campaigns, was essential for building farmers' capacity to adapt to changing conditions.

**Adaptation Strategies in Emerging Business Opportunities:** The findings also revealed strategies for integrating adaptation measures into emerging business opportunities within the seaweed farming sector. Conservation integration, business management, and sustainability were highlighted as key strategies. Integrating conservation efforts with farming practices presented significant opportunities to enhance both environmental and economic outcomes. Effective business management strategies were crucial for capitalizing on these opportunities, including developing strong management practices, financial planning, and innovation in

product development. Sustainability was a central theme, with a focus on long-term environmental stewardship, traceability, and certification to ensure the industry's growth and viability.

These themes synthesize how institutional actors perceive constraints and levers relevant to the study's questions on the conditions under which seaweed mariculture can provide sustainable livelihoods in SIDS and how the enabling environment might be strengthened.

### 5.2.5 Policy analysis

*Scope and Inventory:* The policy analysis identified legislative and policy frameworks relevant to seaweed mariculture in Belize and addressed the question of the extent to which policy measures were tackling climatic and non-climatic hazards affecting seaweed farming. The objective was to identify, through the PESTEL tool, the provisions and gaps that could affect sectoral sustainability. The inventory demonstrated that relevant instruments were distributed across all six PESTEL factors: Political, Economic, Social, Technological, Environmental, and Legal. This inventory is comprised of the following three types of documents: Binding Frameworks (laws, regulations and statutory instruments;  $n = 41$ ), International Agreements that shape domestic policy ( $n = 4$ ), and Non-Binding Frameworks (policies/strategies/plans;  $n = 21$ ). Figure 5.9. presents the distribution of documents (binding, international agreements and non-binding) relevant to the seaweed mariculture industry in Belize captured in the PESTEL policy analysis.

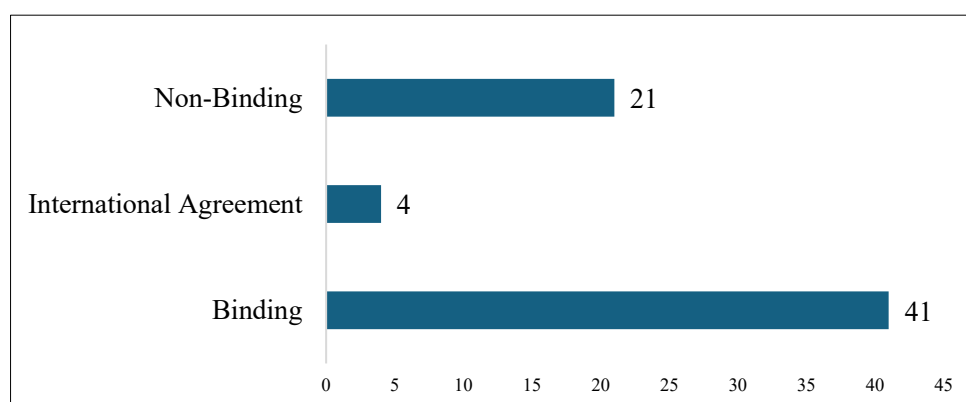


*Figure 5.9. Distribution of Legislative and Policy Frameworks Relevant to the Seaweed Mariculture Industry in Belize (change chart to bar chart) (Author's own elaboration).*

Figure 5.10. presents the full inventory of documents captured in the PESTEL policy analysis while lists these documents by PESTEL category (further elaborated in Appendix G Table 9.89).

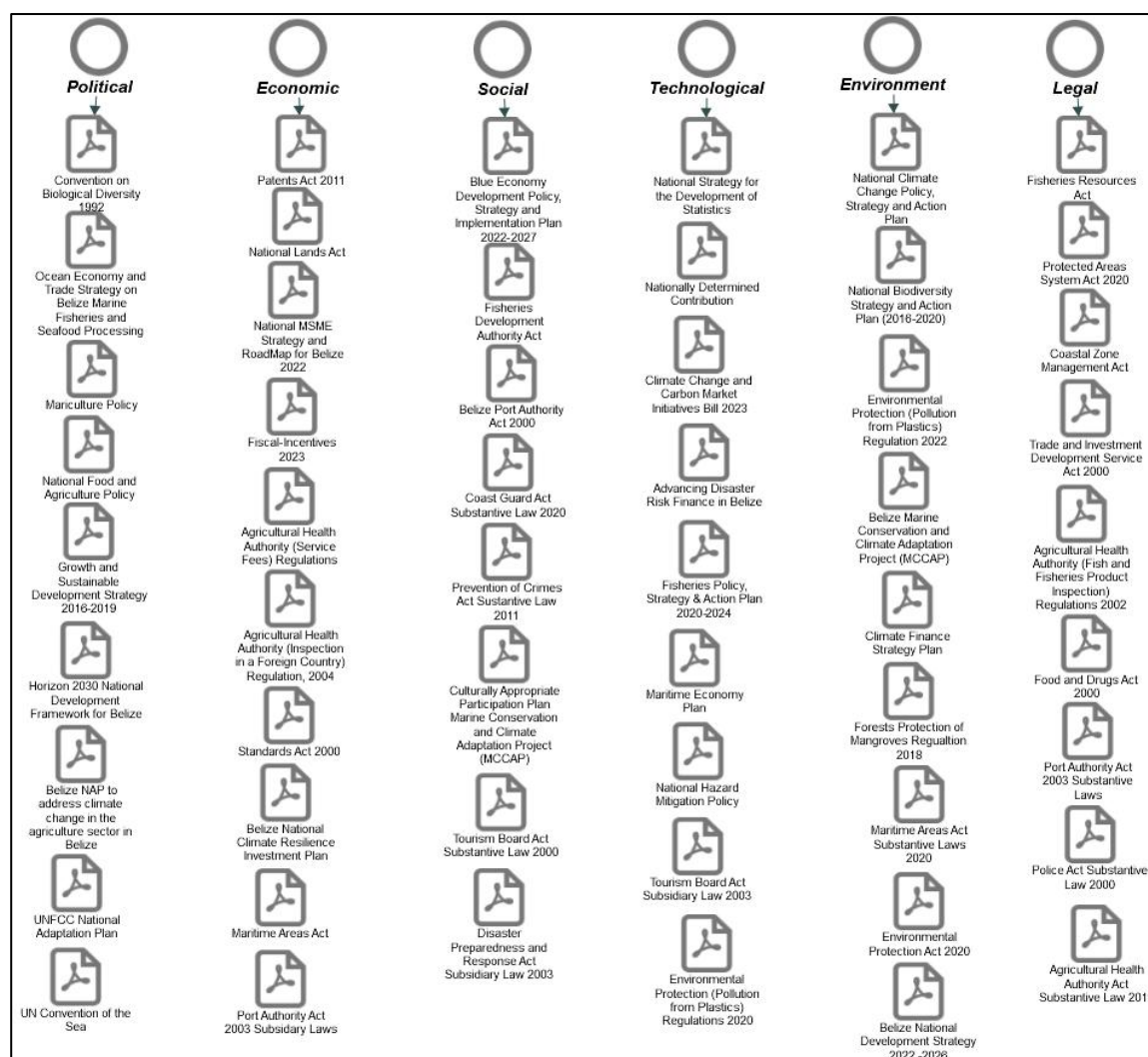


Figure 5.10. Inventory of Documents captured in policy analysis by PESTEL factors in NVivo software (Author's own elaboration).

| Category  | Legislation Frameworks                                                                                |
|-----------|-------------------------------------------------------------------------------------------------------|
| Political | - Convention on Biological Diversity 1992                                                             |
|           | - Ocean Economy and Trade Strategy on Belize Marine Fisheries and Seafood Processing                  |
|           | - Mariculture Policy                                                                                  |
|           | - National Food and Agriculture Policy                                                                |
|           | - Growth and Sustainable Development Strategy 2016-2019                                               |
|           | - Horizon 2030 National Development Framework for Belize                                              |
|           | - Belize National Adaptation Plan (NAP) to address climate change in the agriculture sector in Belize |
|           | -United Nations Framework Convention on Climate Change (UNFCCC) National Adaptation Plan              |
|           | - United Nations Convention on the Law of the Sea (UNCLOS)                                            |
| Economic  | - Patents Act 2011                                                                                    |
|           | - National Lands Act                                                                                  |
|           | - National Micro, Small and Medium Enterprises (MSME) Strategy and Roadmap for Belize 2022            |
|           | - Fiscal-Incentives 2023                                                                              |
|           | - Agricultural Health Authority (Service Fees) Regulations                                            |

|               |                                                                                          |
|---------------|------------------------------------------------------------------------------------------|
|               | - Agricultural Health Authority (Inspection in a Foreign Country) Regulation, 2004       |
|               | - Standards Act 2000                                                                     |
|               | - Belize National Climate Resilience Investment Plan                                     |
|               | - Maritime Areas Act                                                                     |
|               | - Port Authority Act 2003 Subsidiary Laws                                                |
| Social        | - Blue Economy Development Policy, Strategy, and Implementation Plan 2022-2027           |
|               | - Fisheries Development Authority Act                                                    |
|               | - Belize Port Authority Act 2000                                                         |
|               | - Coast Guard Act Subsidiary Law 2020                                                    |
|               | - Prevention of Crimes Act Subsidiary Law 2011                                           |
|               | - Culturally Appropriate Participation Plan                                              |
|               | - Marine Conservation and Climate Adaptation Project (MCCAP)                             |
|               | - Tourism Board Act Subsidiary Law 2000                                                  |
| Technological | - National Strategy for the Development of Statistics                                    |
|               | - Nationally Determined Contribution                                                     |
|               | - Climate Change and Carbon Market Initiatives Bill 2023                                 |
|               | - Advancing Disaster Risk Finance in Belize                                              |
|               | - Fisheries Policy, Strategy and Action Plan 2020-2024                                   |
|               | - Maritime Economy Plan                                                                  |
|               | - National Hazard Mitigation Policy                                                      |
| Environment   | - National Climate Change Policy, Strategy and Action Plan                               |
|               | - National Biodiversity Strategy and Action Plan (2016-2020)                             |
|               | - Environmental Protection (Pollution from Plastics) Regulation 2022                     |
|               | - Belize Marine Conservation and Climate Adaptation Project (MCCAP)                      |
|               | - Climate Finance Strategy Plan                                                          |
|               | - Forests Protection of Mangroves Regulation 2018                                        |
|               | - Environmental Protection Act 2020                                                      |
|               | - Maritime Areas Act Subsidiary Laws                                                     |
| Legal         | - Fisheries Resources Act                                                                |
|               | - Protected Areas System Act 2020                                                        |
|               | - Coastal Zone Management Act                                                            |
|               | - Trade and Investment Development Service Act 2000                                      |
|               | - Agricultural Health Authority (Fish and Fisheries Product Inspection) Regulations 2022 |
|               | - Food and Drugs Act 2000                                                                |
|               | - Port Authority Act 2003 Subsidiary Laws                                                |
|               | - Police Act Subsidiary Law                                                              |
|               | - Agricultural Health Authority Act Subsidiary Law 2011                                  |

*Table 5.33. Inventory of Legislative and Policy Frameworks Relevant to the Seaweed Mariculture Industry in Belize (Author's own elaboration).*

Table 5.33 that Legal and Environmental frameworks represented the largest groupings, reflecting the strong emphasis on regulation, conservation, and compliance within the national policy landscape. Political and Economic frameworks were primarily associated with development strategies, investment mechanisms, and sectoral policies, while Social and Technological frameworks were fewer in number and addressed participation, governance, data systems, and sectoral planning. Only a limited number of instruments explicitly referenced seaweed mariculture, with most frameworks applying indirectly through broader fisheries, aquaculture, coastal management, or climate change policies. Taken together, the

distribution illustrated how binding, international, and non-binding frameworks collectively shaped the enabling environment for the sector.

Binding Frameworks consisted of 41 legally enforceable laws, regulations, and acts that govern various aspects of the seaweed mariculture industry in Belize. These frameworks covered areas such as environmental protection, fisheries management, maritime activities, public health, and economic regulation. They directly impacted seaweed mariculture by establishing standards, procedures, and regulations for operators. For instance, the Fisheries Resources Act regulated the sustainable use of marine resources, the Environmental Protection Act of 2020 set environmental standards to prevent pollution, and the National Climate Change Policy, Strategy, and Action Plan integrated climate change adaptation and mitigation into national development strategies.

International agreements numbered 4 and included those that Belize has signed, setting international standards for its domestic practices. These agreements addressed global environmental protection, sustainable development, climate change adaptation, and marine resource management. Although these agreements were not directly enforceable at the national level, they guided the formulation of binding and non-binding national frameworks, ensuring that Belize's seaweed mariculture industry aligned with international best practices and contributed to global sustainability targets. Examples included the UNFCCC National Adaptation Plan, UNCLOS, and the Convention on Biological Diversity of 1992.

Non-Binding Frameworks accounted for 21 policies, strategies, and plans that provided guidance for the development of the seaweed mariculture industry. These frameworks were not legally enforceable but offered direction for sustainable development and economic planning. They focused on long-term development goals, economic strategies, environmental sustainability, and climate resilience. These frameworks influenced decision-making and policy development, shaping the strategic direction of the industry and promoting best practices and innovation. Examples included the Ocean Economy and Trade Strategy on Belize Marine Fisheries and Seafood Processing, the Mariculture Policy, and the Blue Economy Development Policy, all of which emphasized sustainable growth, innovation, and environmental stewardship in marine industries.

Taken together, binding frameworks established enforceable rules, international agreements provided overarching context, and non-binding frameworks articulated strategic ambitions. Collectively, these instruments constituted the policy environment that shaped seaweed mariculture in Belize and formed the basis for the subsequent analysis of salient provisions and gaps within each PESTEL factor.

*Policy Analysis by PESTEL:* Consistent with the Intergovernmental Panel on Climate Change (IPCC), climate risk was understood as the interaction of hazards with exposure and vulnerability (IPCC, 2001). In this thesis, the CRiSTAL (Community-based Risk Screening Tool - Adaptation and Livelihoods) activities were treated as hazard screening, identifying climate and non-climatic hazards relevant to seaweed farming, while exposure and vulnerability were assessed through livelihood capitals and stakeholder data. The PESTEL policy analysis then interrogated whether policy instruments contained measures that addressed these hazard pathways (e.g., prevention, preparedness, response and recovery) and how such measures interacted with blue-economy ambitions and the SLF Framework. Positive and negative analysis were captured as certain legal frameworks lack specific policy measures to safeguard the seaweed mariculture industry. The analysis was structured to examine the PESTEL factors impacting the industry, with a specific emphasis on identifying the strengths and challenges within each category. This approach aimed to provide a comprehensive understanding of the external factors impacting the industry, while also aligning with international best practices for sustainable development and environmental

management. The analysis considered binding frameworks, international agreements, and non-binding strategies, with the objective of identifying areas where Belize's regulatory environment supports or hinders the growth and sustainability of seaweed mariculture. The study used established methodologies to assess policy-level responses of measures put in place to respond to climatic and non-climatic hazards in seaweed farming in the current legislative and policy framework the seaweed mariculture industry is emerging from in Belize SIDS. Although the PESTEL framework is widely recognized for its utility in strategic planning, there is a scarcity of systematic reviews specifically tailored to the unique contexts of SIDS. This research aimed to fill that gap by offering a detailed examination of how external factors shape the operational landscape of seaweed mariculture in Belize.

*PESTEL factors in seaweed mariculture:* Table 5.34 presents the results of the PESTEL policy analysis coding in NVivo. The legal factors received the highest number of references, with 1,532 across 46 files, followed by Environment category with 413 across 31 files, Economic with 383 across 31 files, Political with 317 across 31 files, Social with 155 across 13 files, and Technological factors with 66 references across 13 files, suggesting less emphasis on technological factors. In summary, legal and environmental dimensions were emphasized with relatively fewer references to technological instruments. The Economic and Political categories also receive significant attention, highlighting their relevance to the overall analysis.

| PESTEL Factor | Files | References |
|---------------|-------|------------|
| Political     | 31    | 317        |
| Economic      | 31    | 383        |
| Social        | 27    | 155        |
| Technological | 13    | 66         |
| Environment   | 32    | 413        |
| Legal         | 46    | 1,532      |

*Table 5.34. Summary of the number of files and references categorized under each PESTEL factor (Author's own elaboration).*

*Key empirical points:* Governance of fisheries and mariculture was anchored in the National Fisheries Policy, Strategy, and Action Plan (2020-2024) and the Fisheries Resources Act (2020) and the National Development Framework and Policy Direction which aligns with Belize's Horizon 2030 Vision. Environmental governance (Environmental Protection Act; Coastal Zone Management Act; National Climate Change Policy, Strategy and Action Plan) supplied the main adaptation and conservation levels. Overall, the legislative base was comprehensive, but its efficacy depended on implementation, enforcement and periodic updating as shown in Table 5.34.

*Opportunities (positive) and Challenges (negative) analysis of PESTEL policy analysis findings:*

#### Political

**Opportunities:** Policy alignment across national development strategies (e.g., Horizon 2030), sectoral plans (Fisheries Policy) and coastal governance created an enabling platform; proposed coordination mechanisms (e.g., climate and coastal advisory bodies) supported joined-up action; stakeholder participation commitments improved inclusivity.

**Challenges:** Seaweed-specific measures were sparse within high-level instruments (e.g., National Adaptation Plans), leaving an implementation gap. Inter-ministerial coordination

and enforcement were uneven, and advisory bodies did not consistently translate community needs, particularly those of smallholder and indigenous producers, into operational support.

#### Economic

**Opportunities:** Disaster-risk finance initiatives and climate-finance strategies signaled pathways to buffer shocks; MSME and investment instruments could be leveraged for value-addition and certification; port and standards regimes offered potential efficiency gains.

**Challenges:** No targeted fiscal incentives for seaweed mariculture were identified; awareness and uptake of standards (e.g., Global Good Aquacultural Practices (GAP), Hazard Analysis and Critical Control Point (HACCP)) appeared limited; high operating costs and thin processing capacity constrained competitiveness; risk-sharing mechanisms for natural-hazard losses were under-developed.

#### Social

**Opportunities:** Policy commitments to culturally appropriate participation, gender balance and community engagement provided a basis for inclusive growth; health and food-safety regulations supported consumer protection and market confidence.

**Challenges:** Evidence of systematic implementation was limited; public awareness of mariculture opportunities and product labelling/protection remained weak; practical frameworks to deliver gender and intergenerational equity were not consistently operationalized; capacity-building support for producers was fragmented.

#### Technological

**Opportunities:** National strategies on statistics, hazard mitigation and fisheries management referenced data systems, monitoring and research, offering entry points for climate-smart technologies, biosecurity and research, development and innovation (RD&I).

**Challenges:** Early warning/monitoring systems were underutilized in seaweed operations; technology-transfer provisions remained generic (non-sector-specific); RD&I efforts lacked coherence and resourcing; digital tools for transparency/compliance were nascent; specialized equipment needs were unmet.

#### Environmental

**Opportunities:** Strong conservation architecture (protected areas, mangrove regulations), alignment with Sustainable Development Goals (SDGs) and climate policy, and ecosystem-based management commitments underpinned long-term environmental stewardship for mariculture sites.

**Challenges:** Operational guidance tailored to seaweed farming (e.g., effluent control, antifouling, escapees' management) was patchy; monitoring and enforcement capacity were uneven; disaster-preparedness instruments did not explicitly integrate seaweed farm contingencies; habitat co-management with farming footprints required clearer rules.

#### Legal

**Opportunities:** A robust body of statutes governing biosecurity, food safety, coastal management and fisheries; disaster law provided emergency authority; IP (intellectual property) and trade statutes offered innovation and market-entry avenues.

**Challenges:** Seaweed-specific regulations and quality-control protocols were not consolidated; fragmentation across authorities generated procedural uncertainty; sector-



tailored IP protection and product standards were underspecified; international commitments were not consistently translated into enforceable domestic provisions for seaweed.

*Pearson correlation analysis of PESTEL factors:* Pearson correlations were computed on NVivo-derived coded reference counts to explore co-variation between PESTEL factors. Normality of code-pair co-occurrence rates was checked (assumptions were acceptable for exploratory Pearson analysis). Strength labels (“High/Moderate/Low”) reflected relative prevalence in the NVivo data (i.e., empirical distribution of co-occurrence), aligned with the elite-interview coding scheme, rather than fixed numerical thresholds. Therefore, table 5.35 shows the correlation of the policy measures by PESTEL factors in place with the capability of responding to climatic and non-climatic hazards impacting seaweed farming based on the significance level of Pearson correlation coefficients.

| Factor A      | Factor B      | Pearson Correlation Coefficient | Correlation Strength |
|---------------|---------------|---------------------------------|----------------------|
| Political     | Legal         | 0.832                           | High                 |
| Political     | Environment   | 0.811                           | High                 |
| Legal         | Environment   | 0.802                           | High                 |
| Social        | Political     | 0.783                           | High                 |
| Social        | Legal         | 0.781                           | High                 |
| Legal         | Economic      | 0.730                           | High                 |
| Social        | Environment   | 0.711                           | High                 |
| Political     | Economic      | 0.709                           | High                 |
| Legal         | Economic      | 0.701                           | High                 |
| Social        | Economic      | 0.697                           | Moderate             |
| Social        | Technological | 0.680                           | Moderate             |
| Technological | Legal         | 0.621                           | Moderate             |
| Technological | Political     | 0.591                           | Moderate             |
| Technological | Economic      | 0.552                           | Moderate             |
| Technological | Environment   | 0.549                           | Moderate             |

Table 5.36. Correlation strengths among PESTEL factors in seaweed farming policy analysis (Author’s own elaboration).

*Key correlation findings:* Table 5.36 shows a strong co-variation among Political, Legal, and Environmental codes indicated that political commitments tended to be accompanied by legal provisions and environmental measures, consistent with a compliance-oriented governance model. Moderate associations linking Social with Political/Legal/Environmental suggested that participation and equity considerations were referenced but less consistently embedded in enforceable instruments. Technological signals co-varied least with other factors, reflecting the relative scarcity of technology-specific provisions and under-utilization of monitoring/early-warning tools.

#### 5.2.6 Summary of elite interviews and policy analysis by PESTEL at a policy level

The subsection synthesized PESTEL-coded findings from both the elite interviews and the policy review. This summary reveals where the existing policy instruments by PESTEL did or did not address the hazard pathways in the seaweed farming industry in Belize. NVivo coding showed the highest salience for Legal and Environmental provisions and the lowest for Technological (elite interview; Table 5.26 and policy analysis; Table 5.36). The policy analysis showed a strong co-variation among Political, Legal, and Environmental codes

(Table 5.36) indicated that political commitments tended to be accompanied by statutory and conservation measures; interview data converged on this pattern while emphasizing operational gaps at farm level (Table 5.26).

*Political:* Micro, small and medium enterprise (MSME) frameworks, investment facilitation and disaster-risk finance signaled scope to buffer income shocks. Interview reports of thin processing capacity, price volatility, and the absence of mariculture-specific incentives indicated constrained effects on producers' financial capital, so vulnerability to non-climatic stressors (costs, markets) remained elevated.

*Economic:* Interviewees reported financing gaps, price volatility and export conformity costs; the policy set referenced MSME and investment tools but few targeted incentives for seaweed. Implication: deploy concessional credit, tax/fee relief and risk-transfer schemes (e.g., parametric cover for storm/disease events), and fund certification/quality systems to improve market access and buffer climatic shocks.

*Social:* Policy commitments to culturally appropriate participation and gender balance, alongside health and food-safety provisions, provided a basis for inclusive practice. Evidence of inconsistent operationalization, uneven producer-organization capacity, and weak consumer awareness suggested that social mechanisms to lower vulnerability (e.g., through collective action, equitable access) were variably embedded.

*Technological:* References to statistical systems, hazard mitigation and fisheries monitoring offered entry points for climate-smart technologies, biosecurity and research, development and innovation (RD&I). Low coding prevalence, generic technology-transfer clauses, and under-use of early-warning/monitoring in seaweed operations indicated a capability gap, so hazard detection and adaptive response at farm level appeared limited.

*Environmental:* A strong conservation and climate policy base (e.g., Environmental Protection Act, mangrove regulations, protected areas) supported ecosystem integrity at farming sites. Interviewees confirmed salient hazards such as evidence of warming waters, seasonal hydrodynamics, disease and sargassum disruptions. There was scarcity of seaweed-specific operational guidance (e.g., invasive species control, antifouling, cultivated species escapees' management) and uneven enforcement implied that day-to-day controls to reduce exposure and vulnerability were incomplete.

*Legal:* Comprehensive statutes across fisheries, food safety (e.g., HACCP), coastal management and disaster law addressed compliance pathways. Fragmentation across authorities, unclear quality-control routes, and limited seaweed-specific standards indicated procedural uncertainty, so legal instruments managed hazards while leaving parts of exposure and vulnerability reduction underspecified.

Overall, the policy level summary integrated evidence from the elite interviews and policy analysis by PESTEL which indicated a governance configuration that prioritized statutory control and environmental stewardship (hazard management) but provided mixed, and often generic, support for the capitals that moderate exposure and vulnerability, notably technological capability, consistent social inclusion mechanisms, and producer-level financial strengthening. These results informed the subsequent thesis contributions by identifying where existing policy architecture already mitigated hazards and where additional specification or operational capacity was most consequential for reducing exposure and vulnerability in Belize's seaweed mariculture.

## 5.3 Summary

The mixed-methods design assessed the sustainability of seaweed farming in Belize, understood as a climate adaptation strategy for blue growth in this study, by integrating qualitative assessment (interviews, focus groups, surveys), quantitative (survey) assessments, and policy analysis. Taken together, the results demonstrated that livelihood outcomes emerge from the interaction of environmental pressures, socio-economic conditions, and governance arrangements, and that farmers mobilize multiple capitals (SLF) and strategy sets (CbA/EbA) to sustain production.

### 5.3.1 Community-level integration in seaweed mariculture development

The survey data indicated Belizean seaweed farmers drew heavily on CbA practices embedded in cooperatives, associations, and informal networks, which supported collective action, knowledge sharing, and mutual aid. These structures were significant in helping farmers address environmental and economic challenges. Farmers also applied elements of EbA into their seaweed mariculture practices, particularly by aligning farming methods with local environmental conditions, which helped minimize ecological disruption and sustain marine biodiversity.

However, differences were observed in the understanding and application of these strategies. While many farmers intuitively applied practices consistent with EbA and CbA, others reported gaps in technical knowledge or uncertainty about formal strategies. The findings highlighted the importance of organizational support, as community structures were often constrained by limited resources, technical assistance, and regulatory complexity.

The following climatic and non-climatic factors were identified in the statistical analysis as significant (further elaborated in Table 9.5; appendix C).

*Climatic factors:* The analysis found that temperature had a positive correlation with productivity, supporting evidence that some species (e.g., *Eucheuma isiforme*) grow better under warmer conditions. Ocean wave velocity showed a negative, though not significant, correlation with yield, consistent with literature on storm and current impacts on farms. Disease outbreaks, such as ‘ice-ice’ seaweed disease, were also reported; while correlations were not conclusive, global evidence shows that climate-related stressors can increase susceptibility to disease.

*Non-Climatic Factors:* Among socio-economic and demographic characteristics, several variables impacted productivity. Gender was significant which revealed differences in outcomes between male and female farmers. Experience was also significant, which indicated that practical knowledge accumulated through years of farming enhances yields. Seaweed income and household income both impacted productivity, which evidenced that financial stability allows farmers to maintain or reinvest in operations. By contrast, remittances and savings were not significant in the final model. Other contextual factors, such as residential status and the presence of rubbish problems, were close to significance but not retained in the final model. These were pointed to broaden socio-economic and environmental conditions that can shape farming outcomes, even if not statistically significant in this study.

*Hazards and responses:* Analysis of hazard and response data showed statistically significant associations between the categories of hazards faced by farmers and the coping strategies they employed (Pearson correlation = 73.55,  $p < 0.001$ ; Likelihood ratio = 32.325,  $p = 0.009$ ) in Table 5.7. However, the reliability of these results was limited by small, expected counts in the contingency table. No significant linear-by-linear trend was found ( $p = 0.594$ ), indicating that the relationship between hazards and responses is not strictly linear.

The results indicated that farmers adjusted responses to hazard types. For example, adopting EbA approaches when facing environmental hazards through government or external support was seldom reported as a coping strategy.

*Quantitative Model:* The regression analysis identified a set of socio-economic and demographic factors that significantly impacted seaweed production, measured as wet weight harvested monthly (further elaborated in Table 9.6, appendix C). The results in Table 5.10 highlighted the relative importance of human, social, natural, financial, physical, and cultural capitals, showing that production outcomes were shaped more by intangible and practice-based resources than by physical assets or external transfers.

Within human capital, experience was found to have had a significant positive impact on productivity, indicating that farmers with longer involvement in seaweed farming achieved higher yields. By contrast, education, formal training, and health status did not emerge as significant predictors. This indicated that productivity was not dependent on formal schooling or training initiatives, but rather on knowledge accumulated through practical engagement and informal learning.

Social capital also played an important role. Gender had a significant impact on seaweed production, revealing that outcomes differed between male and female farmers. In addition, CbA practices were significant, demonstrating the importance of community-led strategies in supporting farming performance. Other social factors, including household size and the integration of CbA with EbA, were not significant in the final model, highlighting that collective approaches were important but that their benefits were not necessarily amplified through formal integration of multiple strategies.

Natural capital proved to be particularly important. EbA had a significant positive impact on productivity, indicating that practices aligned with ecological processes, such as tailoring cultivation to local environmental conditions, enhanced seaweed yields. Seaweed loss appeared relevant in the models indicating that this variable was embedded in EbA practices which may have reduced the direct effects of seaweed loss events on production.

Physical capital variables, including farm size, boats, and value-adding activities, were not significant in the final model. This suggested that neither scale of operations nor investments in processing infrastructure translated directly into higher yields. Instead, productivity appeared to have depended more on how farmers mobilized ecological knowledge and community strategies.

Financial capital showed a more direct relationship with production. Both household income and seaweed income were significant predictors, revealing that financial stability supported higher levels of productivity. Farmers with greater household resources or reinvestment from seaweed income were better positioned to maintain their operations and achieve higher yields. By contrast, remittances and savings did not significantly impact production, implying that external financial inflows and stored assets were less relevant for ongoing productivity.

Finally, cultural capital also emerged as an important dimension. Traditional knowledge significantly impacted seaweed yields, evidencing the continuing relevance of experiential and intergenerational knowledge in sustaining farming practices. Farmers frequently described their methods as “learning as they went,” indicating the widespread use of informal, field-based adaptation rather than the systematic application of formal strategies.

In summary, the quantitative assessment demonstrated that seaweed farming productivity in Belize was most strongly shaped by a combination of experiential knowledge, ecological

alignment, social differentiation, and financial stability. Climatic factors such as temperature and ocean conditions, non-climatic conditions including gender and socio-economic context, and the hazards and coping strategies reported by farmers all converged to show that livelihoods were sustained primarily through practice-based learning, community and ecosystem approaches, and access to reliable income. In contrast, variables associated with physical expansion or external financial transfers were not significant, indicating that the sustainability of seaweed mariculture rested less on scale and infrastructure, and more on the mobilization of intangible capitals and adaptation strategies embedded in local contexts.

### 5.3.2 Policy-level integration in the seaweed farming governance

*Key Characteristics of Seaweed Mariculture:* The PESTEL analysis of seaweed mariculture governance revealed how political, economic, social, technological, environmental, and legal factors interacted in shaping the sector in Table 5.36. Strong correlations were observed between political and legal factors ( $r = 0.832$ ), indicating close alignment between political will and legal enforcement. Similarly, environmental considerations were strongly integrated with political ( $r = 0.811$ ) and legal ( $r = 0.802$ ) frameworks, demonstrating that environmental sustainability had been prioritized in governance. By contrast, correlations involving social, technological, and economic factors were moderate to low, which indicated that these areas were not fully aligned with environmental or legal frameworks. This indicated challenges for marginalized farming communities, particularly where technological support and economic incentives were limited.

Economic factors showed only moderate alignment with technology ( $r = 0.552$ ), revealing that while some innovation was supported, technological development was not fully optimized for the sector. Interviews confirmed that financing for specialized equipment and post-harvest infrastructure was scarce and often short-term. Environmental and economic factors showed a relatively strong relationship ( $r = 0.701$ ), indicating some balance between growth and sustainability. However, interviewees reported that economic incentives for seaweed farming were still limited compared with tourism and fisheries.

Legal frameworks were closely linked with political ( $r = 0.832$ ) and environmental ( $r = 0.802$ ) dimensions, confirming that legal instruments were central to implementing environmental priorities. Interviewees noted that regulations existed for biosecurity, marine management, and product standards, but they also highlighted complexity in licensing procedures, overlapping mandates, and gaps in technical guidance specific to seaweed mariculture.

Social factors showed a moderate to strong correlation with legal frameworks ( $r = 0.781$ ), reflecting some responsiveness of laws to social concerns. However, elite interviews revealed persistent barriers related to gender, youth participation, and community equity, which were only partially addressed in policy texts. Social and environmental alignment ( $r = 0.711$ ) was also evident, although interviewees stressed that implementation was uneven and depended heavily on external project funding.

Technological support was less integrated across governance factors. Correlations between technology and environment ( $r = 0.549$ ), technology and legal ( $r = 0.621$ ), and technology and economy ( $r = 0.552$ ) were relatively low, demonstrating that legal and economic policies provided limited support for technological innovation. Interviewees described reliance on farmer-to-farmer transfer and learning-by-doing, with limited institutionalized extension or research and development.

*Climatic and Non-climatic Hazards and Responses using PESTEL Tool:* The PESTEL framework was also used to assess how policy-level factors addressed climatic and non-climatic hazards affecting seaweed farming in Table 5.36. Strong alignment between political, legal, and environmental factors indicated that Belize possessed formal mechanisms to address climate-related hazards. Political commitments to environmental sustainability were

reinforced by legal frameworks and environmental policies, as reflected in references to biosecurity regulations, resource management strategies, and marine conservation laws.

Moderate alignments were observed between social and political ( $r = 0.783$ ) and between social and legal ( $r = 0.781$ ) dimensions, indicating that policy frameworks were responsive to community concerns. However, elite interviewees noted that high compliance costs and barriers to entry often limited the participation of small-scale farmers, particularly women. While social and environmental correlations ( $r = 0.711$ ) indicated some integration of community concerns into environmental management, interviewees reported that policy support for gender equity, security at sea, and community financing was limited.

Lower correlations were observed for economic and technological factors. For example, technological and legal ( $r = 0.621$ ) and technological and economic ( $r = 0.552$ ) alignments were weak, revealing that legal and economic instruments did not strongly promote technological innovation for hazard management. Interviewees consistently reported gaps in research and development, strain selection, disease monitoring, and post-harvest processing infrastructure.

Overall, chapter 5 provides a comprehensive analysis of seaweed farming in Belize demonstrated considerable potential to contribute to sustainable livelihoods and act as a climate adaptation strategy within the blue growth agenda. The qualitative findings revealed that farmers relied heavily on community-based and ecosystem-based practices, local knowledge, and cooperative structures, though gaps remained in technical expertise, resource access, and organizational capacity. The quantitative assessment confirmed that productivity was significantly impacted by experience, gender, household and seaweed income, traditional knowledge, and the adoption of CbA and EbA approaches, while physical expansion and external financial inflows were not significant predictors. Climatic conditions such as temperature were positively associated with yield, whereas wave velocity and disease presented challenges. The policy analysis indicated that governance frameworks in Belize provided a foundation for supporting mariculture development, but integration, financing mechanisms, and farmer participation were limited. Taken together, these findings revealed both opportunities and constraints in positioning seaweed farming as a viable livelihood option and climate adaptation strategy. These results form the basis for the following chapter, which discusses their implications for sustainability, blue growth, and climate change adaptation in Belize and comparable SIDS.

## 6. DISCUSSION

The discussion chapter critically examines the key findings of the study on the sustainability of seaweed mariculture livelihoods in Belize, drawing upon the mixed methods approach that integrated community-level qualitative analysis and quantitative survey modelling, and policy-level qualitative analysis through Political, Economic, Social, Technological, Environmental and Legal (PESTEL) tool supported by policy documents and elite interview data. While Chapter 5 presented the findings in detail, this chapter critically interprets them in relation to the research questions, situates them within the wider literature on sustainable livelihoods and climate adaptation in Small Island Developing States (SIDS), and highlights their implications for the role of seaweed farming as a viable livelihood option and climate adaptation strategy for blue growth. The chapter is structured to move from the community level to the policy level, and finally to the quantitative modelling of livelihoods.

At community-level, section 6.1 begins by discussing the qualitative analysis of focus group discussions conducted in Belize, guided by the Community-based Risk Screening Tool - Adaptation and Livelihoods (CRiSTAL) toolkit, which explored the role of livelihood capitals in shaping adaptation strategies and sustainability of seaweed farming communities. Section 6.2 extends this by integrating qualitative survey findings with global literature, examining farmer characteristics, perceptions of climate change, and opportunities and challenges for sustaining livelihoods. Chapter 6.3 synthesizes all the qualitative insights.

At policy level, Section 6.4 presents the PESTEL analysis, which assesses the institutional, legal and strategic framework relevant to seaweed mariculture in Belize, complemented by insights from elite interviews that highlight governance gaps, opportunities and challenges for embedding seaweed farming within the national Blue Economy agenda. The focus then shifts to the quantitative analysis. Section 6.5 interprets the survey-based quantitative findings, including hazards and responses (6.5.1) and the regression model for measuring and strengthening seaweed livelihoods (6.5.2). Section 6.6 and 6.7 concludes the quantitative assessment, identifying the most significant livelihood capitals for seaweed farming production.

Section 6.8 presents the limitations and shortcomings of the study, structured into sub-sections addressing the use of PRAs and the CRiSTAL toolkit (6.8.1), sampling of survey respondents and survey data (6.8.2), sampling of elite interviewees (6.8.3), socio-economic and socio-legal overlap of the PESTEL tool (6.8.4), and other challenges arising from the choice of a mixed-methods design (6.8.5). Finally, section 6.9 provides a summary of the discussion chapter, synthesizing the key insights across community, household, and policy levels.

Together, these strands of analysis provide a comprehensive interpretation of the sustainability of seaweed farming in Belize, linking community practices, household production outcomes, and governance frameworks. This integrated discussion situates the Belizean experience within the broader academic discourse on sustainable livelihoods and climate adaptation in SIDS.

### 6.1 Qualitative Analysis with CRiSTAL and Implications

*Livelihood Characteristics by Capitals:* The focus group discussions in Belize highlighted a diverse range of livelihood capitals underpinning the sustainability of seaweed farming. These included human skills, social networks, natural marine environments, physical infrastructure, financial support, and cultural heritage. Such findings evidenced that seaweed farming is not merely an economic activity but also a socially embedded livelihood shaped by multiple forms of capital. The importance of human capital, particularly practical skills and knowledge,

emerges strongly. This aligns with Torre-Castro et al. (2022) who demonstrated in Zanzibar that empowering local farmers through capacity-building and access to resources enhances both livelihood sustainability and adaptation to climate change.

Social capital, expressed through community cohesion and environmental nongovernmental organization (E-NGOs) support, was also identified as critical. As in Tanzania, Matoju et al. (2022), these networks function as informal safety nets that help farmers manage uncertainty and environmental stress. Similarly, access to nutrient-rich waters and wild seaweed beds highlights the centrality of natural capital, echoing evidence from Brazil's *Hypnea pseudomusciformis* farming (Pereira et al., 2021). Taken together, these insights confirm that sustainable seaweed farming depends on the interplay of human, social, and natural capitals which are particularly significant in the resource-dependent context of SIDS.

*Climatic and Non-Climatic Hazards:* The discussions highlighted a range of climatic and non-climatic hazards, such as theft, seaweed die-offs, extreme weather events, rising sea temperatures, and extended droughts, that directly undermine seaweed farming. These hazards parallel those identified globally. For instance, Ndobe et al. (2020) documented rising sea temperatures and disease outbreaks in Indonesia, emphasizing the vulnerability of seaweed to climate stressors. Similarly, Thiel et al. (2007) highlighted how extreme weather is linked to the Humboldt Current destabilized mariculture operations.

These hazards demonstrate that Belizean farmers are on the frontline of both environmental and socio-economic pressures. The convergence of climatic hazards and human-induced challenges (e.g., theft, market pressures) illustrates the complexity of sustaining seaweed mariculture as a livelihood. Importantly, this finding highlights that adaptation in SIDS must simultaneously address climate variability and non-climatic stressors to secure long-term viability.

*Coping Strategies and Sustainability:* Belizean farmers have developed coping mechanisms such as routine site monitoring, the cultivation of resilient seaweed species, and the adoption of buoy systems. These strategies mirror global best practices. For example, Ndobe et al. (2020) noted the importance of *Eucheuma denticulatum* as a resilient species under rising temperatures, while Rubekie et al. (2022) in Tanzania highlighted the role of community monitoring and security systems in addressing theft and gender vulnerabilities. However, while these coping strategies demonstrate adaptation capacity, they remain largely reactive and community-driven, relying heavily on informal arrangements. The systematic literature review suggests that without integrated management frameworks and policy support (Bhuyan et al., 2021; Radulovich et al., 2015), such grassroots adaptations risk being insufficient against escalating climate hazards. In this regard, the Belizean case illustrates both the ingenuity of small-scale farmers and the structural weaknesses of relying solely on community-based strategies in the absence of robust institutional backing.

*Synthesis:* The CRiSTAL findings shows that Belizean seaweed farmers mobilize multiple livelihood capitals to manage hazards exposure, but these capitals are under increasing strain by the combined pressures of climate change and socio-economic pressures. Effective adaptation is social and institutional as well as ecological. Traditional knowledge and cultural capital strengthen practice but require complementary formal support to endure. The Belize case aligns with wider SIDS evidence. Small-scale mariculture is viable where policy frameworks bolster local capacities, formalize community practices, and provide targeted technical and financial resources so that seaweed farming can contribute credibly to climate adaptation and a sustainable blue economy.



## 6.2 Qualitative analysis with Surveys and Implications

*Livelihood Characteristics by Sociodemographic profiling:* The surveys depicted a relatively young, predominantly male group (56% of respondents) with varied educational backgrounds (39% having completed secondary education) and household compositions. This demographic profile was consistent with global trends observed in the literature, where younger (44% of farmers aged between 25-34 years), relatively educated individuals are increasingly involved in seaweed farming, particularly in regions where it presents a viable alternative livelihood (Hossain et al., 2021; Jagtap et al., 2022). Ethnically, the majority identified as Creole (72%), indicating the cultural roots of the community involved in seaweed farming. Cultural heritage and traditional knowledge are prominent in Belize, which resonates with scholarship on their role in resilience (Radulovich et al., 2015) and with gendered contributions across the value chain (Torre-Castro et al., 2022). These findings aligned with global studies that emphasize the role of cultural and educational factors in the adaptability of seaweed farming communities (Radulovich et al., 2015). The following points emerged from the findings in the qualitative surveys and literature review on the seaweed farmer's characteristics.

*Farming Practices and Techniques:* In Belize, the farming practices were diverse, with the majority (56%) owning their seaweed farms and employing the submerged plots method known locally as the tie-tie method. The surveys revealed a strong preference for cultivating *Kappaphycus alvarezii* (a non-native species), with other species like *Eucheuma isiforme* and *Gracilaria crassissima* also being farmed. Farmers exhibited adaptability in their practices, with some using a mix of shallow and deep-water farming techniques.

The systematic literature review also emphasized the diversity of farming practices globally, with many regions employing species and techniques suited to their local environmental conditions. Studies such as those by Schwahofer et al. (2021) and Pereira et al. (2021) discussed the importance of adapting farming techniques to environmental conditions, particularly in the face of climate change. The use of resilient species and mixed farming techniques was highlighted as a key strategy for enhancing the sustainability and productivity of seaweed farms.

This is consistent with international evidence that species choice and technique diversification underpin resilience under changing conditions. The preference for species like *Kappaphycus alvarezii* in Belize mirrors global trends where specific species are favored for their robustness properties and market value with lesser considerations on species origin. The use of mixed farming techniques in Belize reflects a broader recognition in the literature of the need to adapt to varying environmental conditions, especially in the context of climate change (Ndobe et al., 2020). This adaptability is crucial for ensuring the long-term viability of seaweed farming as a livelihood.

*Income Generation and Livelihood Diversification:* Seaweed farming largely served as a secondary income, complementing fishing, tour guiding, or freelance work. Such diversification aligns with global findings that portfolio livelihoods buffer households from market and environmental volatility.

The literature review similarly highlighted the role of seaweed farming as part of a diversified livelihood strategy, particularly in coastal communities where reliance on a single income source can be risky. Studies by Geggs and Wells (2019) and Matoju et al. (2022) emphasized the importance of integrating seaweed farming with other livelihood activities, noting that this approach enhances resilience against economic and environmental shocks.

The findings from Belize align with global insights that emphasize the role of seaweed farming within a broader livelihood portfolio. The fact that none of the Belizean respondents reported seaweed farming as their primary occupation reflects the global trend where seaweed farming often supplements other income-generating activities, providing a buffer against economic uncertainty. This diversification is critical for resilience, particularly in regions vulnerable to climate change and market fluctuations.

*Support Structures and Motivations:* Engagement with associations, cooperatives, and community organizations was central to training, market access, and advocacy. Farmers expressed a strong commitment to seaweed farming, motivated by factors such as family tradition, market opportunities, and environmental benefits. Training and support were identified as crucial for success, with many farmers having received cooperative or E-NGO training.

These patterns reflect international evidence of the importance of collective organization and capacity building for sector stability. Studies like those by Hossain et al. (2021) and Matoju et al. (2022) emphasized the need for robust support systems to enhance the sustainability of seaweed farming and ensure that farmers can navigate the challenges posed by market and environmental conditions.

The strong reliance on community-based organizations and cooperatives in Belize is consistent with global findings, which recognize these entities as critical for the success of seaweed farming. The motivations for engaging in seaweed farming in Belize, such as market opportunities and environmental benefits, also resonate with global trends where economic and ecological incentives are key drivers. The need for continuous training and support, as highlighted by Belizean farmers, is a common theme in the literature, emphasizing the importance of capacity-building initiatives to enhance productivity of seaweed farming communities through knowledge and skills sharing platforms.

*Awareness and Perceptions of Climate Change:* The qualitative surveys conducted among seaweed farmers in Belize revealed significant insights into their awareness and perceptions of climate change and its impacts on their farming practices and communities. Therefore, the universal awareness of climate change among Belizean seaweed farmers, as revealed by the qualitative surveys, was strongly supported by the literature, which consistently demonstrates a high level of climate change awareness among coastal and farming communities worldwide (Matoju et al., 2022; Ndobe et al., 2020). This widespread awareness is a crucial foundation for building resilience, as it enables farmers to recognize and respond to environmental changes that impact their livelihoods. For instance, studies by Hossain et al. (2021) in Bangladesh and Torre-Castro et al. (2022) in Tanzania found that seaweed farmers and other coastal community members often view climate change as a critical threat to their livelihoods, infrastructure, and overall community well-being. These studies highlight that climate change impacts are not just environmental but also deeply socio-economic, affecting food security, income stability, and social cohesion.

However, the surveys also revealed a divergence in perceptions regarding the specific impacts of climate change on seaweed crops. While a majority of farmers observed negative impacts, a significant portion did not perceive any impact, and some were uncertain. Specifically, a majority (61%) believed that climate change had a direct effect on their seaweed crops, citing observations of changes in crop health, growth, or yield. However, 22% of farmers did not perceive any impact, and 17% were uncertain about the impacts of climate change on their crops.

Studies like those by Schwahof et al. (2021) in Brazil and Ndobe et al. (2020) in Indonesia found that while some farmers report significant changes in seaweed productivity due to climate-related factors such as temperature fluctuations, salinity changes, and increased frequency of extreme weather events, others do not perceive these changes or attribute them to non-climatic factors. As the literature supports the need for localized studies and interventions, further considerations need to be made for the specific environmental and socio-economic contexts of different farming communities. Additionally, the uncertainty expressed by some farmers points to a potential gap in knowledge or monitoring, suggesting that further education and research could help clarify the specific impacts of climate change on seaweed farming. This points to a need for localized monitoring and advisory services.

*Opportunities and Challenges in Seaweed Farming:* Opportunities included economic diversification, value-added products, health and wellness uses, cultural continuity, and strong market demand. These are well documented in the literature (Hossain et al., 2021; Jagtap et al., 2022; Pereira et al., 2021; Bhuyan et al., 2021; Rubekie et al., 2022; Geggs and Wells, 2019). Challenges included limited technical knowledge, high operating costs and credit constraints, environmental and infrastructure limits, erosion of traditional practices under commercialization, and inadequate policy support. These constraints mirror global experience (Matoju et al., 2022; Ndobe et al., 2020; Thiel et al., 2007; Kraan, 2020; Radulovich et al., 2015). The following findings of the qualitative surveys go into detail with the points that emerged highly correlated in the opportunities and challenges in seaweed farming.

#### *Opportunities*

**Seaweed Farming as a Family Tradition and Community Practice:** The survey data indicated a strong correlation (12 qualitative surveys, 38 codes) between seaweed farming and its role as a family tradition and community practice. This finding is consistent with studies like Torre-Castro et al. (2022), which emphasize the empowerment of women in seaweed farming through community-led initiatives. The alignment between survey findings and literature highlights the resilience of seaweed farming as a cultural practice, particularly in regions where it has been historically significant. The community-driven approach not only supports the preservation of cultural heritage but also enhances social cohesion and the intergenerational transfer of knowledge, critical for the continuity of the practice.

**Economic Diversification and Alternative Livelihoods:** The high correlation in the survey data (14 qualitative surveys, 46 codes) regarding economic diversification and alternative livelihoods provided by seaweed farming aligns with the literature, such as Hossain et al. (2021), which underscores the role of seaweed farming in advancing sustainable development goals and contributing to the Blue Economy. This consistency between the survey findings and the literature highlights the importance of seaweed farming in reducing dependency on traditional, often over-exploited, marine resources. It offers a viable economic alternative that aligns with broader sustainability and resilience goals, particularly in vulnerable coastal communities.

**High Returns from Value-Added Products:** Survey findings revealed a high correlation (13 qualitative surveys, 40 codes) between high returns from value-added seaweed products and financial viability, which is strongly supported by the literature. For example, Jagtap et al. (2022) highlight the economic benefits of integrating seaweed farming with other agricultural practices to enhance sustainability and profitability. The survey data supports the literature's argument that value-added products can significantly improve the economic returns from seaweed farming, making it an attractive livelihood option that can support local economies and promote sustainable practices.

**Health and Wellness Benefits of Seaweed Products:** The survey data showed a moderate correlation (11 qualitative surveys, 30 codes) regarding the health and wellness benefits of seaweed products. This finding aligns with Bhuyan et al. (2021), who discuss seaweed's role in providing ecological services, including health benefits. While moderate correlation suggests that health and wellness are recognized benefits, they may not be as primary a motivator for farmers as the economic opportunities. This could indicate a need for further education and marketing efforts to promote these benefits more widely among consumers and producers.

**Preservation of Cultural Practices through Seaweed Farming:** The preservation of cultural practices through seaweed farming, as reflected in the survey data (8 qualitative surveys, 22 codes), aligns with Rubekie et al. (2022). The literature discusses the significance of cultural heritage in coastal communities, particularly among women, and how seaweed farming practices can be maintained alongside modern innovations. The moderate correlation in the survey data suggests that while cultural preservation is important, it faces challenges from the pressures of commercialization and modernization.

**Strong Market Demand and Profitability:** The survey data indicated a high correlation (10 qualitative surveys, 35 codes) between strong market demand and profitability, aligning with studies like Geggs and Wells (2019) and Pereira et al. (2021). These studies emphasize the growing global demand for seaweed and its derivatives, reinforcing the survey findings that highlight profitability as a key driver for many farmers. This correlation highlights the potential for seaweed farming to be a profitable and sustainable livelihood, particularly if market access and infrastructure are well-developed.

### *Challenges*

**Insufficient Technical Knowledge and Assistance:** The insufficient technical knowledge and assistance was a major obstacle identified in the survey results (based on 6 qualitative surveys and 18 codes), which demonstrated a strong correlation. This finding is consistent with the study by Matoju et al. (2022), which emphasizes the significance of technical proficiency in conquering climate-related challenges in seaweed cultivation. The shortage of technical support revealed in both the survey and literature implies that improving technical education and knowledge-sharing platforms is essential for the sustainable advancement of seaweed farming.

**Challenges of High Operational Costs and Limited Access to Finances:** The survey data collected from 7 qualitative surveys and 22 codes revealed that high operational costs and limited access to finances were significant challenges, which align with the findings of Ndobe et al. (2020) in literature. The systematic literature frequently discusses the financial constraints faced by small-scale farmers, particularly in relation to the costs of equipment, infrastructure, and transportation. The survey results emphasize the need for improved financial services and access to credit, which are critical for enabling farmers to invest in their operations and expand their farms.

**Environmental Challenges and Infrastructure Limitations:** In the survey data collected from 8 qualitative surveys and 26 codes, environmental challenges and infrastructure limitations were frequently mentioned, which aligns with the findings of Thiel et al. (2007). The literature emphasizes the need for long-term ecological monitoring to effectively manage these challenges. The survey results highlight the necessity of adequate infrastructure and environmental management to sustain seaweed farming, particularly considering the impacts of climate change and environmental degradation.

**Erosion of Traditional Practices:** The erosion of traditional practices due to modern pressures was another challenge identified in the survey data (4 qualitative surveys, 10 codes). This finding aligns with Kran (2020), who discusses the tension between maintaining traditional practices and adapting to modern economic demands. The survey results suggest that while traditional practices are valued, they are increasingly threatened by commercialization, indicating a need for strategies that balance cultural preservation with economic growth.

**Ineffective Policy Support and Financial Barriers:** Surveys identified ineffective policy support and financial barriers as significant challenges in 6 surveys with 21 codes. This aligns with the literature, as Radulovich et al. (2015) and other studies have criticized the lack of coherent policy frameworks and bureaucratic hurdles that hinder the growth of the seaweed farming sector. The survey findings emphasize the necessity of more supportive policies and streamlined processes to enable farmers to access the necessary resources and markets.

### *Perceptions of Blue Economy and Recommendations*

The qualitative surveys revealed mixed opinions among seaweed farmers regarding the blue economy, with some seeing potential benefits such as economic growth and opportunities for female entrepreneurs. However, a significant portion of respondents expressed skepticism, viewing the blue economy as a government-driven initiative lacking transparency and community involvement. Concerns were raised about regulatory frameworks restricting local practices rather than empowering them.

A systematic literature review highlighted broader global perspectives on the blue economy's potential, emphasizing its role in achieving Sustainable Development Goals (SDGs) and enhancing coastal resilience through community engagement and policy support. Studies like Geggs and Wells (2019) and Bhuyan et al. (2021) discussed the environmental benefits of integrating seaweed farming into climate adaptation strategies, including carbon sequestration and habitat restoration. However, these studies also acknowledged challenges related to governance, economic incentives, and the need for comprehensive policy frameworks.

Challenges in seaweed farming include complex regulatory processes, lack of government support, and difficulties in accessing financial resources. Farmers felt that their needs were often overlooked in favor of larger, more politically driven agendas. The lack of infrastructure and technical support was also a significant barrier to the industry's growth and sustainability.

Recommendations for improvement include more straightforward and supportive regulatory frameworks, increased financial support, and better integration of local knowledge into policy decisions. Farmers called for greater involvement of grassroots organizations in decision-making processes and policies that directly address their needs. A more inclusive approach to governance could address many of the challenges faced by seaweed farmers, both in Belize and globally.

The qualitative survey findings and the systematic literature review reveal a strong alignment in the identification of key challenges and recommendations for improving seaweed farming within the blue economy framework. Both sources point to the need for more inclusive, transparent, and supportive policies that empower local communities and integrate their knowledge into broader climate adaptation and sustainability strategies. Addressing these issues is crucial for realizing the full potential of seaweed farming as a sustainable livelihood and a key component of the blue economy.

**Synthesis:** The survey analysis reinforces the CRiSTAL insights. Belizean seaweed livelihoods are adaptive, diversified, and socially organized, yet constrained by technical gaps, finance, infrastructure, and uneven policy implementation. To translate strong

awareness and community motivation into durable gains, targeted capacity building, reliable extension and monitoring, affordable finance, and participatory governance are required. These measures can reduce perceived uncertainty, enable uptake of resilient techniques and species, and capture more value locally through ethical and gender-sensitive upgrading.

### 6.3 Conclusion of the Qualitative Assessment

Belize's seaweed farming is anchored in small independent groups and registered associations and cooperatives like the Belize Woman Seaweed Farmers Association (BWSFA), Blue Waters Fishermen Association (BWFA), Turneffe Seaweed Growers Association (TSGA) and Placencia Producers Cooperative Society Limited (PPCSL). Collectively, these communities have cultivated species such as *Kappaphycus alvarezii*, *Eucheuma isiforme*, and *Gracilaria crassissima* for over a decade, producing significant quantities of seaweed despite facing numerous challenges. The operations are relatively small-scale, typically involving 2 to 6 individuals per group working in the field, with production levels ranging from 120 pounds to 1000 pounds of dried seaweed.

In comparison with other SIDS, the Belizean seaweed farming community shares common characteristics, such as reliance on grants, personal financing, and the critical importance of natural resources like healthy marine environments for successful cultivation. The challenges identified, such as theft, seaweed die-offs, and extreme weather events, are also prevalent in other SIDS, as evidenced by the systematic literature review. Studies from regions like Zanzibar and Tanzania (Torre-Castro et al., 2022; Matoju et al., 2022) highlight similar issues, with additional emphasis on the need for stronger policy support, community-led initiatives, and gender-sensitive approaches to strengthen the sustainability of seaweed farming.

The systematic literature review further highlights the importance of integrating traditional knowledge with modern techniques to improve farming practices against climate-related hazards, a practice observed in Belize's seaweed farming communities. Local adaptation strategies employed, including adjusting farm depths, using resilient seaweed species, and relocating farms to safer areas, mirror those recommended in global studies, such as the use of *Eucheuma denticulatum* in Indonesia for its resilience to higher temperatures (Ndobe et al., 2020).

However, scaling remains hampered by finance, technical support gaps, and limited policy communication. As in other SIDS, sustained progress depends on clearer policy guidance, strengthened extension, infrastructure investment, and market access.

*Overall synthesis:* Across focus groups and surveys, Belizean seaweed farmers demonstrate ingenuity, strong social organization, and a capacity to adapt. The durability of these livelihoods under climate stress depends on converting community-led and reactive strategies into supported and system-level adaptation. The qualitative evidence points to a coherent agenda. Formalize and resource community practices. Institutionalize gender-sensitive and participatory governance. Invest in technical services and localized monitoring. Enable value-chain upgrading. These actions would better align Belize's community capabilities with national Blue Economy ambitions and would position seaweed mariculture as a resilient and equitable contributor to climate adaptation and sustainable livelihoods in SIDS.

### 6.4 Policy Analysis using PESTEL Tool

This study applied the PESTEL tool (Political, Economic, Social, Technological, Environmental and Legal factors) to assess the legislative and policy frameworks governing the seaweed mariculture industry in Belize. The analysis reveals a complex but evolving

landscape, in which binding legislation, non-binding strategic policies, and international agreements interact to shape opportunities and constraints for sustainable seaweed farming.

Binding Frameworks encompassed enforceable laws, such as the Fisheries Resources Act and Aquaculture Development Act, which provided the legal foundation for regulating mariculture activities. These frameworks established mandatory compliance requirements, environmental protections, and operational guidelines essential for sustainable development. Non-Binding Frameworks included strategic policies and plans, such as the Ocean Economy and Trade Strategy and the Mariculture Policy. Although these frameworks were not legally enforceable, they offered guidance and strategic direction for implementing initiatives aimed at promoting sustainable aquaculture practices. International Agreements involved commitments under global conventions like the United Nations Framework Convention on Climate Change (UNFCCC) National Adaptation Plan, which aligned Belize's national policies with international standards and supported marine conservation and climate adaptation efforts. Together, these instruments show Belize's political will to embed mariculture in its Blue Economy vision, yet they also reveal structural and enforcement challenges that constrain effective governance. The following goes in detail of the legislative framework that relates to seaweed farming operations and governance in Belize.

*Legislation framework:* The Belize Blue Economy Development Policy, Strategy, and Implementation Plan (2022-2027) represent the most comprehensive articulation of national intent to address various challenges related to the development of a sustainable blue economy. The policy emphasizes the need for a Blue Economy Act and strengthening existing sectoral regulations to ensure coherent policy implementation. It also highlights the need for enhanced institutional capacity, including the establishment of a Blue Economy Commission, to ensure effective inter-institutional collaboration and policy coherence.

Furthermore, the policy emphasizes financial innovation, capacity building, community engagement, and promotion of integrated and traceable sustainability standards. In this context, the creation of incentive packages to attract sustainable investments in both established and emerging sectors include developing sustainability criteria and monitoring their effectiveness. Strategies to mobilize investments beyond traditional financing are outlined, including blue bonds, carbon markets, and international funding sources. The policy prioritizes education and capacity building, focusing on reducing the skills gap, improving communication between education and blue industries, and enhancing ocean literacy. National academic institutions like the University of Belize and Galen University are crucial in this effort. Community engagement is prioritized, with the policy prioritizing blue justice and promoting the interests of ordinary workers, small-scale fishers, and vulnerable communities. Technological research and innovation are underlined, with investment in state-of-the-art scientific knowledge and predictive analytics essential for informed policy and investment decisions. The policy promotes an integrated management approach across sectors impacting species and habitats to ensure the sustainability of resources and ecosystems. Sustainable practices are associated with certifiable and traceable standards, promoting sustainability across all sectors.

However, there is the absence of an overarching legislative act and the persistence of legal gaps in frameworks. Specifically, the absence of a comprehensive Blue Economy Act is a significant barrier, and the policy suggests reforms to existing laws, such as the Coastal Zone Management Act and the Fisheries Resources Act, to better support blue economy principles. Legal gaps exist in several acts, including the Lands Act and Mines and Minerals Act, which lack provisions for blue space management, hampering effective policy implementation.

Moreover, the Belize Tourism Board Act, while not directly related to seaweed farming, plays a supportive role in aligning environmental sustainability and economic development across coastal industries. By aligning tourism policies with environmental protection and sustainable use principles, the tourism sector can support broader policy measures aimed at addressing hazards impacting seaweed farming.

*Correlation:* The interrelationships among the various PESTEL elements offer valuable insights into the ways in which different policy domains interact and mutually reinforce each other in addressing both climate-related and non-climatic hazards, notably in the context of seaweed farming. The policy analysis illustrates how different policy domains reinforce or undermine each other. These correlations have an impact on policies in the following manner:

The correlation between political and legal factors is strong, with a coefficient of 0.832 indicating strong interactions. This suggests that political decisions are closely linked to the legal environment. For example, if a government supports seaweed farming as a climate change strategy, the legal framework will establish clear regulations, effective enforcement systems, and penalties for non-compliance. This ensures that policies are effectively implemented, reducing the risk of maladaptation and protecting people's livelihoods. Thus, political and legal factors are interconnected and interconnected.

The correlation between politics and the environment is strong, with a coefficient of 0.811. This suggests that environmental factors are effectively incorporated into political decisions, leading to more resilient environmental policies promoting sustainable practices in seaweed farming. However, a decline in political backing may diminish the strength of these safeguards, exposing seaweed growers to heightened environmental hazards.

The relationship between legal and environmental factors is significant, with a weight of 0.802. It suggests that legally binding frameworks support environmental measures, ensuring compliance with standards and responsibility for harm. Seaweed farming could benefit from regulatory safeguards to prevent damage to marine ecosystems, ensuring industry sustainability. However, the effectiveness of these regulations depends on enforcement mechanisms' robustness and legal criteria's precision.

The moderate correlation indicates that political acts support social programs, particularly those focusing on community engagement and participation. This can lead to more comprehensive policies that effectively cater to local communities engaged in seaweed farming. However, the extent of influence could be restricted if persistent political backing or prioritization of social programs is lacking. This could result in policies that inadequately address climate and non-climatic hazards, resulting in ineffective community involvement or neglect of marginalized groups' needs.

Legal frameworks consider social issues, such as community rights and resource access in seaweed farming. However, a lack of comprehensive incorporation of social factors may lead to policies that are disconnected from practical circumstances, worsening poverty or imposing obstacles for aspiring seaweed growers, as the absence of such considerations can have significant implications.

The weight of social and environmental factors in this context is 0.711, suggesting a partial alignment between social and environmental policies. This alignment can help ensure environmental safeguards are not at the cost of social fairness, such as protecting marine ecosystems while ensuring the prosperity of local populations involved in seaweed cultivation. However, weak alignment may lead to policies disregarding environmental considerations or inadequately safeguarding social interests.



The coefficient correlation between the environment and the economy is 0.701. This suggests a balance between economic advancement and environmental preservation. However, for seaweed farming, the economic incentives for environmentally friendly practices may not be sufficient to overcome climate change challenges. Insufficient alignment between economic policies and environmental objectives could undermine seaweed farming's economic feasibility, potentially leading to maladaptation or increased poverty in coastal areas.

There were weaker correlations (less strong interactions) with technology and legal factors (0.621). The less significant correlation implies that legislative frameworks lack sufficient support for technological advancements. This could hinder the adoption of new technologies in seaweed farming, which are crucial for improving productivity and resilience to environmental changes. Without strong legal support, there might be insufficient protection for innovations or inadequate regulations to ensure the safe and effective use of new technologies, limiting the sector's ability to adapt to climatic and non-climatic hazards.

The lack of technological and economic policies in seaweed farming may hinder the adoption of technology, potentially leading to lost opportunities for productivity improvement or cost reduction. This could result in difficulties in competing or adapting to changing circumstances, potentially making the farmers economically susceptible.

The weak interaction between technological and environmental policies indicates that environmental goals are not strongly integrated with technological initiatives. This could lead to seaweed farming being more vulnerable to environmental dangers, such as pollution control technologies and climate-resistant farming techniques, thereby increasing the likelihood of maladaptation.

The study revealed that while some PESTEL factors interact strongly, others are less integrated, impacting the effectiveness of policy measures in addressing climate and non-climatic hazards in seaweed farming. While some areas, like legal and environmental protections, are supported by political actions, weaker correlations in technological and economic factors indicate gaps that could undermine policy effectiveness, leading to inadequate responses to hazards, higher barriers for new farmers, and increased compliance costs, potentially escalating poverty and hindering seaweed farming's development as a viable livelihood strategy.

#### 6.4.1 Challenges and opportunities in seaweed mariculture livelihoods

##### *High Correlations*

##### Political and Legal (0.832)

**Opportunities: Strong Policy Support:** The high correlation between political and legal factors suggests that policy frameworks and legal regulations are well-aligned in Belize. This alignment creates opportunities for seaweed mariculture by providing a stable legal environment, where policies can be effectively implemented and enforced, ensuring the protection of farmers' rights and access to resources.

**Institutional Strengthening:** With strong legal backing, there is an opportunity to develop comprehensive legal frameworks that support sustainable seaweed farming practices, enhance resource management, and ensure compliance with international standards.

**Challenges: Implementation Gaps:** Despite strong alignment, challenges may arise in the actual implementation of these policies, particularly in remote coastal areas where enforcement capacity may be limited. The legal framework needs to be adaptable to local contexts to address this challenge effectively.

#### Political and Environment (0.811)

**Opportunities: Environmental Prioritization:** The strong correlation between political and environmental factors indicates that environmental considerations are integral to political decision-making in Belize. This creates opportunities for promoting environmentally sustainable seaweed farming practices, which can help mitigate the impacts of climate change and protect marine ecosystems.

**Climate Change Mitigation:** Political support for environmental policies opens avenues for integrating seaweed farming into national climate adaptation strategies, leveraging seaweed's potential for carbon sequestration and ecosystem restoration.

**Challenges: Balancing Development and Conservation:** The challenge lies in balancing economic development with environmental conservation. While political support is strong, there may be pressure to prioritize short-term economic gains over long-term environmental sustainability, which could threaten the viability of seaweed farming.

#### Legal and Environment (0.802)

**Opportunities: Legal Protection of Ecosystems:** The strong correlation between legal and environmental factors highlights the role of legal frameworks in protecting marine ecosystems, which are vital for seaweed farming. Opportunities exist to strengthen these legal protections, ensuring that seaweed farming practices do not harm the environment and that critical habitats are preserved.

**Challenges: Enforcement of Environmental Laws:** A key challenge is ensuring that environmental laws are effectively enforced, particularly in areas where illegal fishing or pollution might threaten seaweed farming operations. Strengthening enforcement mechanisms and community-based monitoring could address this challenge.

#### *Moderate Correlations*

#### Social and Political (0.783)

**Opportunities: Community Engagement:** The connection between social and political factors suggests that community engagement and public participation are politically supported. This provides an opportunity to involve local communities in decision-making processes related to seaweed farming, ensuring that their needs and knowledge are integrated into policy development.

**Challenges:**

**Effective Implementation:** The challenge is to translate political support into effective community engagement that genuinely empowers seaweed farmers and addresses their concerns. There is a risk that top-down approaches may dominate, limiting the effectiveness of community participation.

#### Social and Legal (0.781)

**Opportunities: Socially Inclusive Legal Frameworks:** The moderate correlation indicates that legal frameworks are somewhat responsive to social concerns, offering an opportunity to develop legal measures that protect marginalized communities involved in seaweed farming. This could include ensuring fair access to resources, reducing barriers to entry, and promoting equitable benefits distribution.

**Challenges: High Compliance Costs:** A significant challenge is that the high cost of compliance with legal regulations may disproportionately affect small-scale seaweed farmers, potentially leading to exclusion from the formal market or increased vulnerability.

#### Environment and Economic (0.701)

**Opportunities: Sustainable Economic Growth:** The interaction between environmental and economic policies reflects an opportunity to promote economic growth in the seaweed farming sector while ensuring environmental sustainability. Properly structured economic incentives could support environmentally friendly practices and boost the sector's contribution to the national economy.

**Challenges: Inadequate Economic Incentives:** The challenge is ensuring that economic policies are fully aligned with environmental needs. Without adequate incentives, seaweed farmers may struggle to adopt sustainable practices, especially if these involve higher upfront costs or longer timeframes to realize economic benefits.

#### *Lower Correlations*

#### Technological and Legal (0.621)

**Opportunities: Technological Integration:** The moderate correlation suggests some potential for integrating technology into legal frameworks. Opportunities exist to develop legal support for technological advancements in seaweed farming, such as through the regulation of bioprospecting or the use of monitoring technologies.

**Challenges: Regulatory Gaps:** A key challenge is the gap in legal support for adopting new technologies, which could hinder innovation in the seaweed sector. Legal frameworks need to be updated to accommodate new technological developments and ensure that they are accessible to all farmers.

#### Technological and Economic (0.552)

**Opportunities: Innovation and Growth:** There is potential to drive economic growth in seaweed farming through technological innovation, such as the development of new farming techniques or processing methods that increase productivity and reduce costs.

**Challenges: Limited Support for Innovation:** The relatively low correlation indicates that economic policies may not sufficiently encourage technological innovation in seaweed farming. This could hinder the sector's ability to scale up and compete in international markets.

#### Technological and Environment (0.549)

**Opportunities: Environmental Monitoring:** There is an opportunity to use technology for environmental monitoring and risk management in seaweed farming, which could help mitigate the impacts of climate-related hazards and ensure sustainable practices.

**Challenges: Integration Issues:** The low correlation suggests that environmental policies are not strongly integrated with technological initiatives. This could mean missing opportunities to leverage technology for improving environmental sustainability in seaweed farming.

**Synthesis:** Overall, the PESTEL analysis indicates that Belize possesses a relatively strong political and legal foundation for seaweed mariculture, complemented by international commitments to climate adaptation. However, the weaker integration of social, economic, and technological dimensions reduces the coherence and effectiveness of existing frameworks.

This unevenness risks perpetuating barriers to entry for small-scale farmers, undermining inclusivity, and constraining the sector's potential to serve as both a sustainable livelihood and a climate adaptation strategy. Strengthening enforcement mechanisms, aligning economic incentives with environmental and social goals, and integrating technological innovation into legal and policy frameworks will be critical for advancing seaweed mariculture within Belize's Blue Economy agenda.

## 6.5 Conclusion of the PESTEL Policy Analysis

The PESTEL analysis of institutional and policy support for seaweed mariculture in Belize reveals a complex landscape with both significant opportunities and notable challenges. PESTEL policy analysis revealed both challenges and opportunities that align closely with global experiences. Politically, the emphasis on gender-sensitive policies and integration with coastal management practices is crucial. Economically, the sector must focus on integrating with broader mariculture practices and urban development strategies. Socially, building community resilience and addressing gender-specific challenges are key. Technologically, advancements in research and large-scale production are needed, while environmentally, long-term monitoring and sustainable practices must be prioritized. Legally, robust frameworks are essential to support the sector's role in climate change mitigation and resource management. By learning from global experiences, Belize can address these challenges and leverage the opportunities presented by seaweed farming to contribute to sustainable livelihoods and climate resilience. The following goes in detail of each factor in PESTEL.

### Political Factors

*Empowerment of Women in Seaweed Farming:* The potential for empowering women in Belize's seaweed farming sector mirrors that found in Zanzibar. Political support is essential for implementing gender-sensitive policies that ensure women's active participation and address gender-specific barriers, such as limited access to markets and resources (Torre-Castro et al., 2022). By adopting community-led adaptation initiatives, Belize could align its political strategies with those proven effective in Zanzibar, fostering a more inclusive industry.

*Integration with Coastal Management and Conservation Practices:* Belize's political commitment to integrating seaweed farming with broader coastal management and conservation efforts is vital for supporting the Blue Economy. However, the limited policy support and community engagement observed in Belize suggest a need for stronger political frameworks. In Bangladesh, similar challenges are addressed through enhanced policy support and greater community involvement, which could serve as a model for Belize to strengthen its political approach to coastal management (Hossain et al., 2021).

### Economic Factors

*Socio-economic Benefits and Food Security:* Economically, seaweed farming in Belize offers significant socio-economic benefits and enhances food security for coastal communities. However, challenges remain in integrating seaweed farming with other agricultural practices and broader climate adaptation strategies. India's experience with integrating seaweed farming into the broader agricultural economy highlights the importance of diversified economic practices for sustainability. Belize could leverage this approach to enhance its economic resilience and food security (Jagtap et al., 2022).

*Sustainable Urban Mariculture:* Urbanization poses economic challenges to Belize's coastal management, particularly concerning the integration of mariculture with urban sustainability goals. The Brazilian experience underscores the need for comprehensive urban-coastal

management policies that balance economic development with environmental sustainability. Belize could adopt similar policies to mitigate the economic pressures of urban development on coastal ecosystems (Schwahofer et al., 2021).

#### Social Factors

*Resilience Building in Seaweed Farming:* Socially, building resilience within Belize's seaweed farming communities is crucial for addressing climate change challenges. Improved farming techniques and community participation are essential, though economic barriers and gaps in technical support pose significant challenges. Tanzania's focus on community-driven adaptation strategies highlights the importance of social resilience, a practice that could be beneficially adopted in Belize to strengthen the social fabric of seaweed farming communities (Matoju et al., 2022).

*Gender-Specific Challenges in Seaweed Farming:* In terms of social equity, women in Belize's seaweed farming sector face gender-specific challenges similar to those identified in Tanzania, such as limited access to resources and decision-making power. Addressing these challenges through targeted support and policy interventions is crucial for social inclusion. Tanzania's approach to gender-sensitive policies could inform Belize's strategies to empower women in the sector (Rubekie et al., 2022).

#### Technological Factors

*Seaweed Farming as a Climate Adaptation Strategy:* From a technological perspective, Belize's seaweed farming holds potential as a climate adaptation strategy. However, further technological advancements are needed, particularly in research and market expansion. Indonesia's success with disease-resistant seaweed species suggests that Belize could explore similar technological innovations to enhance the sector's resilience to climate change (Ndobe et al., 2020).

*Challenges in Large-Scale Production:* Technologically, Belize faces challenges in scaling up seaweed farming due to limitations in genetic diversity and disease resistance. The experience in Brazil emphasizes the need for detailed technological understanding of physiological processes, which Belize could focus on to overcome these production challenges (Hayashi et al., 2019).

#### Environmental Factors

*Sustainable Seaweed Farming and Economic Inclusion:* Environmentally, seaweed farming in Belize is considered a sustainable practice that promotes economic inclusion. However, there are gaps in technical knowledge and a need for capacity-building initiatives to ensure environmental sustainability. Brazil's approach to eco-friendly practices and local community involvement provides a framework that Belize could adopt to enhance the environmental sustainability of its seaweed farming (Pereira et al., 2021).

*Long-term Ecological Monitoring:* Long-term environmental monitoring and adaptive management are critical for the sustainability of seaweed farming in Belize. Drawing from Chile's Humboldt Current System, which emphasizes continuous ecological monitoring, Belize could implement similar environmental monitoring strategies to adapt to changing conditions and ensure the long-term health of its marine ecosystems (Thiel et al., 2007).

#### Legal Factors

*Seaweed as a Tool for Climate Change Mitigation:* Legally, seaweed farming in Belize has the potential to contribute significantly to climate change mitigation through carbon

sequestration and habitat restoration. The legal frameworks that support such activities are crucial for maximizing their environmental benefits. Bangladesh's experience illustrates the importance of robust legal support to enhance the ecological services provided by seaweed farming, a lesson that Belize could apply to strengthen its legal frameworks (Bhuyan et al., 2021).

*Sustainable Management of Wild Seaweed Resources:* Legal regulations are also essential for balancing the wild harvest of seaweed with cultivated practices to ensure sustainability. Global practices suggest that integrated legal approaches are necessary to protect wild seaweed resources while promoting sustainable farming practices. Belize could develop such legal frameworks to safeguard its marine resources while supporting the growth of the seaweed farming industry (Kraan, 2020).

Overall, the PESTEL analysis highlights a dual narrative. Belize has political and legal momentum to advance seaweed farming as a livelihood strategy and climate adaptation measure, but weak integration of social, economic, and technological dimensions undermines this potential. Specifically, the political dimensions revealed a strong alignment between policy frameworks and legal regulations, which were crucial for effective governance in seaweed mariculture. However, challenges remain in the implementation of these policies, particularly in ensuring that they were adaptable to local contexts and effectively enforced in remote coastal areas. Economically, the sector presented opportunities for sustainable growth, particularly when environmental considerations were integrated into economic policies. However, the lack of sufficient economic incentives for environmentally friendly practices posed a challenge, potentially hindering the sector's ability to thrive sustainably. Socially, there was political support for community engagement, but the challenge lied in ensuring that this translates into genuine empowerment and inclusion of marginalized communities. The legal frameworks were somewhat responsive to social concerns, offering opportunities for socially inclusive policies, yet high compliance costs could exclude small-scale farmers from the formal market. Technologically, there were opportunities to enhance the sector through innovation and integration with environmental monitoring, but the relatively low correlation between technological and legal or economic factors indicated gaps that need to be addressed. Without stronger support for technological advancements, the sector may struggle to adopt new methods that could improve productivity and adaptation. Environmentally, Belize has a strong legal framework supporting the protection of marine ecosystems, which was essential for the sustainability of seaweed farming. However, the challenge remained in enforcing these laws effectively and ensuring that economic policies do not undermine environmental sustainability. Addressing these gaps are crucial for realizing seaweed mariculture as a cornerstone of Belize's sustainable Blue Economy. Strengthened institutional capacity, inclusive governance, targeted economic incentives, and investment in technological innovation are essential to ensure that seaweed farming contributes not only to livelihood security but also to national climate adaptation strategies and broader sustainable development goals in SIDS.

## 6.6 Quantitative Analysis with Surveys and Implications

The quantitative analysis provides insights into the distribution of livelihood resources, seaweed farmer characteristics, the hazards faced by seaweed farmers, and the responses employed to address these challenges. The findings are contextualized within the broader literature, revealing both alignments with and deviations from global trends. This section highlights the critical factors that impact seaweed farming productivity and sustainability, offering an evidence base for targeted interventions and policies to strengthen livelihoods in Belize and SIDS in similar contexts. The following subsections further elaborate on the key findings of the quantitative surveys:

### 6.6.1 Hazards and responses in seaweed farming livelihoods

The study revealed significant association between environmental, climatic, and socio-economic hazards and the strategies employed by farmers to cope with them. The hazards identified, such as environmental and climatic issues, regulatory complexities, and limitations in human and financial resources, were consistent with the broader challenges documented in the literature (e.g., Matoju et al., 2022; Ndobe et al., 2020; Hossain et al., 2021). Table 5.4 provides insights into the capacity of seaweed farming to respond to hazards, including environmental and climatic issues. These were further categorized and cross tabulated in Table 5.5 and illustrated in Figure 5.5 of which the summary reveal a multi-dimensional approach to seaweed farming further elaborated below.

*Climate Resilience and Species Selection:* The findings that environmental and climatic issues are the most prevalent hazards align with the literature's emphasis on the need for climate-resilient seaweed species and improved farming techniques. Ndobe et al. (2020) demonstrated that certain species like *Eucheuma denticulatum* show higher resilience to adverse environmental conditions, indicating the importance of selecting appropriate species to cope with climate variability.

*Role of Community-Based Approaches:* The frequent use of community-based approaches and social capital as coping mechanisms highlights the importance of collective action in enhancing adaptive capacity. This is supported by Matoju et al. (2022), who stressed the significance of community participation and indigenous knowledge in building long-term resilience. However, the study also points out that these strategies may only be effective in the short term, necessitating more sustainable, long-term solutions.

*Policy and Institutional Support:* The underutilization of government and external support as a response strategy suggests a gap in policy and institutional frameworks that could better support seaweed farmers in managing risks. This echoes the findings of Hossain et al. (2021), who called for stronger policy support and community engagement to integrate seaweed farming with broader climate adaptation strategies effectively.

*Economic and Infrastructure Challenges:* The even distribution of responses related to infrastructure and financial capital across different hazards indicates that economic and infrastructure challenges are pervasive and multifaceted. Schwahofer et al. (2021) and Pereira et al. (2021) highlighted similar concerns, emphasizing the need for targeted investments in technical assistance, research and development, and financial credit to enhance the sustainability of seaweed farming.

*Complex Interactions and the Need for Adaptive Management:* The lack of significant linear relationships between hazards and responses suggests that the interactions between these variables are complex and context dependent. Thiel et al. (2007) and Bhuyan et al. (2021) also noted the intricate nature of sustainability in seaweed farming, advocating for adaptive and co-participative management strategies to respond effectively to environmental changes and socio-economic pressures.

Overall, these findings emphasize the need for a multi-faceted approach to managing seaweed farming livelihoods, one that integrates climate-resilient practices, community-based initiatives, robust policy support, and adaptation management strategies. Addressing these challenges will be crucial for sustaining the livelihoods of seaweed farmers in the future. Without this integration, adaptation strategies will remain fragmented and reactive.

### 6.6.2 Model for measuring and strengthening seaweed livelihoods

The multiple linear regression model (Model 13, backward method) examined the impact of livelihood capitals on seaweed production (determined by wet weight). The model integrated human, social, natural, physical, financial, and cultural capital variables derived from SLF. The results in Table 5.10 revealed that specific variables across these capitals significantly

impacted productivity, highlighting the multi-dimensional nature of seaweed farming livelihoods in Belize.

*Significant Predictors of Seaweed Production:* Key findings from the model indicated that years of experience, gender, seaweed loss, ecosystem-based adaptation (EbA), community-based adaptation (CbA), and traditional knowledge approaches were significant predictors of seaweed production. This confirmed that human capital (years of experience), financial capital (household income and seaweed income), natural capital (EbA and seaweed losses), social capital (gender approaches), and cultural capital (traditional knowledge) were pivotal for seaweed farming in Belize of which these significant findings are further elaborated below.

Among the human capital variables, years of experience in seaweed farms ( $p = 0.045$ ,  $R^2 = 0.597$ ) emerged as a significant determinant of productivity. This indicated that farmers with longer engagement in seaweed cultivation were able to achieve higher yields, likely due to accumulated practical knowledge and adaptive techniques. This finding was consistent with studies such as Ndobe et al. (2020), who found that experienced Indonesian farmers developed effective adaptive practices, such as optimizing depth placement and selecting temperature-tolerant species that improved yield under climatic stress. Similarly, Hossain et al. (2021) observed in Bangladesh that experience enhanced farmers' technical competence, risk perception, and willingness to adopt innovations, contributing to more sustainable outcomes. The Belizean results therefore demonstrated that experience functioned as a crucial human capital asset for sustaining seaweed production under changing environmental conditions.

Within social capital, gender ( $p = 0.045$ ,  $R^2 = 0.228$ ) and CbA approaches ( $p = 0.034$ ,  $R^2 = 0.462$ ) were both statistically significant. This suggested that gender roles and participation in community-driven adaptation practices significantly affected productivity. The gender-related result reflected the structural realities of coastal mariculture systems in which men and women occupied distinct but complementary roles. Comparable findings were reported in Tanzania and Zanzibar, where women's empowerment through community cooperatives enhanced farm performance and collective adaptation to environmental stress (Rubekie et al., 2022; Torre-Castro et al., 2022). The significance of the CbA variable indicated that collective social organization and participatory learning approaches played an essential role in strengthening farmers' adaptive capacity, aligning with Matoju et al. (2022), who emphasized that community-driven adaptation strategies enhance long-term sustainability in seaweed farming livelihoods.

For natural capital, both seaweed loss ( $p = 0.044$ ,  $R^2 = 0.667$ ) and EbA approaches ( $p = 0.034$ ,  $R^2 = 0.462$ ) significantly impacted production. These results suggested that environmental degradation, species vulnerability, and ecological management practices were decisive in determining output levels. Similar associations were observed by Bhuyan et al. (2021), who reported that seaweed ecosystems provide crucial ecological services such as nutrient cycling and carbon sequestration but are increasingly threatened by warming seas and disease outbreaks. Pereira et al. (2021) also demonstrated that in Brazil, sustainable farming practices and ecosystem-based management improved both productivity and environmental outcomes in *Hypnea pseudomusciformis* farming. The Belizean results thus underscored the necessity of embedding ecosystem-based strategies within mariculture management to mitigate environmental risks and sustain yields.

Regarding financial capital, both household income and seaweed income ( $p = 0.045$ ,  $R^2 = 0.643$  for both variables) were found to have statistically significant effects on production. This indicated that financial stability and diversified income sources enabled farmers to invest in inputs, maintenance, and equipment that enhanced productivity. These findings aligned with those of Gegg and Wells (2019), who argued that access to finance and investment



incentives were vital for scaling seaweed-related enterprises, and with Matoju et al. (2022), who emphasized that financial security supported adaptive decision-making among Tanzanian farmers. The Belizean evidence similarly demonstrated that stable financial capital strengthened resilience by allowing farmers to absorb shocks and reinvest in their operations.

The final significant predictor was traditional knowledge ( $p = 0.046$ ,  $R^2 = 0.500$ ), which represented cultural capital. This finding reaffirmed the enduring relevance of indigenous and community-based knowledge systems in guiding sustainable and adaptive practices. Kraan (2020) observed that traditional ecological knowledge was central to maintaining sustainability in global seaweed collection and cultivation systems, while Torre-Castro et al. (2022) highlighted that integrating traditional practices with modern approaches enhanced both gender inclusion and adaptive responses in East African seascapes. Similarly, in Belize, farmers' inherited knowledge and cultural familiarity with marine ecosystems contributed meaningfully to the ecological and social sustainability of their livelihoods.

*Non-Significant Predictors:* Other variables, including education, health, formal training, household size, integration of CbA and EbA, farm size, boat equipment, value-adding, remittance, and savings, were not statistically significant ( $p > 0.05$ ). These results indicated that while such factors contributed indirectly to livelihood sustainability, they did not exert a direct measurable effect on production levels. Comparable findings were reported by Schwahofer et al. (2021), who found that although education and technological inputs contributed to broader sustainability outcomes, productivity in Brazilian mariculture was primarily driven by experiential learning and access to natural and financial resources.

The use of transformed variables such as square root and logarithmic transformations was crucial for meeting the assumptions of linear regression, ensuring the robustness and reliability of the model. This model offers valuable insights for policymakers and development practitioners.

*Synthesis:* The regression model highlighted that seaweed farming productivity in Belize was predominantly influenced by the interplay of human, social, natural, financial, and cultural capitals. The results provided quantitative confirmation that farmers' experience, gendered participation, community-based and ecosystem-based approaches, financial stability, and traditional knowledge formed the core determinants of production success. These findings aligned closely with global evidence (Bhuyan et al., 2021; Hossain et al., 2021; Matoju et al., 2022; Ndobe et al., 2020; Pereira et al., 2021; Torre-Castro et al., 2022), demonstrating that sustainable seaweed livelihoods depend on the simultaneous strengthening of social and ecological systems.

The findings evidenced that policy interventions should prioritize capacity-building initiatives that enhance experiential learning and the integration of traditional and scientific knowledge; expand financial access mechanisms tailored to small-scale farmers; and reinforce institutional frameworks that link community-based adaptation with ecosystem-based management. Strengthening these interrelated livelihood capitals would not only improve production but also advance the broader objectives of the Blue Economy and climate adaptation strategies in Belize and other SIDS.

## 6.7 Conclusion of Quantitative Assessment

The quantitative assessment of seaweed mariculture livelihoods in Belize provided valuable empirical insights into the sustainability of mariculture within the context of SIDS. The study identified that sustainability is shaped by a complex interaction between environmental hazards, socio-economic characteristics, and livelihood capitals. The evidence demonstrated that while seaweed farming contributes to economic diversification and coastal livelihood

security, its long-term sustainability depends on strengthening ecological, financial, social, and cultural foundations simultaneously. The following conclusions were made based on the findings of the quantitative aspects of that seaweed farmers responded to in the survey.

*Socio-economic Characteristics and Livelihood Context:* The socio-economic analysis revealed that seaweed farming in Belize was concentrated in small coastal communities, primarily within Stann Creek and Belize Districts. The sector engaged a relatively young and active demographic, with a balanced gender distribution, indicating growing inclusivity and evolving gender roles within mariculture. Similar trends were observed in East African contexts, where women's participation in seaweed cooperatives enhanced livelihood diversification and collective sustainability (Torre-Castro et al., 2022; Rubekie et al., 2022).

The analysis also showed that while most farmers possessed at least secondary-level education and moderate technical training, the sustainability of their operations was more strongly linked to experiential learning and traditional ecological knowledge than to formal education. This aligns with findings by Schwahofer et al. (2021), who observed that experiential knowledge and local environmental understanding were more influential for sustainable mariculture practices than technological or academic factors. The higher rate of home ownership compared to national averages further reflected a degree of socio-economic stability that supported continuous engagement in the sector, reinforcing the role of livelihood security as an essential dimension of sustainability.

Overall, the demographic and socio-economic characteristics confirmed that Belize's seaweed farmers are embedded within a multi-livelihood coastal economy that integrates fishing, tourism, and mariculture. This diversification offers both a safety net and a pathway for sustainable development within the Blue Economy framework.

*Hazards and Responses:* The assessment of hazards and responses revealed that seaweed farmers face a variety of challenges, with environmental and climatic hazards being the most commonly reported, followed by limitations in human and financial resources, regulatory barriers, and safety issues. Statistical tests confirmed significant associations between specific hazards and corresponding response strategies. EbA and CbA were the most frequently employed responses, demonstrating the importance of ecological management and collective organization in sustaining seaweed farming operations.

These results reflected global evidence where community-driven and ecosystem-based responses form the backbone of sustainable mariculture in the face of environmental uncertainty (Matoju et al., 2022; Pereira et al., 2021). However, the limited use of government and external support in Belize indicated an institutional gap in policy implementation and resource mobilization for small-scale seaweed farmers. Similar governance challenges have been observed in Tanzania and Brazil, where fragmented institutional frameworks hindered long-term sustainability despite community commitment (Schwahofer et al., 2021; Hossain et al., 2021).

The absence of significant linear relationships between hazards and responses indicated that sustainability outcomes were impacted by non-linear and context-dependent interactions among social, ecological, and economic variables. As Bhuyan et al. (2021) and Thiel et al. (2007) emphasized, the sustainability of seaweed farming requires adaptive management approaches that are flexible enough to address environmental variability and socio-economic diversity simultaneously.

*Livelihood Capitals and Sustainability Determinants:* The multiple linear regression model further identified specific variables across livelihood capitals that significantly impacted seaweed farming sustainability. Human (years of experience), social (gender), natural (EbA and seaweed losses), financial (household and seaweed income), and cultural (traditional

knowledge) capitals emerged as the most significant predictors. These results confirmed that sustainability was reinforced through the integration of knowledge systems, inclusive participation, ecological stewardship, and economic stability. Farmers with longer experience were better equipped to manage environmental challenges and sustain production through accumulated skills and locally relevant practices, consistent with findings from coastal regions of Indonesia and Bangladesh (Ndobe et al., 2020; Hossain et al., 2021).

Gender participation and community engagement reflected the importance of social capital in strengthening collective governance and knowledge sharing, echoing Torre-Castro et al. (2022) and Rubekie et al. (2022), who documented similar outcomes in coastal regions of East African mariculture. Natural capital, represented by ecosystem-based management and seaweed loss variables, emphasized the dependence of Belizean farmers on healthy marine environments for sustaining yields, consistent with global evidence that ecological degradation undermines mariculture viability (Bhuyan et al., 2021; Pereira et al., 2021).

Financial stability, captured through household and seaweed income, was another critical determinant of sustainability. Consistent with the conclusions of Gegg and Wells (2019) and Matoju et al. (2022), financial capital not only enabled investment in farm maintenance but also allowed farmers to diversify income sources, enhancing their long-term viability within the Blue Economy. Cultural capital, through the integration of traditional knowledge ( $p = 0.046$ ,  $R^2 = 0.500$ ), reinforced the sector's social and ecological sustainability by maintaining continuity between inherited knowledge systems and contemporary practices, as emphasized by Kraan (2020) and Torre-Castro et al. (2022).

Nevertheless, this study contributes new empirical evidence specific to Belize and the wider Caribbean by identifying the critical need for enhanced institutional coordination, financial inclusion mechanisms, and the formal integration of traditional and community-based knowledge into policy frameworks. These findings highlight that sustainability cannot rely on ecological or financial dimensions alone but require an integrated approach that connects community-driven practices with national-level governance and the objectives of the Blue Economy.

Strengthening these interdependent livelihood capitals will not only safeguard the long-term sustainability of seaweed farming in Belize but will also contribute to broader regional strategies for climate change adaptation and sustainable ocean-based development in SIDS.

## 6.8 Limitations and Shortcomings of Study

The study faced limitations, both methodological and contextual, that influenced the depth, scope, and interpretation of its findings. The most significant limitation was the availability of information. The existing research gap on this topic meant that there was an insufficient body of literature to gather relevant information from, hindering the ability to perform deeper analytical methods, such as in-depth statistical analysis using socio-economic and environmental data at a national scale. Consequently, the results in this research primarily served as a baseline for future studies. Many publications on seaweed farming in Belize lacked detailed information, and some were pre-release documents to which the researcher could not gain full access, making direct evaluation challenging. Additionally, some articles used were not peer-reviewed, as they were sourced from government websites that provided policies and documentation related to the country. Access to actual seaweed production data before and after hazards (both climate and non-climate related) would have been beneficial for further analysis.

The researcher had intended to disseminate questionnaires and conduct interviews with individuals directly associated with blue bonds in government offices. However, despite

attempts to contact the relevant government department, no favorable response was received, suggesting a reluctance to share certain information. Moreover, certain government documents related to the blue economy and seaweed mariculture were still in various stages of preparation, and although available for perusal, they could not be used as references or evidence to support the research narrative.

The researcher's Belizean nationality provided insider knowledge of seaweed farming practices, which was advantageous for contextual interpretation. However, this familiarity introduced the potential for subjective bias. This bias was mitigated by employing scientific methods of thematic and content analysis. Ethical considerations were rigorously adhered to throughout the research process, guided by the principles of respect for people, beneficence, and justice (The National Commission for Protection of Human Subjects of Biomedical and Behavioral Research, 1979). During the scoping and systematic literature review, the researcher occasionally encountered published articles that did not include a discussion of ethics. This omission limited the researcher's understanding of the ethical considerations in those studies. Attempts to contact the authors for more concrete details were unsuccessful, leaving the researcher to rely on the information provided in gray literature and other sources.

#### 6.8.1 The use of PRAs and the CRiSTAL toolkit

The application of Participatory Rural Appraisals (PRAs) and the CRiSTAL (Community-based Risk Screening Tool Adaptation and Livelihoods) toolkit presented methodological limitations that impacted the depth and breadth of the analysis. While PRAs have been lauded for their effectiveness in involving community members and eliciting high levels of responsiveness during interviews (Buyinza et al., 2009; Bales et al., 2014), their application in this study was not without challenges. One notable limitation was the potential for the standardized nature of PRAs to restrict genuine participation. As noted by Riemer (1999), there is a risk that PRAs can devolve into a "fill-in-the-blank exercise", where the format dictates responses, thereby limiting the depth of community involvement and the richness of data collected.

Moreover, the CRiSTAL toolkit, while useful for assessing livelihood and environment interactions including hazard screening, was limited in capturing the complexity of the socio-economic and environmental dynamics within the seaweed farming communities. The tool's reliance on qualitative data required extensive community engagement, which was difficult to achieve consistently across the dispersed and remote locations of the study sites in Belize. This logistical challenge limited the comprehensiveness of the data collected, as not all relevant stakeholders could be reached. Additionally, its implementation required considerable local knowledge and contextual interpretation, which could have introduced unintentional bias or overlooked critical nuances.

Another limitation of the CRiSTAL toolkit was its static framework, which did not adequately account for the evolving nature of climate hazards and the need for adaptations strategies over time. This limitation hampered the ability to fully understand how adaptation measures had changed or needed to evolve in response to ongoing environmental changes. Additionally, the toolkit's effectiveness was constrained by the need for significant local knowledge and expertise to accurately interpret the data, which may have introduced biases or led to the overlooking of critical local insights.

The focus group discussions, integral to both PRAs and the CRiSTAL toolkit application, also encountered challenges. Group dynamics sometimes led to dominant voices overshadowing quieter participants, potentially skewing the findings and providing an incomplete representation of the community's perspectives. Furthermore, the diversity of participants' backgrounds and education levels made facilitation and clear communication challenging,

occasionally resulting in misinterpretations or superficial responses that did not fully capture the complexity of the issues. These limitations emphasized the need for triangulation and complementary qualitative tools, such as in-depth interviews and participatory observation, to achieve a holistic understanding of sustainability in seaweed farming livelihoods. Incorporating the six livelihood capitals within such frameworks would allow for more comprehensive assessments of sustainability in future applications (Riemer, 1999; Buyinza et al., 2009; Bales et al., 2014).

#### 6.8.2 Sampling of survey respondents and survey data

A targeted non-probability sampling approach was employed to identify and survey active seaweed farmers in Belize. The sample was drawn from a list provided by the Belize Fisheries Department and environmental non-governmental organizations (E-NGOs), focusing exclusively on identified seaweed farmers. The researcher contacted these farmers through letters of invitation to participate in a CRiSTAL workshop, followed by surveys to gather data. This method ensured the inclusion of active seaweed farmers, aligning with the study's focus. However, the non-probability nature of sampling introduced potential biases, particularly a lack of randomization, which may have led to selection bias. The sample may have overrepresented farmers who are more engaged with these organizations, possibly excluding less connected or more isolated farmers. As a result, generalizations from the survey results to the broader population of seaweed farmers in Belize should be approached with caution, acknowledging that the sample might not fully represent the diversity and variability of the entire seaweed farming community. A significant challenge encountered during the study was the length of the survey, which required a minimum of 45 minutes to complete. This extended duration may have contributed to respondent fatigue, potentially affecting the quality and accuracy of the responses. The length of the survey could also have deterred some participants from fully engaging in or completing the survey, thereby impacting on the overall data collection process.

Moreover, the in-depth survey of 95 questions consisted of closed-ended and open-ended questions, combining them with data for both qualitative and quantitative analysis. Even though the sample group was small, with less than 20 participants, it was critical to obtain in-depth information about the components of seaweed farming to understand the complexity of respondents' perspectives on achieving sustainability in this livelihood activity. This approach allowed the researcher to capture nuanced insights that may not have been evident through quantitative data alone. Incorporating open-ended questions alongside closed-ended ones enriched the data collection process by providing respondents with the opportunity to elaborate on their answers, express personal experiences, and offer detailed opinions (Rahman, 2016). This method acknowledged the complexity of human thoughts and behaviors, enabling a comprehensive understanding of the research topic beyond numerical data. Segmenting data analysis techniques into quantitative and qualitative methods was advantageous for categorizing information, but it had the potential to intensify conflicts between quantitative and qualitative researchers (Silverman, 2010). The survey design incorporated a blend of closed-ended and optional open-ended questions, enabling respondents to offer more context or explanation, thereby augmenting the depth of the gathered data.

The open-ended questions in the online surveys were made optional to accommodate respondents' varying levels of engagement, allowing for in-depth responses while respecting their time and willingness to share. The responses from all open-ended questions were gathered and analyzed in a centralized database for systematic purposes. Data cleaning involved removing personal identifiers to maintain respondent confidentiality, correcting minor grammatical and spelling errors, and handling incomplete responses to ensure clear and

complete data. Researchers read through the responses multiple times to familiarize themselves with the data and understand its depth and breadth, ensuring that conclusions were drawn from clear and complete data.

Open-ended responses offered depth of insight, revealing underlying motivations and experiences that quantitative data may have overlooked. They allowed for unexpected themes and insights, providing a more comprehensive understanding of the subject matter. Additionally, open-ended responses gave respondents a voice, potentially increasing engagement and satisfaction with the survey process. Qualitative data analysis presented challenges such as time-consuming analysis, subjectivity due to researcher bias, and variability in response quality due to optional questions, which could affect data consistency across participants and lead to varied response rates and depths.

#### 6.8.3 Sampling of elite interviews

The elite interviewees faced limitations in terms of methodological limitations, restricted access to information related to seaweed in ongoing projects and policy developments, small sample size potential response bias, ethical concerns, and generalizability. Scheduling constrains limited participation, reducing the intended pool of high-level policy and institutional respondents. Access to these individuals was often limited due to their busy schedules, which led to a smaller sample size than initially planned.

Response reliability was another concern, as elite interviewees were often more guarded or strategic in their responses due to their positions of power or influence. This compromised the authenticity and reliability of the data collected. Power dynamics between the researchers and elite interviewees also influenced the interview process, with elites sometimes dominating the conversation or resisting probing questions. Small sample sizes were common due to the limited number of individuals who qualified as elites in a given context. While this allowed for in-depth exploration of each interviewee's perspective, it limited the generalizability of the findings. Non-response bias occurred when certain elites declined participation, leading to an overrepresentation of certain views or experiences and an underrepresentation of others.

Ethical concerns arose from interviewing elites, particularly regarding confidentiality and the potential consequences of disclosing sensitive information. Elites often required assurances of anonymity or refused to share certain information, which limited the depth of the interview. Generalizability was another limitation, as the findings from elite interviews were not easily generalizable to other groups or settings. To address these limitations, careful consideration of the research design and thorough analysis were necessary.

The elite interviews utilized qualitative data from open-ended questions, following a thematic analysis approach described by Braun and Clarke (2006). The coding process was divided into three stages: open coding, axial coding, and selective coding. Qualitative data analysis software like NVivo was used to efficiently organize, manage, and retrieve information from the data. Inter-coder reliability was ensured through the involvement of multiple researchers, reducing bias and discussing discrepancies. An audit trail maintained detailed documentation of the analysis process, enhancing the credibility and trustworthiness of the findings.

#### 6.8.4 Socio-economic and socio-legal overlap of PESTEL tool

The application of PESTEL (Political, Economic, Social, Technological, Environmental, Legal) policy analysis tool presented limitations related to categorization and scope. While PESTEL provided a valuable macro-level overview, it often oversimplified complex, interdependent relationships between categories. It provided broad categories that might have oversimplified complex issues, leading to a loss of nuance in how different elements interacted within a category or across categories. For example, political and legal factors were

closely intertwined in Belize's regulatory context, making strict separation artificial. Similarly, cultural dimensions, though interwoven throughout social and environmental factors, were not explicitly represented within the framework.

PESTEL was typically used as a snapshot analysis tool, which could have overlooked the dynamic nature of policy environments. Subjectivity in categorization could have led to potential inconsistencies in the analysis. The complexity of multi-sectoral policies, particularly in areas like sustainable development, might not have been fully captured, resulting in an incomplete understanding of the policy landscape. PESTEL focused more on identifying external factors that impacted policies rather than on the implementation of these policies. The risk of overemphasis on external factors might have underrepresented internal organizational factors, such as capacity, leadership, or institutional culture, which were crucial for understanding policy outcomes. While PESTEL included social factors, it might not have fully captured the perspectives and influence of various stakeholders involved in the policy-making process. Challenges in quantifying impact could have affected the ability to prioritize actions or allocate resources effectively.

PESTEL was not perfectly suited for all types of policy analysis, especially those requiring a more detailed or sector-specific approach. In summary, while PESTEL was a useful framework for identifying and categorizing factors influencing policy decisions, its limitations should have been acknowledged and mitigated through the use of complementary tools and methods in policy analysis.

#### 6.8.5 Analytical and methodological challenges of the mixed methods design

The mixed-methods approach combined contextual understanding with qualitative insights to provide a comprehensive perspective on the findings, aiming to add depth and scholarly relevance by highlighting the reasons and context behind certain views. While this approach offered valuable insights, it also presented significant challenges in data integration, managing diverse data sources, and ensuring that the findings from different methods were balanced and aligned. This complexity was heightened by the multidisciplinary nature of the study, combining socio-economic analysis, policy analysis, and environmental assessment within a single framework.

Qualitative surveys often generated rich, detailed narratives that were difficult to systematically analyze and integrate with quantitative data, leading to varied interpretations and complicating efforts to identify common trends. Similarly, elite interviews, involving individuals with significant influence or expertise, introduced bias and may not have fully represented the broader population, potentially skewing the findings. The PESTEL policy analysis posed another challenge, particularly in integrating broad contextual findings with specific, localized data from surveys and interviews. The wide range of factors covered in the PESTEL analysis sometimes did not directly influence localized farming practices, adding another layer of complexity to the data integration process.

Quantitative surveys faced their own set of challenges, including issues in survey design and data alignment. Capturing relevant quantitative data while ensuring alignment with qualitative insights was difficult, particularly in diverse farming communities. Ensuring the reliability and validity of quantitative survey data was also challenging. Model complexity further complicated the process, such as developing and interpreting a linear regression model that accurately reflected the socio-economic and environmental factors influencing seaweed farming required careful integration of qualitative insights. Additionally, generalizability posed a challenge, as findings from quantitative models may not have been applicable across

different contexts, especially if the models did not account for region-specific variables identified in qualitative data.

Even though the sample size captured all active seaweed farmers in Belize (N = 18), there were limited statistical power and generalizability. Similarly, focus group discussions, though providing valuable qualitative depth, were geographically restricted to key communities such as Belize City, Placencia, and Riversdale. This limited geographic scope may not reflect the full diversity of experiences among seaweed farmers in SIDS. Sampling a specific group of the population also introduced potential biases. Self-reported data from surveys and interviews could be subject to recall or social desirability bias. Power imbalances in elite interviews may also have influenced responses. Furthermore, cross-sectional design restricted the ability to observe change over time; longitudinal studies would provide stronger evidence of how sustainability practices evolve in relation to environmental or policy shifts.

Interpreting relationships between variables was further complicated by low expected counts in certain Chi-Square tests, reducing statistical reliability. Non-linear relationships between hazards and livelihood responses indicated that sustainability in seaweed farming was shaped by multi-directional interactions that did not conform to simple causal patterns, a challenge similarly recognized by Pereira et al. (2021). These methodological issues reflected broader analytical difficulties noted in sustainability research, where human, ecological, and institutional systems interact in complex, context-dependent ways (Gegg and Wells, 2019).

Despite these challenges, the mixed-methods approach provided a comprehensive understanding of the factors influencing seaweed farming livelihoods. Overcoming the difficulties in data integration, managing diverse data sources, and aligning findings from different methods required careful planning, methodological rigor, and a thoughtful approach to data synthesis. This ensured that the final conclusions were robust and reflective of the complex realities faced by seaweed farming communities. For instance, the study by Torre-Castro et al. (2022) in Zanzibar, Tanzania, utilized a mixed-methods approach combining both quantitative and qualitative analysis to explore the adaptive capacity of women in seaweed farming against climate change. The study highlighted the challenge of integrating qualitative insights with quantitative data, particularly when dealing with complex social issues like gender and empowerment. The authors addressed this challenge by applying a thematic analysis to qualitative data and aligning it with quantitative indicators of adaptive capacity, thereby offering a more holistic understanding of the factors influencing resilience among seaweed farmers. This method ensured that both the numerical data and the narratives from the participants were effectively synthesized to provide a comprehensive view of the subject matter. Similarly, the research by Schwahofer et al. (2021) along the Brazilian coast employed a mixed-methods approach, emphasizing the integration of mariculture practices with urban sustainability goals. The study encountered challenges in synthesizing diverse data sources, particularly when trying to align broad contextual findings from urban planning and environmental policies with specific, localized data from mariculture practices. The authors managed these challenges by systematically analyzing qualitative interviews alongside quantitative production data, ensuring that the findings from both methods informed the overall strategic recommendations for sustainable development in the region.

The mixed methods approach therefore required significant analytical discipline to balance methodological rigor with interpretive flexibility. This research design enabled to capture the interconnected social, ecological, and institutional dynamics shaping the sustainability of seaweed mariculture in Belize. The process also reinforced the importance of methodological transparency and reflexivity in future studies examining sustainability within small-scale mariculture systems in SIDS. Future studies could strengthen this field by expanding the



sample size to include a broader representation of seaweed farmers across multiple islands or coastal regions, applying longitudinal designs to observe changes over time, and integrating participatory and quantitative methods in a more systematically balanced manner. Enhancing methodological rigor in these areas would increase the reliability, comparability, and generalizability of findings, thereby contributing to a more comprehensive understanding of the sustainable development of seaweed farming and its role in blue economy strategies in SIDS.

## 6.9 Summary

Chapter 6 provided a comprehensive examination of the livelihoods of seaweed farmers in Belize, integrating qualitative and quantitative evidence to interpret the sustainability of seaweed mariculture within the context of SIDS. Through focus group discussions, semi-structured survey interviews, elite interviews, and policy analysis, the chapter demonstrated how environmental, social, economic and institutional factors impact the sustainability of seaweed farming livelihoods. The analysis was contextualized within global literature, identifying both alignments and divergences between Belizean experiences (local practices) and international findings. The key results were synthesized into thematic areas that reflect the interdependence of socio-economic, environmental and governance dimension impacting the development of sustainable seaweed aquaculture in Belize.

*Adaptation Strategies and Community Innovation:* A central theme emerging from the discussion was the range of strategies that seaweed farmers in Belize employed to address both environmental and non-environmental challenges. The focus group discussions revealed that Belizean seaweed farmers have adopted various context-specific practices, such as cultivating more resilient seaweed species (in this case study, a non-native species such as *Kappaphycus alvarezii*), adjusting harvesting schedules, and relocating farms, to mitigate the impacts of warming sea temperatures, water quality changes, amongst other extreme weather events. These strategies reflect broader practices observed across SIDS, where community-based innovation has been key to sustaining mariculture under climate uncertainty (Matoju et al., 2022; Ndobe et al., 2020).

The creativity and leadership displayed by the Belizean seaweed farming community, particularly initiatives led by women, highlight the significance of local innovation in strengthening livelihood resilience and sustainability. These findings correspond with those of Torre-Castro et al. (2022) in Zanzibar, who found that capacity-building and inclusive participation empower women to play transformative roles in coastal livelihoods. Nonetheless, persistent challenges such as theft, periodic die-offs, and extreme weather events illustrate that continued institutional and technical support is required to secure long-term sustainability.

*Socio-Economic and Demographic Impacts:* The analysis highlights the importance of socio-economic and demographic factors in shaping the livelihoods of seaweed farmers. The qualitative surveys revealed that the Belizean seaweed farming community is relatively young and slightly male-predominated, consistent with trends in other SIDS where younger generations view seaweed mariculture as an emerging economic opportunity (Hossain et al., 2021; Jagtap et al., 2022).

However, the findings also pointed to complexities in the impact of education, formal training, and gender on seaweed harvesting. While education and formal training did not significantly impact harvest quantities, the near-significance patterns indicated an indirect effect on farming efficiency, knowledge sharing and adaptability (Aswani et al., 2018; Torre-Castro et al., 2022). Gender emerged as a statistically significant factor impacting seaweed harvesting reaffirming the need for gender-sensitive approaches and interventions, to livelihood development as women face distinct challenges in accessing resources within the sector (Rubekie et al., 2022).

*Policy Frameworks and Regulatory Challenges:* Another prominent theme is the critical role of policy frameworks, and the challenges posed by regulatory environments. The elite interviews and policy review revealed that while Belize's Blue Economy framework provides a promising foundation, gaps in policy coordination, enforcement and resources allocation limit its effectiveness. In line with findings from Hossain et al. (2021) and Jagtap et al. (2022), the analysis highlighted the absence of a cohesive national policy specifically addressing mariculture and coastal livelihood integration.

Implementation gaps, particularly in remote coastal areas, constrain farmers' ability to access technical and financial support. Similar challenges have been documented across SIDS, where limited institutional capacity and overlapping mandates impede the operationalization of sustainability policies (Torre-Castro et al., 2022). Addressing these governance limitations through clear regulatory frameworks and multi-stakeholder coordination will be essential for strengthening the sustainability of the sector.

*Economic Viability and Financial Mechanisms:* Economic viability emerged as another critical dimension impacting sustainability. The quantitative assessment indicated that farm size and income were significant determinants of seaweed harvests, affirming that access to physical and financial capital remains central to productivity and stability (World Bank, 2008). However, the findings also emphasized that increasing production alone does not guarantee sustainability without value-added products and equitable market access (Neven et al., 2009).

The study identified the need for innovative financial mechanisms, such as microcredit and insurance tailored to the needs of small-scale seaweed farmers, was emphasized as crucial for supporting the economic sustainability of the sector. Such tools are vital to help farmers invest in infrastructure, processing equipment, and farm expansion, while mitigating the risks associated with environmental and market shocks (Hayashi et al., 2019; Hossain et al., 2021).

*Technological Integration and Environmental Management:* The integration of technology and environmental management practices was found to be uneven and underdeveloped in Belize's seaweed sector. The PESTEL analysis highlighted that technological advancements, particularly in monitoring systems, farm design, and environmental data collection, has yet to be fully integrated into Belize's policy framework, limiting the sector's capacity for innovation and effective environmental management (Ndobe et al., 2020).

Although Belize has established legal frameworks to safeguard environmental sustainability, weak enforcement and fragmented institutional oversight continue to constrain progress. As observed by Thiel et al. (2007), effective environmental governance requires not only regulation but also capacity-building and resource support for implementation. The integration of digital monitoring tools, ecosystem-based management, and training programmes could significantly enhance the environmental sustainability of seaweed mariculture in Belize.

In summary, chapter 6 demonstrated that the sustainability of seaweed farming in Belize is shaped by the dynamic interaction among environmental, socio-economic, and institutional factors. The findings collectively indicate that while Belize's seaweed sector holds considerable potential to contribute to sustainable livelihoods and blue growth, its long-term success will depend on strengthening social networks, ensuring equitable access to financial and physical capital, improving policy coherence, and integrating technological innovation into both production and environmental management.

By situating the Belizean case within the broader literature on SIDS, this study advances understanding of how small-scale mariculture systems can promote sustainability through community participation, innovation, and adaptive governance. The insights derived from Belize's experience have wider implications for other SIDS pursuing blue economy strategies,

providing an empirical foundation for informed policy development and future research on sustainable coastal livelihoods.

The next chapter (Chapter 7) builds upon these findings to articulate the overall contributions of this doctoral research. It synthesizes the empirical evidence from the mixed-methods analysis, outlines the theoretical and policy implications, and presents key recommendations for enhancing the sustainability of seaweed farming livelihoods in Belize and comparable SIDS contexts.

## 7. CONCLUSION AND RECOMMENDATION

### 7.1 Introduction

This doctoral research examined the sustainability of seaweed farming livelihoods in the context of Small Island Developing States (SIDS), using Belize as a focal case study in the Caribbean region. The study investigated how climatic and non-climatic pressures shape farmers' strategies, how these strategies drew upon various livelihood capitals, and how they, in turn, impacted the sustainability of seaweed mariculture and the enabling role of policy frameworks.

As outlined in Chapters 1, 2, and 3, the research was motivated by the increasing recognition of seaweed aquaculture as a nature-based option that can support livelihood diversification, climate adaptation, and blue economy development. While seaweed mariculture can contribute to both climate change mitigation and adaptation, this thesis focused adaptation. It examined how farming communities in Belize responded to environmental and institutional pressures through adaptation strategies grounded in the Sustainable Livelihoods Framework (SLF). Despite its growing global relevance, limited empirical evidence on the socio-ecological and institutional dynamics that impacted the sustainability of seaweed farming in the Caribbean. This study therefore addressed a distinct research gap: although seaweed mariculture offered potential as a livelihood and adaptation strategy, its long-term viability was constrained by environmental stressors and fragmented policy support. The research problem, therefore, centered on understanding how farmers deployed multiple livelihood capitals to sustain production under climatic and institutional pressures, and how governance mechanisms could better embed their expertise to strengthen policies in this sector.

This study was guided by the SLF, which provided a integrative lens to analyze how human, social, natural, physical, financial, and cultural capitals shape livelihood outcomes. The framework was complemented by Community-Based Adaptation (CbA) and Ecosystem-Based Adaptation (EbA) principles to link local livelihood practices to broader environmental and governance processes. This conceptual integration enabled the thesis to capture both micro-level adaptation strategies and macro-level policy responses within a coherent analytical structure.

A mixed methods research design was employed to examine these relationships systematically using both qualitative and quantitative approaches to capture both depth and breadth in understanding the sustainability of seaweed farming livelihoods. At the community level, data were collected through semi-structured household surveys and Community-based Risks Screening - Adaptation and Livelihoods (CRiSTAL) focus group discussions which elicited farmers' perceptions of hazards, livelihood assets, and adaptation strategies. At the policy level, elite interviews with institutional stakeholders and policy analysis, both using the Political, Economic, Social, Technological, Environmental and Legal (PESTEL) tool were undertaken to evaluate governance arrangements and regulatory gaps affecting mariculture development. These qualitative insights were complemented by quantitative analyses, including Pearson's chi-square tests and multiple linear-regression models, were applied to explore the statistical relationships between socio-economic factors and seaweed-production outcomes. This combination of methods ensured methodological triangulation, enhancing validity and reliability through cross-verification across data sources.

Accordingly, the study was structured around five guiding research questions:

RQ1: What are the key characteristics of seaweed aquaculture in the context of SIDS?

RQ2: What are the main opportunities and challenges that seaweed aquaculture is facing in the context of SIDS?

RQ3: What are the climatic and non-climatic hazards impacting the livelihoods of seaweed farmers in SIDS?

RQ4: What are the existing responses, practices, and strategies being implemented by seaweed farmers to cope with and adapt to climate- and non-climatic hazards in SIDS?

RQ5: To what extent, if at all, are the policy measures in place in the SIDS of Belize capable of tackling climate and non-climatic hazards in relation to seaweed farming?

These questions collectively reflect the logical sequence of inquiry established in the earlier chapters:

- Pressures: climatic and non-climatic hazards;
- Responses: farmers' coping strategies and deployment of livelihood capitals; and
- Outcomes: sustainable livelihood development and policy integration.

The study hypothesized that the sustainability and growth of seaweed farming in Belize were significantly impacted by a combination of socio-economic, demographic, and environmental factors. It also posited that the effectiveness of community-based and ecosystem-based strategies, supported by robust institutional frameworks, is crucial for minimizing the impacts of both climate change and non-climatic hazards, thereby enhancing the production and economic success of seaweed farms.

Through a case study approach, this thesis identified and analyzed both the community-level dynamics and the institutional frameworks governing the emerging seaweed mariculture industry in Belize. This dual perspective provided actionable insights into how livelihood capitals were mobilized under environmental pressures and how policy coherence could enhance or constrain adaptation outcomes. The findings contribute to filling a significant empirical gap in the literature on Caribbean SIDS, offering evidence of the complex interactions among climate impacts, local agency, and governance structures in shaping sustainable marine livelihoods. In synthesizing these results, the remainder of this chapter integrated evidence from across the mixed methods designed to answer the five research questions. The analysis presented in this chapter shows two interrelated dimensions at community level and policy level. This demonstrates how these perspectives converge to explain the sustainability and adaptation potential of seaweed farming in Belize.

Chapter 7 is organized into eight sections. Section 7.2 presents key findings structured by research questions. Section 7.3 synthesizes the findings and develops the theoretical and conceptual implications. Section 7.4 consolidates the novel empirical findings for Belize and the wider Caribbean context. Section 7.5 sets out the study's contributions. Section 7.6 provides community and policy recommendations. Section 7.7 identifies directions for future research. Section 7.8 offers concluding reflections on global significance.

## 7.2 Overall Key Findings (structured by research questions)

This section synthesized the empirical evidence across mixed methods to answer the five research questions. It integrated community-level findings from CRiSTAL focus groups and qualitative surveys with the quantitative survey and regression analysis, and it incorporated policy-level insights from elite interviews and the policy review by PESTEL. Findings are reported as triangulated conclusions rather than repetitions of detailed results.

*Research Question 1: What were the key characteristics of seaweed aquaculture in the context of SIDS (Belize case)?*

Across methods, seaweed farming in Belize was characterized by small-scale, community-anchored production with diverse organizational forms and mixed livelihood portfolios. Farmers typically operated submerged plot systems using *Kappaphycus alvarezii* as the primary species, with some cultivation of *Eucheuma isiforme* and *Gracilaria crassissima*. Ownership of farms was common, but sea sites were often located more than ten miles from homes, which shaped labor scheduling and operating costs. Seaweed farming functioned mainly as a secondary or tertiary income source alongside fishing and tourism, and it drew on family tradition, local knowledge and cooperative arrangements.

The quantitative profile corroborates these characteristics. The sample comprised younger and middle-aged farmers with varied schooling, moderate experience, and generally secure access to basic physical assets. Farm size did not impact monthly harvests in the final model (Model 13;  $p = 0.397$ ), indicating that production outcomes were not explained by scale alone. By contrast, experience did impact harvests positively ( $p = 0.045$ ), and traditional knowledge also had a positive impact ( $p = 0.046$ ), highlighting the centrality of practice-based learning and intergenerational know-how for production. These patterns supported a characterization of the sector in which intangible capitals and technique selection mattered more than expansion of area under cultivation.

Policy-level informants described a maturing, but still emergent sub-sector situated within a broader Blue Economy agenda. They emphasized that sector performance depended on clearer licensing and tenure rules, improved post-harvest systems, and better coordination of training and extension. Taken together, the thesis concluded that Belizean seaweed mariculture was defined by smallholder professionalism, strong social organization, and an operational model in which experience, local knowledge and site management were decisive.

*Research Question 2: What were the main opportunities and challenges facing seaweed aquaculture in SIDS?*

Opportunities centered on livelihood diversification, local and niche market demand, and value-added products. Farmers reported clear market pull for raw gels and cosmetics, and they linked seaweed use to health and wellness narratives that sustained consumer interest. Word-frequency and thematic analyses highlighted persistent references to cooperatives, government, specific species and market terms, reinforcing the prominence of market organization and governance in shaping opportunities.

Challenges clustered around four areas. First, environmental and climatic pressures affected seaweed crop health and scheduling regular farm visits. Second, operational and logistical costs were high, particularly fuel and transport to distant sites, and freshwater access for rinsing harvested seaweed (initial post harvesting practices on farm sites). Third, technical support and training were uneven, which limited consistency in cultivation and post-harvest handling practices. Fourth, governance and regulatory uncertainties increased transaction costs and deterred investment.

The quantitative results aligned with this profile. Household income and seaweed income both impacted harvests positively (each  $p = 0.045$ ), indicating that financial stability supported production, whether through input purchases, time allocation, or the ability to absorb losses. A gender effect on harvests was observed ( $p = 0.045$ ), signaling differentiated constraints and support needs. Physical scale and boat ownership did not impact harvests (each  $p > 0.10$ ), suggesting that replacing or enlarging physical assets alone would not resolve production challenges.

Elite interviews and the policy analysis identified complementary opportunity spaces at policy level: targeted incentives for value-addition and certification, concessional finance and hazard-transfer mechanisms, and streamlined licensing. The main structural challenges were fragmented rules, limited extension and research, development and innovation (RD&I), and under-specified quality standards for seaweed products. Overall, the opportunities were real but contingent on governance clarity, basic finance, and diffusion of improved practices.

*Research Question 3: What climatic and non-climatic hazards impacted seaweed-farming livelihoods?*

Farmers reported theft, die-offs (also referred to as ‘ice-ice’ seaweed disease in the literature) and breakoffs, storms and floods, rising sea temperature, and dry-season water quality issues as salient hazards. Impacts included direct crop loss, equipment damage, downtime, and increased costs related to replanting, security, and freshwater logistics. The focus groups consistently ranked theft and disease-linked die-offs as high-frequency, high-impact events.

The quantitative analysis showed that simple bivariate correlations between hazard counts, and production were generally weak and not statistically significant for most pairings, which reflected heterogeneous responses at farm level. However, seaweed loss as an indicator of cumulative biophysical stress did impact harvests negatively in the regression model ( $p = 0.044$ ), confirming that loss events were consequential when modelled alongside other factors. Cross-tabulations demonstrated significant associations between hazard categories and response categories (Pearson  $\chi^2 = 73.55$ ,  $df = 16$ ,  $p < 0.001$ ; Fisher–Freeman–Halton exact  $p = 0.003$ ), indicating that farmers patterned their strategies to the type of threat even when production totals did not co-vary linearly with every hazard indicator.

At policy level, interviewees distinguished climatic pressures, especially warming waters, seasonal hydrodynamics, disease and sargassum, from non-climatic pressures rooted in licensing, compliance costs, price volatility, and infrastructure gaps. The policy analysis showed strong co-variation among Political, Legal and Environmental codes, consistent with a governance approach that emphasized statutory control and conservation. Nevertheless, the absence of seaweed-specific operational guidance and uneven enforcement limited the day-to-day management of hazard pathways at farm level.

*Research Question 4: What responses, practices and strategies were implemented by farmers to cope with and adapt to these hazards?*

Farmers combined immediate measures with longer-term strategies. Short-term actions included frequent site monitoring, community watch for theft, adjusting farm depth, relocating farming plots on a seasonal basis, and using buoy systems before storms. Longer-term strategies included hiring security, shifting towards submerged methods, improving anchors, experimenting with more resilient strains, and revising post-harvest handling to address freshwater constraints.

The quantitative model showed that ecosystem-based approaches had a positive impact on harvests ( $p = 0.034$ ), and community-based approaches also impacted harvests positively ( $p = 0.034$ ). Farmers who reported experience and traditional knowledge achieved higher production (experience  $p = 0.045$ ; traditional knowledge  $p = 0.046$ ). The integration of community- and ecosystem-based approaches into a single reported category did not reach significance in the final model (integration  $p = 0.221$ ), which suggested that effectiveness depended on the content and quality of practices rather than on their nominal combination. These results indicated that well-targeted, practice-specific strategies had measurable production benefits.

Policy-level respondents identified enabling mechanisms consistent with these patterns: smart siting and environmental screening, diffusion of improved systems, and structured producer-group development. They also emphasized that progress required predictable licensing, lower compliance frictions, and access to working capital and insurance. The overall conclusion was that farmers already used a credible repertoire of responses and that policy action could amplify their effects by lowering persistent non-climatic constraints.

*Research Question 5: To what extent did policy measures in Belize address climatic and non-climatic hazards relevant to seaweed farming?*

The inventory and coding showed a comprehensive legislative base across fisheries, environmental protection, coastal management, food safety and disaster law. Political, Legal and Environmental provisions tended to move together, indicating that high-level commitments were accompanied by statutory and conservation measures. This configuration addressed important elements of hazard management. However, sector-specific measures for seaweed were sparse, technology transfer provisions were generic, and enforcement and extension capacity were uneven. Instruments for finance and market development existed in Micro, Small & Medium Enterprises (MSME) and investment policies, but targeted incentives for seaweed operations, risk-sharing for storm or disease events, and streamlined routes to certification were limited.

Elite interviews converged on these findings. Policymakers and partners recognized progress under the Blue Economy agenda but pointed to fragmentation across authorities, procedural uncertainty, and high conformity costs for export readiness. They highlighted scope for dedicated mariculture regulations, clearer tenure and licensing, blended finance and concessional credit, and coordinated RD & I and knowledge transfer. In sum, policy measures covered important foundations for environmental stewardship and compliance, but they only partially addressed the non-climatic constraints that affected production and livelihoods at farm level.

Taken together, the evidence showed that production outcomes were most strongly impacted by experience, traditional knowledge, and the deliberate use of CbA and EbA strategies, with financial stability enabling their consistent application. Physical expansion alone did not impact harvests. Policy frameworks established important environmental and legal safeguards, yet gaps in sector-specific rules, financing instruments, and operational guidance limited the effectiveness of farmers' strategies. Section 7.3 now synthesizes these relationships to explain how adaptation strategies, livelihood outcomes and governance processes interacted in practice, and to identify where consequential adjustments at policy and programme levels would strengthen the sustainability of seaweed mariculture in Belize and other SIDS.

## 7.3 Synthesis of Findings and Theoretical and Conceptual Implications

This synthesis shows how the empirical results contribute to understanding adaptation and livelihood sustainability in SIDS, while advancing the frameworks set out in Chapters 2 and 3. By triangulating the quantitative, qualitative, and policy-level evidence, this section elucidates the interconnections among livelihood capitals, adaptation strategies, and governance mechanisms, thereby clarifying how these dynamics jointly impacted the sustainability of seaweed mariculture in Belize.

### 7.3.1 Integrating livelihood capitals and adaptation strategies

Sustainability was driven by intangible and practice-based attributes rather than scale or asset accumulation in seaweed farming livelihoods. Intangible and practice-based capitals



included; experience, traditional knowledge, and community and ecosystem-based adaptation practices. This aligns with the broader theoretical understanding of the SLF (Chambers & Conway, 1991; Scoones, 1998), which posits that diverse forms of capital interact to shape livelihood outcomes. However, this study extends prior work by empirically quantifying how specific capitals within SLF impact production outcomes in a marine-based livelihood, a domain in which the framework has been comparatively underapplied (Allison & Ellis, 2001; Cinner & Barnes, 2019).

While prior studies in coastal and agricultural contexts emphasized the role of financial and physical assets in improving livelihood sustainability (Ellis, 2000; Bebbington, 1999), the Belize case showed that human and cultural capitals, operationalized through farmers' experience and inherited traditional knowledge, were statistically significant predictors of productivity. This finding reinforces the argument that experiential learning and cultural embeddedness remain core to adaptation practices in artisanal systems (Blythe et al., 2014; Berkes, 2018). The inclusion of cultural capital in this study as a distinct analytical category represents a methodological innovation within SLF-based research, highlighting how traditional ecological knowledge acts not only as a cultural inheritance but also as an adaptive resource that sustains production amid environmental uncertainty.

### 7.3.2 Adaptation as a livelihood practice in SIDS

Adaptation operated as a supplementary livelihood practice rather than a discrete technical intervention. Farmers combined social organization/networking, ecological understanding, and diversified income strategies. The quantitative evidence that community- and ecosystem-based strategies are associated with higher production supports the theoretical claim that socially embedded and ecologically aligned practices are more sustainable. Strategies such as modifying farm depth, shifting plots seasonally, or employing integrated CbA and EbA approaches, demonstrated a continuous process of learning by doing. This resonates with the literature emphasizing that adaptation in SIDS is inherently incremental, experiential, and socially mediated (Adger, 2003; Pelling & Manuel-Navarrete, 2011; Robinson, 2019). However, unlike studies that conceptualize adaptation mainly in terms of resilience or vulnerability, this thesis deliberately avoided such constructs in its theoretical and conceptual framework, focusing instead on the impacts of specific adaptation strategies on measurable livelihood outcomes.

The quantitative findings validated the significance of community-based ( $p = 0.034$ ) and ecosystem-based ( $p = 0.034$ ) adaptation strategies in improving production outcomes. These results empirically support the theoretical premise that livelihood strategies integrating social cohesion and ecological alignment are more sustainable (Reed et al., 2015; Rahman et al., 2021). The case of Belize thus contributes empirical evidence to ongoing debates on the operational effectiveness of CbA and EbA in the context of small-scale aquaculture and blue economy development (UNFCCC, 2021; FAO, 2020; Troell et al., 2017).

### 7.3.3 Linking local practices to policy and governance

Community-level adaptation was enabled or constrained by institutions. Belizean farmers developed credible practices, yet policy and regulatory systems lagged behind. Gaps in sector-specific regulation, licensing clarity, and inter-agency coordination reduced efficiency and access to finance and legal protection of individual farms in the event of reporting a theft crime. This supported the argument advanced in the literature that successful adaptation in SIDS depends on multi-scalar governance linkages between local resource users and national frameworks (Nunn et al., 2021; Robinson & Wren, 2020). Additionally, seaweed farmers developed credible adaptation practices, such as seasonal relocation, species diversification, and anchored submerged systems, but the policy and regulatory context lagged behind these

innovations. The policy analysis revealed gaps in sector-specific legislation, inconsistent licensing frameworks, and limited institutional coordination, mirroring challenges identified in other SIDS aquaculture sectors (Asiedu et al., 2019; Bennett et al., 2018).

Policy-level interviewees emphasized that fragmented governance hindered efficiency and limited access to finance, technical support, and insurance against natural disasters and/or theft events. These findings highlight the theoretical claim that governance coherence, rather than regulatory abundance, determines the capacity of small-scale systems to adapt effectively (Ostrom, 2009; Blythe et al., 2017). This thesis thereby advances a governance-oriented understanding of adaptation, arguing that enabling policies must not only provide environmental safeguards but also institutionalize the expertise of farmers within decision-making structures, ensuring that local adaptation practices inform national marine policies. Thus, institutionalizing farmer expertise in decision processes is a practical route to improve fit between policy intent and ground realities.

#### 7.3.4 Theoretical extensions to the sustainable livelihoods framework (SLF)

This study contributed to the theoretical refinement of the SLF in three main ways.

First, it empirically demonstrated how the interactions among human, cultural, and financial capitals directly impacted livelihood outcomes, challenging the assumption that physical and financial capitals are always the dominant determinants of success (DFID, 1999; Scoones, 2015).

Second, by integrating the SLF with CbA and EbA principles, the study operationalized a hybrid analytical model capable of linking local adaptation practices to ecological processes and governance frameworks. This interdisciplinary synthesis extends the SLF beyond its terrestrial and household focus, making it more applicable to marine-based and blue economy contexts (Bennett et al., 2014; Troell et al., 2017; FAO, 2021).

Third, by incorporating policy-level analysis through PESTEL, the thesis bridged micro-level livelihood analysis with macro-level governance evaluation, a connection often missing in previous applications of the framework. This methodological advancement offers a template for future research seeking to assess livelihood adaptation in similarly complex socio-ecological systems.

#### 7.3.5 Synthesis of implications

Sustainable seaweed livelihoods in Belize emerged from interaction of experience, knowledge, community organization, and enabling policy. The study confirmed that practice-based adaptation, rooted in farmers' everyday decisions (autonomous adaptation) and traditional knowledge (cultural heritage), was the cornerstone of sustainability, yet its effectiveness was contingent on institutional coherence and access to financial and infrastructural support. These findings collectively advance theoretical and empirical understanding of how adaptation operates as both a social and ecological process in SIDS, filling a significant gap in the literature on marine-based livelihoods and providing a model for policy and practice in the wider Caribbean and other SIDS contexts.

### 7.4 Novel Findings in Seaweed Farming Livelihoods in Belize

This section consolidates empirical contributions and clarifies what is new relative to the Caribbean evidence base.

#### 7.4.1 Seaweed farming as a dual adaptation and livelihood strategy in SIDS

Seaweed mariculture in Belize functioned as a dual strategy for livelihood diversification and climate adaptation. It provided alternative income streams while also contributing to the

ecological services that support coastal adaptation, such as habitat enhancement and carbon uptake. Seaweed farming thus served as a practical expression of the sustainable livelihood framework, where multiple capitals were mobilized to sustain household wellbeing under climatic and institutional pressures.

However, the findings also indicated that this adaptation pathway entailed environmental trade-offs that warranted careful management. Farmers expressed growing concern regarding the cultivation of *Kappaphycus alvarezii*, a non-native red seaweed species introduced to Belize in 2017. Initially identified in the tributaries of the Placencia Lagoon near Big Creek Port, *K. alvarezii* has since been propagated widely across the country following training workshops due to its profitability and tolerance to varying salinity and seawater temperature conditions. Farmers reported that the species grows aggressively, requiring regular harvesting on a two-month cycle to prevent overgrowth. If left unmanaged, fragments can break off, spread, and colonize new habitats, including sensitive coral reef ecosystems. This study categorizes these instances as escape events, which may represent early signs of maladaptation if not properly monitored. While *K. alvarezii* contributes significantly to economic returns and adaptive diversification, its invasive potential underscores the need for environmental safeguards, such as routine ecological monitoring and containment measures. This duality illustrates that adaptation pathways can carry inherent ecological risks when species selection and cultivation practices are not matched by adequate biosecurity and spatial management.

Moreover, farmers reported that farm infrastructure such as ropes, anchors, and buoys frequently broke loose during storms and hurricanes, occasionally contributing to marine debris. Additionally, the reliance on fuel to access farms located five to ten miles offshore introduced energy dependence that partially offset the sector's low-carbon potential. These observations suggested that, although seaweed farming strengthened livelihoods, it could also lead to maladaptive outcomes if not supported by appropriate governance, materials management, emergency recovery protocols, and environmental safeguards. Due to its potential environmental liability attributes, this sector demands proactive governance and technical oversight to avoid unintended environmental risks and maladaptive outcomes.

#### 7.4.2 Identification of non-climatic hazards as major threats

This study identified non-climatic hazards, particularly theft, seaweed die-offs, and equipment damage, as the most frequent and disruptive threats to seaweed production. While climatic hazards such as rising sea temperature and extreme weather events were recognized, the persistent occurrence of non-climatic hazards had greater cumulative effects on productivity and income stability. This finding challenged the dominant narrative in adaptation literature that prioritizes climatic hazards, demonstrating that in SIDS contexts, governance failures, inadequate infrastructure, and social vulnerabilities can exert equally significant impacts on livelihood sustainability. The recognition of these non-climatic hazards expands the analytical scope of adaptation studies by incorporating the socio-institutional dimensions of risk that shape real-world outcomes for mariculture communities.

#### 7.4.3 Development and implementation of long-term adaptation strategies

This thesis captured the transition from short-term coping responses to the emergence of long-term adaptation practices among Belizean seaweed farmers. Farmers implemented strategies such as breeding and cultivating more resilient seaweed strains (such as *K. alvarezii*), adopting submerged farming systems, and experimenting with alternative anchoring and buoy designs to minimize storm losses. These practices illustrated proactive adaptation based on experiential learning and traditional ecological knowledge, rather than reactive crisis management. The integration of long-term strategies into routine production practices

underscored the agency and innovation of local communities in enhancing the resilience of their livelihoods under changing climatic and environmental conditions.

#### 7.4.4 Strengthening of community-based adaptation mechanisms

Social capital played a central role in sustaining adaptation and ensuring the continuity of seaweed farming in Belize. Cooperative structures such as the Belize Women's Seaweed Farmers Association (BWSFA), Blue Waters Fisherman Association (BWFA), Turneffe Seaweed Growers Association (TSGA) and the Placencia Producers Cooperative Society Limited (PPCSL) provided organizational capacity, knowledge exchange, and peer support that enhanced adaptive effectiveness. The success of these cooperatives illustrated the practical value of CbA strategies that align with collective management traditions and participatory decision-making. This thesis was among the first to document how CbA mechanisms in Caribbean mariculture systems contribute to livelihood security and environmental stewardship simultaneously, offering a model for similar initiatives across SIDS.

#### 7.4.5 Synthesis of novel findings

Overall, the novel findings of this study demonstrated that the sustainability of seaweed farming livelihoods in Belize depended on the interaction between community initiative, institutional support, and environmental stability. The mixed-method design enabled the identification of cross-scale linkages: quantitative modelling showed that human, social, and natural capitals had the greatest impact on productivity, while qualitative analyses revealed the socio-political barriers that constrained adaptation. The integration of community-level and policy-level evidence provided a holistic understanding of seaweed farming as a dynamic adaptation system rather than a static livelihood activity. This synthesis contributes new empirical evidence to global discussions on nature-based livelihoods, demonstrating that sustainable mariculture can serve as both a climate adaptation measure and an economic development pathway when appropriately governed and environmentally managed.

### 7.5 Contribution of This Research

This thesis provides one of the first systematic analyses of seaweed mariculture livelihoods in Belize and the wider Caribbean. It builds an original evidence base using household surveys, CRiSTAL focus groups, elite interviews, and a PESTEL policy review. At community level, it shows that experience, traditional knowledge, and community- and ecosystem-based practices are associated with higher production, while physical scale was not. At policy level, it maps a broad but fragmented enabling environment, clarifying where operational gaps limit adaptation.

#### 7.5.1 Empirical contributions

Empirically, this study provides the first baseline analyses of seaweed mariculture livelihoods in Belize and the wider Caribbean region, addressing a critical gap identified in the literature. Previous studies on marine-based livelihoods in SIDS (e.g., Troell et al., 2017; Bennett et al., 2014; Robinson, 2019) have rarely examined the micro-level realities of seaweed farmers in the Caribbean context, where data scarcity has constrained both policy and academic understanding. This research offers original quantitative and qualitative datasets derived from household surveys, CRiSTAL-based focus group discussions, PESTEL-informed elite interviews, and PESTEL-informed policy analysis, collectively generating the most comprehensive evidence based to date on the sector.

At the community level, the study empirically demonstrates that seaweed farming livelihoods are defined by intangible and practice-based capitals, such as experience, traditional knowledge, and the use of ecosystem- and community-based adaptation strategies. These

factors significantly impacted production outcomes, whereas physical scale and asset accumulation did not. This challenges long-held assumptions in livelihood research that financial or physical capital are the primary drivers of sustainability (Ellis, 2000; Bebbington, 1999) and instead highlights the importance of human and cultural capitals as productive assets within marine-based livelihoods.

At the policy level, the research contributes the first empirical mapping of the institutional and legislative architecture affecting seaweed mariculture in Belize using the PESTEL framework. The coding analysis of 66 policy instruments revealed that while Political, Legal, and Environmental provisions were well-developed, they often lacked operational coherence and sector-specific measures. This evidence elucidates the structural fragmentation that constrains adaptation and sustainable livelihood outcomes in SIDS, thereby advancing understanding of governance performance and implementation gaps in the blue economy sector.

#### 7.5.2 Theoretical contributions

Theoretically, the study extends and refines the SLF for marine and aquaculture systems. The incorporation of cultural capital anchored, in traditional ecological knowledge, enhances the SLF's analytical scope by demonstrating that cultural practices and intergenerational learning are not peripheral but central to adaptive livelihood systems. This refinement is particularly salient for SIDS, where local traditions and social cohesion are critical determinants of sustainability (Berkes, 2018; Cinner & Barnes, 2019).

Moreover, by integrating the SLF with CbA and EbA principles, this research advances a hybrid conceptual model capable of capturing the socio-ecological complexity of marine livelihoods. This integration moves beyond the dichotomy between environmental and social approaches to adaptation by showing empirically how livelihood capitals mediate between biophysical stressors and policy processes. The resulting model represents a theoretical innovation that situates adaptation as a continuous livelihood practice embedded in ecological, institutional, and cultural systems rather than as a discrete policy outcome.

Finally, the research contributes to adaptation theory in SIDS by conceptualizing adaptation as an impact-driven process, one that can be empirically measured through its effect on livelihood outcomes. This moves beyond abstract notions of adaptive capacity or resilience and grounds adaptation analysis in observable and quantifiable indicators, thus enhancing both the analytical precision and policy applicability of adaptation research in small-island contexts.

#### 7.5.3 Methodological contributions

Methodologically, this thesis introduces a comprehensive mixed-methods framework that combines community-level and policy-level data within a unified analytical structure. The sequential integration of CRiSTAL, the Sustainable Livelihoods Framework, and PESTEL represents a novel synthesis not previously applied to marine livelihood studies. This design operationalizes vertical triangulation, allowing micro-level perceptions and quantitative outcomes to be directly linked to macro-level governance mechanisms.

The quantitative application of multiple linear regression to assess the impact of livelihood capitals on production outcomes offers a new empirical pathway for testing the SLF within marine contexts. At the same time, the qualitative coding of elite interviews and policy frameworks using PESTEL provides a systematic means of assessing the enabling environment for adaptation, revealing correlations between political, legal, and environmental factors that influence livelihood performance. Together, these techniques establish a methodological precedent for evaluating sustainability transitions in data-scarce SIDS.

In addition, the methodological inclusion of cultural capital and traditional knowledge as measurable constructs within the quantitative framework advances SLF-based modelling by bridging qualitative and quantitative epistemologies. This contributes to the methodological evolution of the SLF by demonstrating how mixed methods can capture both tangible and intangible dimensions of livelihood sustainability.

#### 7.5.4 Policy contributions

From a policy perspective, this research offers actionable insights into how institutional design and policy coherence can enhance the sustainability of seaweed mariculture in Belize and comparable SIDS. The PESTEL-based analysis identified a high level of political and legal commitment to environmental protection but also revealed that economic and technological enablers of adaptation remain underdeveloped. These findings provide a diagnostic framework for policymakers to identify and prioritize gaps in legislation, financing, and implementation.

By evidencing the strong interaction between policy frameworks and livelihood outcomes, the study informs the design of future marine and coastal policies. It recommends the institutionalization of farmers' experiential expertise within governance processes, the formulation of mariculture-specific regulations, the development of targeted financial instruments such as concessional credit and insurance schemes, and the strengthening of research, development, and knowledge-transfer systems. These contributions support the operationalization of the Blue Economy agenda in Belize and align with the Sustainable Development Goals (SDGs), particularly SDG 1 (No Poverty), SDG 13 (Climate Action), and SDG 14 (Life Below Water).

#### 7.5.5 Regional and global relevance

Although grounded in the Belizean context, the findings carry broader implications for SIDS across the Caribbean and other regions. The dual role of seaweed mariculture as both a climate adaptation strategy and a sustainable livelihood positions it as a critical entry point for advancing blue growth while safeguarding community well-being. The evidence generated by this research demonstrates how localized adaptation practices can inform national and regional policy frameworks, contributing to global discussions on nature-based solutions and climate-resilient development.

Furthermore, the thesis contributes to the empirical and theoretical literature on the human dimensions of the blue economy, illustrating how small-scale marine livelihoods can function as laboratories for adaptive governance in climate-vulnerable contexts. By providing a robust empirical model and analytical framework, the study offers a transferable template for future research and policy assessment in other SIDS pursuing sustainable aquaculture and climate adaptation.

### 7.6 Community and Policy Recommendations

Building on the empirical evidence and analytical synthesis presented in this study, this section outlines practical recommendations directed toward both policy stakeholders and community actors to enhance the sustainability and climate-adaptive potential of seaweed farming livelihoods in Belize and other SIDS. These recommendations arise directly from the triangulated findings that revealed both the strengths and the gaps in community-level practices, institutional frameworks, and policy implementation. They emphasize actionable measures aligned with SLF and the principles of CbA and EbA, thus bridging micro-level adaptation practices with macro-level policy coherence.

### 7.6.1 Community-level recommendations

At the community level, seaweed farmers in Belize have demonstrated considerable agency and innovation in adapting to climatic and non-climatic pressures. However, the findings also reveal gaps in capacity, coordination, and market integration that hinder long-term sustainability. The following recommendations aim to strengthen farmers' resilience and improve livelihood outcomes through collective action and empowerment.

*Strengthening Cooperative and Cluster-Based Governance Models:* Given the proven effectiveness of producer organizations (as the ones named previously), collective governance models should be scaled up to other coastal communities. Strengthened cooperatives can improve bargaining power, facilitate training, enhance market access, and increase compliance with quality standards. Cluster-based approaches could also foster economies of scale in logistics and value addition.

*Enhance Capacity Building and Technical Training:* Targeted training programs should be developed to address skill gaps in cultivation, post-harvest handling, value addition, and business management. These programs should be tailored to different demographic groups, particularly women and youth, to ensure inclusivity and intergenerational transfer of knowledge. Collaboration with vocational institutions and extension officers would ensure the continuity and scalability of capacity-building initiatives.

*Promote Community-Based and Ecosystem-Based Adaptation Practices:* Community-led initiatives such as mangrove protection, smart siting of farms, and environmentally responsible cultivation practices should be institutionalized as part of local adaptation plans. Integrating EbA measures, such as biodiversity enhancement and water-quality monitoring, would strengthen the ecological foundation of the industry. In addition, incorporating CbA practices that leverage social networks, and traditional knowledge would reinforce community cohesion and collective response mechanisms.

*Improve Market Linkages and Value-Adding Opportunities:* Farmers should be supported to engage in local and international markets through branding, certification (e.g., organic or fair trade), and partnerships with private-sector actors. Encouraging small-scale processors to innovate in value-added products, such as cosmetics, health supplements, and food-grade gels, can enhance profitability and resilience. Public-private partnerships could also facilitate technology transfer and entrepreneurship development.

*Advance Gender Equity and Social Inclusion:* Policies and programs should ensure equitable access to resources, training, and leadership roles for women in seaweed farming. As demonstrated by the Belize Women's Seaweed Farmers Association, gender-inclusive initiatives enhance productivity, innovation, and social cohesion. Empowering women in decision-making roles contributes to more equitable and sustainable livelihood outcomes across the sector.

*Strengthening Local Data and Information Systems:* At the community level, establishing participatory data-collection and record-keeping systems would improve local monitoring of production, losses, and environmental conditions. These systems could feed into national databases, strengthening evidence-based decision-making and facilitating collaboration between local cooperatives and governmental agencies.

### 7.6.2 Policy-level recommendations

The policy analysis identified that Belize possesses a strong legal and environmental framework for marine governance, but significant gaps persist in sector-specific policy formulation, financing mechanisms, and enforcement capacities. To address these

deficiencies and strengthen the enabling environment for sustainable mariculture, the following recommendations are proposed:

*Establish a Dedicated Mariculture Regulatory Framework:* A clear and unified mariculture policy should be developed to consolidate existing fragmented regulations across fisheries, coastal management, and environmental protection. This framework should include specific licensing procedures, tenure rights for seaweed farmers, and quality-control protocols. Integrating these elements would enhance investor confidence, reduce procedural uncertainty, and support long-term sustainability. Legislative coherence is also essential to ensure that mariculture is recognized as a distinct sector within Belize's Blue Economy portfolio.

*Institutionalize Farmer Participation in Governance Processes:* Seaweed farmers' experiential and traditional knowledge should be systematically incorporated into the design and evaluation of mariculture policies. Establishing participatory platforms such as a National Seaweed Mariculture Council could enable farmers to engage directly with government ministries, environmental non-governmental organizations (E-NGOs), and private investors. This would help align policy objectives with ground-level realities and enhance social legitimacy, reflecting the principles of CbA that emphasize community empowerment and knowledge co-production.

*Strengthening Financial and Risk-Transfer Mechanisms:* The lack of targeted financial instruments for small-scale mariculture remains a critical constraint. The government, in collaboration with financial institutions and development partners, should establish concessional credit schemes, microinsurance products, and risk-transfer mechanisms (e.g., parametric insurance) to buffer farmers against economic and climatic shocks. Integrating these instruments into national climate finance and MSME frameworks would support livelihood stability and sectoral growth.

*Enhance Research, Development, and Innovation (RD&I) Systems:* Institutional coordination should be improved between the Ministry of Blue Economy, the Belize Fisheries Department, and academic or research institutions to promote applied research and technological innovation in seaweed cultivation, processing, and product development. A national mariculture RD&I plan should prioritize improved cultivation systems, strain selection, post-harvest technologies, and knowledge transfer mechanisms. This would bridge the technological gap identified in the PESTEL analysis and advance the integration of EbA principles within operational practices.

*Improve Policy Integration and Inter-Ministerial Coordination:* As revealed by the policy analysis, fragmented governance structures often result in inconsistent implementation. A formal inter-ministerial coordination mechanism should therefore be established to align climate adaptation, blue economy, and fisheries policies. The Blue Economy Unit within the Ministry of Economic Development could serve as the coordinating body for this function, ensuring that adaptation strategies and livelihood considerations are mainstreamed across relevant ministries.

*Develop Monitoring, Evaluation, and Learning Frameworks:* A robust monitoring and evaluation (M&E) system should be implemented to assess progress in seaweed mariculture initiatives and adaptation outcomes. This framework should include socio-economic, environmental, and gender-disaggregated indicators aligned with the Sustainable Development Goals (SDGs) and national adaptation priorities. Continuous learning loops and adaptive management would enable policy refinement based on emerging challenges and best practices.



### 7.6.3 Regional and international collaboration

Beyond the local scale, regional partnerships within the Caribbean should be strengthened to foster knowledge exchange, policy harmonization, and technical cooperation. Collaboration through organizations such as the Caribbean Regional Fisheries Mechanism (CRFM) and the Western Central Atlantic Fishery Commission (WECAFC) can support standardized training programs, research dissemination, and joint adaptation initiatives. Belize's leadership in this emerging sector positions it as a potential hub for regional innovation in sustainable seaweed mariculture and blue economy development.

The recommendations presented in this section highlight that sustainable and climate-resilient seaweed farming in SIDS such as Belize requires a dual approach: empowering local communities through capacity, organization, and knowledge-sharing while strengthening institutional frameworks for coherent policy and governance. Bridging these scales will not only enhance livelihood outcomes but also position seaweed mariculture as a cornerstone of climate adaptation and blue growth in the Caribbean. The next section (7.7) identifies future research pathways that can further consolidate these findings and extend the analytical framework developed in this thesis.

## 7.7 Directions for Future Research

The findings and methodological innovations of this thesis open several promising avenues for future research on sustainable seaweed mariculture and climate change adaptation in SID. Building on the empirical evidence and conceptual synthesis presented, this section identifies key areas where further scholarly inquiry could extend the understanding of livelihood sustainability, strengthen methodological robustness, and enhance the application of integrated adaptation frameworks at both community and policy levels.

### 7.7.1 Expanding the mixed-method tripartite hazard-assessment framework

This thesis developed and applied an integrative tripartite hazard-assessment framework that combined the SLF, the CRiSTAL, and the PESTEL analytical tool. This framework allowed for simultaneous assessment of community-level adaptation strategies and policy-level governance processes. Future research could refine and expand this framework to enhance its analytical power and replicability across diverse island contexts. One valuable research direction would be to test this composite framework in multiple SIDS to evaluate its contextual adaptability and comparative validity. This could involve longitudinal, cross-country applications examining how different socio-political and ecological contexts mediate the relationships between livelihood capitals, adaptation strategies, and policy responses. Such replication would not only verify the robustness of the mixed-method design but also contribute to a replicable methodological model for future climate-livelihood studies in small-island contexts.

### 7.7.2 Integrating the sustainability-focused livelihood model with global climate frameworks

An important extension of this study would be to situate the sustainability-focused livelihood model within broader international climate assessment frameworks, particularly those outlined in the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports (AR5 and AR6). This integration would allow for linking local-scale hazard and impact analyses with global adaptation frameworks that conceptualize risk as a function of hazard, exposure, and vulnerability.

In this sense, future studies could align community-level hazard screening and livelihood findings with IPCC-informed adaptation pathways, without conducting probabilistic risk

modeling. Such work would help ensure that SIDS-specific realities, such as small-scale production, policy fragmentation, and socio-cultural adaptation, are adequately represented in international discussions of climate change, loss and damage, and just transition under the United Nations Framework Convention on Climate Change (UNFCCC).

#### 7.7.3 Longitudinal and comparative studies of seaweed mariculture sustainability

While this study provided cross-sectional evidence of how livelihood capitals impact seaweed production and adaptation outcomes, future research should adopt longitudinal designs to capture changes over time. Tracking seaweed production, adaptation behavior, and governance evolution across multiple years would provide insight into the temporal dynamics of livelihood adaptation and policy adjustment.

Comparative studies across different SIDS, such as Jamaica, St. Lucia, Fiji, and the Solomon Islands, could deepen understanding of how diverse ecological, cultural, and governance settings influence mariculture sustainability. Such comparisons would help identify both context-specific and generalizable determinants of sustainability, offering guidance for policy harmonization across island regions.

#### 7.7.4 Digitalization and technological innovation in seaweed farming

Technological capacity was identified as a persistent constraint in both community-level and institutional analyses. Future research should therefore explore how digital technologies and spatial innovations can enhance productivity, ecological monitoring, and traceability throughout the seaweed value chain.

The use of remote sensing, participatory GIS, and digital oceanographic monitoring could enable more precise environmental management and early hazard detection. Furthermore, blockchain-based traceability systems could ensure product integrity and market transparency. Participatory modeling platforms that integrate farmer-generated data with institutional monitoring would further strengthen adaptive co-management and bridge local and scientific knowledge systems.

#### 7.7.5 Methodological refinement and capital weighting

Future studies could enhance methodological precision by refining how livelihood capitals are measured and weighted. Quantitative weighting of human, social, natural, physical, financial, and cultural capitals could better represent their differential importance in shaping sustainability outcomes. Advanced statistical techniques, such as structural equation modeling (SEM) or hierarchical regression, could capture both direct and indirect effects among capitals.

Additionally, integrating participatory simulation and scenario-based modeling could allow researchers to forecast how various adaptation strategies might perform under different climatic and market conditions. These methodological innovations would strengthen the predictive and policy relevance of future livelihood research, particularly within dynamic and data-limited SIDS contexts.

#### 7.7.6 Gendered and cultural dimensions of adaptation

The qualitative findings of this study highlighted the significance of gender inclusion, traditional knowledge, and cultural continuity in sustaining adaptation strategies. Future research should deepen these insights through intersectional, gender-sensitive, and ethnographic approaches that explore how gender roles, local values, and traditional ecological knowledge interact to shape adaptation behavior.

Understanding these socio-cultural dynamics in greater depth would contribute to the design of inclusive, culturally grounded adaptation policies. Such work would also ensure that the expansion of seaweed mariculture contributes equitably to social empowerment, intergenerational learning, and community resilience in coastal societies.

#### 7.7.7 Linking livelihood adaptation to blue economy transitions

Future studies could further investigate how small-scale mariculture systems, such as seaweed farming, can support broader Blue Economy transitions in SIDS. This includes assessing how local livelihood adaptation can be scaled up to contribute to national economic diversification, marine spatial planning, biodiversity protection, and circular economy initiatives.

Research focusing on the alignment between livelihood-based adaptation and blue-growth policies could clarify how financial instruments, public–private partnerships, and market incentives can enable inclusive and sustainable ocean economies. Such inquiry would help bridge the gap between community adaptation practice and macro-level policy implementation.

#### 7.7.8 Summary of future research directions

In sum, future research should aim to consolidate and extend the methodological and empirical contributions of this thesis through multi-scalar, longitudinal, and comparative approaches. Refining the mixed-method hazard-impact framework, embedding it within global adaptation models, and expanding its application across different SIDS will enhance its validity and practical utility.

Through such efforts, future scholarships can advance theoretical understanding of climate-livelihood interactions while informing coherent, evidence-based policies that promote sustainable, equitable, and climate-resilient mariculture in small island developing states.

### 7.8 Concluding Reflections and Global Significance

This thesis contributes an integrated understanding of how seaweed mariculture can serve as both a livelihood strategy and a climate change adaptation measure within the unique socio-ecological and institutional context of SIDS. The study has demonstrated that seaweed farming in Belize is more than an emerging blue economy sector; it represents a dynamic interface between income diversification, social cohesion, environmental stewardship, and evolving governance systems, yet it remains dependent on fuel to access offshore farms and requires careful environmental management to prevent maladaptive outcomes. By investigating climatic and non-climatic hazards, farmer adaptation practices, and the institutional environment that shapes these responses, this research advances empirical and conceptual debates on sustainable livelihoods and marine resource governance in island economies.

At the community level, the findings revealed that seaweed farming is a viable adaptation strategy that provides supplementary income and social cohesion yet remains dependent on external inputs such as fuel to access farms located several miles offshore. The research also identified that while farmers demonstrated innovation and resilience, particularly through community-based and ecosystem-based adaptation strategies, caution must be exercised to prevent maladaptive outcomes. For instance, seaweed farms rely on physical infrastructure such as ropes, buoys, and anchors that, if damaged or dislodged during hurricanes or storms, can become marine debris and contribute to ocean pollution. Therefore, the development of environmentally responsible farming technologies and emergency recovery protocols is critical to ensure that seaweed mariculture does not inadvertently harm the ecosystems it aims to sustain.

In addition, a critical ecological finding concerns the widespread cultivation of *Kappaphycus alvarezii*, a non-native red seaweed species introduced to Belizean waters in 2017. Farmers recognized its high profitability and adaptive capacity to variable salinity, yet they also observed its invasive growth near coral habitats, describing cases where it spread uncontrollably following storm events or irregular harvesting. These escapees highlight an emerging maladaptation concern. Without structured biosecurity protocols, spatial management, and containment strategies, such introductions may undermine coral reef health and the ecological integrity of coastal ecosystems. Addressing this requires integrating biodiversity safeguards, biosecurity measures, and continuous monitoring into national mariculture policies and blue economy plans.

At the policy level, the study has shown that Belize possesses a strong legislative base across environmental, fisheries, and coastal management frameworks, but gaps remain on lack of sector-specific instruments to manage such bio-ecological risks, effective financing mechanisms, and monitoring protocols. The alignment of legal and environmental frameworks indicated a compliance-oriented governance approach, while technological and social instruments were underdeveloped. Strengthening these dimensions requires clearer cross-ministerial coordination ensuring that environmental impact assessments include species-level monitoring (critical to balancing livelihood development with marine conservation), improved extension services, and enhanced support for value-adding enterprises, particularly those led by women and coastal cooperatives.

Beyond Belize, this research provides an analytical foundation for scaling up sustainable mariculture within SIDS through integrated policy frameworks that link community adaptation, ecosystem protection, and economic diversification. It also highlights the importance of ecological vigilance within adaptation planning, ensuring that climate-resilient livelihood interventions do not produce unintended environmental harm. Sustainable mariculture development must therefore integrate ecological risk screening, species containment strategies, and adaptive monitoring into both community practice and policy frameworks.

Furthermore, the methodological triangulation of CRiSTAL-based hazard screening, PESTEL policy analysis, PESTEL elite interviews, and quantitative modeling demonstrated how mixed methods can bridge local perceptions with institutional realities, producing evidence-based insights for decision-making in climate-sensitive livelihoods. This approach offers a replicable model for other SIDS seeking to design participatory adaptation and blue growth strategies grounded in local knowledge and supported by coherent governance systems.

A key global implication of this study is the recognition that seaweed mariculture should be systematically incorporated into Nationally Determined Contributions (NDCs) under UNFCCC. Doing so would enhance reporting on both adaptation and mitigation benefits while supporting evidence-based monitoring of potential ecological risks. The study also identifies opportunities for Belize and other Caribbean nations to align seaweed mariculture with UNCTAD's Biotrade Initiative, promoting certification and traceability schemes that reward biodiversity-safe production. The literature evidence that seaweed farming contributes to both mitigation and adaptation goals by sequestering carbon, reducing nutrient pollution, and providing low-carbon livelihoods for coastal communities. However, to quantify and report these benefits effectively remains a bottleneck, requiring an urgent need to strengthen data collection, verification, and reporting systems at the farm level. This thesis therefore recommends that seaweed farmers, cooperatives, and extension officers be trained in participatory data monitoring and documentation, enabling the integration of mariculture indicators into national adaptation and mitigation reports. Such efforts would enhance the

visibility of small-scale mariculture within global climate accounting systems, supporting evidence-based policy and resource mobilization for local communities.

Moreover, there is a strategic opportunity to align seaweed mariculture with United Nations Conference on Trade and Development (UNCTAD)'s Biotrade Initiative and its Principles of Sustainable Development, which emphasize biodiversity conservation, equitable benefit-sharing, and sustainable value chain development. Seaweed products, particularly those derived from sustainably harvested and processed species such as *Kappaphycus alvarezii* and *Eucheuma isiforme*, could be certified under Biotrade or related eco-labelling schemes. This would not only open new markets for Belizean and Caribbean farmers but also enhance product traceability, consumer trust, and fair-trade benefits. Establishing pathways for certification and participation in biotrade frameworks would thus elevate seaweed mariculture from a subsistence or small-enterprise activity to a formalized, globally recognized component of sustainable blue economy trade.

In addition, integrating seaweed mariculture into broader marine spatial planning and circular economy strategies can contribute to holistic blue economy transitions in SIDS. By combining livelihood-based adaptation with marine ecosystem restoration and sustainable product innovation, seaweed farming can form part of an integrated economic diversification strategy that aligns with the Sustainable Development Goals (SDGs), particularly SDG 1 (No Poverty), SDG 13 (Climate Action), and SDG 14 (Life Below Water). However, realizing this potential will depend on coherent coordination among ministries, development partners, and local stakeholders, supported by consistent financial mechanisms and inclusive governance.

In conclusion, the Belize case study demonstrates that sustainable seaweed mariculture is not only a technical or economic pursuit but a socio-ecological and institutional transformation. It requires harmonizing livelihood benefits with ecological safeguards and governance coherence. The Belizean case study illustrates both the promise and complexity of embedding local adaptation practices within broader governance frameworks, emphasizing the importance of participatory, evidence-based, and context-sensitive approaches to decision-making and policy design. Moving forward, integrating seaweed farming into NDC reporting, UNCTAD Biotrade initiatives, circular blue economy strategies and national adaptation strategies represent a transformative opportunity to reposition SIDS as leaders in sustainable blue economies development. This integration would support proactive climate adaptation strategies that function as supplementary livelihood options and/or nature-based solutions, delivering tangible benefits for people, planet, and prosperity. Through continued collaboration among scientists, policymakers, and seaweed farmers, sustainable mariculture can evolve into a cornerstone of climate-resilient development and blue growth in SIDS and island nations worldwide.

## 8. REFERENCES

- Abenakyo, A., Sanginga, P., Njuki, J., Kaaria, S., & Delve, R. (2008). Relationship between Social Capital and Livelihood Enhancing Capitals among Smallholder Farmers in Uganda. *AAAE Ghana Conference Proceedings*, 539–541.
- Albasri, H., Arifin, Z., & Sugama, K. (2010). Seaweed farming development: Challenges and opportunities in Indonesia. *Indonesian Aquaculture Journal*, 5(2), 89–97
- Acosta, A. A., Glazer, R. A., Ali, F. Z., & Mahon, R. (2020). *Science and Research Serving Effective Ocean Governance in the Wider Caribbean Region*.
- Adaptation Fund. (2020). *Enhancing the Resilience of Belize's Coastal Communities to Climate Change Impacts*.
- Adato, M., & Meinzen-Dick, R. (2002). *Assessing The Impact of Agricultural Research on Poverty using the Sustainable Livelihoods Framework*.
- Adato, M., & Meinzen-Dick, R. (2003). Assessing the impact of agricultural research on poverty and livelihoods. *Quarterly Journal of International Agriculture*, 42(2), 149–166.
- Adel, Y. S., Moore, A. M., Ndobe, S., Yasir, I., Salanggon, A.-I. M., & Wahyudi, D. (2020). *Eucheumatoid seaweed farming under global change -Tomini Bay seaweed trial indicates Eucheuma denticulatum ( spinosum ) could contribute to climate adaptation Eucheumatoid seaweed farming under global change - Tomini Bay seaweed trial indicates Eucheuma d. September*.
- Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, 16(3), 268–281. <https://doi.org/10.1016/j.gloenvcha.2006.02.006>
- Adger, W. N., Huq, S., Brown, K., Declan, C., & Mike, H. (2003). Adaptation to climate change in the developing world. *Progress in Development Studies*, 3(3), 179–195. <https://doi.org/10.1191/1464993403ps060oa>
- Adger, W. N., Jouni, P., Saleemul, H., & Mace, M. J. (2006). *Fairness in Adaptation to Climate Change*. The Massachusetts Institute of Technology Press. <https://mitpress.mit.edu/9780262511933/fairness-in-adaptation-to-climate-change/#:~:text=Fairness%20in%20Adaptation%20to%20Climate%20Change%20looks%20at%20the%20challenges,burdens%20on%20already%20vulnerable%20populations>.
- Adger, W. N., Lorenzoni, I., & O'Brien, K. (2009). *Adapting to climate change* (W. N. Adger, I. Lorenzoni, & K. L. O'Brien, Eds.). Cambridge University Press.
- Agar, J., Shivilani, M., Fleming, C., & Solís, D. (2019). Small-scale fishers' perceptions about the performance of seasonal closures in the commonwealth of Puerto Rico. *Ocean and Coastal Management*, 175(March), 33–42. <https://doi.org/10.1016/j.ocecoaman.2019.03.025>
- Ahmed, N., & Thompson, S. (2019). The blue dimensions of aquaculture: A global synthesis. *Science of the Total Environment*, 652, 851–861. <https://doi.org/10.1016/j.scitotenv.2018.10.163>

- A.K., E. H., Mukhopadhyay, P., Nepal, M., & Shammin, M. R. (2016). *Climate Change and Community Resilience* (Vol. 15, Issue 2).
- Akhtar, A., Suzan Khan, M., Hasan, M., Farhaduzzaman, A., Hasan Osman, M., & Neamul Hasan Shovon, M. (2022). Baseline Survey Report on Seaweed Cultivation, Processing, and Marketing for Employment Generation in Bangladesh's Coastal Poor Communities. In *International Journal of Innovative Science and Research Technology* (Vol. 7, Issue 11). www.ijisrt.com
- Alemañ, A. E., Robledo, D., & Hayashi, L. (2019). Development of seaweed cultivation in Latin America: current trends and future prospects. *Phycologia*, 58(5), 462–471. <https://doi.org/10.1080/00318884.2019.1640996>
- Alleway, H., Brummett, R., Bank Junning Cai, W., Cao, L., Reilly Cayten, M., Antonio Costa-Pierce, B., Dobbins, P., Dong, Y., Cole Brandstrup Hansen, S., Jones, R., Liu, S., Charles Shelley, C., Theuerkauf, S., Tucker, L., Waters, T., & Wang, Y. (2021). *Global Principles of Restorative Aquaculture*.
- Alleway, H. K. (2023). Reducing global land-use pressures with seaweed farming. *Nature Sustainability*, 6(6), 380–390. <https://doi.org/10.1038/s41893-022-01043-y>
- Alleway, H. K., Gillies, C. L., Bishop, M. J., Gentry, R. R., Theuerkauf, S. J., & Jones, R. (2019). The Ecosystem Services of Marine Aquaculture: Valuing Benefits to People and Nature. *BioScience*, 69(1), 59–68. <https://doi.org/10.1093/biosci/biy137>
- Alley, R. B., Emanuel, K. A., & Zhang, F. (2019). Weather: Advances in weather prediction. In *Science* (Vol. 363, Issue 6425, pp. 342–344). American Association for the Advancement of Science. <https://doi.org/10.1126/science.aav7274>
- Allison, E. H., & Ellis, F. (2001). The livelihoods approach and management of small-scale fisheries. *Marine Policy*, 25(5), 377–388. [https://doi.org/10.1016/S0308-597X\(01\)00023-9](https://doi.org/10.1016/S0308-597X(01)00023-9)
- Alosaimi, F. D., Almufleh, A., Kazim, S., & Aladwani, B. (2015). Stress-coping strategies among medical residents in Saudi Arabia: A cross-sectional national study. *Pakistan Journal of Medical Sciences*, 31(3), 504–509. <https://doi.org/10.12669/pjms.313.7490>
- Al-Taai, S. H. H. (2021a). Green economy and sustainable development. *IOP Conference Series: Earth and Environmental Science*, 779(1). <https://doi.org/10.1088/1755-1315/779/1/012007>
- Al-Taai, S. H. H. (2021b). Green economy and sustainable development. *IOP Conference Series: Earth and Environmental Science*, 779(1). <https://doi.org/10.1088/1755-1315/779/1/012007>
- Altunyan, K. (2023). Decision-making: The Process Contributing to Professional Public Administration. *Journal of Political Science: Bulletin of Yerevan University*, 2(3(6)), 76–87. <https://doi.org/10.46991/jops/2023.2.6.076>
- Álvarez-Viñas, M., Flórez-Fernández, N., Torres, M. D., & Domínguez, H. (2019). Successful approaches for a red seaweed biorefinery. In *Marine Drugs* (Vol. 17, Issue 11). MDPI AG. <https://doi.org/10.3390/md17110620>
- Alves, C. L., Garcia, O. D., & Kramer, R. A. (2022). Fisher perceptions of Belize's Managed Access program reveal overall support but need for improved enforcement. *Marine Policy*, 143. <https://doi.org/10.1016/j.marpol.2022.105192>

- Amri, S. N., & Arifin, T. (2016). Adaptation Strategy of Seaweed Cultivation to Face the Climate Change (Case Study in Segoro Anakan Bay Ngadirojo, Pacitan). *Forum Geografi*, 30(1), 34. <https://doi.org/10.23917/forgeo.v30i1.1114>
- Andriesse, E., & Lee, Z. (2017). Viable insertion in agribusiness value chains ? Seaweed farming after Typhoon Yolanda ( Haiyan ) in Iloilo Province , Philippines : Seaweed farming after Viable insertion in agribusiness value chains ? Seaweed farming after Typhoon Yolanda ( Haiyan ) in I. *Journal of Tropical Geography*, January. <https://doi.org/10.1111/sjtg.12178>
- Angelsen, A., Larsen, H. O., Lund, J. F., Smith-Hall, C., & Wunder, S. (2011). *Measuring Livelihoods and Environmental Dependence: Methods for Research and Fieldwork* (A. Angelsen, H. O. Larsen, J. F. Lund, C. Smith-Hall, & S. Wunder, Eds.). Earthscan.
- Angelsen, A., Overgaard Larsen, H., Friis Lund, J., Smith-Hall, C., & Wunder, S. (2011). *Measuring Livelihoods and Environmental Dependence: Methods for Research and Fieldwork*. Earthscan.
- Apostolides, A., & Moncada, S. (2013). *Development theory & Development in Practice: A Dialogue*. 143.
- Aslan, L. O. M., Supendy, R., Taridala, S. A. A., Hafid, H., Sifatu, W. O., Sailan, Z., & Niampe, L. (2018). Income of Seaweed Farming Households: A Case Study from Lemo of Indonesia. *IOP Conference Series: Earth and Environmental Science*, 175(1). <https://doi.org/10.1088/1755-1315/175/1/012221>
- Ayers, J., & Dodman, D. (2010). Climate change adaptation and development I: The state of the debate. *Progress in Development Studies*, 10(2), 161–168. <https://doi.org/10.1177/146499340901000205>
- Ayers, J., & Forsyth, T. (2009). Community-based adaptation to climate change. *Environment*, 51(4), 22–31. <https://doi.org/10.3200/ENV.51.4.22-31>
- Badjeck, M. C., Allison, E. H., Halls, A. S., & Dulvy, N. K. (2010a). Impacts of climate variability and change on fishery-based livelihoods. *Marine Policy*, 34(3), 375–383. <https://doi.org/10.1016/j.marpol.2009.08.007>
- Badjeck, M. C., Allison, E. H., Halls, A. S., & Dulvy, N. K. (2010b). Impacts of climate variability and change on fishery-based livelihoods. *Marine Policy*, 34(3), 375–383. <https://doi.org/10.1016/j.marpol.2009.08.007>
- Bai, J., & Cheng, J. (2018). International instruments for the prevention of marine alien invasive species. In *World Seas: An Environmental Evaluation Volume III: Ecological Issues and Environmental Impacts* (pp. 353–366). Elsevier. <https://doi.org/10.1016/B978-0-12-805052-1.00022-X>
- Baweja, P., Sahoo, D., García-Jiménez, P., & Robaina, R. R. (2009). Review: Seaweed tissue culture as applied to biotechnology: Problems, achievements and prospects. In *Phycological Research* (Vol. 57, Issue 1, pp. 45–58). Blackwell Publishing. <https://doi.org/10.1111/j.1440-1835.2008.00520.x>
- Bedsworth, L. W., & Hanak, E. (2010). Adaptation to climate change: A review of challenges and tradeoffs in six areas. In *Journal of the American Planning Association* (Vol. 76, Issue 4, pp. 477–495). <https://doi.org/10.1080/01944363.2010.502047>



- Begum, R., Howlader, S., Mamun-Or-Rashid, A. N. M., Rafiquzzaman, S. M., Ashraf, G. M., Albadrani, G. M., Sayed, A. A., Peluso, I., Abdel-Daim, M. M., & Uddin, M. S. (2021). Antioxidant and Signal-Modulating Effects of Brown Seaweed-Derived Compounds against Oxidative Stress-Associated Pathology. In *Oxidative Medicine and Cellular Longevity* (Vol. 2021). Hindawi Limited. <https://doi.org/10.1155/2021/9974890>
- Bhuyan, M. S., Islam, M. N., Sharif, A. S. M., Islam, M. M., Islam, M. S., & Hoq, M. E. (2021). Seaweed: A Powerful Tool for Climate Change Mitigation That Provides Various Ecological Services. In *Springer Climate* (pp. 159–192). Springer Science and Business Media B.V. [https://doi.org/10.1007/978-3-030-71950-0\\_5](https://doi.org/10.1007/978-3-030-71950-0_5)
- Birkmann, J., Liwenga, E., & Pandey, R. (2023). Poverty, Livelihoods and Sustainable Development. In T. Oki, J. M. McMillan, & M. Ravan (Eds.), *Climate Change 2022 – Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)* (pp. 1171–1284). Cambridge University Press. <https://doi.org/10.1017/9781009325844.010>
- Blanco, G., de Coninck, H., Agbemabiese, L., Mbaye Diagne, E. H., Diaz Anadon, L., Lim, Y. S., Pengue, W. A., Sagar, A. D., Sugiyama, T., Tanaka, K., Verdolini, E., & Witajewski-Baltvilks, J. (2022). Innovation, Technology Development and Transfer. In *Climate Change 2022 - Mitigation of Climate Change* (pp. 1641–1726). Cambridge University Press. <https://doi.org/10.1017/9781009157926.018>
- Bondarchuk, O., Balakhtar, V., Pinchuk, N., Pustovalov, I., & Pavlenok, K. (2023). Adaptation of Coping Strategies to Reduce the Impact of Stress and Loneliness on the Psychological Well-Being of Adults. *Journal of Law and Sustainable Development*, 11(10), e1852. <https://doi.org/10.55908/sdgs.v11i10.1852>
- Bondarchuk, O., Balakhtar, V., Pinchuk, N., Pustovalov, I., & Pavlenok, K. (2024). Coping with stressful situations using coping strategies and their impact on mental health. *Multidisciplinary Reviews*, 7, 2024spe034. <https://doi.org/10.31893/multirev.2024spe034>
- Bokhtiar, S. M., Rahman, M. M., Sultana, R., & Alam, M. F. (2022). Constraints and opportunities of seaweed farming as a climate-resilient livelihood option in coastal Bangladesh. *Regional Studies in Marine Science*, 50, 102210. <https://doi.org/10.1016/j.rsma.2022.102210>
- Boswell, R., O’kane, D., & Hills, J. (2022). *The Palgrave Handbook of Blue Heritage*.
- Boulahia-Kheder, S. (2021). Review on major fruit flies (Diptera: Tephritidae) in North Africa: Bio-ecological traits and future trends. In *Crop Protection* (Vol. 140). Elsevier Ltd. <https://doi.org/10.1016/j.cropro.2020.105416>
- Bourgougnon, N., Burlot, A. S., & Jacquin, A. G. (2021). Algae for global sustainability? In *Advances in Botanical Research* (1st ed., Vol. 100). Elsevier Ltd. <https://doi.org/10.1016/bs.abr.2021.01.003>
- Boyd, E., Grist, N., Juhola, S., & Nelson, V. (2009). Exploring development futures in a changing climate: Frontiers for development policy and practice. *Development Policy Review*, 27(6), 659–674. <https://doi.org/10.1111/j.1467-7679.2009.00464.x>
- Braun, B., & Aßheuer, T. (2011). Floods in megacity environments: Vulnerability and coping strategies of slum dwellers in Dhaka/Bangladesh. *Natural Hazards*, 58(2), 771–787. <https://doi.org/10.1007/s11069-011-9752-5>

- Brechin, S. R., & Salas, O. (2011). Government-ngo networks & nature conservation in belize: Examining the theory of the hollow state in a developing country context. *Journal of Natural Resources Policy Research*, 3(3), 263–274. <https://doi.org/10.1080/19390459.2011.591754>
- Bridgewater, P. (2018). Whose nature? What solutions? Linking Ecohydrology to Nature-based solutions. *Ecohydrology and Hydrobiology*, 18(4), 311–316. <https://doi.org/10.1016/j.ecohyd.2018.11.006>
- Briguglio, L. (2016). Exposure to external shocks and economic resilience of countries: evidence from global indicators. *Journal of Economic Studies*, 43(6), 1057–1078. <https://doi.org/10.1108/JES-12-2014-0203>
- British High Commission Belmopan. (2024, May 18). UK Awards to Empower Women in Seaweed Mariculture Sector in Belize. *GOV.UK*, 1–5.
- Brown, A. (2012). Ocean acidification: Flourishing seaweed. *Nature Climate Change*, 2(7).
- Brown, S., Nicholls, R. J., Woodroffe, C. D., Hanson, S., Hinkel, J., Kebede, A. S., Neumann, B., & Vafeidis, A. T. (2013). Sea-level rise impacts and responses: A global perspective. In *Coastal Research Library* (Vol. 1000, pp. 117–149). Springer. [https://doi.org/10.1007/978-94-007-5234-4\\_5](https://doi.org/10.1007/978-94-007-5234-4_5)
- BTB, & MBECA. (2011). *National Sustainable Tourism Masterplan for Belize 2030 Executive Summary*. June, 502 pages.
- Burton, I., Huq, S., Lim, B., Pilifosova, O., & Schipper, E. L. (2002). From impacts assessment to adaptation priorities: The shaping of adaptation policy. *Climate Policy*, 2(2–3), 145–159. <https://doi.org/10.3763/cpol.2002.0217>
- Burton, I., Klein, R. J. T., & Wandel, J. (2000). *An Anatomy of Adaptation to Climate Change and Variability*. 45, 223–251.
- Burbridge, P. R., Hendrick, V. J., Roth, E., & Rosenthal, H. (2001). Environmental and social impacts of aquaculture. In R. R. Stickney (Ed.), *Encyclopedia of aquaculture* (pp. 299–307). John Wiley & Sons.
- Buschmann, A. H., Camus, C., Infante, J., Neori, A., Israel, Á., Hernández-González, M. C., Pereda, S. V., Gomez-Pinchetti, J. L., Golberg, A., Tadmor-Shalev, N., & Critchley, A. T. (2017). Seaweed production: overview of the global state of exploitation, farming and emerging research activity. *European Journal of Phycology*, 52(4), 391–406. <https://doi.org/10.1080/09670262.2017.1365175>
- Busthanul, N., Suwandi, R., & Firmansyah, R. (2019). The dynamics of seaweed market demand and implications for sustainable coastal livelihoods in Indonesia. *Journal of Fisheries and Marine Research*, 3(1), 45–52.
- CABI. (2023). *Eucheuma spp. Summary Datasheet Type(s) Preferred Scientific Name*. In *Invasive Species Compendium*. Wallingford, UK: CAB International. Retrieved from <https://www.cabi.org/isc/datasheet/11702>
- Cabral, P., Levrel, H., Viard, F., Frangoudes, K., Girard, S., & Scemama, P. (2016). Ecosystem services assessment and compensation costs for installing seaweed farms. *Marine Policy*, 71, 157–165. <https://doi.org/10.1016/j.marpol.2016.05.031>

- Cacaj, O., & Melonashi, E. (2019). *Personality traits and stress coping strategies among Albanian young adulthoods. 2.*
- Cai, J. (2021). *Global seaweeds and microalgae production, 1950-2019 WAPI factsheet to facilitate evidence-based policy-making and sector management in aquaculture.* <http://unohrrls.org/about-sids/country-profiles/>.
- Cai, J., Lovatelli, A., Gamarro, E. G., Geehan, J., Lucente, D., Mair, G., Miao, W., Reantaso, M., Roubach, R., Yuan, X., Aguilar-Manjarrez, Cornish, L., Dabbadie, L., Desrochers, A., Diffey, S., Tuati, M., Hurtado, A., Potin, P. P., & Pryzbyla, C. (2021). Seaweeds and Microalgae: An Overview for Unlocking their Potential in Global Aquaculture Development. In *FAO Fisheries and Aquaculture Circular No. 1229*. <https://doi.org/10.4060/cb5670en>
- Camarra, P. C. (1998). *CRiSTAL Supports Climate-Resilient Development in the Peruvian Andes.*
- CARIBSAVE. (2012). *Climate Risks Profile for Belize*. Bridgetown, Barbados: The CARIBSAVE Partnership.
- Cassin, J. (2021). History and development of nature-based solutions: Concepts and practice. In *Nature-Based Solutions and Water Security: An Action Agenda for the 21st Century* (pp. 19–34). Elsevier. <https://doi.org/10.1016/B978-0-12-819871-1.00018-X>
- CAST. (2015). *Sargassum A Resource Guide for the Caribbean*. Cave Hill, Barbados: University of the West Indies, Centre for Resource Management and Environmental Studies (CERMES).
- CBD. (2014). *Connecting biodiversity and climate change mitigation and adaptation : Report of the second Ad Hoc Technical Expert Group on Biodiversity and Climate Change*. Secretariat of the Convention on Biological Diversity.
- CCCCC. (2012). *Delivering Transformational Change 2011-21: Implementing the CARICOM “Regional Framework for Achieving Development Resilient to Climate Change”* (Issue March).
- CDB. (2018a). *Financing the Blue Economy: A Caribbean Development Opportunity*.
- CDB. (2018b). *Financing the Blue Economy: A Caribbean Development Opportunity*. The Caribbean Development Bank.
- Chambers, R., & Conway, G. R. (1991). *Sustainable rural livelihoods: practical concepts for the 21st century*.
- Chambers, R., & Conway, G. R. (1992). Sustainable rural livelihoods: practical concepts for the 21st century. *IDS Discussion Paper*, 296.
- Cherian, A. (2007). Linkages between biodiversity conservation and global climate change in small island developing States (SIDS). *Natural Resources Forum*, 31(2), 128–131. <https://doi.org/10.1111/j.1477-8947.2007.00138.x>
- Cherrington, E. A., Hernandez, B. E., Trejos, N. N., Smith, O. A., Anderson, E. R., Flores, A. I., & Garcia, B. C. (2010). Identifying Threatened & Resilient Mangroves in Belize (1980-2010). *Development, May 2014*, 1–33.

- Chete, O. B. (2019). Factors influencing adaptation to climate change among smallholder farming communities in Nigeria. *African Crop Science Journal*, 27(1), 45. <https://doi.org/10.4314/acsj.v27i1.4>
- Chinowsky, P., Hayles, C., Schweikert, A., Strzepek, N., Strzepek, K., & Schlosser, C. A. (2011). Climate change: comparative impact on developing and developed countries. *Engineering Project Organization Journal*, 1(1), 67–80. <https://doi.org/10.1080/21573727.2010.549608>
- Choi, Y. R. (2017). The Blue Economy as governmentality and the making of new spatial rationalities. *Dialogues in Human Geography*, 7(1), 37–41. <https://doi.org/10.1177/2043820617691649>
- Chudasama, N. A., Sequeira, R. A., Moradiya, K., & Prasad, K. (2021). Seaweed polysaccharide based products and materials: An assessment on their production from a sustainability point of view. In *Molecules* (Vol. 26, Issue 9). MDPI AG. <https://doi.org/10.3390/molecules26092608>
- Cingano, F. (2014). Trends in Income Inequality and its Impact on Economic Growth. *OECD Social, Employment, and Migration Working Papers*, 163, 0\_1,5-59. <https://doi.org/http://dx.doi.org/10.1787/5jxrjncwvxv6j-en>
- Cinner, J. E., & Barnes, M. L. (2019). Social Dimensions of Resilience in Social-Ecological Systems. In *One Earth* (Vol. 1, Issue 1, pp. 51–56). Cell Press. <https://doi.org/10.1016/j.oneear.2019.08.003>
- Climate Resilient Food Systems Alliance. (2022). *Belize: A Case Study Conducted by the Climate Resilient Food Systems Alliance*.
- Cole, D. W., Cole, R., Gaydos, S. J., Gray, J., Hyland, G., Jacques, M. L., Powell-Dunford, N., Sawhney, C., & Au, W. W. (2009). Aquaculture: Environmental, toxicological, and health issues. *International Journal of Hygiene and Environmental Health*, 212(4), 369–377. <https://doi.org/10.1016/j.ijheh.2008.08.003>
- Colls, A., Ash, Neville., Ikkala, N. (Ninni), IUCN--The World Conservation Union., IUCN Commission on Ecosystem Management., & Nature Conservancy (U.S.). (2009). *Ecosystem-based adaptation : a natural response to climate change*. IUCN.
- Comoé, H., & Siegrist, M. (2015). Relevant drivers of farmers' decision behavior regarding their adaptation to climate change: a case study of two regions in Côte d'Ivoire. *Mitigation and Adaptation Strategies for Global Change*, 20(2), 179–199. <https://doi.org/10.1007/s11027-013-9486-7>
- ComSec. (2016). *The Blue Economy and Small States. Commonwealth Blue Economy Series, No. 1* (Issue 1).
- ComSec. (2021). *Commonwealth Blue Charter: Shared Values, Shared Ocean, A Commonwealth Commitment to Work Together to Protect and Manage our Ocean*.
- ComSec. (2022). *An Ocean of Opportunity Commonwealth Blue Charter: Ocean Action Report*.
- Cooper, E., Burke, L., & Bood, N. (2009). Coastal capital: Economic contribution of coral reefs and mangroves to Belize. *World Resources Institute, Washington, DC., January*, 53.

- Corey, P., Kim, J. K., Duston, J., & Garbary, D. J. (2014). Growth and nutrient uptake by *Palmaria palmata* integrated with Atlantic halibut in a land-based aquaculture system. *Algae*, 29(1), 35–45. <https://doi.org/10.4490/algae.2014.29.1.035>
- Cotas, J., Leandro, A., Monteiro, P., Pacheco, D., Figueirinha, A., Gonçalves, A. M. M., Da Silva, G. J., & Pereira, L. (2020). Seaweed phenolics: From extraction to applications. In *Marine Drugs* (Vol. 18, Issue 8). MDPI AG. <https://doi.org/10.3390/MD18080384>
- Cottier-Cook, E., Lim, P. E., Mallinson, S., Yahya, N., Poong, S. W., Wilbraham, J., Nagabhatla, N., & Brodie, J. (2023). *Striking a Balance: Wild Stock Protection and the Future of Our Seaweed Industries*. [https://cris.unu.edu/sites/cris.unu.edu/files/UNU-CRIS\\_Policy-Brief\\_CottierCook\\_Et.al\\_23.06.pdf](https://cris.unu.edu/sites/cris.unu.edu/files/UNU-CRIS_Policy-Brief_CottierCook_Et.al_23.06.pdf)
- Cottier-Cook, E., Nagabhatla, N., Asri, A., Beveridge, M., Bianchi, P., Bolton, J., Bondad-Reantaso, M. G., Brodie, J., Buschmann, A., Cabarubias, J., Matoju, I., Montalescot, V., Msuya, F. E., Potin, P., Puspita, M., Qi, Z., Shaxson, L., Pinto, I. S., Stentiford, G. D., ... Critchle, A. (2021). *Ensuring the sustainable future of the rapidly expanding global seaweed aquaculture industry*.
- Creswell, J. W. (2011). Controversies in Mixed Methodology Research. In *Strategies of Inquiry* (pp. 269–283). <https://doi.org/10.1254/fpj.94.223>
- CRFM. (2020). *CRFM Statistics and Information Report For 2020*. Belize City, Belize: Caribbean Regional Fisheries Mechanism. Retrieved from <https://www.crfm.int/>
- Crouan, P., & Crouan, H. (1866). *Gracilariaria crassissima*. In *Algaebase* (pp. 1–3). (February 5, 2022) from <https://www.algaebase.org>
- CZMAI. (2016). *Belize Integrated Coastal Zone Management Plan*. Belize: Coastal Zone Management Authority and Institute.
- Darmi, Hasbullah, R., & Jahroh, S. (2018). Seaweed Business Development Strategy in Buton Regency, Southeast Sulawesi of Indonesia. *Russian Journal of Agricultural and Socio-Economic Sciences*, 83(11), 353–360. <https://doi.org/10.18551/rjoas.2018-11.42>
- Das, J. (2023). Blue Economy, Blue Growth, Social Equity and Small-scale Fisheries: A Global and National Level Review. *Studies in Social Science Research*, 4(1), p38. <https://doi.org/10.22158/sss.v4n1p38>
- de Góes, H. G., & Reis, R. P. (2011). An initial comparison of tubular netting versus tie-tie methods of cultivation for *Kappaphycus alvarezii* (Rhodophyta, Solieriaceae) on the south coast of Rio de Janeiro State, Brazil. *Journal of Applied Phycology*, 23(3), 607–613. <https://doi.org/10.1007/s10811-010-9647-y>
- de Jong Cleyndert, G., Newman, R., Brugere, C., Cuni-Sanchez, A., & Marchant, R. (2021). Adaptation of Seaweed Farmers in Zanzibar to the Impacts of Climate Change. In *African Handbook of Climate Change Adaptation: With 610 Figures and 361 Tables*. [https://doi.org/10.1007/978-3-030-45106-6\\_54](https://doi.org/10.1007/978-3-030-45106-6_54)
- de la Torre-Castro, M., Lindström, L., Jiddawi, N. S., Pike, F., & Max, A. (2022). Women and adaptive capacity to climate change in East African seascapes – Zanzibar as an example. *Frontiers in Marine Science*, 9. <https://doi.org/10.3389/fmars.2022.931883>
- Debels, P., Fanning, L., Mahon, R., McConney, P., Walker, L., Bahri, T., Haughton, M., McDonald, K., Perez, M., Singh-Renton, S., Toro, C., Van Anrooy, R., Khouri, A. V., & Whalley, P. (2017). The CLME+ Strategic Action Programme: An ecosystems approach

- for assessing and managing the Caribbean sea and North Brazil Shelf Large Marine Ecosystems. *Environmental Development*, 22, 191–205. <https://doi.org/10.1016/j.envdev.2016.10.004>
- Del Rio-Portilla, M. A., Re-Araujo, A. D., & Voltolina, D. (1992). *Growth of the pearl oyster Pteria sterna under different thermic and feeding conditions*. 89, 221–227.
- Dewan, A. M. (2013). *Floods in a Megacity: Geospatial Techniques in Assessing Hazards, Risk and Vulnerability*. Springer Geography . <http://www.springer.com/series/10180>
- DFID. (2010). The Politics of Poverty: Elites, Citizens and States. In *DFID Synthesis Paper*.
- Dhar, T. K., & Khirfan, L. (2016). Community-based adaptation through ecological design: lessons from Negril, Jamaica. *Journal of Urban Design*, 21(2), 234–255. <https://doi.org/10.1080/13574809.2015.1133224>
- Dhungana, A. R., Kc, V., & Dhungana, S. M. (2020). *Determinants of Households' Adaptation Practices against Climate Change Impact on Off-farm Activities in Nawalpur District, Nepal*. <https://scienceforecastoa.com/>
- Diaz, S., Hodgson, J. G., Thompson, K., Cabido, M., Cornelissen, J. H. C., Jalili, A., Zak, M. R., Montserat-Marti, G., Grime, J. P., Zarrinkamar, F., Asri, Y., Band, S. R., Basconcelo, S., Castro-Diez, P., Funes, G., Hamzehee, B., Khoshnevi, M., Perez-Harguindeguy, N., Perez-Rontome, M. C., ... Villar-Savador, P. (2004). The plant traits that drive ecosystems: Evidence from three continents. *Journal of Vegetation Science*, 15, 295–304.
- Dorji, T., Rinchen, K., Morrison-Saunders, A., Blake, D., Banham, V., & Pelden, S. (2024). Understanding How Indigenous Knowledge Contributes to Climate Change Adaptation and Resilience: A Systematic Literature Review. *Environmental Management*. <https://doi.org/10.1007/s00267-024-02032-x>
- Dovie, D. B. K., & Pabi, O. (2023). Partial climatic risk screening, adaptation and livelihoods in a coastal urban area in Ghana. *Habitat International*, 138. <https://doi.org/10.1016/j.habitatint.2023.102868>
- Duarte, C. M., Bruhn, A., & Krause-Jensen, D. (2022). A seaweed aquaculture imperative to meet global sustainability targets. In *Nature Sustainability* (Vol. 5, Issue 3, pp. 185–193). Nature Research. <https://doi.org/10.1038/s41893-021-00773-9>
- Duarte, C. M., Wu, J., Xiao, X., Bruhn, A., & Krause-Jensen, D. (2017). Can Seaweed Farming Play a Role in Climate Change Mitigation and Adaptation? *Frontiers in Marine Science*, 4(April). <https://doi.org/10.3389/fmars.2017.00100>
- Echave, J., Fraga-Corral, M., Garcia-Perez, P., Popović-Djordjević, J., Avdović, E. H., Radulović, M., Xiao, J., Prieto, M. A., & Simal-Gandara, J. (2021). Seaweed protein hydrolysates and bioactive peptides: Extraction, purification, and applications. In *Marine Drugs* (Vol. 19, Issue 9). MDPI. <https://doi.org/10.3390/md19090500>
- Eisenack, K., & Stecker, R. (2012). A framework for analyzing climate change adaptations as actions. *Mitigation and Adaptation Strategies for Global Change*, 17(3), 243–260. <https://doi.org/10.1007/s11027-011-9323-9>
- EIU. (2015). The Blue Economy: Growth, Opportunity and a Sustainable Ocean Economy. In *Green Growth Knowledge Platform*.

- El Boukhari, M. E. M., Barakate, M., Bouhia, Y., & Lyamlouli, K. (2020). Trends in seaweed extract based biostimulants: Manufacturing process and beneficial effect on soil-plant systems. In *Plants* (Vol. 9, Issue 3). MDPI AG. <https://doi.org/10.3390/plants9030359>
- El Ouadi, I., & Ouarda, T. B. M. J. (2023). Climate Uncertainty Modelling in Integrated Water Resources Management: Review. *E3S Web of Conferences*, 364. <https://doi.org/10.1051/e3sconf/202336401013>
- Elasha, B. O., Nagmeldin, Goutbi Elhassan Hanafi, A., & Sumaya, Z. (2005). Sustainable livelihood approach for assessing community resilience to climate change : case studies from Sudan Balgis Osman Elasha \*, Nagmeldin Goutbi Elhassan , Hanafi Ahmed , and Sumaya Zakieldin AIACC Working Paper No . 17 August 2005. *AIACC Working Paper*, 17, 1–26.
- Enríquez-de-Salamanca, Á., Díaz-Sierra, R., Martín-Aranda, R. M., & Santos, M. J. (2017). Environmental impacts of climate change adaptation. *Environmental Impact Assessment Review*, 64, 87–96. <https://doi.org/10.1016/j.eiar.2017.03.005>
- Erenstein, O., Hellin, J., & Chandna, P. (2010). Poverty mapping based on livelihood assets: A meso-level application in the Indo-Gangetic Plains, India. *Applied Geography*, 30(1), 112–125. <https://doi.org/10.1016/j.apgeog.2009.05.001>
- Eriksen, S., Schipper, E. L. F., Scoville-Simonds, M., Vincent, K., Adam, H. N., Brooks, N., Harding, B., Khatri, D., Lenaerts, L., Liverman, D., Mills-Novoa, M., Mosberg, M., Movik, S., Muok, B., Nightingale, A., Ojha, H., Sygna, L., Taylor, M., Vogel, C., & West, J. J. (2021). Adaptation interventions and their effect on vulnerability in developing countries: Help, hindrance or irrelevance? *World Development*, 141. <https://doi.org/10.1016/j.worlddev.2020.105383>
- Erondy, E., & Anyanwu, P. (2011). Potential hazards and risks associated with the aquaculture industry. *African Journal of Food, Agriculture, Nutrition and Development*, 4(13), 1622–1627. <https://doi.org/10.4314/ajfand.v4i13.71775>
- Fakhraini, M. S., Wisnu, W., Khathir, R., & Patria, M. P. (2019). Carbon sequestration in macroalgae *Kappaphycus striatum* in seaweed aquaculture site, Alaang village, Alor Island, East Nusa Tenggara. *IOP Conference Series: Earth and Environmental Science*, 404(1). <https://doi.org/10.1088/1755-1315/404/1/012044>
- FAO. (2014). *The State of World Fisheries and Aquaculture 2014*. <http://www.fao.org/3/a-i3720e.pdf>
- FAO. (2015). *Climate change and food security: risks and responses*.
- FAO. (2016). *Strengthening agricultural water efficiency and productivity on the African and global level*.
- FAO. (2017a). *Blue Growth Initiative: Partnering with countries to achieve the Sustainable Development Goals*.
- FAO. (2017b). *Caribbean Fisheries Data and Statistics Coordination Meeting Report*. [www.fao.org/publications](http://www.fao.org/publications)
- FAO. (2020). *Blue Growth Initiative: Blue finance guidance notes on blended finance*.
- FAO. (2021). *Seaweed and Microalgae: An Overview for Unlocking their Potential in Global Aquaculture* (Vol. 1229). <https://doi.org/10.4060/cb5670en>

- FAO. (2022a). *Expert Meeting on Food Safety For Seaweed Current Status and Future Perspectives Food Safety and Quality*.
- FAO. (2022b). *The State of World Fisheries and Aquaculture 2022*.
- FAO. (2022c). *Thinking About the Future of Food Safety - A foresight report*. (Issue May).
- FAO. (2023). The State of Food and Agriculture - Revealing the True Cost of Food to Transform AgriFood Systems. In *The State of Food and Agriculture 2023*. FAO. <https://doi.org/10.4060/cc7724en>
- FAO. (2024). *The State of World Fisheries and Aquaculture (SOFIA) 2024*. FAO. <https://doi.org/10.4060/cd0683en>
- Farghali, M., Mohamed, I. M. A., Osman, A. I., & Rooney, D. W. (2023). Seaweed for climate mitigation, wastewater treatment, bioenergy, bioplastic, biochar, food, pharmaceuticals, and cosmetics: a review. In *Environmental Chemistry Letters* (Vol. 21, Issue 1, pp. 97–152). Springer Science and Business Media Deutschland GmbH. <https://doi.org/10.1007/s10311-022-01520-y>
- Farmery, A. K., Allison, E. H., Andrew, N. L., Troell, M., Voyer, M., Campbell, B., Eriksson, H., Fabinyi, M., Song, A. M., & Steenbergen, D. (2021). Blind spots in visions of a “blue economy” could undermine the ocean’s contribution to eliminating hunger and malnutrition. *One Earth*, 4(1), 28–38. <https://doi.org/10.1016/j.oneear.2020.12.002>
- Farrelly, D. J., Everard, C. D., Fagan, C. C., & McDonnell, K. P. (2013). Carbon sequestration and the role of biological carbon mitigation: A review. In *Renewable and Sustainable Energy Reviews* (Vol. 21, pp. 712–727). Elsevier Ltd. <https://doi.org/10.1016/j.rser.2012.12.038>
- Fedele, G., Donatti, C. I., Harvey, C. A., Hannah, L., & Hole, D. G. (2019). Transformative adaptation to climate change for sustainable social-ecological systems. *Environmental Science and Policy*, 101, 116–125. <https://doi.org/10.1016/j.envsci.2019.07.001>
- Ferdinand, M. (2020). Global Environmental Governance and Small States: Architectures and Agency in the Caribbean, by Michelle Scobie. *New West Indian Guide / Nieuwe West-Indische Gids*, 94(1–2), 173–174. <https://doi.org/10.1163/22134360-09401009>
- Fleurence, È., Physico-chimie, Â., & Qualite, L. (1999). Seaweed proteins : biochemical , nutritional aspects and potential uses. *Trends Food Science & Technology*, 10, 26–29.
- Foley, J., Smith, D., Foley, J. R., San, M., & Road, A. (2014). *Port Honduras Marine Reserve Commercial Benthic Species Audit 2009 - 2013 Conch, Lobster, Sea Cucumber*.
- Food and Agriculture Organization of the United Nations Statistics Division (FAOSTAT). (2017). FAO Yearbook: Fishery and Aquaculture Statistics. 2015. In *FAO Annual Yearbook*. <https://doi.org/10.5860/CHOICE.50-5350>
- Ford, L., Stratakis, A. Ch., Jaimie, T. A. D., Theodoridou, K., Sheldrake, G. N., Linton, M., Corcionivski, N., & Walsh, P. J. (2020). *Polyphenols from Brown Seaweeds as a Potential Antimicrobial Agent in Animal Feeds*.
- Formosa, S., Briguglio, L., & Moncada, S. (2017). Assessing the Vulnerability of Small Island Developing States to Sea-level rise. In *Occasional Papers on Islands and Small States*.



- Forsyth, T. (2013). Community-based adaptation: A review of past and future challenges. *Wiley Interdisciplinary Reviews: Climate Change*, 4(5), 439–446. <https://doi.org/10.1002/wcc.231>
- Fritz, M., & Koch, M. (2016). Economic development and prosperity patterns around the world: Structural challenges for a global steady-state economy. *Global Environmental Change*, 38, 41–48. <https://doi.org/10.1016/j.gloenvcha.2016.02.007>
- Froehlich, H. E., Afflerbach, J. C., Frazier, M., & Halpern, B. S. (2019a). Blue Growth Potential to Mitigate Climate Change through Seaweed Offsetting. *Current Biology*, 29(18), 3087–3093.e3. <https://doi.org/10.1016/j.cub.2019.07.041>
- Froehlich, H. E., Afflerbach, J. C., Frazier, M., & Halpern, B. S. (2019b). Blue Growth Potential to Mitigate Climate Change through Seaweed Offsetting. *Current Biology*, 29(18), 3087–3093.e3. <https://doi.org/10.1016/j.cub.2019.07.041>
- Galaiti, S. E., Corbin, C., Cox, S.-A., Joseph, G., Mcconney, P., Cashman, A., Springer, C., Keenan, J., Cummings, C. L., Trump, B. D., & Linkov, I. (2024). *Balancing Climate Resilience and Adaptation for Caribbean Small Island Developing States (SIDS) Building Institutional Capacity Environmental Laboratory*. <https://erdclibrary.on.worldcat.org/discovery>.
- Galappaththi, E. K., & Schlingmann, A. (2023). The sustainability assessment of Indigenous and local knowledge-based climate adaptation responses in agricultural and aquatic food systems. In *Current Opinion in Environmental Sustainability* (Vol. 62). Elsevier B.V. <https://doi.org/10.1016/j.cosust.2023.101276>
- Gamble, D. (2014). The neglected climatic hazards of the Caribbean: Overview and prospects in a warmer climate. *Geography Compass*, 8(4), 221–234. <https://doi.org/10.1111/gec3.12125>
- Gao, G., Gao, L., Jiang, M., Jian, A., & He, L. (2022). The potential of seaweed cultivation to achieve carbon neutrality and mitigate deoxygenation and eutrophication. *Environmental Research Letters*, 17(1). <https://doi.org/10.1088/1748-9326/ac3fd9>
- García-Poza, S., Leandro, A., Cotas, C., Cotas, J., Marques, J. C., Pereira, L., & Gonçalves, A. M. M. (2020). The evolution road of seaweed aquaculture: Cultivation technologies and the industry 4.0. In *International Journal of Environmental Research and Public Health* (Vol. 17, Issue 18). <https://doi.org/10.3390/ijerph17186528>
- Gegg, P., & Wells, V. (2017). UK macro-algae biofuels: A strategic management review and future research agenda. In *Journal of Marine Science and Engineering* (Vol. 5, Issue 3). MDPI AG. <https://doi.org/10.3390/jmse5030032>
- Gegg, P., & Wells, V. (2019). The development of seaweed-derived fuels in the UK: An analysis of stakeholder issues and public perceptions. *Energy Policy*, 133. <https://doi.org/10.1016/j.enpol.2019.110924>
- Gettelman, A., & Rood, R. B. (2016). *Earth Systems Data and Models Demystifying Climate Models A Users Guide to Earth System Models*. SpringerNature. <http://www.springer.com/series/10525>
- Giakoumi, S., Katsanevakis, S., Albano, P. G., Azzurro, E., Cardoso, A. C., Cebrian, E., Deidun, A., Edelist, D., Francour, P., Jimenez, C., Mačić, V., Occhipinti-Ambrogi, A., Rilov, G., & Sghaier, Y. R. (2019). Management priorities for marine invasive species.

- Science of the Total Environment*, 688, 976–982.  
<https://doi.org/10.1016/j.scitotenv.2019.06.282>
- Girod, P., Ehrhart, C., Oglethorpe, J., Reid, H., Rossing, T., Gambarelli, G., Jeans, H., Barrow, E., Martin, S., Ikkala, N., & Phillips, J. (2012). Integrating Community and Ecosystem Based Approaches in Climate Change Adaptation Responses. *Ecosystem and Livelihoods Adaptation Network (ELAN)*, 1–19.  
[http://www.careclimatechange.org/files/adaptation/ELAN\\_IntegratedApproach\\_150412.pdf](http://www.careclimatechange.org/files/adaptation/ELAN_IntegratedApproach_150412.pdf)
- GOB. (2014). *Current and Planned Climate Change Adaptation Actions for Belize “exploring financial opportunities”*.
- GOB. (2021). *Belize’s Updated Nationally Determined Contribution*.
- GOB, & CDB. (2010). *Country Poverty Assessment Final Report*. [www.halcrow.com](http://www.halcrow.com)
- GOB MBECA. (2021). *Belize Blue Economy Stocktake and Diagnostic Analysis*.
- Gomez, G. M. (2004). A rapid ecological assesment (REA) of coral reefs and reef fishes of barrier islands within central Belize barrier reef complex utilizing the mesoamerican barrier reef systems (MBRS) protocol. *Marine Resource Management Program, Master of*, 87.
- Gosling-Goldsmith, J., Ricker, B., & Kraak, M. J. (2019). Sustainable Development Goals and Visualizing Small Island Developing States. *Proceedings of the ICA*, 2, 1–8.  
<https://doi.org/10.5194/ica-proc-2-40-2019>
- Grigorieva, E. A., & Revich, B. A. (2021). Health Risks to the Russian Population from Temperature Extremes at the Beginning of the XXI Century. *Atmosphere*, 12(10).  
<https://doi.org/10.3390/atmos12101331>
- Gutierrez-Corley, R., Cruickshank, A., & Moncada, S. (2023). Chapter 3 Network governance and role of environmental non-governmental organizations in Belize. In *Handbook of Civil Society and Social Movement in Small States* (pp. 46–61).
- Handmer, J., & Dovers, S. (2007). *The Handbook of Disaster and Emergency Policies and Institutions*. Earthscan.
- Hansen, H. R., Hector, B. L., & Feldmann, J. (2003). A qualitative and quantitative evaluation of the seaweed diet of North Ronaldsay sheep. *Animal Feed Science and Technology*, 105(1–4), 21–28. [https://doi.org/10.1016/S0377-8401\(03\)00053-1](https://doi.org/10.1016/S0377-8401(03)00053-1)
- Hansen, L. T., & Hoffman, J. R. (2011). Climate savvy: Adapting conservation and resource management to a changing world. *Open Journal of Applied Sciences*, 02(03), 168–176.  
<https://doi.org/10.4236/ojapps.2012.23024>
- Hassan, I. H., & Othman, W. J. (2019). Seaweed ( Mwani ) Farming as an Adaptation Strategy to Impacts of Climate Change and Variability in Zanzibar. *Springer Climate*.  
<https://doi.org/10.1007/978-3-030-04897-6>
- Hasselström, L., Visch, W., Gröndahl, F., Nylund, G. M., & Pavia, H. (2018). The impact of seaweed cultivation on ecosystem services - a case study from the west coast of Sweden. *Marine Pollution Bulletin*, 133(October 2017), 53–64.  
<https://doi.org/10.1016/j.marpolbul.2018.05.005>

- Hayashi, L., Bulboa, C., Kradolfer, P., Soriano, G., & Robledo, D. (2014). Cultivation of red seaweeds: a Latin American perspective. *Journal of Applied Phycology*, 26(2), 719–727. <https://doi.org/10.1007/s10811-013-0143-z>
- Hayashi, L., de J. Cantarino, S., & Critchley, A. T. (2020). Challenges to the future domestication of seaweeds as cultivated species: understanding their physiological processes for large-scale production. *Advances in Botanical Research*, 95, 57–83. <https://doi.org/10.1016/bs.abr.2019.11.010>
- Healthy Reefs. (2022). *Meso-American Reef Report Card: Evaluation of Ecosystem Health*. [www.healthyreefs.org](http://www.healthyreefs.org)
- Hirsch, T., & Hampel, V. (2020). *Climate Risk Insurance and Risk Financing in the Context of Climate Justice A Manual for Development and Humanitarian Aid Practitioners cover photo: alpha kapola/nca*.
- Hoegh-Guldberg, O., Jacob, D., Taylor, M., Guillén Bolaños, T., Bindi, M., Brown, S., Diedhiou, A., Djalante, R., Ebi, K., Engelbrecht, F., Guiot, J., Hijioka, Y., Hope, C. W., Payne, A. J., Pörtner, H., Seneviratne, S. I., Thomas, A., & Zhou, G. (2019). *The human imperative of stabilizing global climate change at 1.5°C* (Vol. 30).
- Holdt, S. L., & Kraan, S. (2011). Bioactive compounds in seaweed: Functional food applications and legislation. In *Journal of Applied Phycology* (Vol. 23, Issue 3, pp. 543–597). <https://doi.org/10.1007/s10811-010-9632-5>
- Hong, S. K. (2013). Biocultural diversity conservation for island and islanders: Necessity, goal and activity. *Journal of Marine and Island Cultures*, 2(2), 102–106. <https://doi.org/10.1016/j.imic.2013.11.004>
- Horwich, R. H., & Lyon, J. (1998). Community-based development as a conservation tool: The Community Baboon Sanctuary and the Gales Point Manatee Project. *Timber, Tourists, and Temples: Conservation and Development in the Maya Forest of Belize, Guatemala, and Mexico*, June, 343–363.
- Hossain, M. S., Sharifuzzaman, S. M., Nobil, M. N., Chowdhury, M. S. N., Sarker, S., Alamgir, M., Uddin, S. A., Chowdhury, S. R., Rahman, M. M., Rahman, M. S., Sobhan, F., & Chowdhury, S. (2021). Seaweeds farming for sustainable development goals and blue economy in Bangladesh. *Marine Policy*, 128. <https://doi.org/10.1016/j.marpol.2021.104469>
- Hossain, S. (2005). Poverty, household strategies and coping with urban life: Examining ‘Livelihood Framework’ in Dhaka City, Bangladesh. *Bangladesh E-Journal of Sociology*, 2(1), 1–8.
- Hrólfssdóttir, A. Þ., Arason, S., Sveinsdóttir, H. I., & Guðjónsdóttir, M. (2022). Added Value of *Ascophyllum nodosum* Side Stream Utilization during Seaweed Meal Processing. *Marine Drugs*, 20(6). <https://doi.org/10.3390/md20060340>
- Hu, Q., Sommerfeld, M., Jarvis, E., Ghirardi, M., Posewitz, M., Seibert, M., & Darzins, A. (2008). Microalgal triacylglycerols as feedstocks for biofuel production: Perspectives and advances. *Plant Journal*, 54(4), 621–639. <https://doi.org/10.1111/j.1365-313X.2008.03492.x>
- Hughes, A. (Adam D. ), Day, J. G., Greenhill, L. (Lucy), Stanley, M. S., & Commonwealth Secretariat. (2016). *Aquaculture*. Commonwealth Secretariat.

- Hughes, A. D. (2021). Defining Nature-Based Solutions Within the Blue Economy: The Example of Aquaculture. *Frontiers in Marine Science*, 8. <https://doi.org/10.3389/fmars.2021.711443>
- Hughes, A. D., Day, J. G., Greenhill, L., & Stanley, M. S. (2016). *Commonwealth Blue Economy: Aquaculture* (A. Huges, J. G. Day, & M. S. Stanley, Eds.; Vol. 2). Commonwealth Secretariat.
- Hughes, T. (1994). *Catastrophes, phase shifts and large-scale degradation of a Caribbean Coral Reef*.
- Hung, C. H., Hung, H. C., & Hsu, M. C. (2024). Linking the interplay of resilience, vulnerability, and adaptation to long-term changes in metropolitan spaces for climate-related disaster risk management. *Climate Risk Management*, 44. <https://doi.org/10.1016/j.crm.2024.100618>
- Huq, S., Reid, H., & Murray, L. (2008). *Climate Change and Development Consultation on Key Researchable Issues*.
- Hurd, C. L., Law, C. S., Bach, L. T., Britton, D., Hovenden, M., Paine, E. R., Raven, J. A., Tamsitt, V., & Boyd, P. W. (2022). Forensic carbon accounting: Assessing the role of seaweeds for carbon sequestration. In *Journal of Phycology* (Vol. 58, Issue 3, pp. 347–363). John Wiley and Sons Inc. <https://doi.org/10.1111/jpy.13249>
- Hurtado, A. Q., Neish, I. C., & Critchley, A. T. (2019). Phyconomy: the extensive cultivation of seaweeds, their sustainability and economic value, with particular reference to important lessons to be learned and transferred from the practice of eucheumatoid farming. *Phycologia*, 58(5), 472–483. <https://doi.org/10.1080/00318884.2019.1625632>
- ID and M. (2021). *Belize National Mariculture Policy*.
- IDB. (2020). *Opportunities in the blue economy: Global Industrial Trends and Opportunities in the Caribbean*.
- ID&M. (2019). *Belize National Fisheries Policy, Strategy and Action Plan*.
- ID&M. (2021). *Belize National Mariculture Policy*.
- IISD. (2012). *CRiSTAL User's Manual Version 5: Community-based Risk Screening Tool - Adaptation and Livelihoods*. 56. [www.iisd.org](http://www.iisd.org)
- IMF. (2018). *Belize Climate Change Policy Assessment*. <http://www.imf.org>
- Ingle, K. N., Polikovskiy, M., Chemodanov, A., & Golberg, A. (2018). Marine integrated pest management (MIPM) approach for sustainable seagrass agriculture. *Algal Research*, 29, 223–232. <https://doi.org/10.1016/j.algal.2017.11.010>
- IPCC. (2001). *Climate change 2001 Impacts, Adaptation and Vulnerability*.
- IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change* (Vol. 9781107025). <https://doi.org/10.1017/CBO9781139177245.003>

- IPCC. (2021). Climate Change 2021 The Physical Science Basis Summary for Policymakers Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In *Climate Change 2021: The Physical Science Basis*.
- IPCC. (2022a). Climate Change 2022: Impacts, Adaptation and Vulnerability Working Group II Contribution to the IPCC Sixth Assessment Report Citations to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor,. In *Cambridge University Press* (Issue August). Cambridge University Press. <https://doi.org/10.1017/9781009325844.CITATION>
- IPCC. (2022b). Summary for Policymakers: Climate Change 2022: Impacts, Adaptation and Vulnerability Working Group II contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In *Working Group II contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Issue August). <https://doi.org/10.1017/9781009325844.CITATIONS>
- IPCC. (2022c). Summary for Policymakers: Climate Change 2022\_ Impacts, Adaptation and Vulnerability\_ Working Group II contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In *Working Group II contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. <https://doi.org/10.1017/9781009325844.Front>
- IPCC. (2023a). *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (P. Arias, M. Bustamante, I. Elgizouli, G. Flato, M. Howden, C. Méndez-Vallejo, J. J. Pereira, R. Pichs-Madruga, S. K. Rose, Y. Saheb, R. Sánchez Rodríguez, D. Ürge-Vorsatz, C. Xiao, N. Yassaa, J. Romero, J. Kim, E. F. Haites, Y. Jung, R. Stavins, ... C. Péan, Eds.). <https://doi.org/10.59327/IPCC/AR6-9789291691647>
- IPCC. (2023b). *State of the Climate in Latin America and the Caribbean*.
- Isabelle, D. A., & Westerlund, M. (2022). A Review and Categorization of Artificial Intelligence-Based Opportunities in Wildlife, Ocean and Land Conservation. *Sustainability (Switzerland)*, 14(4). <https://doi.org/10.3390/su14041979>
- Islam, M. A., Hossain, M. S., & Rahman, M. M. (2023). Market access and value chain challenges of seaweed farmers in coastal Bangladesh. *Marine Policy*, 151, 105627. <https://doi.org/10.1016/j.marpol.2023.105627>
- Ismail, M. M., Alotaibi, B. S., & EL-Sheekh, M. M. (2020). Therapeutic uses of red macroalgae. In *Molecules* (Vol. 25, Issue 19). MDPI AG. <https://doi.org/10.3390/molecules25194411>
- ISSD. (2003). Livelihoods and Climate Change. In *The International Institute for Sustainable Development* (Vol. 181, Issues 6–7). <http://www.ncbi.nlm.nih.gov/pubmed/19759910>
- IUCN. (2024). *The IUCN Red List of Threatened Species*. <http://www.iucnredlist.org>
- Jagtap, A. S., & Meena, S. N. (2021a). Seaweed farming: A perspective of sustainable agriculture and socio-economic development. In *Natural Resources Conservation and Advances for Sustainability* (pp. 493–501). Elsevier. <https://doi.org/10.1016/B978-0-12-822976-7.00022-3>
- Jagtap, A. S., & Meena, S. N. (2021b). Seaweed farming: A perspective of sustainable agriculture and socio-economic development. In *Natural Resources Conservation and*

*Advances for Sustainability* (pp. 493–501). Elsevier. <https://doi.org/10.1016/B978-0-12-822976-7.00022-3>

- Javeed, S. (2023). Climate Change and Sustainable Rural Livelihoods: Constraints and Adaptation Strategies. *Journal of Environmental Impact and Management Policy*, 31, 15–27. <https://doi.org/10.55529/jeimp.31.15.27>
- Jesumani, V., Du, H., Aslam, M., Pei, P., & Huang, N. (2019). Potential use of seaweed bioactive compounds in skincare—a review. In *Marine Drugs* (Vol. 17, Issue 12). MDPI AG. <https://doi.org/10.3390/md17120688>
- Jolly, C. (2017). *OECD-The-Future-of-the-Ocean-Economy-Blue-Planet-Conference*.
- Jones, L., Ludi, E., & Levine, S. (2011). *Towards a Characterisation of Adaptive Capacity: A Framework for Analysing Adaptive Capacity at the Local Level*. <http://community.eldis.org/accra/>
- Joseph, C. (2011). Factors influencing the non-disclosure of sustainability information on Malaysian District Councils websites within an institutional theory framework. *Social and Management Research Journal*, 8(1), 1–22.
- Ju, R. T., Li, X., Jiang, J. J., Wu, J., Liu, J., Strong, D. R., & Li, B. (2020). Emerging risks of non-native species escapes from aquaculture: Call for policy improvements in China and other developing countries. *Journal of Applied Ecology*, 57(1), 85–90. <https://doi.org/10.1111/1365-2664.13521>
- Kalaidjian, E., & Robinson, S. ann. (2022). Reviewing the nature and pitfalls of multilateral adaptation finance for small island developing states. *Climate Risk Management*, 36, 100432. <https://doi.org/10.1016/j.crm.2022.100432>
- Kamal, A. G., & Martens, T. (2015). *Rethinking the Sustainable Livelihoods Framework: An Indigenous Perspective*.
- Kambey, C. S. B., Campbell, I., Cottier-Cook, E. J., Nor, A. R. M., Kassim, A., Sade, A., & Lim, P. E. (2021a). Evaluating biosecurity policy implementation in the seaweed aquaculture industry of Malaysia, using the quantitative knowledge, attitude, and practices (KAP) survey technique. *Marine Policy*, 134. <https://doi.org/10.1016/j.marpol.2021.104800>
- Kambey, C. S. B., Campbell, I., Cottier-Cook, E. J., Nor, A. R. M., Kassim, A., Sade, A., & Lim, P. E. (2021b). Seaweed aquaculture: a preliminary assessment of biosecurity measures for controlling the ice-ice syndrome and pest outbreaks of a *Kappaphycus* farm. *Journal of Applied Phycology*, 33(5), 3179–3197. <https://doi.org/10.1007/s10811-021-02530-z>
- Kambey, C. S. B., Campbell, I., Sondak, C. F. A., Nor, A. R. M., Lim, P. E., & Cottier-Cook, E. J. (2020). An analysis of the current status and future of biosecurity frameworks for the Indonesian seaweed industry. *Journal of Applied Phycology*, 32(4), 2147–2160. <https://doi.org/10.1007/s10811-019-02020-3>
- Katsaliaki, K., Galetsi, P., & Kumar, S. (2022). Supply chain disruptions and resilience: a major review and future research agenda. *Annals of Operations Research*, 319(1), 965–1002. <https://doi.org/10.1007/s10479-020-03912-1>
- Kelman, I. (2020). *Disaster by Choice: How Our Actions Turn Natural Hazards Into Catastrophes*. Oxford University Press.

- Klein, R. J., Alam, M., Berkhout, F. G., Dow, K., Rebecca Shaw, M., Botzen, W., Buhaug, H., Butzer, K. W., Carina Keskitalo, E. H., Gitay, H., Thurlow, J., Buob, S., Thomas, A., Barros, V., Dokken, D., Mach, K., Bilir, T., Chatterjee, M., Ebi, K., ... MacCracken, S. (2014). *Adaptation Opportunities, Constraints, and Limits* (pp. 899–943). Cambridge University Press.
- Klein, R. J. T., Schipper, E. L. F., & Dessai, S. (2005). Integrating mitigation and adaptation into climate and development policy: Three research questions. *Environmental Science and Policy*, 8(6), 579–588. <https://doi.org/10.1016/j.envsci.2005.06.010>
- Klöck, C., & Nunn, P. D. (2019). Adaptation to Climate Change in Small Island Developing States: A Systematic Literature Review of Academic Research. *Journal of Environment and Development*, 28(2), 196–218. <https://doi.org/10.1177/1070496519835895>
- Kraan, S. (2020). Seaweed resources, collection, and cultivation with respect to sustainability. In *Sustainable Seaweed Technologies: Cultivation, Biorefinery, and Applications* (pp. 89–102). Elsevier. <https://doi.org/10.1016/B978-0-12-817943-7.00003-2>
- Kramer, P., Kramer, P. R., Arias-Gonzales, E., & McField, M. (2000). *Status of Coral Reefs of Northern Central America: Mexico, Belize, Guatemala, Honduras, Nicaragua and El Salvador*. 287–313.
- Krantz, L. (2001). The Sustainable Livelihood Approach to Poverty Reduction: Division for Policy and Socio-Economic Analysis. *Division for Policy and Socio-Economic Analysis*, February, 44.
- Krause-Jensen, D., & Duarte, C. M. (2016). Substantial role of macroalgae in marine carbon sequestration. *Nature Geoscience*, 9(10), 737–742. <https://doi.org/10.1038/ngeo2790>
- Krishnan, M., & Narayanakumar, R. (2013). Social and economic dimensions of carrageenan seaweed farming. In *FAO Fisheries and Aquaculture Technical Paper* (Issue 580).
- Kurecic, P. (2017). Small States and Regional Economic Integrations in the Multi-Polar World: Regional Differences in the Levels of Integration and Patterns of Small States' Vulnerability. *World Review of Political Economy*, 8(3). <https://doi.org/10.13169/worlrevipoliecon.8.3.0317>
- Kusumaningrum, P. D., Setyawidati, N. A. R., Savitri C Kusuma, L. P. A., Rahmania, R., Chandra, H., Sianturi, D. S. A., Firdaus, Y., Sufyan, A., & Dillenia, I. (2021). The Seaweed Information System (SIRULA): A Preliminary Concept and Integrated Design. *IOP Conference Series: Earth and Environmental Science*, 925(1). <https://doi.org/10.1088/1755-1315/925/1/012033>
- Lam, M. K., & Lee, K. T. (2012). Microalgae biofuels: A critical review of issues, problems and the way forward. *Biotechnology Advances*, 30(3), 673–690. <https://doi.org/10.1016/j.biotechadv.2011.11.008>
- Landuci, F. S., Bez, M. F., Ritter, P. D., Costa, S., Silvestri, F., Zanette, G. B., Castelar, B., & Santos Costa, P. M. (2021). Mariculture in a densely urbanized portion of the Brazilian coast: Current diagnosis and directions for sustainable development. *Ocean and Coastal Management*, 213. <https://doi.org/10.1016/j.ocecoaman.2021.105889>
- Lee, K. H., Noh, J., Lee, J., & Khim, J. S. (2021). Blue economy and the total environment: Mapping the interface. *Environment International*, 157, 106796. <https://doi.org/10.1016/j.envint.2021.106796>

- Levine, S. (2014). *How to study livelihoods: bringing a sustainable livelihoods framework to life*. September, 1–23.
- Lin, S. (2005). Algal Culturing Techniques. *Journal of Phycology*, 41(4), 906–908. <https://doi.org/10.1111/j.1529-8817.2005.00114.x>
- Lindsey, T. C. (2011). Sustainable principles: Common values for achieving sustainability. *Journal of Cleaner Production*, 19(5), 561–565. <https://doi.org/10.1016/j.jclepro.2010.10.014>
- Liu, B., Siu, Y. L., & Mitchell, G. (2016). Hazard interaction analysis for multi-hazard risk assessment: A systematic classification based on hazard-forming environment. *Natural Hazards and Earth System Sciences*, 16(2), 629–642. <https://doi.org/10.5194/nhess-16-629-2016>
- Liu, Y., Cao, L., Cheung, W. W. L., & Sumaila, U. R. (2023). Global estimates of suitable areas for marine algae farming. *Environmental Research Letters*, 18(6). <https://doi.org/10.1088/1748-9326/acd398>
- Lomartire, S., Cotas, J., Pacheco, D., Marques, J. C., Pereira, L., & Gonçalves, A. M. M. (2021). Environmental impact on seaweed phenolic production and activity: An important step for compound exploitation. In *Marine Drugs* (Vol. 19, Issue 5). MDPI. <https://doi.org/10.3390/md19050245>
- Luis Martín-Ortega, J., Akkermans, S., Da Costa, D., & García, J. C. (2021). *Belize's National Climate Change Policy, Strategy, and Action Plan*.
- Lyons, D. A., & Scheibling, R. E. (2009). Range expansion by invasive marine algae: Rates and patterns of spread at a regional scale. *Diversity and Distributions*, 15(5), 762–775. <https://doi.org/10.1111/j.1472-4642.2009.00580.x>
- MAFFES, B. (2016). Belize's 2016-2020 National Biodiversity Strategy & Action Plan. *Current*. <https://www.cbd.int/doc/world/bz/bz-nbsap-v2-p1-en.pdf>
- Makame, M. O., Hamad, A. R., Said, M. S., Mushi, A., & Sharif, K. (2021). Moving Seaweed Farms from Shallow to Deep Seawater to Cope with Warming and Diseases in Zanzibar. Current Socio-Economic and Cultural Barriers. *Journal of Sustainable Development*, 14(5), 29. <https://doi.org/10.5539/jisd.v14n5p29>
- Makame, M. O., Shackleton, S. E., & Leal Filho, W. (2023). Coping with and adapting to climate and non-climate stressors within the small-scale farming, fishing and seaweed growing sectors, Zanzibar. *Natural Hazards*, 116(3), 3377–3399. <https://doi.org/10.1007/s11069-023-05813-5>
- Mannino, G., Campobenedetto, C., Vigliante, I., Contartese, V., Gentile, C., & Berteà, C. M. (2020). The application of a plant biostimulant based on seaweed and yeast extract improved tomato fruit development and quality. *Biomolecules*, 10(12), 1–19. <https://doi.org/10.3390/biom10121662>
- Manzaneres, M., & Cocom, R. (2015). Cultural change in Gales Point Manatee: Auto-ethnographic reflections from a community member. *Research Reports in Belizean History and Anthropology*, Volume 3, 3, 47–54. [https://www.academia.edu/14336348/Carnival\\_in\\_Caledonia\\_A\\_preliminary\\_ethnographic\\_profile\\_of\\_carnival\\_practices%5Cnhttps://goo.gl/MdpceA](https://www.academia.edu/14336348/Carnival_in_Caledonia_A_preliminary_ethnographic_profile_of_carnival_practices%5Cnhttps://goo.gl/MdpceA)



- María, W. L., Deza, C., Mcmillan, I., Andrade, G., María, A., & Moreno, Z. (2024). *Access to Finance for MSMEs in Belize Challenges and Opportunities*. <http://www.iadb.org>
- Mariño, M., Breckwoldt, A., Teichberg, M., Kase, A., & Reuter, H. (2019). Livelihood aspects of seaweed farming in Rote Island, Indonesia. *Marine Policy*, 107. <https://doi.org/10.1016/j.marpol.2019.103600>
- Martínez-Vázquez, R. M., Milán-García, J., & de Pablo Valenciano, J. (2021). Challenges of the Blue Economy: evidence and research trends. *Environmental Sciences Europe*, 33(1). <https://doi.org/10.1186/s12302-021-00502-1>
- Mateo, J. P., Campbell, I., Cottier-Cook, E. J., Rovilla, M., Luhan, J., Marco, V., Ferriols, E. N., & Hurtado, A. Q. (2021). Understanding biosecurity: knowledge, attitudes and practices of seaweed farmers in the Philippines. *Journal of Applied Phycology*, 997–1010. <https://doi.org/10.1007/s10811-020-02352-5/Published>
- Matoju, I., Le Masson, V., Montalescot, V., Ndawala, M. A., & Msuya, F. E. (2022). A resilience lens to explore seaweed farmers' responses to the impacts of climate change in Tanzania. *Applied Phycology*, 3(1), 132–148. <https://doi.org/10.1080/26388081.2022.2091951>
- MBECA. (2021). *Readiness and Development of the Belize Seaweed (Sea Moss) Industry*.
- MBECA. (2022). *Belize Blue Economy Development Policy, Strategy and Implementation Plan 2022- 2027*.
- McClanahan, T. R., & Cinner, J. E. (2012). *Adapting to a Changing Environment: Confronting the Consequences of Climate Change* (T. R. McClanahan & J. E. Cinner, Eds.). Oxford University Press. <https://global.oup.com/academic/product/adapting-to-a-changing-environment-9780199754489?cc=gb&lang=en&>
- McDonald, G., Harford, B., Arrivillaga, A., Babcock, E. A., Carcamo, R., Foley, J., Fujita, R., Gedamke, T., Gibson, J., Karr, K., Robinson, J., & Wilson, J. (2017). An indicator-based adaptive management framework and its development for data-limited fisheries in Belize. *Marine Policy*, 76, 28–37. <https://doi.org/10.1016/j.marpol.2016.11.027>
- McKoy, S., & Dubon, W. (2021). *Belize Seaweed Industry*.
- Mead, L. (2021). *Small Islands, Large Oceans: Voices on the Frontlines of Climate Change*. <https://www.flickr.com/>
- MEBCA. (2021). *Readiness and Development of the Belize Seaweed (Sea Moss) Industry: Seaweed Wild-harvesting and Mariculture*.
- Meerman, J. (2005). *National Protected Areas Policy and Systems Plan National Protected Areas Analysis*. 1–41.
- Mercer, J., Kelman, I., Alfthan, B., & Kurvits, T. (2012). Ecosystem-based adaptation to climate change in caribbean small island developing states: Integrating local and external knowledge. *Sustainability*, 4(8), 1908–1932. <https://doi.org/10.3390/su4081908>
- Mercer, J., Kurvits, T., Kelman, I., & Mavrogenis, S. (2014). Ecosystem-based adaptation for food security in the AIMS SIDS: Integrating external and local knowledge. In *Sustainability (Switzerland)* (Vol. 6, Issue 9, pp. 5566–5597). MDPI. <https://doi.org/10.3390/su6095566>

- Merino, F., & Prats, M. A. (2020). Sustainable beach management and promotion of the local tourist industry: Can blue flags be a good driver of this balance? *Ocean and Coastal Management*, 198. <https://doi.org/10.1016/j.ocecoaman.2020.105359>
- Michalos, A. C. (2014). *Encyclopedia of Quality of Life and Well-Being Research*.
- Milton, K., Gomersall, S. R., & Schipperijn, J. (2023). Let's get moving: The Global Status Report on Physical Activity 2022 calls for urgent action. In *Journal of Sport and Health Science* (Vol. 12, Issue 1, pp. 5–6). Elsevier B.V. <https://doi.org/10.1016/j.jshs.2022.12.006>
- Mitchell, B. A., Walker, Z., & Walker, P. (2017). A governance spectrum: Protected areas in Belize. *Parks*, 23(1), 45–60. <https://doi.org/10.2305/IUCN.CH.2017.PARKS-23-1BAM.en>
- Mitchell, T., Simon, A., & Huq, S. (2008). *Principles for Delivering Adaptation Finance*. [www.ids.ac.uk](http://www.ids.ac.uk)
- Moncada, S. (2016). *Adapting to Climate Change within an Informal Urban Settlement in a Least Developed Country: Effects of a Foreign Aid Intervention and Policy Implications*. University of Malta.
- Moncada, S., Briguglio, L., Bambrick, H., Kelman, I., Iorns, C., & Nurse, L. (2021). *Small Island Developing States Vulnerability and Resilience Under Climate Change*. <http://www.springer.com/series/15142>
- Monnereau, I., Mahon, R., Mcconney, P., Nurse, L., Turner, R., & Vallès, H. (2015). *Vulnerability of the fisheries sector to climate change impacts in Small Island Developing States and the Wider Caribbean*. 81. [https://www.cavehill.uwi.edu/cermes/getdoc/bfaee058-763d-40aa-8722-1794b5c18c0e/monnereau\\_et\\_al\\_2015\\_vulnerability\\_of\\_the\\_fisherie.aspx](https://www.cavehill.uwi.edu/cermes/getdoc/bfaee058-763d-40aa-8722-1794b5c18c0e/monnereau_et_al_2015_vulnerability_of_the_fisherie.aspx)
- Monnereau, I., & Oxenford, H. A. (2017). Impacts of climate change on sea temperature in the coastal and marine environments of Caribbean small island developing states (SIDS). *Science Review*, 124–154.
- Monsanto, M., Kohler, P., Binetti, U., Silburn, B., Russell, J., Corbin, C., Lyons, B., Birchenough, S. N. R., & Maes, T. (2023). A Blue Future: developing a national marine litter action plan in SIDS - lessons learnt in Belize. *ICES Journal of Marine Science*, 80(8), 2171–2182. <https://doi.org/10.1093/icesjms/fsac206>
- Morozova, A. (2016). *Sustainable Community Tourism in Belize: Assessing Community Involvement, Product Development, and Social and Economic Impact*.
- Morrison, L., Baumann, H. A., & Stengel, D. B. (2008). An assessment of metal contamination along the Irish coast using the seaweed *Ascophyllum nodosum* (Fucales, Phaeophyceae). *Environmental Pollution*, 152(2), 293–303. <https://doi.org/10.1016/j.envpol.2007.06.052>
- Moser, S. C., & Boykoff, M. T. (2013a). Climate change and adaptation success: The scope of the challenge. In S. C. Moser & M. T. Boykoff (Eds.), *Successful adaptation to climate change: Linking science and policy in a rapidly changing world* (pp. 1–33). Routledge. <https://doi.org/10.4324/9780203593882>

- Mphande, F. A. (2016). Infectious diseases and rural livelihood in developing countries. In *Infectious Diseases and Rural Livelihood in Developing Countries*. Springer Singapore. <https://doi.org/10.1007/978-981-10-0428-5>
- Msuya, F. E. (2006). *The Impact of Seaweed Farming on the Social and Economic Structure of Seaweed Farming Communities in Zanzibar, Tanzania*.
- Msuya, F. E. (2011). *The impact of seaweed farming on the socioeconomic status of coastal communities in Zanzibar, Tanzania*.
- Msuya, F. E. (2012). *A Study of Working Conditions in the Zanzibar Seaweed Farming Industry*. [www.wiego.org](http://www.wiego.org)
- Msuya, F. E., Bolton, J., Pascal, F., Narrain, K., Nyonje, B., & Cottier-Cook, E. J. (2022). Seaweed farming in Africa: current status and future potential. *Journal of Applied Phycology*, 34(2), 985–1005. <https://doi.org/10.1007/s10811-021-02676-w>
- Mustafa, M. G., Wakamatsu, S., Takeda, T. aki, Umino, T., & Nakagawa, H. (1995). Effects of Algae Meal as Feed Additive on Growth, Feed Efficiency, and Body Composition in Red Sea Bream. *Fisheries Science*, 61(1), 25–28. <https://doi.org/10.2331/fishsci.61.25>
- Mwendwa, P., & A. Giliba, R. (2012). Climate Change Impacts and Adaptation Strategies in Kenya. *Chinese Journal of Population Resources and Environment*, 10(4), 22–29. <https://doi.org/10.1080/10042857.2012.10685104>
- Mwendwa, R., Wawire, M., & Kahenya, P. (2023). Potential for Use of Seaweed as a Fish Feed Ingredient: A Review. *Journal of Agricultural Science*, 15(2), 96. <https://doi.org/10.5539/jas.v15n2p96>
- Nalau, J., & Becken, S. (2018). *Ecosystem-based Adaptation to Climate Change: Review of Concepts* WORLD-LEADING TOURISM RESEARCH [griffith.edu.au/institute-tourism](http://griffith.edu.au/institute-tourism) GRIFFITH INSTITUTE FOR TOURISM World Leading Tourism Research. <https://www.griffith.edu.au/research/research-excellence/ecoadapt-in-the->
- Narayan, D., & Pritchett, L. (1999). Cents and sociability: Household income and social capital in rural Tanzania. *Economic Development and Cultural Change*, 47(4), 870–897. <https://doi.org/10.1086/452436>
- Narwal, S., Kaur, M., Yadav, D. S., & Bast, F. (2024). Sustainable blue economy: Opportunities and challenges. In *Journal of Biosciences* (Vol. 49, Issue 1). Springer. <https://doi.org/10.1007/s12038-023-00375-x>
- Natarajan, N., Newsham, A., Rigg, J., & Suhardiman, D. (2022). A sustainable livelihoods framework for the 21st century. *World Development*, 155. <https://doi.org/10.1016/j.worlddev.2022.105898>
- Natale, F. (2015). Enhancing sustainable seaweed aquaculture through capacity development and innovation. FAO Fisheries and Aquaculture Technical Paper No. 615. Food and Agriculture Organization of the United Nations.
- Nath, T. K., Li, W., Liu, J., Cao, L., & Geng, Y. (2023). *Application of riparian buffer zone in agricultural non-point source pollution control - A review*.
- Naylor, R. L., Hardy, R. W., Buschmann, A. H., Bush, S. R., Cao, L., Klinger, D. H., Little, D. C., Lubchenco, J., Shumway, S. E., & Troell, M. (2021). A 20-year retrospective

- review of global aquaculture. *Nature*, 591(7851), 551–563. <https://doi.org/10.1038/s41586-021-03308-6>
- Ndawala, M. A., Msuya, F. E., Cabarubias, J. P., Buriyo, A., & Cottier-Cook, E. J. (2021). Seaweed biosecurity in Tanzania: Lessons to be learned from other major plant crops. *Environmental Challenges*, 5. <https://doi.org/10.1016/j.envc.2021.100319>
- Neori, A. (2009). Essential role of seaweed cultivation in integrated multi-trophic aquaculture farms for global expansion of mariculture: an analysis. In *Nineteenth International Seaweed Symposium* (pp. 117–120). Springer Netherlands. [https://doi.org/10.1007/978-1-4020-9619-8\\_16](https://doi.org/10.1007/978-1-4020-9619-8_16)
- Neori, A., Shpigiel, M., & Ben-Ezra, D. (2000). A sustainable integrated system for culture of fish, seaweed and abalone. *Aquaculture*, 186(3–4), 279–291. [https://doi.org/10.1016/S0044-8486\(99\)00378-6](https://doi.org/10.1016/S0044-8486(99)00378-6)
- Nguyen, T. T., Grote, U., Neubacher, F., Rahut, D. B., Do, M. H., & Paudel, G. P. (2023). Security risks from climate change and environmental degradation: implications for sustainable land use transformation in the Global South. *Current Opinion in Environmental Sustainability*, 63. <https://doi.org/10.1016/j.cosust.2023.101322>
- Nill, D., Lead, M. W., Lopez Venegas, G., & Richter, L. (2016). *Community-based Adaptation (CbA), Ecosystem-based Adaptation (EbA) and the Landscape Approach (LA)-Characteristics and Commonalities*. <http://www.icccad.net/wp-content/uploads/2015/12/A-brief-overview-of-Community-Based->
- Nurein, S. A. (2022). *Opportunities and Challenges of Enterprise Development in the Blue Economy* (pp. 18–30). <https://doi.org/10.4018/978-1-6684-3393-5.ch002>
- Nurse, L. A., McLean, R. F., Agard, J., Briguglio, L. P., Duvat-Magnan, V., Pelesikoti, N., Tompkins, E., & Webb, A. (2015). Small Islands. *Climate Change 2014: Impacts, Adaptation and Vulnerability: Part B: Regional Aspects: Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 1613–1654. <https://doi.org/10.1017/CBO9781107415386.009>
- Obonyo, E., Achieng, F., Indiazzi, H., Cheruto, A., Okwaro, G., & Russell, A. J. M. (2013). *Testing the CRiSTAL-Forest in East Africa Workshop and Adaptive Strategies Report from Kapsokwony Division ,.*
- Ode, L., Aslan, M., Iba, W., Ode, L., Bolu, R., Ingram, B. A., Gooley, G. J., & Silva, S. S. De. (2015). Ocean & Coastal Management Mariculture in SE Sulawesi , Indonesia : Culture practices and the socio economic aspects of the major commodities. *Ocean & Coastal Management*, 116, 44–57.
- OECD. (2009). Integrating Climate Change Adaptation into Development Co-operation. In *Organization for economic co-operation and development*.
- O’Hogain, S., & McCarton, L. (2018). Nature-Based Solutions. In *A Technology Portfolio of Nature Based Solutions* (pp. 1–9). Springer International Publishing. [https://doi.org/10.1007/978-3-319-73281-7\\_1](https://doi.org/10.1007/978-3-319-73281-7_1)
- Olago, D., Marshall, M., Wandiga, S. O., Opondo, M., Yanda, P. Z., Kanlawe, R., Githeko, A. K., Downs, T., Opere, A., Kavumvuli, R., Kirumira, E., Ogallo, L., Mugambi, P., Apindi, E., Githui, F., Kathuri, J., Olaka, L., Sigalla, R., Nanyunja, R., ... Achola, P. (2007). Climatic, Socio-economic, and Health Factors Affecting Human Vulnerability

- to Cholera in the Lake Victoria Basin, East Africa. *Ambio*, 36(4), 350–358. [https://doi.org/10.1579/0044-7447\(2007\)36\[350:CSAHFA\]2.0.CO;2](https://doi.org/10.1579/0044-7447(2007)36[350:CSAHFA]2.0.CO;2)
- Olsson, L., Opondo, M., Tschakert, P., Agrawal, A., Eriksen, S. H., Ma, S., Perch, L. N., Zakieldean, S. A., Cutter, S., Piguert, E., & Kaijser, A. (2015). Livelihoods and poverty. *Climate Change 2014 Impacts, Adaptation and Vulnerability: Part A: Global and Sectoral Aspects*, 793–832. <https://doi.org/10.1017/CBO9781107415379.018>
- Ortiz-Carabantes, E. J. (2020). *Using a Systems Thinking Approach and Health Risk Assessment to Analyze the Food-Energy-Water System Nexus of Seaweed Farming in Belize*. University of Florida.
- OSPESCA. (2015). *Fisheries and Aquaculture Integration Policy for the Central American Isthmus*.
- Paavola, J. (2008). Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environmental Science and Policy*, 11(7), 642–654. <https://doi.org/10.1016/j.envsci.2008.06.002>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *International Journal of Surgery*, 88. <https://doi.org/10.1016/j.ijsu.2021.105906>
- Paine, E. R., Schmid, M., Boyd, P. W., Diaz-Pulido, G., & Hurd, C. L. (2021). Rate and fate of dissolved organic carbon release by seaweeds: A missing link in the coastal ocean carbon cycle. In *Journal of Phycology* (Vol. 57, Issue 5, pp. 1375–1391). John Wiley and Sons Inc. <https://doi.org/10.1111/jpy.13198>
- Pandey, R., Jha, S. K., Alatalo, J. M., Archie, K. M., & Gupta, A. K. (2017). Sustainable livelihood framework-based indicators for assessing climate change vulnerability and adaptation for Himalayan communities. *Ecological Indicators*, 79, 338–346. <https://doi.org/10.1016/j.ecolind.2017.03.047>
- Patil, P. G., Virdin, J., Diez, S. M., Roberts, J., & Singh, A. (2016). *Toward a Blue Economy: A Promise for Sustainable Growth in the Caribbean; An Overview*. [www.oceanarthur.org](http://www.oceanarthur.org)
- Patlins, A. (2017). Improvement of Sustainability Definition Facilitating Sustainable Development of Public Transport System. *Procedia Engineering*, 192, 659–664. <https://doi.org/10.1016/j.proeng.2017.06.114>
- Pelling, M. (2011). *Adaptation to Climate Change: From Resilience to Transformation*. Routledge Taylor & Francis Group.
- Pelling, M. (2014). *Adaptation to Climate Change: From resilience to transformation*. In *Routledge London 203: Vol. 2011 SRC*.
- Pengra, B. (2012). One Planet , How Many People ? *UNEP Global Environmental Alert Service, June*, 1–17.
- Pereira, S. A., Kimpara, J. M., & Valenti, W. C. (2021). Sustainability of the seaweed *Hypnea pseudomusciformis* farming in the tropical Southwestern Atlantic. *Ecological Indicators*, 121. <https://doi.org/10.1016/j.ecolind.2020.107101>

- Perkins, R. (2013). The Effects of Climate Change and Ocean Acidification on Corallina Seaweeds. *Cardiff University*.
- Pomeroy, R. S., & Goetze, T. (2003). *Belize Case Study: Marine Protected Areas Co-Managed By Friends of Nature*.
- Pouvreau, S., Bacher, C., & Héral, M. (2000). Ecophysiological model of growth and reproduction of the black pearl oyster, *Pinctada margaritifera*: Potential applications for pearl farming in French Polynesia. *Aquaculture*, 186(1–2), 117–144. [https://doi.org/10.1016/S0044-8486\(99\)00373-7](https://doi.org/10.1016/S0044-8486(99)00373-7)
- Prats, M. A. ., & Merino, Fernando. (2024). *Blue Flag beaches : economic growth, tourism and sustainable management*. Routledge, Taylor & Francis Group.
- PROBLUE. (2023). *Global Seaweed: New and Emerging Markets Report 2023*.
- Purcell, D., Packer, M. A., & Hayes, M. (2022). Angiotensin-I-Converting Enzyme Inhibitory Activity of Protein Hydrolysates Generated from the Macroalga *Laminaria digitata* (Hudson) JV Lamouroux 1813. *Foods*, 11(12). <https://doi.org/10.3390/foods11121792>
- Putri Maslia, A., Prayitno, G., Dinanti, D., Suhartini, W., Zahid, U., & Mahmood Khan, R. (2024). Social Capital and Human Capital in Supporting Sustainable Aquaculture: The Case of Patuguran Village, Indonesia. *Regional and Rural Studies*, 2(1), 41–50. <https://doi.org/10.21776/rrs.v2i1.24>
- Radulovich, R., Neori, A., Valderrama, D., Reddy, C. R. K., Cronin, H., & Forster, J. (2015). Farming of seaweeds. In *Seaweed Sustainability: Food and Non-Food Applications* (pp. 27–59). Elsevier Inc. <https://doi.org/10.1016/B978-0-12-418697-2.00003-9>
- Rajendran, A., & Hu, B. (2016). Mycoalgae biofilm: Development of a novel platform technology using algae and fungal cultures. *Biotechnology for Biofuels*, 9(1), 1–13. <https://doi.org/10.1186/s13068-016-0533-y>
- Rakodi, C., & Lloyd-Jones, T. (2002). Urban livelihoods: A people-centred approach to reducing poverty. In *Urban Livelihoods: A People-centred Approach to Reducing Poverty*. <https://doi.org/10.4324/9781849773805>
- Rakotomahazo, C., Ravaoarinorotsihoarana, L. A., Randrianandrasaziky, D., Glass, L., Gough, C., Boleslas Todinanahary, G. G., & Gardner, C. J. (2019). Participatory planning of a community-based payments for ecosystem services initiative in Madagascar’s mangroves. *Ocean and Coastal Management*, 175(March), 43–52. <https://doi.org/10.1016/j.ocecoaman.2019.03.014>
- Ramu Ganesan, A., Subramani, K., Shanmugam, M., Seedeivi, P., Park, S., Alfarhan, A. H., Rajagopal, R., & Balasubramanian, B. (2020). A comparison of nutritional value of underexploited edible seaweeds with recommended dietary allowances. *Journal of King Saud University - Science*, 32(1), 1206–1211. <https://doi.org/10.1016/j.jksus.2019.11.009>
- Räsänen, A., Juhola, S., Nygren, A., Käkönen, M., Kallio, M., Monge Monge, A., & Kanninen, M. (2016). Climate change, multiple stressors and human vulnerability: a systematic review. In *Regional Environmental Change* (Vol. 16, Issue 8, pp. 2291–2302). Springer Verlag. <https://doi.org/10.1007/s10113-016-0974-7>

- Ray Biswas, R., & Rahman, A. (2023). Adaptation to climate change: A study on regional climate change adaptation policy and practice framework. *Journal of Environmental Management*, 336. <https://doi.org/10.1016/j.jenvman.2023.117666>
- Rebours, C., Marinho-Soriano, E., Zertuche-González, J. A., Hayashi, L., Vásquez, J. A., Kradolfer, P., Soriano, G., Ugarte, R., Abreu, M. H., Bay-Larsen, I., Hovelsrud, G., Rødven, R., & Robledo, D. (2014a). Seaweeds: An opportunity for wealth and sustainable livelihood for coastal communities. *Journal of Applied Phycology*, 26(5), 1939–1951. <https://doi.org/10.1007/s10811-014-0304-8>
- Rebours, C., Marinho-Soriano, E., Zertuche-González, J. A., Hayashi, L., Vásquez, J. A., Kradolfer, P., Soriano, G., Ugarte, R., Abreu, M. H., Bay-Larsen, I., Hovelsrud, G., Rødven, R., & Robledo, D. (2014b). Seaweeds: An opportunity for wealth and sustainable livelihood for coastal communities. *Journal of Applied Phycology*, 26(5), 1939–1951. <https://doi.org/10.1007/s10811-014-0304-8>
- Recinos, K., & Blue, L. (2019). Improving Capacity Development for Threatened Maritime and Marine Cultural Heritage Through the Evaluation of a Parameter Framework. *Journal of Maritime Archaeology*, 14(3), 409–427. <https://doi.org/10.1007/s11457-019-09246-9>
- Reed, M. S., Podesta, G., Fazey, I., Geeson, N., Hessel, R., Hubacek, K., Letson, D., Nainggolan, D., Prell, C., Rickenbach, M. G., Ritsema, C., Schwilch, G., Stringer, L. C., & Thomas, A. D. (2013a). Combining analytical frameworks to assess livelihood vulnerability to climate change and analyse adaptation options. In *Ecological Economics* (Vol. 94, pp. 66–77). <https://doi.org/10.1016/j.ecolecon.2013.07.007>
- Reed, M. S., Podesta, G., Fazey, I., Geeson, N., Hessel, R., Hubacek, K., Letson, D., Nainggolan, D., Prell, C., Rickenbach, M. G., Ritsema, C., Schwilch, G., Stringer, L. C., & Thomas, A. D. (2013b). Combining analytical frameworks to assess livelihood vulnerability to climate change and analyse adaptation options. In *Ecological Economics* (Vol. 94, pp. 66–77). <https://doi.org/10.1016/j.ecolecon.2013.07.007>
- Regona, M., Yigitcanlar, T., Xia, B., & Li, R. Y. M. (2022). Opportunities and Adoption Challenges of AI in the Construction Industry: A PRISMA Review. *Journal of Open Innovation: Technology, Market, and Complexity*, 8(1). <https://doi.org/10.3390/joitmc8010045>
- Reid, H. (2016). Ecosystem- and community-based adaptation: learning from community-based natural resource management. *Climate and Development*, 8(1), 4–9. <https://doi.org/10.1080/17565529.2015.1034233>
- Reid, H., Alam, M., Berger, R., Cannon, T., Saleemul, H., & Milligan, A. (2009). Community-based Adaptation to Climate Change. *IIED*.
- Reid, H., & Alam, S. (2014). *Ecosystem-based Approaches to Adaptation: Evidence from two sites in Bangladesh*. [www.iied.org@iiedwww.facebook.com/theIIED](http://www.iied.org@iiedwww.facebook.com/theIIED)
- Reid, H., Argumedo, A., & Swiderska, K. (2018). *Ecosystem-based approaches to adaptation: strengthening the evidence and informing policy*. <http://pubs.iied.org/17619IIED>
- Reis, R. P., Castelar, B., Moura, A. L., & Kirk, R. (2009). Invasive potential of *Kappaphycus alvarezii* off the south coast of Rio de Janeiro state, Brazil: A contribution to environmentally secure cultivation in the tropics. *Botanica Marina*, 52(4), 283–289. <https://doi.org/10.1515/BOT.2009.002>

- Reis, R. P., das Chagas Pereira, R. R., & de Góes, H. G. (2015). The efficiency of tubular netting method of cultivation for *Kappaphycus alvarezii* (Rhodophyta, Gigartinales) on the southeastern Brazilian coast. *Journal of Applied Phycology*, 27(1), 421–426. <https://doi.org/10.1007/s10811-014-0330-6>
- Remling, E., & Persson, Å. (2015). Who is adaptation for? Vulnerability and adaptation benefits in proposals approved by the UNFCCC Adaptation Fund. *Climate and Development*, 7(1), 16–34. <https://doi.org/10.1080/17565529.2014.886992>
- Renaud, L. (2020). Cruise Tourism Threatens to Drive Land Speculation and Displacement in Belize. *NACLA Report on the Americas*, 52(4), 442–447. <https://doi.org/10.1080/10714839.2021.1840177>
- Res, C., Scheraga, J. D., & Grambsch, A. E. (1998). *Risks , opportunities , and adaptation to climate change*. 10, 85–95.
- Reser, J. P., & Swim, J. K. (2009). *Adapting to and Coping With the Threat and Impacts of Climate Change*.
- Reser, J. P., & Swim, J. K. (2011). Adapting to and Coping With the Threat and Impacts of Climate Change. *American Psychologist*, 66(4), 277–289. <https://doi.org/10.1037/a0023412>
- Rising, J. A., Taylor, C., Ives, M. C., & Ward, R. E. T. (2022). Challenges and innovations in the economic evaluation of the risks of climate change. In *Ecological Economics* (Vol. 197). Elsevier B.V. <https://doi.org/10.1016/j.ecolecon.2022.107437>
- Rivera, L., & Pratt, L. (2005). *Belize : Country Environmental Analysis : Towards Competitiveness and Belize Country Environmental Analysis : Towards Competitiveness and Sustainable Development 1. August 2016*. <https://doi.org/10.13140/RG.2.2.27399.80800>
- Riyaz, S. U. M., Prabhu, N. S., Nalini, S., Tejaswini, G., Christy, H. J., & Inbakandan, D. (2020). Microbiome identification from *ice ice* disease infected *Kappaphycus alvarezii* using 16S rRNA gene sequence analysis and in silico docking studies against carrageenan degrading bacteria. *Biocatalysis and Agricultural Biotechnology*, 27. <https://doi.org/10.1016/j.bcab.2020.101707>
- Roberts, J. (2015). The Blue Economy: From Concept to Reality in the Caribbean Region. Discussion paper for the Caribbean Regional Dialogue with the G20 Development Working Group. *G20 Development Working Group Summary*, 23. <http://www.ouroceanwealth.ie/SiteCollectionDocuments/Harnessing Our Ocean Wealth Report>
- Robinson, S. ann. (2018). Climate change adaptation in small island developing states: Insights and lessons from a meta-paradigmatic study. *Environmental Science and Policy*, 85, 172–181. <https://doi.org/10.1016/j.envsci.2018.03.030>
- Robinson, S. ann. (2020). Climate change adaptation in SIDS: A systematic review of the literature pre and post the IPCC Fifth Assessment Report. *Wiley Interdisciplinary Reviews: Climate Change*, 11(4), 1–21. <https://doi.org/10.1002/wcc.653>
- Robledo, C., Clot, N., Hammill, A., & Riché, B. (2012). Forest Policy and Economics The role of forest ecosystems in community-based coping strategies to climate hazards : Three examples from rural areas in Africa. *Forest Policy and Economics*, 24, 20–28. <https://doi.org/10.1016/j.forpol.2011.04.006>



- Rodeldo, E., Hurtado, A., & Critchley, A. (2014). The role of policy and governance in supporting sustainable seaweed farming: Lessons from developing countries. *Journal of Applied Phycology*, 26(2), 695–701. <https://doi.org/10.1007/s10811-013-0070-1>
- Ross, F. W. R., Boyd, P. W., Filbee-Dexter, K., Watanabe, K., Ortega, A., Krause-Jensen, D., Lovelock, C., Sondak, C. F. A., Bach, L. T., Duarte, C. M., Serrano, O., Beardall, J., Tarbuck, P., & Macreadie, P. I. (2023). Potential role of seaweeds in climate change mitigation. In *Science of the Total Environment* (Vol. 885). Elsevier B.V. <https://doi.org/10.1016/j.scitotenv.2023.163699>
- Rotter, A., Barbier, M., Bertoni, F., Bones, A. M., Cancela, M. L., Carlsson, J., Carvalho, M. F., Ceglowska, M., Chirivella-Martorell, J., Conk Dalay, M., Cueto, M., Dailianis, T., Deniz, I., Díaz-Marrero, A. R., Drakulovic, D., Dubnika, A., Edwards, C., Einarsson, H., Erdoğan, A., ... Vasquez, M. I. (2021). The Essentials of Marine Biotechnology. In *Frontiers in Marine Science* (Vol. 8). Frontiers Media S.A. <https://doi.org/10.3389/fmars.2021.629629>
- Rotter, A., Žuljević, A., & Mihanović, H. (2021). Harmful algal blooms and their impact on coastal seaweed ecosystems. *Marine Pollution Bulletin*, 162, 111845. <https://doi.org/10.1016/j.marpolbul.2020.111845>
- Rougier, J., Sparks, S., & Hill, L. J. (2011). Risk and uncertainty assessment for natural hazards. In *Risk and Uncertainty Assessment for Natural Hazards* (Vol. 9781107006195). Cambridge University Press. <https://doi.org/10.1017/CBO9781139047562>
- Rubekie, A. P., & Bwathondi, P. O. J. (2022). Logistic regression analysis to determine gender specific challenges and factors affecting seaweed farming along the coast of Tanzania mainland. *Journal of Applied Aquaculture*. <https://doi.org/10.1080/10454438.2022.2128963>
- Ruggerio, C. A. (2021). Sustainability and sustainable development: A review of principles and definitions. In *Science of the Total Environment* (Vol. 786). Elsevier B.V. <https://doi.org/10.1016/j.scitotenv.2021.147481>
- Ruhana, F., Suwartiningsih, S., Mulyandari, E., Handoyo, S., & Afrilia, U. A. (2024). Innovative Strategies for Achieving Sustainable Development Goals Amidst Escalating Global Environmental and Social Challenges. In *International Journal of Science and Society* (Vol. 6, Issue 1). <http://ijsoc.goacademica.com>
- Rusekwa, S. B., Campbell, I., Msuya, F. E., Buriyo, A. S., & Cottier-Cook, E. J. (2020). Biosecurity policy and legislation of the seaweed aquaculture industry in Tanzania. *Journal of Applied Phycology*, 4411–44222. <https://doi.org/10.1007/s10811-020-02194-1>/Published
- Salas, Osmany., & Shal, Valentino. (2015). National protected areas system plan. *Ministry of Forestry, Fisheries and Sustainable Government of Belize.*, August, 107. [https://conservationcorridor.org/cpb/Salas\\_and\\_Shal\\_2015.pdf?source=post\\_page](https://conservationcorridor.org/cpb/Salas_and_Shal_2015.pdf?source=post_page)
- Salayo, N. D., Perez, M. L., Garces, L. R., & Pido, M. D. (2012). Mariculture development and livelihoods: The role of governance and social equity in Asian fisheries. *Marine Policy*, 36(4), 867–881. <https://doi.org/10.1016/j.marpol.2011.12.003>
- Sale, P. F., Chavez, E. A., Hatcher, B. G., Mayfield, C., & Ciborowski, J. J. H. (2010). *Conservation and Sustainable Use Of The Mesoamerican Barrier Reef System (MBRS)*

*in México, Belize, Guatemala And Honduras: Guidelines For Developing A Regional Monitoring And Environmental Information System.*

- Saleh, C., Hendrik, E., Zauhar, S., & Nuh, M. (2021). Collaborative Governance in Public Administration Perspective. *Journal of Southwest Jiaotong University*, 56(6), 655–665. <https://doi.org/10.35741/issn.0258-2724.56.6.58>
- Salgueiro-Otero, D., & Ojea, E. (2020). A better understanding of social-ecological systems is needed for adapting fisheries to climate change. *Marine Policy*, 122. <https://doi.org/10.1016/j.marpol.2020.104123>
- Samuels, L. J., Setati, M. E., & Blancquaert, E. H. (2022). Towards a Better Understanding of the Potential Benefits of Seaweed Based Biostimulants in *Vitis vinifera* L. Cultivars. In *Plants* (Vol. 11, Issue 3). <https://doi.org/10.3390/plants11030348>
- Sapkota, B. (2021). *Farmers' Risk Perceptions, Attitudes and Management Strategies, and Willingness to Pay for Crop Insurance in Nepal.*
- Sarkar, S. K. (2018). Algal Blooms: Potential Drivers, Occurrences and Impact. In *Marine Algal Bloom: Characteristics, Causes and Climate Change Impacts.* [https://doi.org/10.1007/978-981-10-8261-0\\_2](https://doi.org/10.1007/978-981-10-8261-0_2)
- Sarstún, R. (2011). *FUNDAECO aplica la herramienta CRiSTAL para valorar los efectos del Cambio Climático sobre los Medios de Vida de las comunidades costeras en el.*
- Sato, Y., Fujiwara, T., & Endo, H. (2023). Density regulation of aquaculture production and its effects on commercial profit and quality as food in the cosmopolitan edible seaweed *Undaria pinnatifida*. *Frontiers in Marine Science*, 10. <https://doi.org/10.3389/fmars.2023.1085054>
- Schipper, E. L. F., Ayers, J., Reid, H., Huq, S., & Rahman, A. (2014). *Community-Based Adaptation to Climate Change: Scaling it up* (E. L. F. Schipper, J. Ayers, H. Reid, S. Huq, & A. Rahman, Eds.). Routledge. <https://www.routledge.com/Community-Based-Adaptation-to-Climate-Change-Scaling-it-up/Schipper-Ayers-Reid-Huq-Rahman/p/book/9780415623704>
- Schipper, E. L. F., Tanner, T., Pauline Dube, O., Adams, K., & Huq, S. (2020). *The Debate: Is Global Development Adapting to Climate Change?*
- Schipper, L. (2007). Climate Change Adaptation and Development Exploring the Linkages. In *Tyndall Centre Working Paper* (Issue 107). <https://doi.org/10.18782/2582-2845.8038>
- Schipper, L. E., Ayers, J., Reid, H., Huq, S., & Rahman, A. (2014). *Community-Based Adaptation to Climate Change: Scaling it up*. Routledge.
- Scoones, I. (1998). *Sustainable Rural Livelihoods: A Framework for Analysis.*
- Scoones, I. (2009). Livelihoods perspectives and rural development. *Journal of Peasant Studies*, 36(1), 171–196. <https://doi.org/10.1080/03066150902820503>
- Seara, T., Clay, P. M., & Colburn, L. L. (2016). Perceived adaptive capacity and natural disasters: A fisheries case study. *Global Environmental Change*, 38, 49–57. <https://doi.org/10.1016/j.gloenvcha.2016.01.006>
- Setiawan, A., Sahar, J., Santoso, B., Mansyur, M., & Syamsir, S. B. (2024a). Coping Mechanisms Utilized by Individuals With Drug Addiction in Overcoming Challenges During the Recovery Process: A Qualitative Meta-synthesis. In *Journal of Preventive*

- Medicine and Public Health* (Vol. 57, Issue 3, pp. 197–211). Korean Society for Preventive Medicine. <https://doi.org/10.3961/jpmph.24.042>
- Setiawan, A., Sahar, J., Santoso, B., Mansyur, M., & Syamsir, S. B. (2024b). Coping Mechanisms Utilized by Individuals With Drug Addiction in Overcoming Challenges During the Recovery Process: A Qualitative Meta-synthesis. In *Journal of Preventive Medicine and Public Health* (Vol. 57, Issue 3, pp. 197–211). Korean Society for Preventive Medicine. <https://doi.org/10.3961/jpmph.24.042>
- Shal, V. (2014). *Culturally appropriate participation plan*. Belize: The Nature Conservancy (TNC), Belize Fisheries Department (BFD), and Marine Conservation and Climate Adaptation Project (MCCAP).
- Shal, V., Salas, O., & Requena, N. (2014a). *Economic alternatives and fisheries diversification plan*. Belize: The Nature Conservancy (TNC), Belize Fisheries Department (BFD), and Marine Conservation and Climate Adaptation Project (MCCAP).
- Shal, V., Salas, O., & Requena, N. (2014b). *Economic Alternatives & Fisheries Diversification Plan*.
- Shen, P., & Slater, P. (2021). The Effect of Occupational Stress and Coping Strategies on Mental Health and Emotional Well-Being Among University Academic Staff During the COVID-19 Outbreak. *International Education Studies*, 14(3), 82. <https://doi.org/10.5539/ies.v14n3p82>
- Silvestre, V. (2010). *La Fundación Defensores de la Naturaleza , utiliza la herramienta CRiSTAL para identificar y valorar los efectos del cambio climático ; en comunidades de la Reserva de Biosfera Sierra de las Minas y el Refugio de*.
- Singh, A. (2022). *Climate Change Vulnerability and Livelihood Assessment of Selected Fisheries and Coastal Areas in Belize*.
- Singh, R. (2024). Assessing the Impact of Sustainable Agriculture Practices on Biodiversity Conservation. *Journal of Sustainable Solutions*, 1(3), 1–5. <https://doi.org/10.36676/j.sust.sol.v1.i3.13>
- Sjøblom, I. S. (2018). *Assessing the Need for State- Driven Governance in the Aquaculture Sector of Belize*.
- Smit, B., Burton, I., Klein, R. J. T., & Wandel, J. (2000). *An anatomy of adaptation to climate change and variability*.
- Smith-Godfrey, S. (2016). Defining the blue economy. *Maritime Affairs*, 12(1), 58–64. <https://doi.org/10.1080/09733159.2016.1175131>
- Sobuj, M. A., Chowdhury, M. S. N., & Rahman, M. M. (2023). Knowledge gaps and capacity needs in seaweed cultivation among coastal communities of Bangladesh. *Ocean & Coastal Management*, 243, 106704. <https://doi.org/10.1016/j.ocecoaman.2023.106704>
- Sondak, C. F. A., Ang, P. O., Beardall, J., Bellgrove, A., Boo, S. M., Gerung, G. S., Hepburn, C. D., Hong, D. D., Hu, Z., Kawai, H., Largo, D., Lee, J. A., Lim, P. E., Mayakun, J., Nelson, W. A., Oak, J. H., Phang, S. M., Sahoo, D., Peerapornpis, Y., ... Chung, I. K. (2017). Carbon dioxide mitigation potential of seaweed aquaculture beds (SABs). *Journal of Applied Phycology*, 29(5), 2363–2373. <https://doi.org/10.1007/s10811-016-1022-1>

- Spiegelhalter, M. R., Rodrigues, L. C., Dekker-Arlain, J. den, Papadopoulou, O., Gharbia, S., Anton, L., & Tiwari, A. (2022). *Synthesis of socio-economic assessment methods, databases, and studies addressing EBA and other adaptation strategies*.
- Spillias, S., Cottrell, R. S., Kelly, R., O'Brien, K. R., Adams, J., Bellgrove, A., Kelly, B., Kilpatrick, C., Layton, C., Macleod, C., Roberts, S., Stringer, D., & McDonald-Madden, E. (2022). Expert perceptions of seaweed farming for sustainable development. *Journal of Cleaner Production*, 368. <https://doi.org/10.1016/j.jclepro.2022.133052>
- Srivastava, M. (2012). A study on Sustainability and Sustainable development: Detailed explanation of the terms and its evolution, concept and meaning including discussion on how to enable sustainable development. *International Journal of Advanced Research in Management and Social Sciences*, 1(1), 1–14. <https://garph.co.uk/IJARMSS/Feb2012/1.pdf>
- Strittmatter, M., Murúa, P., Arce, P., Perrineau, M. M., & Gachon, C. (2022). My seaweed looks weird: a community web portal to accelerate pathogen discovery in seaweeds. *Applied Phycology*, 3(1), 300–305. <https://doi.org/10.1080/26388081.2022.2059783>
- Suckall, N., Tompkins, E., & Stringer, L. (2014). Identifying trade-offs between adaptation, mitigation and development in community responses to climate and socio-economic stresses: Evidence from Zanzibar, Tanzania. *Applied Geography*, 46, 111–121. <https://doi.org/10.1016/j.apgeog.2013.11.005>
- Sudarwati, W., Hardjomidjojo, H., Machfud, & Setyaningsih, D. (2020a). Literature review: Potential and opportunities for the development of seaweed agro-industry. *IOP Conference Series: Earth and Environmental Science*, 472(1). <https://doi.org/10.1088/1755-1315/472/1/012063>
- Sudarwati, W., Hardjomidjojo, H., Machfud, & Setyaningsih, D. (2020b). Literature review: Potential and opportunities for the development of seaweed agro-industry. *IOP Conference Series: Earth and Environmental Science*, 472(1). <https://doi.org/10.1088/1755-1315/472/1/012063>
- Sultana, F., Wahab, M. A., Nahiduzzaman, M., Mohiuddin, M., Iqbal, M. Z., Shakil, A., Mamun, A. Al, Khan, M. S. R., Wong, L. L., & Asaduzzaman, M. (2023). Seaweed farming for food and nutritional security, climate change mitigation and adaptation, and women empowerment: A review. In *Aquaculture and Fisheries* (Vol. 8, Issue 5). <https://doi.org/10.1016/j.aaf.2022.09.001>
- Sun, R. (2023). Economic Mathematical Models: Examining Their Impact on Individuals. *Advances in Economics, Management and Political Sciences*, 50(1), 16–22. <https://doi.org/10.54254/2754-1169/50/20230542>
- Sun, Y., Li, H., Wang, X., Li, H., & Deng, Y. (2023). Kelp Culture Enhances Coastal Biogeochemical Cycles by Maintaining Bacterioplankton Richness and Regulating Its Interactions. *MSystems*, 8(2). <https://doi.org/10.1128/msystems.00002-23>
- Tahiluddin, T., & Terzi, H. (2021). Effects of water quality degradation on seaweed growth and aquaculture sustainability. *Aquaculture Studies*, 21(2), 77–88. [https://doi.org/10.4194/2618-6381-v21\\_2\\_01](https://doi.org/10.4194/2618-6381-v21_2_01)
- Tang, Q., Zhang, J., & Fang, J. (2011). Shellfish and seaweed mariculture increase atmospheric CO<sub>2</sub> absorption by coastal ecosystems. *Marine Ecology Progress Series*, 424, 97–104. <https://doi.org/10.3354/meps08979>

- Tanna, B., & Mishra, A. (2019). Nutraceutical Potential of Seaweed Polysaccharides: Structure, Bioactivity, Safety, and Toxicity. In *Comprehensive Reviews in Food Science and Food Safety* (Vol. 18, Issue 3, pp. 817–831). Blackwell Publishing Inc. <https://doi.org/10.1111/1541-4337.12441>
- Tchonkouang, R. D., Onyeaka, H., & Nkoutchou, H. (2024). Assessing the vulnerability of food supply chains to climate change-induced disruptions. In *Science of the Total Environment* (Vol. 920). Elsevier B.V. <https://doi.org/10.1016/j.scitotenv.2024.171047>
- Templeton, J., Davenport, D., Gutiérrez, M., & Hansen, G. (2022). *Earth Negotiations Bulletin A Reporting Service for Environment and Development Negotiations IPCC-56 FINAL*. <https://bit.ly/ipcc56-wgIII-I4>
- Terauds, K., & Zhuawu, C. (2021). *Alternative Development Strategies for SIDS Alternative Development Strategies for SIDS Building Competitiveness in New*.
- Thomas, A., Baptiste, A., Martyr-Koller, R., Pringle, P., & Rhiney, K. (2020). Climate change and small island developing states. *Annual Review of Environment and Resources*, 45, 1–27. <https://doi.org/10.1146/annurev-environ-012320-083355>
- Thompson, D. D. P. (2022). Compounding challenges for disaster resilience in small island developing states. *Disaster Prevention and Resilience*. <https://doi.org/10.20517/dpr.2021.04>
- The Nature Conservancy (TNC). (2017). *Belize sustainable seaweed*. The Nature Conservancy. <https://anthrocean.org/wp-content/uploads/2019/08/Belize-Seaweed-Final-Report-Anthropocene-Institute.pdf> anthrocean.org
- The Nature Conservancy (TNC). (2020). *Sustainable seaweed cultivation: Testing results and implications for local and international markets*. The Nature Conservancy. <https://static1.squarespace.com/static/64f79fffaa1a5c7f98a0a4b4/t/64f80c1e0482b21ad147aae3/1693977633091/Sustainable%2BSeaweed%2BCultivation-Technical%2BReport%2B3-FINAL.pdf> Squarespace
- The Nature Conservancy (TNC). (2021). *Case study: Belize blue bonds for ocean conservation*. Arlington, VA: The Nature Conservancy. <https://www.nature.org/en-us/what-we-do/our-insights/perspectives/belize-blue-bonds-ocean-conservation/>
- The Nature Conservancy (TNC). (2024a). *A case study for regenerative and restorative aquaculture*. Arlington, VA: The Nature Conservancy. <https://www.nature.org/en-us/what-we-do/our-insights/perspectives/regenerative-restorative-aquaculture/>
- The Nature Conservancy (TNC). (2024b, June 17). *Sowing in the seas: Aquaculture for coastal restoration in Belize*. The Nature Conservancy, 1–6.
- The Nature Conservancy (TNC), Belize Fisheries Department (BFD), & Marine Conservation and Climate Adaptation Project (MCCAP). (2014). *Culturally appropriate participation plan*.
- Townhill, B. L., Birchenough, S. N. R., Engelhard, G. H., Harrod, O., McHarg, E., Monnereau, I., & Buckley, P. J. (2021). *Responding to climate change in Caribbean fisheries and aquaculture through adaptation*. Commonwealth Marine Economies Programme.
- United Nations (UN). (2015b). *The Paris Agreement*. United Nations Framework Convention on Climate Change. [https://unfccc.int/sites/default/files/english\\_paris\\_agreement.pdf](https://unfccc.int/sites/default/files/english_paris_agreement.pdf)

- United Nations Sustainable Development Knowledge Platform (UN SDKP). (2013). *Blue economy concept paper*. <https://sustainabledevelopment.un.org/content/documents/2978BEconcept.pdf>
- United Nations Conference on Trade and Development (UNCTAD). (2014). *The oceans economy: Opportunities and challenges for Small Island Developing States*. Geneva, Switzerland: UNCTAD. <https://unctad.org/webflyer/oceans-economy-opportunities-and-challenges-small-island-developing-states>
- United Nations Conference on Trade and Development (UNCTAD). (2021). *SIDS in context*. Geneva, Switzerland: UNCTAD. <https://unctad.org/topic/sids-in-context>
- United Nations Conference on Trade and Development (UNCTAD). (2023). *Voluntary sustainability standards and BioTrade: Is there a connection?* Geneva, Switzerland: UNCTAD. <https://unctad.org/publication/voluntary-sustainability-standards-and-biotrade-there-connection>
- United Nations Conference on Trade and Development (UNCTAD). (2024). *An ocean of opportunities: The potential of seaweed to advance food, environmental and gender dimensions of the SDGs*. Geneva, Switzerland: UNCTAD. <https://unctad.org/publication/ocean-opportunities-seaweed>
- United Nations Conference on Trade and Development (UNCTAD), & Food and Agriculture Organization of the United Nations (FAO). (2021). *The seaweed sector as a lever for sustainable economic recovery*. Geneva, Switzerland: UNCTAD.
- UNDP. (2017). *Guide Note: Application of the Sustainable Livelihoods Framework in Development Projects*. New York, NY: UNDP.
- UNDP. (2021). *Belize SDG Investor Map Report: Investment Opportunity Areas Annual Report 2021*. New York, NY: UNDP. <https://sdginvestorplatform.undp.org/>
- UNEP. (2021). Global progress on adaptation finance. In *United Nations Environment Programme (UNEP)*. <https://doi.org/10.18356/9789280738957c008>
- UNEP. (2023a). *Adaptation Gap Report 2023: Underfinanced. Underprepared. Inadequate investment and planning on climate adaptation leaves world exposed*. United Nations Environment Programme. <https://doi.org/10.59117/20.500.11822/43796>
- United Nations Environment Programme (UNEP). (2023b). *Seaweed farming: Assessment of the potential of sustainable upscaling for climate, communities and the planet*. Nairobi, Kenya: UNEP. <https://www.unep.org/resources/report/seaweed-farming-assessment-sustainable-upscaling>
- United Nations Environment Programme (UNEP). (2023c). *Seaweed farming: Assessment on the potential of sustainable upscaling for climate, communities and the planet*. <https://www.unep.org/resources/report/seaweed-farming-assessment-sustainable-upscaling>
- United Nations Educational, Scientific and Cultural Organization (UNESCO). (2024). *State of the Ocean Report 2024* (IOC Technical Series No. 190). Paris, France: UNESCO.
- UNFCCC. (2023). *Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on its fifth session, held in the United Arab Emirates from 30 November to 13 December 2023*.

- UNFCCC. (2024). *Report of the Conference of the Parties serving as the meeting of the Parties to Paris Agreement on its fifth session, held in the United Arab Emirates from 30 November to 13 December 2023*.
- United Nations. (2015). Arsenic and the 2030 Agenda for sustainable development. *Arsenic Research and Global Sustainability - Proceedings of the 6th International Congress on Arsenic in the Environment, AS 2016*, 12–14. <https://doi.org/10.1201/b20466-7>
- United Nations Framework Convention on Climate Change, 1 (1992).
- van der Velden, M. (2022). *The Role of Seaweed Farms in the Social Development of Small Island States*. University of Groningen.
- van Oirschot, R., Thomas, J. B. E., Gröndahl, F., Fortuin, K. P. J., Brandenburg, W., & Potting, J. (2017). Explorative environmental life cycle assessment for system design of seaweed cultivation and drying. *Algal Research*, 27(August 2016), 43–54. <https://doi.org/10.1016/j.algal.2017.07.025>
- Vernon, D. G. (2013). Big Game, Small Town: Clientelism and Democracy in the Modern Politics of Belize. In *University College of London*.
- Vijayaraghavan, K., & Joshi, U. M. (2015). Application of seaweed as substrate additive in green roofs: Enhancement of water retention and sorption capacity. *Landscape and Urban Planning*, 143, 25–32. <https://doi.org/10.1016/j.landurbplan.2015.06.006>
- Vincent, A., Stanley, A., & Ring, J. (2020). *Hidden champion of the ocean*.
- Wade, E., Spalding, A. K., & Biedenweg, K. (2019). Integrating property rights into fisheries management: The case of Belize's journey to managed access. *Marine Policy*, 108. <https://doi.org/10.1016/j.marpol.2019.103631>
- Ward, G. M., Faisan, J. P., Cottier-Cook, E. J., Gachon, C. M. M., Hurtado, A. Q., Lim, P. E., Matoju, I., Msuya, F. E., Bass, D., Brodie, J. (2019). A review of diseases and pests in cultivated seaweeds worldwide: Implications for management and future research. *Reviews in Aquaculture*, 12(2), 2024–2049. <https://doi.org/10.1111/raq.12302>
- WBG, & UNDESA. (2017). *The Potential of the Blue Economy: Increasing Long-term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries*. [https://doi.org/10.1007/978-3-319-95726-5\\_300008](https://doi.org/10.1007/978-3-319-95726-5_300008)
- WCED. (1987). World Commission On Environment And Development. In *World Commission on Environment and Development* (Vol. 17).
- Wilkins, E. J., Chikamoto, Y., Miller, A. B., & Smith, J. W. (2021). Climate change and the demand for recreational ecosystem services on public lands in the continental United States. *Global Environmental Change*, 70. <https://doi.org/10.1016/j.gloenvcha.2021.102365>
- Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2003). *At Risk: natural hazards, people's vulnerability and disaster* (Second Edition).
- WMO. (2023). *The Global Climate 2011-2020 A decade of accelerating climate change*. World Meteorological Organization.
- Worku, A., Pretzsch, J., Kassa, H., & Auch, E. (2014). The significance of dry forest income for livelihood resilience: The case of the pastoralists and agro-pastoralists in the drylands

- of southeastern Ethiopia. *Forest Policy and Economics*, 41, 51–59. <https://doi.org/10.1016/j.forpol.2014.01.001>
- World Bank (WB). (2022). *Unleashing the Blue Economy of the Caribbean*. The World Bank.
- World Bank. (2023). *Global Seaweed New and Emerging Markets Report*. [www.worldbank.org](http://www.worldbank.org)
- World Bank; United Nations Department of Economic and Social Affairs (UN DESA). (2017). *The potential of the blue economy: Increasing long-term benefits of the sustainable use of marine resources for Small Island Developing States and coastal least developed countries*. Washington, DC: World Bank. <https://hdl.handle.net/10986/26843>
- World Bank Group. (2016). Seaweed Aquaculture for Food Security, Income Generation and Environmental Health in Tropical Developing Countries. *Seaweed Aquaculture for Food Security, Income Generation and Environmental Health in Tropical Developing Countries*. <https://doi.org/10.1596/24919>
- Yang, Y., Chai, Z., Wang, Q., Chen, W., He, Z., & Jiang, S. (2015). Cultivation of seaweed *Gracilaria* in Chinese coastal waters and its contribution to environmental improvements. In *Algal Research* (Vol. 9, pp. 236–244). Elsevier B.V. <https://doi.org/10.1016/j.algal.2015.03.017>
- Yigitcanlar, T. (2021). Greening the artificial intelligence for a sustainable planet: An editorial commentary. In *Sustainability (Switzerland)* (Vol. 13, Issue 24). MDPI. <https://doi.org/10.3390/su132413508>
- Yong, W. T. L., Thien, V. Y., Rupert, R., & Rodrigues, K. F. (2022). Seaweed: A potential climate change solution. *Renewable and Sustainable Energy Reviews*, 159(January), 112222. <https://doi.org/10.1016/j.rser.2022.112222>
- Young, C. A. (2008). Belize's Ecosystems: Threats and Challenges to Conservation in Belize. *Tropical Conservation Science*, 1(1), 18–33. <https://doi.org/10.1177/194008290800100102>
- Young, C., & Horwich, R. (2007). History of Protected Area Designation, Co-management and Community Participation in Belize. *Taking Stock: Belize at 25 Years of Independence, 1817*(Leslie 1997), 123–150.
- Yüksel, I. (2012). Developing a Multi-Criteria Decision Making Model for PESTEL Analysis. *International Journal of Business and Management*, 7(24). <https://doi.org/10.5539/ijbm.v7n24p52>
- Zamroni, A., Apriliani, T., Rosyidah, L., Muliawan, I., & Hatanaka, K. (2020). Sustainability index of the seaweed farmers household economy in Serewe Bay, West Nusa Tenggara, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 564(1). <https://doi.org/10.1088/1755-1315/564/1/012068>
- Zhang, C., & Fang, Y. (2020). Application of capital-based approach in the measurement of livelihood sustainability: A case study from the Koshi River basin community in Nepal. *Ecological Indicators*, 116(August 2019), 106474. <https://doi.org/10.1016/j.ecolind.2020.106474>
- Zhang, L., Liao, W., Huang, Y., Wen, Y., Chu, Y., & Zhao, C. (2022). Global seaweed farming and processing in the past 20 years. In *Food Production, Processing and Nutrition* (Vol. 4, Issue 1). BioMed Central Ltd. <https://doi.org/10.1186/s43014-022-00103-2>



- Zhong, B., Robinson, N. A., Warner, R. D., Barrow, C. J., Dunshea, F. R., & Suleria, H. A. R. (2020). LC-ESI-QTOF-MS/MS characterization of seaweed phenolics and their antioxidant potential. *Marine Drugs*, 18(6). <https://doi.org/10.3390/md18060331>
- Zulfachri, B., & Som Puad Mat, A. (2017). The Development of the Concept of Social Capital. *Universiti Sultan Zainal Abidin*, 1–13.

## 9. APPENDICES

### 9.1 APPENDIX A (Scoping Literature)

While the scoping literature review doesn't explicitly categorize hazards into climatic and non-climatic groups, this thesis proposes a classification of livelihood hazards as illustrated in Table 9.1. . The review primarily concentrates on climate-related hazards and their wide-ranging impacts on society and the environment. These hazards, which are extensively discussed in the literature, include extreme temperatures, precipitation, drought, wildfires, wind threats, river and coastal flooding, sea-level rise, coastal erosion, tropical cyclones, and heatwaves (Laino and Iglesias, 2024). These phenomena are often interlinked and intensified by climate change (Harkness et al., 2020). Notably, while the focus is predominantly on climate-related hazards, some potentially non-climatic hazards like landslides are also mentioned (Laino and Iglesias, 2024). However, it's worth noting that even these ostensibly non-climatic hazards may be indirectly influenced by climate change, making the distinction between climatic and non-climatic categories less clear-cut. In summary, rather than explicitly categorizing hazards, the reviewed papers emphasize the broad spectrum of climate-related hazards and their impacts on various sectors, including human health, agriculture, and urban environments and non-climatic hazards their impacts on livelihood activities. The literature highlights the necessity for comprehensive assessment and management strategies to address these hazards within the context of climate change (Harkness et al., 2020; Hiwasaki et al., 2015; Laino and Iglesias, 2024).

|   | Category        | Hazard Origin          | Definition                                                                                                                                                              | Examples                                                                                        | Reference                          |
|---|-----------------|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|------------------------------------|
| 1 | Climate-related | Natural                | Events or processes of the Earth, atmosphere, hydrosphere, or space that may cause disruption of activities, damage to infrastructure, and lead to loss of livelihoods. | Hydrological hazards, geological hazards and climatological hazards.                            | (Dewan, 2013; Wisner et al., 2003) |
| 2 |                 | Climate change-related | An event or condition that arises from changes in climate patterns and poses a threat to human life, property, ecosystems, or other elements of the environment.        | Extreme weather events, sea-level rise, ocean acidification, changes in precipitation patterns. | (Dewan, 2013; Wisner et al., 2003) |

|   |              |                                  |                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                  |                                                                            |
|---|--------------|----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| 3 |              | Environmental degradation/damage | Any change or disturbance to the environment perceived to be deleterious or undesirable. It involves the deterioration of the environment through the depletion of natural resources such as air, water, and soil. Long-term changes in ecosystems, climate, or natural resources. | Loss of biodiversity, loss of mangrove forests, habitat destruction, loss of ecosystem services, pollution, disruption of ecosystems, extinction of species, and increased susceptibility to pests and diseases. | (Adato and Meinzen-Dick, 2002; Badjeck et al., 2010b; Elasha et al., 2005) |
| 4 |              | Ecological                       | It affects the health and sustainability of ecosystems, potentially impacting both biotic and abiotic components.                                                                                                                                                                  | Pathogens, epiphytes, and diseases hazards, nutrient imbalances, environmental stress (eg. fluctuations in temperature, salinity, and light exposure, etc.)                                                      | (Adato and Meinzen-Dick, 2002; Badjeck et al., 2010b; Elasha et al., 2005) |
| 5 | Non-climatic | Man-made                         | Human-induced activities result in physical damage, displacement, and economic losses, posing significant threats to livelihoods and the environment. This may involve negative impacts from technology due to rapid changes that may lead to                                      | Development (dredging), industrial accidents, national and international conflicts, and technological disruptions due to technological advancements, automation, and digital divides.                            | (S. Brown et al., 2013; IPCC, 2021; Paavola, 2008)                         |

|   |  |                       |                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                        |                                                                     |
|---|--|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|
|   |  |                       | economic disparities, thus affecting those who may struggle to adapt.                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                        |                                                                     |
| 6 |  | Policy and governance | Understood as risks or threats that emanate from policy decisions, governance structures, sudden policy shifts or lack of effective governance can create uncertainties and negatively impact livelihoods and potentially can contribute to corruption, thus impacting the equitable distribution of resources. | Regulatory and legal hazards, compliance with environmental standards, inadequate governance structures, mismanagement, corruption, and lack of infrastructure (e.g. roads, digitalization, transparent and accountable systems, etc.) | (Ayers and Forsyth, 2009; Olago et al., 2007; Rusekwa et al., 2020) |
| 7 |  | Economic              | A condition or event that poses a risk or threat to the economic well-being of individuals, businesses, or a larger economy through economic downturns, inflation, and job losses that may undermine income stability and financial security, thus impacting livelihoods.                                       | Supply chain hazards, price volatility, market access issues, operational hazards, job availability, compliance with customer standards (quality of commodity), lack of business investment                                            | (FAO, 2015, 2023; Tchoukoua et al., 2024)                           |
| 8 |  | Social                | Risks or threats that arise from                                                                                                                                                                                                                                                                                | Social inequality, discrimination,                                                                                                                                                                                                     | (Ayers and Forsyth,                                                 |

|    |  |          |                                                                                                                                                                                                                           |                                                                                                                                                                                                                                              |                                                                  |
|----|--|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|
|    |  |          | human interactions and societal structures.                                                                                                                                                                               | familial issues, medical conflicts within a community or society, and theft.                                                                                                                                                                 | 2009; Birkmann et al., 2023)                                     |
| 9  |  | Cultural | Risks that stem from changes or disruptions to the cultural values, practices, and traditions of a community. These hazards can result from external influences, technological advancements, or shifts in societal norms. | Loss of traditional knowledge and practices due to modernization, cultural displacement or assimilation due to migration or globalization, changes in cultural heritage and identity, threats to indigenous languages, customs, and rituals. | (Makame et al., 2021; Manzaneres and Cocom, 2015; Paavola, 2008) |
| 10 |  | Health   | Involves risks to individuals' well-being and the ability to work. Health-related challenges can lead to increased healthcare costs, loss of productivity, and disruptions in various economic sectors.                   | Spread of diseases (epidemics or pandemics), diet-related diseases, and exposure to elements in work sites.                                                                                                                                  | (Cole et al., 2009; Rusekwa et al., 2020)                        |

*Table 9.1. A Summary of Hazards Classification of Livelihood Hazards and Definitions.*

## 9.2 APPENDIX B (Systematic Literature Review)

### 9.2.1 Data: Systematic Literature Review (PRISMA) Publication Listings

The following table (Table 9.2) present the key findings from a systematic review of literature on seaweed farming and its role in climate change adaptation using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol. The studies are categorized based on content type, country of study, research context, and effectiveness of adaptation measures.

| No. | Content Type | Reference             | Country of Study | Assessment Method                                     | Title                                                                                                 | Study                 | Research Design                                   | Effectiveness                                                                                                                                                                                                                           |
|-----|--------------|-----------------------|------------------|-------------------------------------------------------|-------------------------------------------------------------------------------------------------------|-----------------------|---------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Article      | Torre-Castro et al.   | Tanzania         | Mixed methods (quantitative and qualitative)          | Women and adaptive capacity to climate change in East African seascapes – Zanzibar as an example      | Torre-Castro et al.   | Empirical study                                   | Successfully enhanced adaptive capacity and resilience of women in seaweed farming communities. Emphasized the need for gender-sensitive policies and programs to support climate adaptation.                                           |
| 2   | Article      | Hossain et al. (2021) | Bangladesh       | Mixed methods (quantitative and qualitative analysis) | Seaweeds farming for sustainable development goals and blue economy in Bangladesh                     | Hossain et al. (2021) | Systematic literature review and empirical study  | Demonstrated potential for significant contributions to the Blue Economy and SDGs, particularly in enhancing coastal resilience and providing sustainable livelihoods. Emphasized the need for policy support and community engagement. |
| 3   | Article      | Jagtap et al. (2022)  | India            | Sustainability Review and Synthesis                   | Chapter 23 - Seaweed farming: A perspective of sustainable agriculture and socio-economic development | Jagtap et al. (2022)  | Comprehensive review of seaweed farming practices | Highly effective in providing socio-economic benefits and enhancing food security. Contributes to sustainable agricultural practices and community resilience. Needs further integration with broader climate adaptation strategies.    |

|                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                  |                                                                                                                                                                                                                            |                                                                                                                                                                                                                                              |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7                                                                                                                                                                                                                                 | 6                                                                                                                                                                                                                                | 5                                                                                                                                                                                                                          | 4                                                                                                                                                                                                                                            |
| Article                                                                                                                                                                                                                           | Article                                                                                                                                                                                                                          | Article                                                                                                                                                                                                                    | Article                                                                                                                                                                                                                                      |
| Geggs and Wells (2019)                                                                                                                                                                                                            | Ndobe et al. (2020)                                                                                                                                                                                                              | Matoju et al. (2022)                                                                                                                                                                                                       | Schwahofer et al. (2021)                                                                                                                                                                                                                     |
| UK                                                                                                                                                                                                                                | Indonesia                                                                                                                                                                                                                        | Tanzania                                                                                                                                                                                                                   | Brazil                                                                                                                                                                                                                                       |
| Qualitative Methods (stakeholder perceptions analysis)                                                                                                                                                                            | Experimental Methods (physiological analysis)                                                                                                                                                                                    | Qualitative Methods (stakeholder perceptions analysis)                                                                                                                                                                     | Sustainability Review and Synthesis                                                                                                                                                                                                          |
| The development of seaweed-derived fuels in the UK: An analysis of stakeholder issues and public perceptions                                                                                                                      | Eucheumatoid seaweed farming under global change-Tomini bay seaweed trial indicates <i>Eucheuma denticulatum</i> (Spinosum) could contribute to climate adaptation                                                               | A resilience lens to explore seaweed farmers' responses to the impacts of climate change in Tanzania                                                                                                                       | Mariculture in a densely urbanized portion of the Brazilian coast: Current diagnosis and directions for sustainable development                                                                                                              |
| Geggs and Wells (2019)                                                                                                                                                                                                            | Ndobe et al. (2020)                                                                                                                                                                                                              | Matoju et al. (2022)                                                                                                                                                                                                       | Schwahofer et al. (2021)                                                                                                                                                                                                                     |
| Empirical study using PESTEL Framework                                                                                                                                                                                            | Empirical study using experimental trials in the field with different seaweed species                                                                                                                                            | Empirical study by case study                                                                                                                                                                                              | Empirical study by case study                                                                                                                                                                                                                |
| Seaweed farming showed potential for significant environmental benefits, including carbon sequestration and habitat restoration. Need for comprehensive policy frameworks and economic incentives for large-scale implementation. | <i>E. denticulatum</i> showed better growth and resistance to adverse conditions, indicating its potential for climate adaptation. Highlighted the need for downstream research and market development for effective adaptation. | Effective in improving resilience and adaptive capacity of seaweed farmers. Highlighted the importance of community participation and indigenous knowledge. Identified economic challenges and need for technical support. | Demonstrated the potential for integrating mariculture with urban sustainability goals. Identified challenges related to pollution and urban development pressures. Emphasized the need for comprehensive urban-coastal management policies. |

|                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                           |                                                                                                                                                                                                                  |                                                                                                                                                                                     |                       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| 12                                                                                                                                                                                                                          | Chapter                                                                                                                                                                                                                                           | 11                                                                                                                                                                                                                                        | 10                                                                                                                                                                                                               | 9                                                                                                                                                                                   | 8                     |
| Hayashi et al. (2019)                                                                                                                                                                                                       | Chapter                                                                                                                                                                                                                                           | Bhuyan et al. (2021)                                                                                                                                                                                                                      | Thiel et al. (2007)                                                                                                                                                                                              | Rubekie et al. (2022)                                                                                                                                                               | Pereira et al. (2021) |
| Brazil                                                                                                                                                                                                                      | Various global locations                                                                                                                                                                                                                          | Chile                                                                                                                                                                                                                                     | Tanzania                                                                                                                                                                                                         | Brazil                                                                                                                                                                              |                       |
| Experimental Methods (physiological)                                                                                                                                                                                        | Mixed Methods (qualitative and quantitative analysis)                                                                                                                                                                                             | Sustainability Review and Synthesis                                                                                                                                                                                                       | Mixed methods (quantitative and qualitative analysis)                                                                                                                                                            | Mixed methods (quantitative and qualitative analysis)                                                                                                                               |                       |
| Challenges to the future domestication of seaweeds as cultivated species: understanding their physiological processes for large-scale production                                                                            | Chapter 5 - Seaweed: A Powerful Tool for Climate Change Mitigation That Provides Various Ecological Services                                                                                                                                      | The Humboldt Current System of northern and central Chile - Oceanographic processes, ecological interactions and socioeconomic feedback                                                                                                   | Logistic regression analysis to determine gender specific challenges and factors affecting seaweed farming along the coast of Tanzania mainland                                                                  | Sustainability of the seaweed <i>Hypnea pseudomusciformis</i> farming in the tropical Southwestern Atlantic                                                                         |                       |
| Hayashi et al. (2019)                                                                                                                                                                                                       | Bhuyan et al. (2021)                                                                                                                                                                                                                              | Thiel et al. (2007)                                                                                                                                                                                                                       | Rubekie et al. (2022)                                                                                                                                                                                            | Pereira et al. (2021)                                                                                                                                                               |                       |
| Empirical study by laboratory and field experiments                                                                                                                                                                         | Systematic literature reviews and meta-analyses                                                                                                                                                                                                   | Empirical study of oceanographic conditions                                                                                                                                                                                               | Quantitative analysis of gender-specific challenges                                                                                                                                                              | Empirical study and sustainability assessment                                                                                                                                       |                       |
| Effective in improving large-scale production techniques and disease management. Limited by challenges in genetic diversity and physiological adaptability. Essential for sustaining long-term productivity and resilience. | Effective in enhancing marine ecosystem health and providing a sustainable livelihood. Contributes significantly to carbon sequestration and nutrient cycles. Addresses multiple aspects of climate change adaptation through ecosystem services. | Provided valuable insights into the long-term impacts of seaweed farming on marine ecosystems. Highlighted the importance of continuous monitoring and adaptive management to respond to environmental changes and ensure sustainability. | Identified significant gender-specific challenges affecting seaweed farming. Recommended targeted interventions to address these challenges and improve the livelihoods of women in seaweed farming communities. | Highlighted the ecological and economic benefits of sustainable seaweed farming. Identified gaps in technical knowledge and the need for capacity-building initiatives for farmers. |                       |



|    |         |                   |                          |                                     |                                                                                           |                   |                                                          |                                                                                                                                                                                                                                                                   |
|----|---------|-------------------|--------------------------|-------------------------------------|-------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13 | Chapter | Kran (2020)       | Various global locations | Sustainability Review and Synthesis | Chapter 3 - Seaweed resources, collection, and cultivation with respect to sustainability | Kran (2020)       | Comprehensive review of global seaweed farming practices | Effective in balancing wild harvest with cultivation to ensure sustainability. Significant contribution to ecosystem services such as nutrient cycling and habitat provision. Requires continuous monitoring and adaptation to changing environmental conditions. |
| 14 | Chapter | Radulovich et al. | Various global           | Sustainability Review and Synthesis | Chapter 3 - Farming of seaweeds                                                           | Radulovich et al. | Comprehensive review of global seaweed farming practices | Demonstrated the potential for seaweed farming to contribute to food security and climate resilience. Highlighted the need for integrated management approaches and support for local communities.                                                                |

Table 9.2. Key findings from a systematic review of literature on seaweed farming and its role in climate change adaptation using PRISMA protocol.

### 9.2.2 Analysis: PRISMA Findings

Figure 9.1 below illustrates the distribution of content types analyzed in the PRISMA findings. The two content types represented are Chapters and Articles. The chart shows that 71% of the reviewed content consists of Articles (10 articles), while 29% comprises Chapters (4 chapters). This indicates that the majority of the literature included in the systematic review came from journal articles, with a smaller proportion drawn from book chapters.

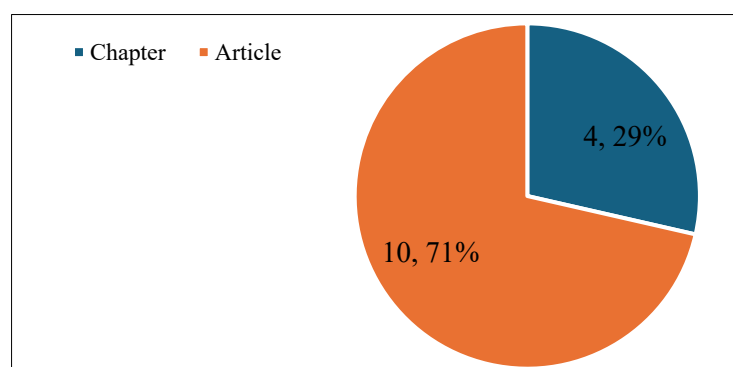


Figure 9.1. The number of publications on seaweed farming and climate change adaptation from 2006 to 2023.

The number of publications on seaweed farming and climate change adaptation from 2006 to 2023 remained stable at 1, with a slight increase in 2020. The trend in Figure 9.2 continued with 3 publications in 2021 and 4 in 2022, reaching its peak in 2023 at 5. This indicates growing academic interest in seaweed farming and its role in climate change adaptation.

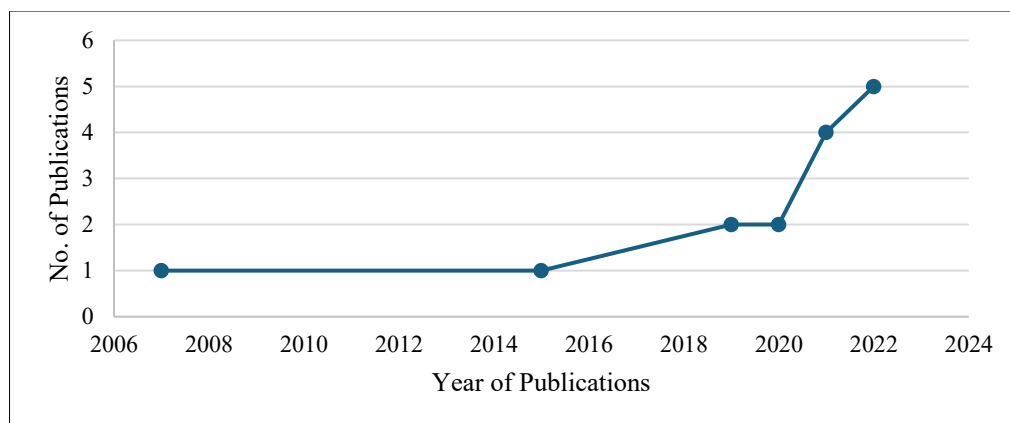


Figure 9.2. World map displays the geographical distribution of seaweed farming and climate change adaptation studies.

The world map displays the geographical distribution of seaweed farming and climate change adaptation studies, with Tanzania and Brazil being the most prominent countries. The color gradient indicates the intensity of research, with darker blue indicating more publications (Figure 9.3). Yellow indicates less relevant research output. The visualization highlights the concentration of seaweed farming and climate adaptation studies in East Africa and South America, suggesting areas for further research.

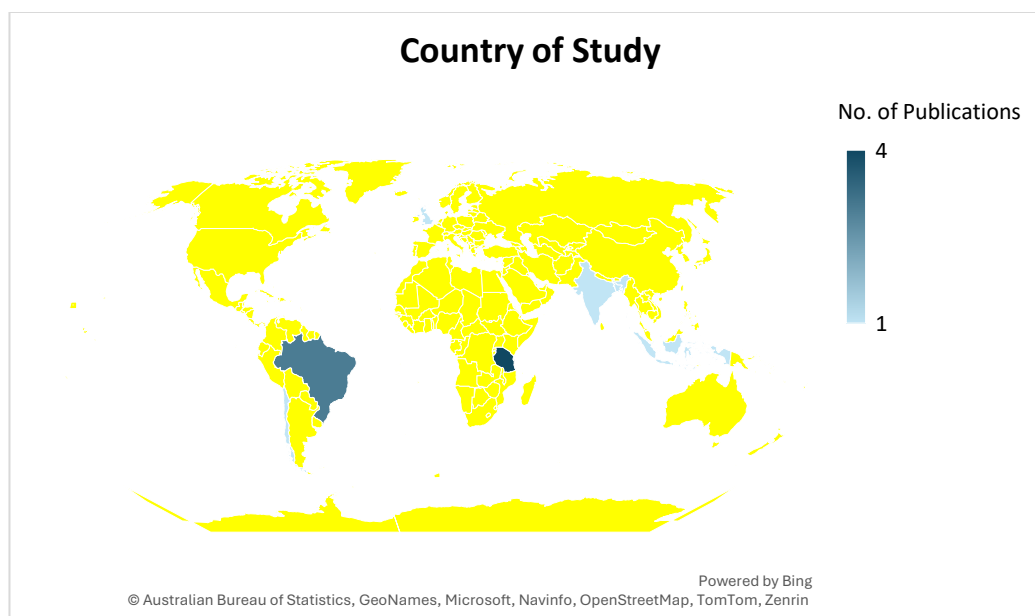


Figure 9.3. World map showing the geographical distribution of climate change adaptation studies in seaweed farming initiatives.

The table below (Table 9.3) presents a comprehensive overview of the assessment methods used in studies related to seaweed farming and climate adaptation. It covers 14 studies, dividing them into four key assessment methods: mixed methods (qualitative and quantitative analysis), experimental and physiological analysis, community-based adaptation, qualitative analysis (stakeholder perceptions), and sustainability review and synthesis. The table covers 36% of the total studies, with the remaining 24% focusing on the latter. The strategy contexts include ecosystem-based adaptation (EbA) by Bhuyan et al. (2021), community-based adaptation (CbA) by Hossain et al. (2021), Pereira et al. (2021), Torre-Castro et al. (2022), and Rubekie et al. (2022). The table also includes 14% of the studies involving stakeholder

perceptions. The sustainability review and synthesis are also included. The table provides a comprehensive breakdown of how different research methodologies are applied across ecosystem-based and community-based adaptation strategies in seaweed farming and climate adaptation contexts.

| Assessment Method                                     | Adaptation Strategy Context | % over the total | References                 |
|-------------------------------------------------------|-----------------------------|------------------|----------------------------|
| Mixed Methods (qualitative and quantitative analysis) |                             | 36%              | 5                          |
|                                                       | EbA                         |                  | Bhuyan et al. (2021)       |
|                                                       | CbA                         |                  | Hossain et al. (2021)      |
|                                                       | CbA                         |                  | Pereira et al. (2021)      |
|                                                       | CbA                         |                  | Torre-Castro et al. (2022) |
|                                                       | CbA                         |                  | Rubekie et al. (2022)      |
| Experimental and physiological analysis               |                             | 14%              | 2                          |
|                                                       | CbA                         |                  | Hayashi et al. (2019)      |
|                                                       | CbA                         |                  | Ndobe et al. (2020)        |
| Qualitative Analysis (Stakeholder Perceptions)        |                             | 14%              | 2                          |
|                                                       | EbA                         |                  | Geggs and Wells (2019)     |
|                                                       | CbA                         |                  | Matoju et al. (2022)       |
| Sustainability Review and Synthesis                   |                             | 36%              | 5                          |
|                                                       | EbA                         |                  | Thiel et al. (2007)        |
|                                                       | CbA                         |                  | Jagtap et al. (2022)       |
|                                                       | CbA                         |                  | Schwahofer et al. (2021)   |
|                                                       | Other                       |                  | Kran (2020)                |
|                                                       | Other                       |                  | Radulovich et al. (2015)   |
| Grand Total                                           |                             | 100%             | 14                         |

*Table 9.3. Summary of PRISMA findings and their research methodologies applied (ecosystem-based and community-based adaptation strategies) in seaweed farming and climate adaptation contexts (Author's own elaboration).*

### 9.2.3 Key findings in the systematic literature review

A vast majority of the literature emphasizes the opportunities and applications that seaweed farming has for climate change adaptation and mitigation, both from an ecological and socioeconomic standpoint. Although a healthy body of literature does address the challenges faced by industry, very few studies address challenges directly related to climate change. Challenges most often identified and studied relate to the socioeconomic sphere of the industry. Although not completely ignored, the environmental impacts of climate change on farmed seaweed do present a gap in the literature reviewed.

#### *Classification of categories*

This systematic literature review yielded three categories by which all articles were grouped; the basis of this grouping was each article’s main thematic context in relation to the research question. The three categories identified included (1) Opportunities of seaweed culture for Blue Growth and Climate Change Adaptation; (2) Challenges of seaweed cultivation; and (3) Analysis of adaptive capacity for the cultivation of seaweed (Figure 9.4.). In essence, to fully understand the sustainability of seaweed culture as a mechanism for blue growth and climate change adaptation, a study of the potential opportunities and challenges must be completed, as well as an analysis of the capacity of the industry to optimize these opportunities whilst simultaneously adapting to challenges present in the cultivation of seaweed.

Together these three categories give a better understanding of the potential of SIDS to cultivate seaweed as a successful mechanism for Climate Change Adaptation and Blue Growth. The figure below (Figure 9.4.) summarizes the categories observed in the literature review:

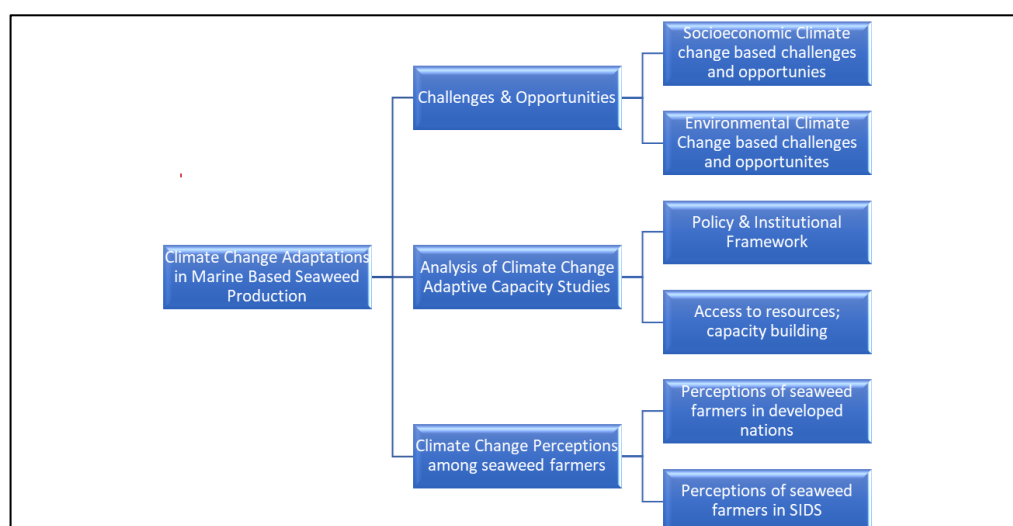


Figure 9.4. PRISMA key findings outlined thematically according to the nature of the articles (Author’s own elaboration).

#### *Opportunities of seaweed aquaculture for blue growth and climate change adaptation*

The first and most prominent category identified was “Opportunities”; the literature reviewed focused on the extensive benefits of seaweed cultivation as an agent for climate change adaptation and mitigation. Seaweed is the ideal candidate for climate change mitigation and adaptation (Bhuyan et al., 2021) providing various services and opportunities. Some of these opportunities include carbon sequestration, reduction of ocean acidification, mitigation of coastal eutrophication, shoreline protection and food production with a reduced CO<sub>2</sub> footprint (Bhuyan et al., 2021; Hayashi et al., 2020; Jagtap and Meena, 2021b).

The most lauded benefits of seaweed cultivation [as an agent of climate change adaptation] were carbon sequestration and the reduction of ocean acidification. Seaweeds are carbon sinks that can reduce ocean acidification through the uptake of CO<sub>2</sub> from water at a scale that depends on the scale of the farming operations (Radulovich et al., 2015). Given seaweed’s rate of use of CO<sub>2</sub> in its photosynthetic process, carbon sequestration via seaweed farming is considered a crucial mechanism to decrease the atmospheric CO<sub>2</sub> and thereby alleviate the trend toward global warming (Jagtap and Meena, 2021b). The use of this CO<sub>2</sub> stabilizes the pH concentration of the ocean water, thereby reducing the occurrence of ocean acidification (Bhuyan et al., 2021).

Other ecological services of seaweed farming include the protection of coastal dwellers and their livelihoods through the dampening of wave energy, provision of food and habitat and

removal of excess nutrients from the water (Bhuyan et al., 2021). Seaweed is also an important source for future supply of food and feed additives, pharmaceuticals, cosmetics, biomaterials and bioenergy (Kraan, 2020). Thus, the opportunities of seaweed production transcend beyond the ecological services but translate to numerous socioeconomic benefits and opportunities.

A study in Bangladesh by Hossain et al. (2021) reported the perceptions of stakeholders to the role of the seaweed industry in attaining sustainable development goals and blue economic development. Results showed that seaweed production could be linked to 26 targets of SDGs including the goals of 'No Poverty', 'Zero Hunger', 'Gender Equality', 'Decent work and economic growth', etc. Socioeconomic opportunities of seaweed production include its potential solution for our growing world population's food security challenges and as a job opportunity for coastal rural dwellers in developing countries (Jagtap and Meena, 2021b; Kraan, 2020).

### *Challenges and identified gaps in the Seaweed Industry*

In the categorization of the literature, whilst it was noted that most opportunities and benefits of the seaweed industry focused on its environmental and ecological services, the challenges of the industry mostly studied were of a socio-economic nature.

Seaweed farming offers many opportunities, but it will be a challenge to overcome limitations to the sector's expansion (Rubekie and Bwathondi, 2022). Limited funding, underdeveloped markets, and a lack of standardization are some of the economic factors that require attention for a successful seaweed industry. These challenges were also noted in a study by Rubekie and Bwathondi (2022) in Tanzania; socioeconomic challenges affecting seaweed farmers included lack of financial support (funding), inadequate market information, and low seaweed price as well as poor infrastructure and limited opportunities for training.

Farming seaweed is a relatively young form of aquaculture (Radulovich, 2015) and as such requires extensive research and stakeholder involvement to inform policy and planning of the industry. A thorough evaluation of the potential of seaweed farming in all maritime countries and an estimate of species that can be utilized for food and related products (including its use as a biofuel) is necessary (Radulovich, 2015) and may be able to assess the potential for growth and profitability of the industry. Involvement of stakeholders from an early stage is also crucial to the development of the industry.

A stakeholder and public perception study by Gegg and Wells (2019), found that an expanding seaweed industry may cause conflicts and uncertainties among stakeholders. From a social perspective, stakeholders highlighted potential marine-user conflicts where large-scale production would cause limitations in marine recreational and industrial (fishing) use. According to Radulovich et al. (2015), seaweed farming can encroach navigational and recreational areas, create aesthetic visual nuisance, obstruct fisheries, and conflict with other uses of sea areas. Involvement of stakeholders at an early stage may better inform policy and planning of the industry.

Challenges of seaweed cultivation are not limited to the socioeconomic sphere. There are several biotic and abiotic stressors that impinge on yields in terms of quantity and quality of cultivated seaweed (Radulovich et al., 2015). Biotic stressors include pathogenic microorganisms, fouling organisms, and invertebrates and vertebrates that feed on tissue. A major challenge of the seaweed industry is the outbreak of diseases, which of the species studied share the common point of their spread being directly related to the intensification of large-scale production (Radulovich et al., 2015).

Abiotic stressors, which are a more widely occurring limitation, include water current and movement, irradiance and photoperiod, water temperature, nutrients dispersion, salinity, and water quality (Hayashi et al. 2020; Radulovich, 2015). Seaweed farming is also seen to be

negatively affected by climate change including storms, typhoons, ocean warming, earthquakes, prolonged rainy seasons, and strong water currents (Jagtap and Meena, 2022).

Beyond major storm phenomenon, climate change has a direct effect on abiotic stressors that affect seaweed cultivation, an increase in water temperature being the most obvious one. Depending on their region, different seaweed species will have differing reactions to an increase in surface water temperature, CO<sub>2</sub> and other environmental factors (Hayashi et al., 2020; Kraan, 2020). An understanding of the responses to the temperature inside the context of ocean acidification of commercially important seaweeds is an important issue for the management of seaweed aquaculture (Hayashi et al., 2020).

To meet the needs and expectations of seaweed production as a mechanism for the mitigation and adaptation of climate change, both ecological and socioeconomic challenges must be addressed and considered in the development and expansion of the industry.

#### *Adaptation Strategies Capacity in the Sustainability of the Seaweed Aquaculture*

The final identified category consisted of those studies that sought out to identify the adaptation strategies in the sustainability of the seaweed industry. Given that most of the challenges identified in the seaweed industry were of a socioeconomic nature, it was of no surprise that most adaptation strategies capacity studies centered on the social and economic sustainability of the industry.

The study by Matoju et al., (2022) identified the risks and capacities within four seaweed-producing regions of Tanzania to analyze the resilience of the industry. The major risks highlighted by farmers in this region included disease and weather-related challenges (both tied to climate change); whilst those found to be most vulnerable were low-income households and women. The second part of this study focused on the identification of resilience capacities in response to identified risks; these included increased farm maintenance, ‘wait and see’ approach, farm relocation, alternative source of seeds, income diversification and suspension of farming activities. Upon analysis of these resilience capacities, it was noted that the seaweed farmers mostly employed short term coping mechanisms; these strategies did not reduce their vulnerability to risks and climate change (Matoju et al., 2022).

Similarly, de la Torre-Castro et al. (2022) found that women in the Tanzania seaweed industry were more vulnerable than their male counterparts. Their study focused the analysis of the adaptive capacity [to climate change] of female seaweed farmers in Zanzibar. One of the most interesting findings showed that the understanding of what climate change was and how it affected their industry was lacking; this despite the various recorded efforts from state, civil society and E-NGOs to disseminate information. To determine the level of adaptive capacity Zanzibar female seaweed farmers had, the study utilized Cinner and Barnes (2019) five domains for adaptive capacity, i.e., assets, flexibility, organizations, learning and agency. Overall Zanzibar female seaweed farmers’ adaptive capacity was found to be low. To enhance women’s adaptive capacity, implementation of empowerment measures through Zanzibar’s organizational structure was recommended. It was noted however, moving beyond the individual level and connecting with regional and global agendas was needed (De la Torre-Castro et al., 2022). As Matoju et al., (2022) stated, seaweed farmers resilience strategies are not enough to cope with the impacts of climate change and environmental degradation; this requires coordinated support and investment by the government, seaweed industry and other partners such as research organizations.

Unlike the other studies, Pereira et al. (2021) looked at not only at the social and economic but also the environmental sustainability of *Hypnea pseudomusciformis* seaweed culture in the municipality of Trairi, in Northeastern Brazil. This study included the formation of a pilot farm to test environmental indicators, and a socioeconomic analysis of the benefits and challenges derived from this industry in the area. Ultimately the seaweed culture of *H. pseudomusciformis* was found to have environmental, social and economic sustainability in

this area. Like the previous studies reviewed, Pereira et al. (2020) serves as an example of the considerations that need to be included to complete a sustainability analysis of any given seaweed culture. It must be noted however that a significant gap in the study was the lack of an analysis of the potential challenges of climate change to seaweed culture.

The only study found to analyze the adaptive capacity of seaweed farming against the environmental implications of climate change was Ndobe et al. (2020). Their study focused on the adaptive capacity of seaweeds *E. denticulatum* and *K. alvarezii* farmed in the Tomini Bay in Indonesia. During the time of the study, the water temperature was relatively high (28-33°C, mostly 30-31°C) while pH was relatively low (6.2-7.8). These conditions were due to a prolonged high temperature anomaly in the area and were like conditions predicted to become widespread under anthropogenic climate change (Ndobe et al., 2020). Results of the study found that *E. denticulatum* was able to thrive and performed significantly better than *K. alvarezii* under the localized marine heatwave. Farming of climate tolerant seaweed (such as *E. denticulatum*) is an important step towards achieving a successful application of the Blue Carbon concept and Climate Change adaptation (Ndobe et al., 2020).

Need to include one paragraph on the remaining 2 studies which do not sufficiently capture seaweed farming activities/seaweed resources. P. Gegg and Wells (2019) is a study of the entire mariculture industry in Rio (Brazil) which is mostly focuses on scallops with minimal mention to seaweed farming; their analysis of challenges is focused on the scallop's mariculture. Thiel et. al provides an extensive study of the Humbolt current system in Chile and how it influences various marine life species; it does not directly address seaweed culture but makes reference to other macroalgae species and how their growth is affected by temperature, salinity etc.

Therefore, to ensure the sustainability of seaweed culture as a mechanism for blue growth and climate change adaptation, a thorough understanding of the opportunities, challenges and most importantly the adaptive capacity of the industry must be gained. As highlighted by De la Torre-Castro et al. (2022), adaptive capacity and adaptation are an ongoing process that needs to be framed within an environmental, socio-economic and political context.

## 9.3 APPENDIX C (Survey Instrument and Analysis)

### 9.3.1 Survey Data Collection: Seaweed Farmers Survey Instruments

The following Seaweed Research Survey Instrument was used during the semi-structured interview surveys with active seaweed farms to gather data on demographic, economic, and employment information, as well as to understand the operations and characteristics of seaweed farms in Belize. The following shows the outline of the survey instrument used in this study:

#### Seaweed Research Survey Instrument

##### Survey Information

1. Survey No/Code: \_\_\_\_\_
2. Date (dd/mm/yy): \_\_\_\_\_
3. Country: ☐ Belize ☐ St. Lucia
4. Community name: ☐ Corozal Town ☐ Sartenja ☐ Belize City ☐ San Pedro ☐ Caye Caulker ☐ Dangriga ☐ Hopkins ☐ Placencia ☐ Independence ☐ Riversdale ☐ Seine Bight ☐ Punta Gorda ☐ Other: \_\_\_\_\_
5. Seaweed farm GPS location (if provided): \_\_\_\_\_
6. Farm district location (show on map): ☐ Corozal ☐ Belize ☐ Stann Creek ☐ Toledo ☐ Other: \_\_\_\_\_
7. Seaweed farm description: ☐ Bamboo ☐ Pipes ☐ Tubular nets ☐ Mixed (specify) ☐ Other: \_\_\_\_\_

##### Biological, Demographics, Employment and Income Information

8. Nationality: ☐ Belizean ☐ St. Lucian ☐ Other: \_\_\_\_\_
9. Gender: ☐ Male ☐ Female ☐ Other: \_\_\_\_\_
10. Age (specific age required, if resistant provide range): \_\_\_\_ years  
☐ 18-24 ☐ 25-34 ☐ 35-44 ☐ 45-54 ☐ 55 – 64 ☐ 65+
11. Ethnicity: ☐ Garifuna ☐ Creole ☐ Mestizo/ Hispanic ☐ Caucasian/White ☐ Other (please specify): \_\_\_\_\_
12. How long have you resided in the community: ☐ 0-2 ☐ 2-5 ☐ 5-10 ☐ 10-15 ☐ 15+
13. Is this community your place of birth? ☐ No ☐ Yes
14. Indicate the number of persons above 18 years living within your household: \_\_\_\_ (Adults)
15. Indicate the number of persons below 18 years living within your household: \_\_\_\_ (Children/Teens)
16. Your level of education (highest): ☐ Never attended ☐ Pre-school ☐ Some primary school ☐ Primary school completed ☐ Some secondary/High school ☐ High school/secondary completed ☐ Technical/vocational training ☐ Some post-secondary/University ☐ Post-secondary/University completed ☐ Post graduate (Masters)
17. Which group/sector does your main income generating activity fall under? ☐ Business ☐ Tourism ☐ Fisheries ☐ Aquaculture ☐ Agriculture ☐ Construction ☐ Government/Civil Service ☐ NGO ☐ Other: \_\_\_\_\_
18. Primary Occupation: \_\_\_\_\_
19. Second Occupation/part-time job: \_\_\_\_\_
20. Thinking about the last 12 months, were you mostly: ☐ Employed ☐ Unemployed ☐ Not employed at all in last 12 months ☐ Other arrangement (specify): \_\_\_\_\_
21. In an average month (4 weeks), how much income does your household earn from paid work (before tax)? Estimate: \_\_\_\_\_ (USD)
22. In an average month (4 weeks), how much income does your household receive from other non-labor sources? (For example, from relatives living elsewhere, child support or from family, friends or neighbors) Estimate: \_\_\_\_\_ (USD)
23. In an average month (4 weeks), how much money does your household manage to save, if any? Estimate: \_\_\_\_\_ (USD)
24. What is the residential status of the house you live in at present? ☐ Own with a mortgage ☐ Own without a mortgage ☐ Rent-Private (paying) ☐ Lease ☐ Rent free ☐ Squat ☐ Other (specify): \_\_\_\_\_



## Life Satisfaction and Health

25. All things considered, how satisfied are you with life as whole these days?  
(On the scale below, 1 means you are “completely dissatisfied”, and 10 means you are “completely satisfied”: please cross or tick where you would rate your satisfaction with your life as a whole.)  
(Completely dissatisfied) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 (Completely satisfied)
26. Thinking of the last 4 weeks, how is your recent overall physical health?  
☐ 1=Very poor ☐ 2=Poor ☐ 3=Fair ☐ 4=Good ☐ 5=Very good ☐ 6=Don't know
27. Thinking of the last 4 weeks, how is your recent overall mental health?  
☐ 1=Very poor ☐ 2=Poor ☐ 3=Fair ☐ 4=Good ☐ 5=Very good ☐ 6=Don't know

The following questions are very general perceptions of the participant. Tick the box that applies on the scale from 1 to 6 where 1 means (=) Strongly Disagree, 2= Disagree, 3= Neither agree nor disagree, 4= Agree, 5= Strongly Agree, and 6= No Opinion). Thinking back over the last 4 weeks.

28. I am satisfied with the services delivered by local authorities  
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5  
☐ 6
29. I am satisfied with my participation in decision-making  
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5  
☐ 6
30. I have family and friends I can rely on for help if I need it  
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5  
☐ 6
31. I am afraid of crime and violence in my community  
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5  
☐ 6
32. Rubbish is a problem in my community  
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5  
☐ 6
33. Poor sanitation is a problem in my community  
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5  
☐ 6
34. Most people can be trusted  
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5  
☐ 6
35. Food is becoming less affordable to buy  
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5  
☐ 6

## Essentials

In the past year, how often, if ever, have you or has anyone in your household had to go without the following things? Tick the box that applies; you can choose ‘Never, Just 1 or 2 times, Several times, Very often, or Always’.

- | 1                                                       | 2                          | 3                          | 4                          | 5                          | 6                          |
|---------------------------------------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Never                                                   | Rarely                     | Sometimes                  | Very often                 | Always                     |                            |
| Don't                                                   |                            |                            |                            |                            |                            |
| (0 out of 10)                                           | (1-3 times)                | (4-6 times)                | (7-9 times)                | (10 times out of 10)       | know                       |
| 36. Gone without enough clean water                     | <input type="checkbox"/> 1 | <input type="checkbox"/> 2 | <input type="checkbox"/> 3 | <input type="checkbox"/> 4 | <input type="checkbox"/> 5 |
|                                                         | <input type="checkbox"/> 6 |                            |                            |                            |                            |
| 37. Gone without enough kerosene/fuel to cook your food | <input type="checkbox"/> 1 | <input type="checkbox"/> 2 | <input type="checkbox"/> 3 | <input type="checkbox"/> 4 | <input type="checkbox"/> 5 |
|                                                         | <input type="checkbox"/> 6 |                            |                            |                            |                            |
| 38. Gone without enough medicines or medical treatment  | <input type="checkbox"/> 1 | <input type="checkbox"/> 2 | <input type="checkbox"/> 3 | <input type="checkbox"/> 4 | <input type="checkbox"/> 5 |
|                                                         | <input type="checkbox"/> 6 |                            |                            |                            |                            |
| 39. Gone without enough income to buy what you need     | <input type="checkbox"/> 1 | <input type="checkbox"/> 2 | <input type="checkbox"/> 3 | <input type="checkbox"/> 4 | <input type="checkbox"/> 5 |
|                                                         | <input type="checkbox"/> 6 |                            |                            |                            |                            |
| 40. Gone without enough food to eat                     | <input type="checkbox"/> 1 | <input type="checkbox"/> 2 | <input type="checkbox"/> 3 | <input type="checkbox"/> 4 | <input type="checkbox"/> 5 |
|                                                         | <input type="checkbox"/> 6 |                            |                            |                            |                            |
| 41. Gone without electricity                            |                            |                            |                            |                            |                            |

☐ 1                      ☐ 2                      ☐ 3                      ☐ 4                      ☐ 5  
☐ 6

Does your household or does anyone in your household own?

42. A TV ☐ Yes ☐ No  
43. A radio ☐ Yes ☐ No  
44. A mobile phone ☐ Yes ☐ No  
45. A personal computer ☐ Yes ☐ No  
46. A washing machine ☐ Yes ☐ No  
47. A boat ☐ Yes ☐ No  
48. Canoe ☐ Yes ☐ No  
49. A car ☐ Yes ☐ No  
50. A motorbike ☐ Yes ☐ No  
51. Another type of vehicle: ☐ Yes (please specify) \_\_\_\_\_ ☐ No

#### Experience & Value-added Products Information:

52. Do you have ownership of your seaweed farm (including seabed leasing permits)? ☐ No ☐ Yes ☐  
Other arrangements: \_\_\_\_\_
53. What was your main reason for venturing into producing this seaweed commodity? ☐ Family tradition  
☐ Good labor wages ☐ Alternative livelihood to fishing due to less fish ☐ Alternative livelihood to tourism due to COVID-19 ☐ Good market price for raw seaweed ☐ High local market demand ☐  
High international market ☐ High returns from value-added products ☐ Other (specify): \_\_\_\_\_
54. How long have you been working with seaweed? ☐ 1- 2 years ☐ 3 - 5 years ☐ 5 - 9 years  
☐ More than 10 ☐ Other (specify): \_\_\_\_\_
55. How often do you work on a seaweed farm? ☐ Only visit ☐ 3-5 times/week ☐  $\geq 2$  times/week ☐  
Every 2 weeks ☐ One a month ☐ Other arrangements (specify): \_\_\_\_\_
56. If you farm, how would you describe your working arrangement in seaweed work? ☐ Full-time (40 hours hrs/wk) ☐ Part-time (< 35 hrs/wk) ☐ Fixed term and/or contract (specify) ☐ Casual Employment (specify) ☐ Other (specify): \_\_\_\_\_
57. What do you think your seaweed is used for when you supply the market: (tick the boxes that apply):  
☐ Cosmetics ☐ Direct human food consumption (eg. shakes, porridges, etc) ☐  
Pharmaceutical/nutraceuticals ☐ Bioenergy/fuel ☐ Bio-liquid fertilizer/composting (agriculture)  
☐ Seaweed biotechnology (tissue culture) ☐ Livestock food supplements (husbandry) ☐ Other: \_\_\_\_\_
58. If you have ventured into making seaweed value-added products, what were your reasons when you started? ☐ Low barriers to enter market ☐ Profitable (high revenue) ☐ Environmentally friendly ☐  
Attractive for tourism ☐ Health & Wellness ☐ Other (specify): \_\_\_\_\_
59. What value-added products do you make from the following seaweed species (write local names, if necessary)?  
☐ *Kappaphycus alvarezii*  
☐ *Eucheuma isiforme*  
☐ *Kappaphycus denticulatum*/*Eucheuma denticulatum*/*E. spinosum*  
☐ *Kappaphycus cottonii* / *Eucheuma cottonii*  
☐ *Gracilaria crassissima*  
☐ Other (specify): \_\_\_\_\_
60. What are the challenges you are facing in expanding your seaweed business? ☐ Finance ☐ A consistent market ☐ Infrastructure for processing seaweed ☐ Limited access to resources (specify: \_\_\_\_\_) ☐ Other: \_\_\_\_\_
61. Do you see yourself continue working with seaweed in the future? ☐ No ☐ Yes ☐ I don't know ☐  
Depends (please explain): \_\_\_\_\_

#### Seaweed Farm/Harvesting Site Information:

62. Indicate when your seaweed farms in the sea were first built? ☐ Before 1989 ☐ 1990-1999 ☐  
2000-2019 ☐ 2020-2022 ☐ Other (specify) \_\_\_\_\_

63. What is the distance to your seaweed farming?  
☐ 0 – 3 miles ☐ 4 – 9 miles ☐ More than 10 miles ☐ I don't know ☐ Other (specify): \_\_\_\_\_
64. Site Location Characteristics: ☐ Lagoon/Mangroves ☐ Tidal range (less than 1 mile) ☐ Off the coastline (less than 5 miles) ☐ Around islands (more than 10 miles) ☐ Other: \_\_\_\_\_
65. Type of ocean bottom/environment: ☐ Muddy ☐ Sandy ☐ Seagrass ☐ Mixed substrate ☐ Other \_\_\_\_\_
66. Farming/harvesting depth (indicate depth of water: \_\_\_\_\_ feet or meters): ☐ Sea surface ☐ 1 foot below sea surface ☐ Mid water column ☐ Sea bottom ☐ Other: \_\_\_\_\_
67. Which seaweed group do you farm? ☐ Red ☐ Brown ☐ Green ☐ Don't know
68. Indicate the seaweed species that you farm or wild harvest (Provided pictures, if necessary):  
☐ *Kappaphycus alvarezii*  
☐ *Eucheuma isiforme*  
☐ *Kappaphycus denticulatum*/*Eucheuma denticulatum*/*E. spinosum*  
☐ *Kappaphycus cottonii* / *Eucheuma cottonii*  
☐ *Gracilaria crassissima*  
☐ Other (specify): \_\_\_\_\_
69. What is your seaweed farming technique used (indicate size measurements of these infrastructures used)?  
☐ Off-bottom technique (tie-tie method)  
☐ Off-bottom technique (raffia method)  
☐ Floating raft technique (raffia method)  
☐ Floating raft technique (tie-tie method)  
☐ Mixed techniques (specify): \_\_\_\_\_
70. What is your current farming system?  
☐ Monofarming  
☐ Multiple commercial seaweed species  
☐ Integrated multi-tropic aquaculture (farming multiple mariculture species in one system such as shellfish, seaweed and fish in one location – specify)  
☐ Other: \_\_\_\_\_
71. In your opinion, what is the best water depth for cultivating seaweed?  
☐ Shallow water / shallow intertidal water  
☐ Deep water  
☐ Mixed shallow and deep water  
☐ I haven't noticed or kept track (no farm record)  
☐ Don't know

#### Climate Change and Seaweed Resources

72. Do you know what climate change is? ☐ No ☐ Yes ☐ Don't know
73. Do you think climate change is affecting your community? ☐ No ☐ Yes ☐ Don't know
74. Do you think climate change affects your seaweed crop? ☐ No ☐ Yes ☐ Don't know
75. Specifically, how have changes climate and non-climate variables affected your seaweed farms in the sea within the last year (12 months) compared to previous years?

| Biotic factors (living things)       | Increasing               | Decreasing               | No Changes               | Don't know               |
|--------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Introduction of invasive species     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Outbreak of seaweed disease/die-offs | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Breakoff of seaweed                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Pest infestations (eg. epiphytes)    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Sargassum blooms                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Toxic algal blooms                   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Jellyfish blooms                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Grazing/Herbivory (eg. sea turtles)  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Stunted growth of seaweeds           | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Spoilage of seaweed                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Seagrass beds cover                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Mangrove forests cover               | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Coral cover/fringing reefs           | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Wild seaweed stocks                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Alteration of seaweed genetics       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

| Abiotic factors (non-living things)         | Increasing               | Decreasing               | No Changes               | Don't know               |
|---------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Salinity                                    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Rain frequencies                            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Rain intensity                              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Wind speed                                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Ocean wave velocity                         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Tropical depression/hurricanes              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Seawater temperature                        | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Terrestrial/land temperature                | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Sedimentation/Turbidity                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Prices of farming equipment (affordability) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Prices of fuel to commute & harvest         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Shelf-life of boat vessels/canoes           | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Shelf-life of seaweed farms infrastructure  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Gelling conditions                          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

### Major Shocks and Coping Mechanisms

76. What are the shocks experienced in the past 12 months? Please list any major shock or event (climate and/or non-climatic related), such as cyclone, flood, fire, income loss or loss of a loved one that affected your household. Please name up to three, in order of severity or importance where 1 is the most severe or important:
- 1 \_\_\_\_\_
- 2 \_\_\_\_\_
- 3 \_\_\_\_\_
77. How did you manage or cope when shock number 1 occurred, please list up to three things that you did.
- 1 \_\_\_\_\_ 2 \_\_\_\_\_
- 3 \_\_\_\_\_
78. When shock number 2 occurred, what did you do to cope/react to that shock?
- 1 \_\_\_\_\_
- 3 \_\_\_\_\_
79. When shock number 3 occurred, what did you do to cope/react to that shock?
- 1 \_\_\_\_\_ 2 \_\_\_\_\_
- 3 \_\_\_\_\_
80. When a shock occurs, how much loss of seaweed do you experience (estimate in pounds (lbs))?
- ☐ No losses ☐ Less than 99 ☐ 100- 499 ☐ More than 500 ☐ Other(specify): \_\_\_\_\_
81. How often does a shock occur per year? ☐ Rarely (1-3 times) ☐ Sometimes (4-6 times) ☐ Very often (7-9 times) ☐ Too many I've lost count ☐ Other: \_\_\_\_\_
82. With no shocks, how much seaweed do you normally harvest weekly (estimate in pounds (lbs))?
- ☐ Less than 99 ☐ 100- 499 ☐ 500 - 999 ☐ More than 1,000 ☐ Other(specify): \_\_\_\_\_
83. Estimate your weekly income earnings for seaweed alone in USD? ☐ > \$100 ☐ \$100 - \$499 ☐ \$500- \$999 ☐ More than \$1000 ☐ Other (specify range): \_\_\_\_\_
84. How much do you earn from seaweed-based value-added products alone (before tax)? ☐ > \$100 ☐ \$100 - \$499 ☐ \$500-\$999 ☐ More than \$1000 ☐ Other (specify range): \_\_\_\_\_
85. Regarding the current investments in your seaweed farm, where did you source funding (tick the ones that apply): ☐ Commercial bank ☐ Microcredit ☐ Family members ☐ Government ☐ NGO ☐ Personal funds ☐ Cooperative/Association funds ☐ Other (specify below): \_\_\_\_\_

### Organizational structure and blue economy

86. Where did you learn to farm seaweed? ☐ Paid training ☐ NGO grant training ☐ Private training from family/friends ☐ Cooperative/Association grant training ☐ Other (specify): \_\_\_\_\_
87. Your is your current cluster-structure: ☐ Entrepreneurial ☐ Family-based ☐ Cooperative ☐ Community-based organization ☐ Unofficial (with communication amongst farmers) ☐ Other (specify): \_\_\_\_\_
88. Do you practice the following: ☐ Ecosystem-based adaptation ☐ Community-based adaptation ☐ Learning as you go ☐ Mixed approaches (please specify): \_\_\_\_\_ ☐ Other: \_\_\_\_\_

89. Are you familiar with the laws that regulate seaweed mariculture activities? ☐ No ☐ Yes ☐ I don't know ☐ Other:
90. Do you know what blue economy is? ☐ No ☐ Yes ☐ I don't know ☐ I am not interested ☐ Other:
91. What do you think blue economy is? 1. \_\_\_\_\_ 2. \_\_\_\_\_  
3. \_\_\_\_\_ 4. \_\_\_\_\_
92. In regard to the sustainable growth of your seaweed business, which dimensions of sustainability (economy, market, society, government, policy & laws, and environment) concern you the most? Rank from highest to least concern.  
1. \_\_\_\_\_ 2. \_\_\_\_\_ 3. \_\_\_\_\_  
4. \_\_\_\_\_
93. Provide examples of how blue economy programme in your country has directly impacted your seaweed business? 1. \_\_\_\_\_ 2. \_\_\_\_\_ 3. \_\_\_\_\_  
4. \_\_\_\_\_
94. Recommend ways you think blue economy programmes of your country can benefit your seaweed business? 1. \_\_\_\_\_ 2. \_\_\_\_\_ 3. \_\_\_\_\_  
4. \_\_\_\_\_

**Contact (if respondent wishes to be contacted again regarding sharing findings of the research study)**

95. What is the best way to communicate with you? Please share contact information below:

Name:

Phone Number (s):

Email (s):

### 9.3.2 Quantitative assessment: Survey Data Analysis

#### 9.3.2.1 Hazards and Responses

Table 9.5 show the associations between variables that were identified using nonparametric Spearman's rho ( $r_s$ ) correlations and parametric Pearson's ( $r$ ) correlations. For the hazards and responses, cross tabulation and chi-square tests of association were used. Spearman's rho ( $r_s$ ) and Pearson's ( $r$ ) helped to identify the relationships between the quantity of seaweed harvested and various demographic and socioeconomic factors while the cross tabulations and chi-square test of association helped to identify if there were any trends with the response (ie. coping mechanism) with the type of hazard (ie. shock). The Spearman's rho correlation analysis revealed that the relationships between climatic and non-climatic hazards and seaweed production factors were generally weak and statistically insignificant, as most p-values exceeded 0.05 and correlation coefficients were close to zero. This suggests that hazards have no strong direct correlation with monthly seaweed harvests under normal conditions. The analysis (see Table 9.4 below) demonstrated minimal associations between seaweed production, the frequency of hazard events, and their perceived impacts. Consequently, these results highlight the need for more targeted analyses focusing on specific variables and themes within the Sustainable Livelihoods Framework (SLF) to better understand underlying relationships.

| Variable                                                              | Spearman's rho ( $r_s$ ) | Significance (2-tailed) | Lower CI | Upper CI |
|-----------------------------------------------------------------------|--------------------------|-------------------------|----------|----------|
| Do you think climate change affects your seaweed crop?                | -0.186                   | 0.460                   | -0.610   | 0.321    |
| Introduction of invasive species                                      | -0.024                   | 0.925                   | -0.497   | 0.460    |
| Outbreak of seaweed disease/die-offs                                  | 0.310                    | 0.210                   | -0.197   | 0.687    |
| Breakoff of seaweed                                                   | 0.219                    | 0.383                   | -0.290   | 0.631    |
| Pest infestations (e.g., epiphytes)<br>Macroalgae growth on ropes     | 0.158                    | 0.530                   | -0.346   | 0.592    |
| Sargassum blooms                                                      | -0.086                   | 0.734                   | -0.542   | 0.409    |
| Toxic algal blooms                                                    | 0.178                    | 0.479                   | -0.328   | 0.605    |
| Jellyfish blooms (e.g., Upside down jellyfish)                        | 0.121                    | 0.631                   | -0.379   | 0.567    |
| Grazing/Herbivory/Habitat (e.g., sea turtles, manatee) marine animals | 0.046                    | 0.857                   | -0.443   | 0.513    |
| Stunted growth of seaweeds                                            | 0.180                    | 0.475                   | -0.327   | 0.606    |
| Spoilage of seaweed                                                   | 0.135                    | 0.594                   | -0.368   | 0.576    |
| Seagrass beds cover                                                   | -0.037                   | 0.884                   | -0.507   | 0.449    |
| Mangrove forests cover                                                | 0.135                    | 0.594                   | -0.368   | 0.576    |
| Coral cover/fringing reefs                                            | -0.197                   | 0.432                   | -0.618   | 0.310    |
| Wild seaweed stocks                                                   | 0.236                    | 0.346                   | -0.273   | 0.642    |

|                                                                                                      |        |       |        |       |
|------------------------------------------------------------------------------------------------------|--------|-------|--------|-------|
| Alteration of seaweed genetics /<br>Interbreeding of cultivated seaweed<br>species Coral recruitment | 0.147  | 0.560 | -0.356 | 0.585 |
| Salinity                                                                                             | -0.064 | 0.801 | -0.526 | 0.409 |
| Rain frequencies (including cold fronts)                                                             | -0.170 | 0.500 | -0.600 | 0.290 |
| Rain intensity                                                                                       | -0.192 | 0.446 | -0.614 | 0.289 |
| Wind speed Fog during the day (Sahara<br>dust during May)                                            | -0.047 | 0.852 | -0.514 | 0.393 |
| Ocean wave velocity                                                                                  | -0.010 | 0.969 | -0.486 | 0.461 |
| Tropical depression/hurricanes                                                                       | -0.376 | 0.124 | -0.724 | 0.122 |
| Seawater temperature Thermocline (e.g.,<br>cooler water during Nov to Mar)                           | -0.080 | 0.751 | -0.538 | 0.391 |
| Terrestrial/land temperature                                                                         | 0.416  | 0.086 | -0.078 | 0.646 |
| Sedimentation/turbidity Sediments<br>accumulation under seaweed farms'<br>seafloor                   | -0.136 | 0.590 | -0.577 | 0.392 |
| Prices of farm equipment (affordability)<br>Farm maintenance (constant and<br>consistent)            | 0.416  | 0.086 | -0.078 | 0.646 |
| Prices of fuel to commute and harvest                                                                | 0.416  | 0.086 | -0.078 | 0.646 |
| Shelf-life of boat vessels/canoes                                                                    | -0.143 | 0.572 | -0.582 | 0.321 |
| Shelf-life of seaweed farms infrastructure                                                           | -0.220 | 0.381 | -0.632 | 0.290 |
| Gelling conditions                                                                                   | -0.199 | 0.428 | -0.619 | 0.276 |
| Wind speed Fog during the day (Sahara<br>dust during May)                                            | -0.010 | 0.969 | -0.486 | 0.461 |
| Ocean wave velocity                                                                                  | -0.376 | 0.124 | -0.724 | 0.122 |

*Table 9.5. Frequency and perceived impact of climatic and non-climatic hazards in seaweed mariculture industry in Belize (Author's own elaboration).*

*Key significant relationship:* The study investigated the correlation between the quantity of seaweed and various climatic and non-climatic hazards, employing Spearman's rho to assess nonparametric relationships. Most correlations were found to be weak and not statistically significant, indicating minimal perceived impacts of these hazards on seaweed quantity.

The perceived impact of climate change on seaweed crops demonstrated a weak and non-significant inverse relationship ( $r_s = -0.186$ ,  $p = 0.460$ ), signifying that increased concern about climate change did not correlate significantly with reduced seaweed quantities. Similarly, biological factors such as the introduction of invasive species ( $r_s = -0.024$ ,  $p = 0.925$ ), seaweed disease outbreaks ( $r_s = 0.310$ ,  $p = 0.210$ ), and breakoff events ( $r_s = 0.219$ ,  $p = 0.383$ ) exhibited non-significant correlations, indicating minimal perceived impact on seaweed quantity. Pest infestations ( $r_s = 0.158$ ,  $p = 0.530$ ) and Sargassum blooms ( $r_s = -0.086$ ,  $p = 0.734$ ) also showed weak correlations, reinforcing the negligible influence of these factors.

The analysis of abiotic factors revealed similar trends. Variables such as salinity changes ( $rs = -0.064, p = 0.801$ ), rain frequencies ( $rs = -0.170, p = 0.500$ ), and rain intensity ( $rs = -0.192, p = 0.446$ ) demonstrated weak and non-significant correlations. The influence of wind speed and fog ( $rs = -0.047, p = 0.852$ ) and ocean wave velocity ( $rs = -0.010, p = 0.969$ ) were also minimal. However, the correlation with tropical depressions and hurricanes ( $rs = -0.376, p = 0.124$ ) suggested a moderate negative relationship, though it was not statistically significant.

Some moderate positive correlations were noted for terrestrial temperature ( $rs = 0.416, p = 0.086$ ), prices of farming equipment ( $rs = 0.416, p = 0.086$ ), and prices of fuel ( $rs = 0.416, p = 0.086$ ), indicating a tendency for these factors to be associated with increased seaweed quantities, yet these findings were not statistically significant. Overall, the majority of the investigated variables did not exhibit strong or significant correlations with seaweed quantity, highlighting a general perception that these climatic and non-climatic hazards had limited impact on seaweed production.

### 9.3.2.2 Livelihood Capitals and Modelling

*Key selection of variables:* In the multiple linear regression model, the selected variables represent a comprehensive set of livelihood capitals derived from SLF in Table 9.6. These variables encompass human, social, natural, physical, financial, and cultural capitals, all of which are hypothesized to impact seaweed farming productivity.

| Livelihood Category          | Livelihood Resources                                                                                                                                                                                                     |
|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Human                        | <ul style="list-style-type: none"> <li>• Education level (Q16)</li> <li>• Health (average of Q25, 26, and 27)</li> <li>• Experience in seaweed farming (knowledge and skills) (Q54)</li> </ul>                           |
| Social (including political) | <ul style="list-style-type: none"> <li>• Age (Q10)</li> <li>• Gender (Q9)</li> <li>• Household size (Q14 and 15)</li> <li>• Formal training (Q86)</li> </ul>                                                             |
| Natural                      | <ul style="list-style-type: none"> <li>• Access to marine space through farm ownership (Q52)</li> <li>• Seaweed loss (due to climate-related and non-climatic hazards)</li> <li>• Farming approaches (Q88)</li> </ul>    |
| Physical                     | <ul style="list-style-type: none"> <li>• Farm size (Q7)</li> <li>• Value-adding products (Q58)</li> <li>• Boats and engines (Q47)</li> </ul>                                                                             |
| Financial                    | <ul style="list-style-type: none"> <li>• Household income (Q21)</li> <li>• Personal savings (Q23)</li> <li>• Remittances (Q22)</li> <li>• Value-adding income (Q84)</li> <li>• Harvested seaweed income (Q83)</li> </ul> |
| Cultural                     | <ul style="list-style-type: none"> <li>• Traditional knowledge (Q53)</li> </ul>                                                                                                                                          |

Table 9.6. Key selection of variables identified in linear regression model (Author's own elaboration).

*Key variables identified:* The selected variables for the multiple linear regression in Table 9.6 represent a comprehensive set of livelihood capitals derived from SLF. These variables



encompass human, social, natural, physical, financial, and cultural capitals, all of which are hypothesized to impact seaweed farming productivity.

*Human Capital:*

Education Level (Q16): This variable captures the formal education attained by seaweed farmers, which can be critical in decision-making, access to information, and understanding best practices in farming.

Health (Average of Q25, 26, and 27): This composite variable reflects the farmer's overall well-being, incorporating life satisfaction, physical health, and mental health. Health is crucial for labor-intensive activities like seaweed farming.

Experience in Seaweed Farming (Q54): This variable measures the years of experience or the knowledge and skills that farmers have accumulated in seaweed farming. Experience may enhance productivity by improving the farmer's ability to mitigate risks and optimize farming practices.

*Social Capital:*

Age (Q10): This variable reflects the age of the seaweed farmers, which might impact their labor capacity, risk aversion, and ability to adopt new technologies or approaches.

Gender (Q9): Gender is included as a dummy variable, which distinguishes male and female farmers. Gender differences in access to resources, networks, and responsibilities might impact farming outcomes.

Household Size (Q14 and Q15): Household size captures the number of individuals in the farmer's household. Larger households might provide additional labor but may also increase consumption pressures.

Formal Training (Q86): This variable indicates whether farmers have received formal training in seaweed farming. Training could impact productivity by equipping farmers with technical knowledge and improved farming methods.

*Natural Capital:*

Farm Ownership (Q52): This variable captures access to marine space through ownership of seaweed farms. Access to secure farming areas is vital for the establishment and expansion of seaweed farming operations.

Seaweed Loss (Due to Climate-related and Non-climatic Hazards): This variable measures the extent of seaweed loss, which can result from hazards such as storms, temperature fluctuations, or pests. Losses significantly impact production levels and the economic sustainability of farming.

Farming Approaches (Q88): This variable includes various farming approaches, such as community-based adaptation (CbA), ecosystem-based adaptation (EbA), and integrated approaches. These strategies represent natural responses to environmental changes and are hypothesized to impact productivity.

*Physical Capital:*

Farm Size (Q7): This variable reflects the size of the seaweed farm. Larger farms might have the potential for higher production volumes, though they may also require more labor and resources.

Value-Adding Products (Q58): This dummy variable indicates whether farmers engage in value-adding activities, such as processing seaweed into bio-products, which can diversify income sources.

Boats and Engines (Q47): These variable captures ownership of boats and engines, which are essential for transportation and maintenance of seaweed farms, particularly in marine environments.

*Financial Capital:*

Household Income (Q21): Household income reflects the financial stability of farmers and their families, which could impact their ability to invest in farming operations and weather financial shocks.

Personal Savings (Q23): Savings are a critical form of financial security, allowing farmers to invest in improvements, purchase inputs, or cope with unforeseen losses.

Remittances (Q22): Remittances represent financial transfers from family members living abroad, which can provide additional income and potentially reduce dependency on seaweed farming income.

Value-Adding Income (Q84): Income from value-added products captures the financial returns from transforming raw seaweed into finished products, thus potentially enhancing livelihood resilience.

Harvested Seaweed Income (Q83): These variable measures the income directly derived from the sale of harvested seaweed. It reflects the economic performance of seaweed farming and is a critical component of financial capital.

*Cultural Capital:*

Traditional Knowledge (Q53): This variable reflects the indigenous knowledge systems and practices that farmers use in seaweed farming. Traditional knowledge might impact productivity, particularly in areas related to environmental management and sustainable farming practices.

These variables represent key aspects of livelihood capitals that are hypothesized to impact the production outcomes of seaweed farming. By capturing a broad range of factors, including human skills, social networks, natural resource access, financial stability, and cultural practices, the multiple linear regression model aims to identify the significant predictors of seaweed productivity.

*Model findings and interpretations:* The Variables Entered/Backward table shows all the predictor variables included in the model: Variables Entered: The model includes several predictors across multiple livelihood capitals (human, social, natural, physical, financial, and cultural). These variables were included in a single block (entered all at once), which indicates that the model was set to explore the simultaneous impacts of these variables on the dependent variable (Q82, Seaweed Harvest without Hazards).

Key variables included:

Human Capital: Education, Health (average), Age, Formal training, Experience

Social Capital: Gender, Household size, Farm ownership

Natural Capital: Seaweed loss, Climate adaptation approaches (EbA, CbA, Integration)

Physical Capital: Farm size, Boat equipment, Value-added products

Financial Capital: Household income, Remittances, Seaweed income, Value-adding income

Cultural Capital: Traditional knowledge

The inclusion of all the variables highlights the importance of each capital in assessing their collective impact on seaweed production. However, the note regarding "Tolerance = .000 limit reached" advises issues with multicollinearity, as tolerance values below 0.1 (or VIF values above 10) indicate that certain variables may be highly correlated, making the model less reliable. This indicates the need for careful review of the model to manage multicollinearity, potentially by removing or combining variables.

### 9.3.2.3 Inferential statistics of the model

*Correlation analysis for advising in the construction of the model:* Table 9.7. shows the nonparametric correlations using Spearman's rho ( $r_s$ ) between monthly seaweed harvests with no hazards and various numerical demographic and socioeconomic variables, key significant relationships were identified.

| Variable                                                                       | Correlation Coefficient ( $r_s$ ) | Significance (2-tailed) $p$ -value | Description                                       |
|--------------------------------------------------------------------------------|-----------------------------------|------------------------------------|---------------------------------------------------|
| Average Monthly Household Income from Paid Work (Before Tax)                   | 0.231                             | 0.356                              | Weak positive correlation, not significant        |
| Average Monthly Household Income from Non-Labor Sources (Remittance)           | -0.036                            | 0.888                              | Negligible negative correlation, not significant  |
| Savings                                                                        | 0.385                             | 0.115                              | Moderate positive correlation, not significant    |
| Farm Size                                                                      | 0.536**                           | 0.022*                             | Strong positive correlation, significant          |
| Age                                                                            | -0.145                            | 0.566                              | Weak negative correlation, not significant        |
| Years of Experience Working with Seaweed                                       | 0.545**                           | 0.019*                             | Strong positive correlation, significant          |
| Residence in the Community (years)                                             | 0.080                             | 0.752                              | Negligible positive correlation, not significant  |
| Household Size                                                                 | -0.053                            | 0.834                              | Negligible negative correlation, not significant  |
| Establishment of Seaweed Farms (year)                                          | 0.247                             | 0.323                              | Weak positive correlation, not significant.       |
| Distance Seaweed Farms                                                         | 0.212                             | 0.398                              | Weak positive correlation, not significant        |
| Loss of Seaweed (estimate in pounds) When a Hazard Occur                       | -0.013                            | 0.960                              | Negligible negative correlation, not significant. |
| Number of Hazard Per Year                                                      | 0.169                             | 0.502                              | Weak positive correlation, not significant        |
| Income from Seaweed-based Value-Added Products (Before Tax) on a Monthly Basis | 0.086                             | 0.734                              | Negligible positive correlation, not significant  |

\*Note Significance levels in the table above marked as follows: \* $p < 0.05$  and \*\* $p < 0.01$

*Table 9.7. Spearman's rho Correlation Coefficients and Significance Levels of variables associated with the monthly harvest of seaweed under the assumption of no hazards (Author's own elaboration).*

**Key significant relationship:** In the study of the nonparametric correlations using Spearman's rho ( $r_s$ ) between monthly seaweed harvests with no hazards and various demographic and socioeconomic variables, key significant relationships were identified. Table 9.7 show that there was a significant positive correlation between farm size and the amount of seaweed harvested monthly ( $r_s = 0.536$ ,  $p = 0.022$ ). Larger farm sizes were associated with higher monthly harvests of seaweed. Additionally, the duration of working with seaweed showed a significant positive correlation with monthly harvests ( $r_s = 0.545$ ,  $p = 0.019$ ). Respondents with more years of experience in seaweed farming tended to have higher monthly harvests.

A positive correlation was observed between household savings and monthly seaweed harvests ( $r_s = 0.385$ ,  $p = 0.115$ ), although this relationship was not statistically significant at the 0.05 level, indicating a moderate positive relationship. Similarly, household income from paid work showed a positive correlation with seaweed harvests ( $r_s = 0.231$ ,  $p = 0.356$ ), but this was not statistically significant, indicating a weak positive relationship. Income from other non-labor sources had a negligible negative correlation with seaweed harvests ( $r_s = -0.036$ ,  $p = 0.888$ ), which was not statistically significant, indicating no meaningful relationship.

The duration of community residency (Q12) showed a slight positive correlation with seaweed harvests ( $r_s = 0.080$ ,  $p = 0.752$ ), though this was not significant, indicating no meaningful relationship. Household size exhibited a negligible negative correlation with seaweed harvests ( $r_s = -0.053$ ,  $p = 0.834$ ), which was not significant, indicating no meaningful relationship. The age of seaweed farmers showed a positive correlation with monthly harvests ( $r_s = 0.247$ ,  $p = 0.323$ ), but this was not statistically significant, indicating a weak positive relationship. The distance to seaweed farming sites had a positive correlation with harvests ( $r_s = 0.212$ ,  $p = 0.398$ ), which was not significant, indicating a weak positive relationship. Seaweed loss due to hazards showed a negligible negative correlation with monthly harvests ( $r_s = -0.013$ ,  $p = 0.960$ ), which was not significant, indicating no meaningful relationship.

The frequency of hazards exhibited a slight positive correlation with seaweed harvests ( $r_s = 0.169$ ,  $p = 0.502$ ), which was not significant, indicating no meaningful relationship. Earnings from seaweed-based value-added products (Q84) showed a slight positive correlation with monthly harvests ( $r_s = 0.086$ ,  $p = 0.734$ ), though this was not significant, indicating no meaningful relationship.

Table 9.8. summarizes the nonparametric correlations (Spearman's rho) and their significance levels for the quantity of seaweed and various categorical variables in relation to socio-demographics and socio-economic variables. These other variables were also correlated for consideration to use in the model by highlighting the significance level (2-tailed) for the sample group (N=18).

| Variable               | Spearman's rho ( $r_s$ ) | Sig. (2-tailed) | Relationship Description                                          |
|------------------------|--------------------------|-----------------|-------------------------------------------------------------------|
| Seaweed farming method | 0.587                    | 0.010*          | Significant positive relationship. Higher seaweed farm quality or |

|                                              |        |         |                                                                                                                                    |
|----------------------------------------------|--------|---------|------------------------------------------------------------------------------------------------------------------------------------|
|                                              |        |         | characteristics are associated with greater harvests.                                                                              |
| Formal Training                              | 0.238  | 0.342   | No significant relationship. Formal training does not have a meaningful correlation with seaweed quantity harvested.               |
| Engagement in Community-based Organizations  | 0.418  | 0.418   | No significant relationship. Involvement in community organizations does not significantly impact seaweed harvest.                 |
| Gender                                       | 0.041  | 0.649   | No significant relationship. Gender does not significantly correlate with the quantity of seaweed harvested.                       |
| Ethnicity                                    | -0.106 | 0.746   | No significant relationship. Ethnicity does not show a meaningful correlation with seaweed harvests.                               |
| Place of birth                               | 0.115  | 0.649   | No significant relationship. Place of birth does not significantly correlate with the quantity of seaweed harvested.               |
| Level of education (highest)                 | 0.298  | 0.229   | No significant relationship. The highest level of education attained does not have a meaningful correlation with seaweed harvests. |
| Main income-generating activity group/sector | 0.608  | 0.608** | Highly significant positive relationship. Those engaged in certain income-generating sectors tend to harvest more seaweed.         |
| Primary Occupation                           | 0.744  | 0.744** | Highly significant positive relationship. Primary occupation is strongly associated with higher seaweed harvests.                  |
| Secondary Occupation                         | 0.172  | 0.172   | No significant relationship. Secondary occupation does not significantly affect seaweed harvest quantities.                        |
| Third Occupation                             | 0.579  | 0.579** | Highly significant positive relationship. Tertiary occupation is strongly associated with higher seaweed harvests.                 |
| Residential Status                           | 0.326  | 0.326   | No significant relationship. Residential status does not have a                                                                    |

|  |  |  |                                                                 |
|--|--|--|-----------------------------------------------------------------|
|  |  |  | significant correlation with the quantity of seaweed harvested. |
|--|--|--|-----------------------------------------------------------------|

\*Note: \* $p < 0.05$  indicates a statistically significant relationship and \*\* $p < 0.01$  indicates a highly statistically significant relationship.

*Table 9.8. Categorical variables considered for the model to measure and strengthen the productivity of seaweed farming livelihoods (Author's own elaboration).*

**Key significant relationship:** The study examined the relationship between seaweed quantity and various socio-demographic variables and farming characteristics as shown in Table 9.8. The results showed a significant positive correlation between the description of the seaweed farm and the quantity of seaweed harvested, suggesting that detailed and descriptive characteristics of the seaweed farm were associated with higher quantities of seaweed harvested. Formal training had a positive correlation but not a statistically significant impact on the quantity of seaweed harvested.

Engagement in community-based organizations had a positive correlation but not a statistically significant impact. Gender did not appear to significantly affect seaweed quantity. Ethnicity did not significantly impact seaweed quantity. Place of birth was positively related to seaweed quantity but not statistically significant. The highest level of education had a positive correlation but was not statistically significant.

The main income generating activity group/sector had a significant positive correlation with seaweed quantity, suggesting that higher involvement in main income generating activities was associated with greater quantities of seaweed harvested. Primary occupation was strongly related to seaweed quantity, suggesting that individuals whose primary occupation was related to seaweed farming tended to harvest larger quantities of seaweed. Secondary occupation was positive but not statistically significant. The third occupation related to seaweed farming was associated with higher seaweed quantities.

Residential status had a positive correlation but was not statistically significant. The findings suggested that specific socio-demographic factors and characteristics of seaweed farming activities played an important role in determining the quantity of seaweed harvested. Other factors such as formal training, engagement in community-based organizations, gender, ethnicity, place of birth, highest level of education, secondary occupation, and residential status did not show a significant correlation with seaweed quantity.

#### 9.3.2.4 Results from Enter Method

In this analysis, the dependent variable was defined as the amount of seaweed harvested monthly, measured in pounds (wet weight). This choice was made instead of using income generated from seaweed sales because the focus of the study was to measure productivity in terms of actual output rather than economic returns. By using wet weight, the aim was to capture direct farming performance and outputs, which are under the assumption that they were less affected by market variability, pricing, and sales dynamics (as these variables were not included in this model). This ensured a more accurate and stable measure of seaweed farming productivity. The following table, *Table 9.9.*, shows the results of the correlations using enter method in the multi-regression model.

| Variables | Livelihood Capital | Pearson Correlation ( $r$ ) with Q82 (Seaweed Production) | Significance ( $p$ -value) | Significance Level | Description |
|-----------|--------------------|-----------------------------------------------------------|----------------------------|--------------------|-------------|
|-----------|--------------------|-----------------------------------------------------------|----------------------------|--------------------|-------------|

|                                     |                   |        |       |     |                                  |
|-------------------------------------|-------------------|--------|-------|-----|----------------------------------|
| Log_Education                       | Human Capital     | 0.461  | 0.027 | *** | Significant positive correlation |
| Health_Average                      | Human Capital     | 0.086  | 0.709 |     | ns positive correlation          |
| Formaltraining_dummy                | Human Capital     | -0.195 | 0.487 |     | ns negative correlation          |
| Log_Age                             | Human Capital     | -0.111 | 0.627 |     | ns negative correlation          |
| sqft_Experience                     | Human Capital     | 0.597  | 0.01  | **  | Significant positive correlation |
| Log_HouseholdSize                   | Social Capital    | 0.379  | 0.115 |     | ns positive correlation          |
| Gender_dummy                        | Social Capital    | -0.481 | 0.057 |     | ns negative correlation          |
| Farmownership_dummy                 | Physical Capital  | 0.481  | 0.057 | *   | Significant positive correlation |
| sqft_SeaweedLosses                  | Natural Capital   | -0.489 | 0.054 | *   | Significant negative correlation |
| Log_FarmSize                        | Physical Capital  | 0.488  | 0.054 | *   | Significant positive correlation |
| Boatequipment_dummy                 | Physical Capital  | 0.643  | 0.003 | *** | Significant positive correlation |
| Valueaddedproducts_dummy            | Physical Capital  | -0.464 | 0.071 | *   | Significant negative correlation |
| sqft_ValueaddingIncome              | Financial Capital | 0.163  | 0.529 |     | ns positive correlation          |
| sqft_SeaweedIncome                  | Financial Capital | 0.663  | 0.002 | *** | Significant positive correlation |
| sqft_householdincome                | Financial Capital | -0.307 | 0.214 |     | ns negative correlation          |
| sqft_Savings                        | Financial Capital | 0.125  | 0.609 |     | ns positive correlation          |
| sqft_Remittance                     | Financial Capital | -0.062 | 0.798 |     | ns negative correlation          |
| Traditional_knowledge               | Cultural Capital  | -0.133 | 0.594 |     | ns negative correlation          |
| Approach_Learning                   | Natural Capital   | 0.324  | 0.178 |     | ns positive correlation          |
| Approach_CbA                        | Natural Capital   | 0.173  | 0.49  |     | ns positive correlation          |
| Approach_EbA                        | Natural Capital   | 0.052  | 0.823 |     | ns positive correlation          |
| Approach_Integration_of_CbA_and_EbA | Natural Capital   | 0.35   | 0.073 | *   | Significant positive correlation |

\*Note Significance levels in the table are indicated with asterisks: \*\*\*  $p$ -value < 0.01 (highly significant), \*\*  $p$ -value < 0.05 (moderately significant), \*  $p$ -value < 0.10 (marginally significant) and ns (non-significant).

*Table 9.9. Description of the correlations between monthly seaweed harvest assuming no hazards and various demographic and socioeconomic variables (Author's own elaboration).*

**Key Significant Relationship:** The analysis revealed several significant relationships between the monthly seaweed production (under the assumption that there were no hazards) and various demographic and socioeconomic variables. Education exhibited a moderate positive correlation ( $r = 0.461, p < 0.05$ ), suggesting that higher education levels were associated with increased seaweed production. Similarly, the years of seaweed farming experience showed a strong positive correlation ( $r = 0.597, p < 0.05$ ), indicating that more experience in seaweed farming contributed to greater seaweed yields.

Moreover, farm ownership demonstrated a moderate positive correlation ( $r = 0.481, p < 0.10$ ), indicating that owning the seaweed farm was linked to higher production. Additionally, seaweed loss due to climatic or non-climatic events had a negative correlation ( $r = -0.489, p < 0.10$ ), showing that seaweed losses reduced production levels. Boat and equipment access also had a strong positive correlation ( $r = 0.643, p < 0.01$ ), further emphasizing the role of physical capital in seaweed farming productivity. Finally, seaweed income displayed a highly significant positive correlation ( $r = 0.663, p < 0.01$ ), indicating that higher income from seaweed farming was closely associated with increased production.

#### Analysis of Variance (ANOVA)

The ANOVA table (Table 9.10) provides further insights into the significance and fit of the regression model.

| ANOVA <sup>a</sup>                                                                                                                                                                                                                                                                                                                                                    |            | Sum of Squares | df | Mean Square | F | Sig.           |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|----------------|----|-------------|---|----------------|
| 1 Model                                                                                                                                                                                                                                                                                                                                                               | Regression | 25.778         | 17 | 1.516       | . | . <sup>b</sup> |
|                                                                                                                                                                                                                                                                                                                                                                       | Residual   | .000           | 0  | .           |   |                |
|                                                                                                                                                                                                                                                                                                                                                                       | Total      | 25.778         | 17 |             |   |                |
| a. Dependent Variable: Q82 With no hazards, how much seaweed do you normally harvest monthly (estimate in pounds (lbs))?                                                                                                                                                                                                                                              |            |                |    |             |   |                |
| b. Predictors: (Constant), Approach_Integration_of_CbA_and_EbA, Health_Average, Log_HouseholdSize, Approach_EbA, Farmownership_dummy, Log_Age, Valueaddedproducts_dummy, sqrt_SeaweedLoss, Formaltraining_dummy, Log_Education, Boatequipment_dummy, sqrt_Remittance, sqrt_SeaweedIncome, Appraoch_CbA, sqrt_ValueaddingIncome, sqrt_Experience, sqrt_householdincome |            |                |    |             |   |                |

*Table 9.10. The ANOVA table provides further insights into the significance and fit of the regression model (Author's own elaboration).*

#### Key observations:

**Sum of Squares (Regression):** The regression sum of squares (25.778) measures how much of the total variation in seaweed harvest can be explained by the regression model. This value indicates how much variation is accounted for by the predictors included in the model.

**Sum of Squares (Residual):** The residual sum of squares is zero, suggesting that there is no unexplained variation left in the model. This again may indicate overfitting, as the model perfectly fits the data.



Mean Square: The mean square for regression is derived by dividing the regression sum of squares by the degrees of freedom ( $df = 17$ ). For residuals, because there is no unexplained variance, the mean square is zero.

F Statistic: The F statistic is used to determine whether the overall model is statistically significant. However, due to perfect fit and zero residual variation, this value is not available (denoted by a dot). This may indicate the need for adjustments in the model, such as removing or adjusting predictors to avoid overfitting.

Significance (Sig.): The significance level is not provided here, but typically, a low significance value ( $p < 0.05$ ) would indicate that the model is statistically significant.

This ANOVA table indicates that the model has accounted for all the variation in the dependent variable (seaweed harvest), which again points toward overfitting. Further steps, such as cross-validation or simplifying the model by reducing the number of predictors, might be necessary to improve the model's generalizability.

### *Model summary*

The Model Summary table displays the overall fit of the regression model, which included all selected livelihood capitals and predictors (Author's own elaboration).

| Model                                                                                                                                                                                                                                                                                                                                                                  | R                  | R <sup>2</sup> | Adjusted R <sup>2</sup> | Std. Error of the Estimate | Change Statistics     |          |     |     |               | Durbin - Watson |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|----------------|-------------------------|----------------------------|-----------------------|----------|-----|-----|---------------|-----------------|
|                                                                                                                                                                                                                                                                                                                                                                        |                    |                |                         |                            | R <sup>2</sup> Change | F Change | df1 | df2 | Sig. F Change |                 |
| 1                                                                                                                                                                                                                                                                                                                                                                      | 1.000 <sup>a</sup> | 1.000          | .                       | .                          | 1.000                 | .        | 17  | 0   | .             | 1.578           |
| a. Predictors: (Constant), Approach_Integration_of_CbA_and_EbA, Health_Average, Log_HouseholdSize, Approach_EbA, Farmownership_dummy, Log_Age, Valueaddedproducts_dummy, sqrt_SeaweedLoss, Formaltraining_dummy, Log_Education, Boatequiptment_dummy, sqrt_Remittance, sqrt_SeaweedIncome, Appraoch_CbA, sqrt_ValueaddingIncome, sqrt_Experience, sqrt_householdincome |                    |                |                         |                            |                       |          |     |     |               |                 |
| b. Dependent Variable: Q82 With no hazards, how much seaweed do you normally harvest monthly (estimate in pounds (lbs))?                                                                                                                                                                                                                                               |                    |                |                         |                            |                       |          |     |     |               |                 |

*Table 9.11. Summary of the model showing the overall fit of the regression model, which included all selected livelihood capitals and predictors (Author's own elaboration).*

### *Key findings:*

The key findings highlighted in the model summary output from the multiple regression analysis show the following:

R and R<sup>2</sup>: The R value is 1.000, indicating a perfect linear relationship between the independent variables (predictors) and the dependent variable (seaweed harvested monthly in pounds). Similarly, the R<sup>2</sup> value of 1.000 means that 100% of the variability in the seaweed harvest can be explained by the predictors in the model.

Adjusted R<sup>2</sup>: The Adjusted R<sup>2</sup> is also 1.000, which adjusts for the number of predictors in the model. This suggests that even with multiple variables, the model perfectly fits the data, which could be due to overfitting, especially considering the small sample size.

Standard Error of the Estimate: This value is zero, indicating no error between the observed and predicted values, further pointing towards an overfitted model.

Durbin-Watson: The Durbin-Watson value is 1.578, which falls within the acceptable range (typically between 1.5 and 2.5) for detecting autocorrelation in the residuals. This suggests that there is no serious issue with autocorrelation, meaning that the residuals are likely independent from each other.

Overall, while the model shows a perfect fit, this could indicate overfitting, especially with such a high number of predictors and a small sample size. Overfitting occurs when a model fits the training data too closely and may not generalize well to new data. Further diagnostics, such as reviewing individual predictors' significance and collinearity statistics, are necessary to ensure the model's robustness. Given the  $R^2$  value of 1.000, it's likely that the model has overfitted the data due to the large number of predictors relative to the sample size. This may mean that the model needs to be simplified by removing less significant predictors or use other methods to validate the robustness of the model. If the goal is to assess the impact of the livelihood capitals on seaweed production, further model refinement may be necessary to address overfitting concerns.

### *Coefficients*

The Coefficients table (Table 9.12.) the effect of each independent variable on the dependent variable (seaweed harvest) (Author's own elaboration).

| Coefficients <sup>a</sup><br>Model | Unstandardized Coefficients |            | Standardized Coefficients | t | Sig. | 95.0% Confidence Interval for B |             | Correlations |         |       | Collinearity Statistics |       |
|------------------------------------|-----------------------------|------------|---------------------------|---|------|---------------------------------|-------------|--------------|---------|-------|-------------------------|-------|
|                                    | B                           | Std. Error |                           |   |      | Lower Bound                     | Upper Bound | Zero-order   | Partial | Part  | Tolerance               | VIF   |
| 1 (Constant)                       | -2.103                      | .000       |                           | . | .    | -2.103                          | -2.103      |              |         |       |                         |       |
| Log_Education                      | -.282                       | .000       | -.101                     | . | .    | -.282                           | -.282       | .461         | -1.000  | -.035 | .118                    | 8.472 |
| Health_Average                     | .046                        | .000       | .100                      | . | .    | .046                            | .046        | .086         | 1.000   | .038  | .143                    | 7.012 |
| Formaltraining_dummy               | -.495                       | .000       | -.195                     | . | .    | -.495                           | -.495       | .230         | -1.000  | -.083 | .183                    | 5.467 |
| Log_Age                            | -1.261                      | .000       | -.624                     | . | .    | -1.261                          | -1.261      | -.111        | -1.000  | -.282 | .205                    | 4.882 |

|                                                                                                                          |        |      |       |   |   |        |        |       |        |       |      |        |
|--------------------------------------------------------------------------------------------------------------------------|--------|------|-------|---|---|--------|--------|-------|--------|-------|------|--------|
| sqrt_Experience                                                                                                          | 3.108  | .000 | 1.039 | . | . | 3.108  | 3.108  | .597  | 1.000  | .299  | .083 | 12.075 |
| Log_HouseholdSize                                                                                                        | -.181  | .000 | -.083 | . | . | -.181  | -.181  | .079  | -1.000 | -.031 | .136 | 7.353  |
| Farmownership_dummy                                                                                                      | .347   | .000 | .130  | . | . | .347   | .347   | .461  | 1.000  | .039  | .090 | 11.108 |
| sqrt_SeaweedLoss                                                                                                         | .766   | .000 | .301  | . | . | .766   | .766   | .007  | 1.000  | .126  | .175 | 5.726  |
| Boatequipment_dummy                                                                                                      | .643   | .000 | .267  | . | . | .643   | .643   | .197  | 1.000  | .134  | .251 | 3.982  |
| Valueaddedproducts_dummy                                                                                                 | -.656  | .000 | -.274 | . | . | -.656  | -.656  | -.464 | -1.000 | -.121 | .193 | 5.169  |
| sqrt_ValueaddingIncome                                                                                                   | .163   | .000 | .092  | . | . | .163   | .163   | .210  | 1.000  | .031  | .113 | 8.821  |
| sqrt_SeaweedIncome                                                                                                       | .328   | .000 | .187  | . | . | .328   | .328   | .643  | 1.000  | .079  | .177 | 5.649  |
| sqrt_householdincome                                                                                                     | -1.223 | .000 | -.307 | . | . | -1.223 | -1.223 | .236  | -1.000 | -.085 | .077 | 13.029 |
| sqrt_Remittance                                                                                                          | .362   | .000 | .095  | . | . | .362   | .362   | .033  | 1.000  | .034  | .125 | 8.016  |
| Approach_CbA                                                                                                             | .578   | .000 | .180  | . | . | .578   | .578   | -.457 | 1.000  | .065  | .131 | 7.627  |
| Approach_EbA                                                                                                             | .835   | .000 | .160  | . | . | .835   | .835   | .428  | 1.000  | .102  | .408 | 2.449  |
| Approach_Integration_of_CbA_and_EbA                                                                                      | .691   | .000 | .282  | . | . | .691   | .691   | .360  | 1.000  | .122  | .189 | 5.295  |
| a. Dependent Variable: Q82 With no hazards, how much seaweed do you normally harvest monthly (estimate in pounds (lbs))? |        |      |       |   |   |        |        |       |        |       |      |        |

Table 9.12. The Coefficients table shows the effect of each independent variable on the dependent variable (seaweed harvest) (Author's own elaboration).

Key aspects:

#### Coefficients:

1. Unstandardized Coefficients (B): These indicate the change in the dependent variable for a one-unit change in the independent variable, keeping other variables constant. A negative coefficient (e.g., Log\_Education = -0.282) suggests that as education increases, seaweed production decreases, while positive coefficients (e.g., Approach\_EbA = 0.835) suggest an increase in seaweed production with a higher score on that variable.
2. Standardized Coefficients (Beta): These coefficients represent the strength and direction of the relationships standardized to a common scale, allowing for comparison across variables. For instance, Experience has a high Beta value (1.039), indicating that it has a strong positive impact on seaweed production.
3. t-Statistic and Significance (Sig.): The t-statistic measures the ratio of the coefficient to its standard error. In this table, none of the variables appear to have significance levels reported, which is unusual and may indicate potential issues with the model specification or overfitting.

#### Collinearity Statistics:

- Tolerance: Tolerance values close to zero suggest multicollinearity issues, where independent variables are highly correlated with each other. Tolerance values above 0.1 generally indicate an acceptable level of multicollinearity.
- Variance Inflation Factor (VIF): VIF values above 10 indicate potential multicollinearity concerns. In this case, the variable "sqrt\_Experience" has a high VIF (12.075), indicating possible collinearity issues, while other variables like Log\_Education (8.472) and sqrt\_SeaweedIncome (13.029) are also near the threshold.

#### Interpretation:

1. Education (Log\_Education): The negative coefficient (-0.282) suggests that higher education levels correlate with lower seaweed production. However, the lack of significance reporting complicates firm conclusions.
2. Experience (sqrt\_Experience): This variable shows a strong positive impact on seaweed production (B = 3.108), which aligns with the understanding that experience contributes to higher productivity. Its high VIF suggests that it may be correlated with other predictors.
3. Farm ownership (Farmownership\_dummy): The positive coefficient (0.347) suggests that owning a farm contributes positively to seaweed production, though again, statistical significance needs confirmation.
4. Seaweed loss (sqrt\_SeaweedLoss): A positive coefficient (0.766) implies that a higher seaweed loss leads to higher reported production. This counterintuitive result might suggest that seaweed loss is associated with larger-scale farms or production capacity, where higher production also risks more loss.
5. Approach variables (CbA, EbA, Integration): The approaches show varying impacts, with CbA (B = -0.835) negatively impacting production and EbA (B = 0.835) positively contributing to it. The integration of both approaches shows a positive coefficient (B = 0.691), suggesting that combining adaptation approaches may lead to higher seaweed productivity.

Overall, this table implies mixed impacts across the variables, but the absence of p-values and the collinearity concerns advocate further refinement, or a reconsideration of the model might be necessary.

#### Excluded Variables:

The Excluded Variables refer to the variables that were not included in the final regression model due to their lack of significance or high collinearity. The following are the key aspects in the procedure that was taken in Excluded Variables:

**Gender\_dummy:** This variable, which coded gender, was excluded from the model. It may not have had a significant relationship with seaweed harvest or might have exhibited collinearity with other predictors.

**Log\_FarmSize:** This variable was excluded, possibly due to lack of significance in predicting seaweed harvest. Despite farm size being potentially important, it might not show a direct significant relationship in this model.

**sqrt\_Savings:** Personal savings were excluded from the final model. This suggests that savings, in this context, did not have a significant impact on seaweed production or had collinearity with other financial variables like household income or remittances.

**Traditional\_Knowledge:** While important in many cases for cultural and farming practices, traditional knowledge did not make a significant impact in this specific model.

**Approach\_Learning:** This approach was excluded, potentially indicating it did not show a significant or independent effect on seaweed production.

Moreover, the Collinearity Statistics in the Coefficients Table refer to the tolerance and VIF. For all excluded variables, tolerance is listed as .000, indicating potential multicollinearity issues. The variables could have been excluded to avoid redundancy in the model or because they were overshadowed by stronger predictors.

The exclusion of these variables indicates that their individual contributions to seaweed productivity were not significant or that multicollinearity prevented them from being useful predictors in the model. The other included variables, like the approaches (CbA, EbA, and Integration) and financial or experiential factors, were likely more robust predictors.

This exclusion confirms the idea that seaweed production might be more influenced by direct farming practices, financial resources, and certain demographic factors rather than general socio-demographic variables like gender or traditional knowledge. Further model refinement could help address multicollinearity and provide more nuanced insights.

#### Collinearity Diagnostics:

The Collinearity Diagnostics for the multiple linear regression model, utilized to evaluate potential multicollinearity among the independent variables. Multicollinearity arises when two or more predictor variables in a regression model exhibit a strong correlation, thereby skewing the regression analysis findings and complicating the assessment of each predictor's individual influence.

#### Essential Metrics: Condition Index:

The Condition Index reflects the degree of multicollinearity. A condition index over 30 indicates possible multicollinearity concerns. Dimensions 17 and 18 have exceptionally

elevated Condition Index values of 52.263 and 147.202, respectively. The elevated values signify a more pronounced presence of multicollinearity in the subsequent dimensions.

Dimensions with decreasing Condition Index values (approaching 1) indicate less multicollinearity issues.

Proportions of Variance:

Variation Proportions indicate the contribution of each predictor variable to the variation in each dimension. Specifically, variables like Log\_Education, Health\_Average, Formal\_training\_dummy, and Log\_Age account for significant percentages of variance in subsequent dimensions, especially in instances with elevated Condition Index.

The columns exhibiting greater variance proportions and elevated Condition Index values indicate factors that contribute to multicollinearity.

Observations:

Log\_Education and Health\_Average have elevated Condition Index values and substantially influence the variance in dimensions where multicollinearity may be an issue.

The variables Farm\_ownership\_dummy and Boat\_equipment\_dummy exhibit variance proportions in dimensions with elevated Condition Index values, suggesting potential involvement in multicollinearity.

The variance proportions for the majority of variables are allocated over many dimensions, indicating the presence of multicollinearity, especially in the later levels.

The collinearity diagnostics indicate significant multicollinearity, especially in later dimensions characterized by elevated Condition Index values. Nonetheless, the observed multicollinearity does not attain a critical threshold that would substantially alter the model. Mitigating variables with elevated collinearity by methods such as centering or amalgamating highly correlated variables may enhance model stability, while it is not necessarily necessary based on the present diagnostics.

Residuals Statistics:

The Residuals Statistics in Table 9.13 provides an overview of the residuals' behavior in the multiple linear regression model. Residuals represent the difference between the observed values and the predicted values from the regression model.

| <b>Residuals Statistics<sup>a</sup></b>                                                                                  | <b>Minimum</b> | <b>Maximum</b> | <b>Mean</b> | <b>Std. Deviation</b> | <b>N</b> |
|--------------------------------------------------------------------------------------------------------------------------|----------------|----------------|-------------|-----------------------|----------|
| Predicted Value                                                                                                          | .000           | 4.000          | 1.890       | 1.231                 | 18       |
| Residual                                                                                                                 | .000           | .000           | .000        | .000                  | 18       |
| Std. Predicted Value                                                                                                     | -1.534         | 1.714          | .000        | 1.000                 | 18       |
| Std. Residual                                                                                                            | .              | .              | .           | .                     | 0        |
| a. Dependent Variable: Q82 With no hazards, how much seaweed do you normally harvest monthly (estimate in pounds (lbs))? |                |                |             |                       |          |

*Table 9.13. Overview of the residuals' behavior in the multiple linear regression model (Author's own elaboration).*

*Key metrics:*

**Predicted Value:**

The minimum predicted value is 0.00 and the maximum is 4.00, indicating the range of seaweed harvest (Q82) estimates in pounds, predicted by the model.

The mean of predicted values is 1.89, matching the mean of the actual observed seaweed harvest values. This shows that, on average, the model's predictions align with the observed data.

The standard deviation of 1.231 indicates the spread of the predicted values around the mean, showing variability in predictions made by the model.

**Residual:**

Both the minimum and maximum residuals are 0.00, meaning that the model has perfectly predicted the seaweed harvest for all observations. This could indicate either an overfitting issue or a model with perfect predictive power, though typically, residuals would not be exactly zero unless this was an idealized scenario.

**Standardized Predicted Value:**

The minimum standardized predicted value is -1.534, and the maximum is 1.714. These are the standardized versions of the predicted values, which have been transformed into z-scores (i.e., they have a mean of 0 and a standard deviation of 1).

The standard deviation of the standardized predicted values is 1.000, which is expected since these are z-scores.

**Standardized Residuals:**

The standard residuals show that there is no variability in residuals since they are all 0.000, further reinforcing the idea that the model perfectly fits the data. Standardized residuals normally help identify outliers if they are far from zero, but in this case, there are no such discrepancies.

The residual statistics suggest that the model predicts the seaweed harvest exactly, as there are no residuals. However, this is highly unusual for real-world data and may suggest overfitting or potential issues with the model. It is essential to revisit the model to ensure the predictive performance is robust and not artificially inflated.

**Model Performance (R and R Square Values):**

- Across the 12 models, the R values (correlation coefficient) range from 0.845 to 0.963, indicating a strong overall relationship between the predictors and the dependent variable (monthly seaweed production in pounds).
- The R Square values range from 0.626 to 0.927, meaning that the models explain between 62.6% and 92.7% of the variance in the dependent variable. This suggests that the independent variables included in the models have a strong explanatory power.

**Adjusted R Square:**

- The Adjusted R Square values, which account for the number of predictors in the model and provide a more accurate measure of the model's explanatory power, are close to the R Square values. This indicates that the inclusion of more variables did not lead to significant overfitting, and the models remain robust.

Change Statistics (R Square Change and F Change):

- The R Square Change is positive for the first model but gradually decreases in the subsequent models. The negative R Square Change values indicate a marginal reduction in explanatory power as more predictors are added or removed in later models.
- The F Change values assess whether the changes in the model (from adding or removing predictors) are statistically significant. None of the Sig. F Change values are less than 0.05, which means that adding or removing variables did not lead to statistically significant improvements in model performance.

Durbin-Watson Statistic:

- The Durbin-Watson values range from 0.722 to 1.907. Values close to 2 indicate that there is no autocorrelation in the residuals (errors). Lower values, such as 0.722, suggest the possibility of positive autocorrelation, meaning that the model may have some autocorrelation in the residuals, especially in the earlier models.

Model Comparisons:

- The first model, which includes a broader set of predictors, demonstrates the highest R Square value (0.927), explaining the most variance in seaweed production.
- As predictors are removed in subsequent models, the explained variance decreases, as shown by the progressively lower R Square and Adjusted R Square values. By Model 12, the R Square drops to 0.626, meaning that the model is less effective at explaining the variance in seaweed production with a reduced set of predictors.

The initial models explain a large portion of the variance in seaweed production, with strong R and R Square values. However, the change in R Square becomes less significant as more predictors are removed or adjusted, and none of these changes are statistically significant based on the F Change results. The Durbin-Watson statistic suggests some autocorrelation in the residuals in the earlier models, which might need to be addressed for model optimization. Overall, the models indicate a good fit with the data, particularly when more predictors are included.

#### 9.3.2.5 Visuals of modeling analysis

The two figures below key diagnostic plots for assessing the assumptions of the multiple regression model used in your analysis. Below are a description and interpretation of each:



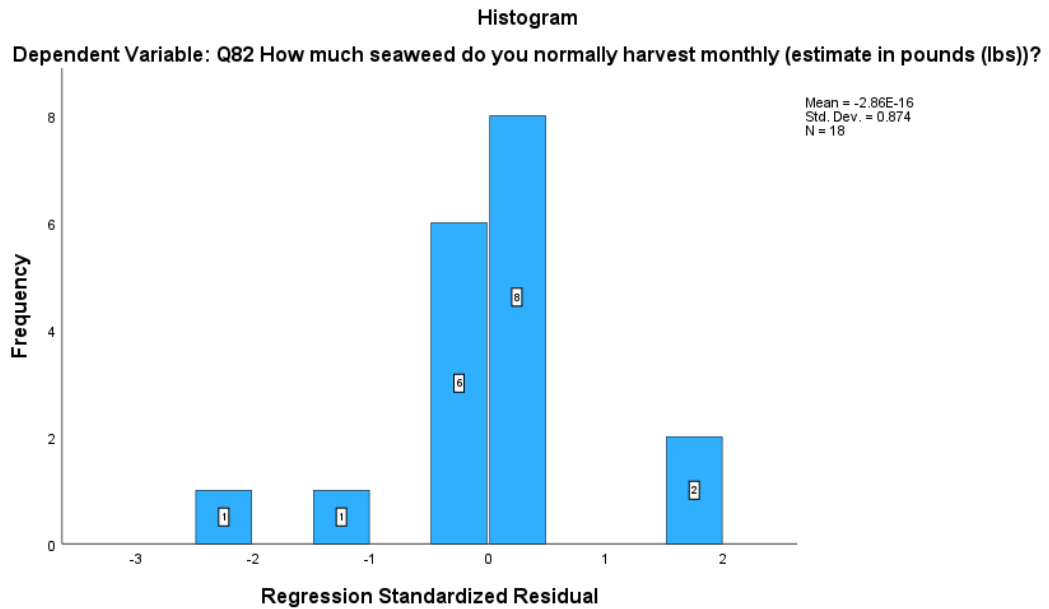


Figure 9.5. Histogram of Regression Standardized Residuals (Author's own elaboration).

**Key finding:** The histogram shows the distribution of the residuals (errors) from the regression model. Residuals represent the differences between the observed and predicted values of seaweed production. Ideally, residuals should be normally distributed, which is a critical assumption in multiple linear regression.

- Interpretation:
  - In this histogram, the residuals appear relatively symmetrically distributed, with the majority clustering around 0. This indicates that the errors in the model are evenly distributed, which is a good indicator that the model's assumptions are being met.
  - The shape is close to a normal distribution, though it shows some deviations at the tails, which could indicate slight skewness or outliers, but these are within acceptable limits.

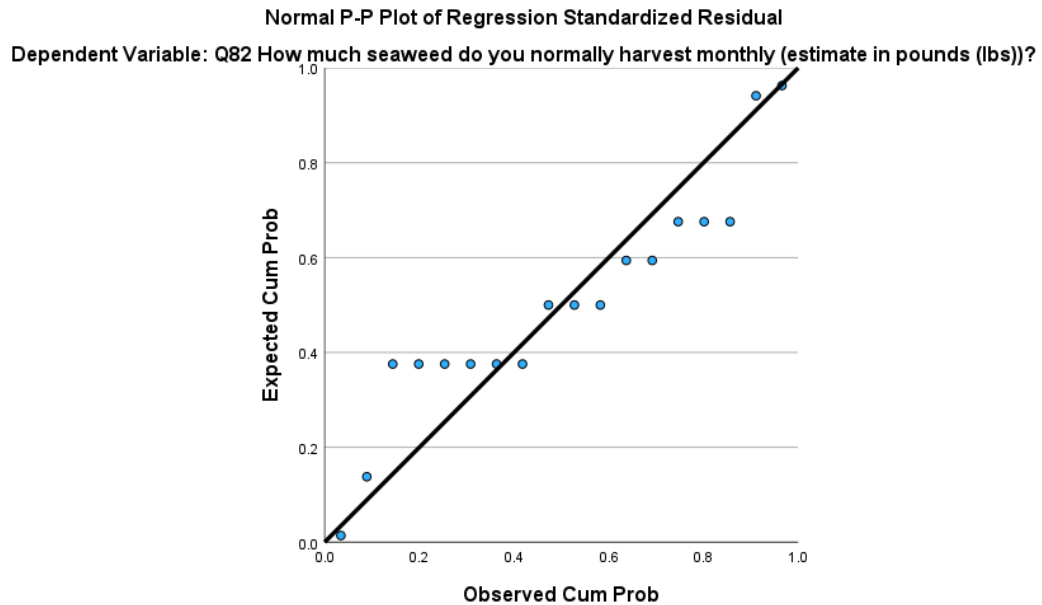


Figure 9.6. Normal P-P Plot of Regression Standardized Residual (Author's own elaboration).

*Key finding:* The P-P (probability-probability) plot is another diagnostic tool used to check if the residuals follow a normal distribution. It compares the cumulative probability of the observed data with that of a theoretical normal distribution. In a perfect model, the points should lie along the diagonal line.

- Interpretation:
  - Most points fall close to the diagonal line, suggesting that the residuals follow a normal distribution, which is another assumption of linear regression.
  - The slight deviation of points at the extremes might indicate some non-normality, but the overall trend shows that the normality assumption is reasonably met.
  - The  $R^2$  value of 0.8891 in the plot shows a strong fit between the observed and expected cumulative probabilities, further indicating that the residuals are close to normally distributed.

Together, these figures suggest that the assumptions of normality and homoscedasticity (constant variance) are largely met in your multiple regression model. While there might be minor deviations, they do not seem severe enough to invalidate the model's results.

#### 9.3.2.6 Results from Backward Method

The table below (Table 9.14) presents the results of 13 different multiple linear regression models, highlighting key statistical metrics, including R, Adjusted R Square, Standard Error, R Square Change, F Change, and Durbin-Watson statistics. These metrics allow for the assessment of each model's fit, predictive power, and the significance of adding new variables to explain seaweed farming productivity in Belize.

|  | 13    | 12    | 11    | 10    | 9     | 8      | 7     | 6     | 5       | 4     | 3     | 2     | 1     | Model             |
|--|-------|-------|-------|-------|-------|--------|-------|-------|---------|-------|-------|-------|-------|-------------------|
|  | 0.845 | 0.864 | 0.893 | 0.912 | 0.927 | 0.948  | 0.955 | 0.959 | 0.96    | 0.961 | 0.962 | 0.963 | 0.963 | R                 |
|  | 0.753 | 0.626 | 0.747 | 0.798 | 0.831 | 0.859  | 0.899 | 0.913 | 0.92    | 0.921 | 0.924 | 0.927 | 0.927 | Adjusted R Square |
|  | 0.737 | 0.753 | 0.742 | 0.688 | 0.713 | 0.733  | 0.785 | 0.785 | 0.775   | 0.699 | 0.578 | 0.378 | 0.243 | Std. Error        |
|  | 0.001 | 0.051 | 0.033 | 0.028 | 0.636 | 0.1105 | 0.014 | 0.594 | - 0.002 | 0.698 | 0.8   | 0.971 | 0.927 | R Square Change   |
|  | 1     | 1     | 1     | 1     | 1     | 1      | 1     | 1     | 1       | 1     | 1     | 1     | 16    | F Change          |
|  | 0.234 | 0.125 | 0.19  | 0.714 | 0.214 | 0.104  | 0.543 | 0.72  | 1       | 0.849 | 0.0*  | 0.0*  | 0.722 | Sig. F Change     |
|  | 1.907 | 1.762 | 1.979 | 0.217 | 0.114 | 1.105  | 0.32  | 0.47  | 0.934   | 0.849 | 0.866 | 0.99  | 1.722 | Durbin-Watson     |
|  | 13    | 12    | 11    | 10    | 9     | 8      | 7     | 6     | 5       | 4     | 3     | 2     | 1     | Model             |
|  | 0.845 | 0.864 | 0.893 | 0.912 | 0.927 | 0.948  | 0.955 | 0.959 | 0.96    | 0.961 | 0.962 | 0.963 | 0.963 | R                 |
|  | 0.753 | 0.626 | 0.747 | 0.798 | 0.831 | 0.859  | 0.899 | 0.913 | 0.92    | 0.921 | 0.924 | 0.927 | 0.927 | Adjusted R Square |

\*Note: Asterisks (\*) were applied where significant changes in the models were detected at the 0.05 threshold.

*Table 9.14. The performance of models in the evaluation of various statistical metrics, to identify the model best fits the data for measuring seaweed farming productivity (Dependent: Wet weight of harvested seaweed in pounds and Independent: Livelihood capitals).*

The key findings from the model summary in the table (Table 9.14) above are as follows:

Table 9.14 summarizes the performance of 13 different models, evaluated on various statistical metrics, with the aim of understanding which model best fits the data for measuring seaweed farming productivity and in extensive sustainability. Below highlights the key results:

**R (Correlation Coefficient):** All models have high R values, indicating a strong relationship between the independent variables and the dependent variable (seaweed production). Model 1 and Model 2 have the highest R values (0.963), but as the models progress, the R values slightly decrease, with Model 13 having the lowest (0.845). However, all R values are still high, suggesting a strong overall fit.

**Adjusted R Square:** Adjusted R Square compensates for the number of predictors in the model and indicates how well the model generalizes. The highest Adjusted R Square (0.927) is observed in Model 1 and Model 2, indicating they explain approximately 92.7% of the variance in the data. As the models progress, the Adjusted R Square decreases, with Model 13 having an Adjusted R Square of 0.753, meaning this model still explains 75.3% of the variance, but it is less than the earlier models.

**Std. Error of the Estimate:** This indicates the average distance that the observed values fall from the regression line. The Standard Error increases as the models progress, suggesting that later models fit the data less precisely than earlier ones. Model 1 has the lowest error (0.243), while Model 13 has an error of 0.737.

**R Square Change:** This indicates how much the R Square increases when a new predictor is added. In Model 1, there is a substantial R Square change (0.927), but in Model 5, the R Square change is negative (-0.002), suggesting that adding more predictors beyond this point does not improve the model. This indicates that Model 5 may be where diminishing returns on added variables start, with Model 13 showing only a marginal change in R Square (0.001).

**F Change:** F Change tests whether the addition of variables improves the model. Significant changes (denoted by \*) are observed between Models 2 and 3 (Sig. F Change = 0.0), suggesting that the addition of variables in these models made a statistically significant improvement. Beyond Model 5, the F Change values are less significant.

**Sig. F Change:** This measures the significance of adding variables to the model. A value below 0.05 indicates a significant change. The significant changes observed in Models 2 and 3 (denoted by \* at 0.0) show that these models improved with the addition of predictors. However, beyond Model 3, the changes become insignificant (greater than 0.05), indicating the added variables do not significantly improve the model's predictive power.

**Durbin-Watson:** This statistic tests for autocorrelation in the residuals. A value close to 2 indicates no autocorrelation. All models have values close to 2, ranging from 0.866 (Model 3) to 1.979 (Model 11). This suggests that the models do not suffer from significant autocorrelation issues.

*Reflective notes*

Model 13 has a relatively lower R and Adjusted R Square compared to other models, but it balances the variables well with a reduced error. It shows a minimal R Square change (0.001) and a non-significant F Change (0.234), suggesting that the model has stabilized with a satisfactory fit.

Model 2 and Model 3 show the most significant improvements in R Square and F Change, but later models provide diminishing returns on the additional variables.

Model 13 is highlighted as the best-fit model based on the criteria that it achieves a balance between predictive power and model complexity. While earlier models (e.g., Model 2 and Model 3) show significant improvements, Model 13 stabilizes with a reasonable Adjusted R Square (0.753) and Durbin-Watson value (1.907), which supports and meets the assumptions of the linear regression model while maintaining statistical significance.

Nevertheless, Table 9.14 provides a strong basis for concluding that while several variables impact seaweed farming, Model 13 presents the most stable and interpretable combination of predictors for strengthening existing adaptation strategies in seaweed farming livelihoods.

## 9.4 APPENDIX D (Ethics and Protection Supporting Documents)

### 9.4.1 University Social Research Permit Approval

Figure 9.7 is a screenshot of a "Research Ethics and Data Protection Form" from the University of Malta, containing the following details:

|                                                                                                                                                                                                          |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| Date of Submission: *                                                                                                                                                                                    | 17/02/2023      |
| If applicable: Date collection start date                                                                                                                                                                |                 |
| <b>Administration</b>                                                                                                                                                                                    |                 |
| REDP Application ID                                                                                                                                                                                      | FEMA-2022-00335 |
| Current Status                                                                                                                                                                                           | Approved        |
| <small>If a submitted application needs to be amended, it can be withdrawn, edited, and resubmitted, and it will retain the same reference number. There is no need to submit a new application.</small> |                 |

*Figure 9.7. Ethical Review and Data Protection (REDP) Application Approval Record (Source: University of Malta Research Ethics and Data Protection Committee (REDP Application ID: FEMA-2022-00335, Approved 17 February 2023).*

Detailed University Information:

- University: University of Malta
- The document provides general instructions regarding the necessity of completing the Research Ethics and Data Protection (REDP) form for research conducted under the University's auspices, with references to relevant policies such as the Research Code of Practice and the Research Ethics Review Procedures. External applicants may also be subject to review.

Applicant and Project Details (Part 1):

- Name: Ruth Julianna
- Surname: Gutierrez-Corley
- Email: ruth.gutierrez-corley.21@um.edu.mt
- Applicant Status: Student
- Department: Doctor of Philosophy (PhD)
- Faculty/Institute/School/Centre: Islands & Small States Institute
- Principal Supervisor: Dr. Stefano Moncada (stefano.moncada@um.edu.mt)
- Co-Supervisor: Professor Alan Deidun
- Course and Study Unit Code: PG Dissertation/Thesis
- Student Number: 2012129

This document is an official form used to register your research for ethical review, of which showed the PhD Candidate/primary researcher under the guidance of two supervisors as part of the doctoral program at the Islands & Small States Institute of the University of Malta.

Figure 9.8 below shows an email notification regarding the status of your REDP (Research Ethics and Data Protection) form, with the following details:

- From: form.urec@um.edu.mt

- Subject: The status of your REDP form (FEMA-2022-00335) has been updated to Approved.
- Recipient: Ruth Julianna Gutierrez-Corley
- Message: The email informs that the status of your REDP form (FEMA-2022-00335) has been updated to "Approved". It also includes a link to track the application status: <https://www.um.edu.mt/research/ethics/redp-form/frontEnd/>.

This confirms the approval of this PhD research ethics application as a follow up email was received apart from the approval stated on the form. The image below shows the approval via email:

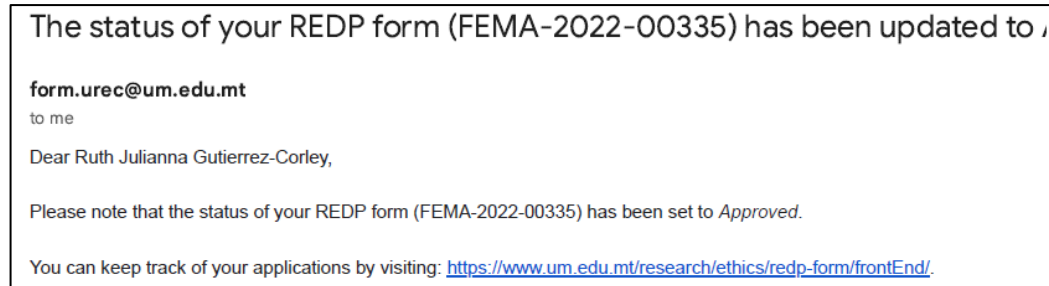


Figure 9.8. Confirmation Email of REDP Application Approval, FEMA-2022-00335 (Source: University of Malta Research Ethics and Data Protection Committee (email notification to author confirming approval status)).

#### 9.4.2 Case Study Country Social Research Permit Approval

Figure 9.9 displays a Permit to Conduct Social Research issued by the Institute for Social and Cultural Research (ISCR) under the National Institute of Culture and History (NICH), Belize. Below are the key details:

- Permit No.: ISCR/ H/2/127
- Grantee:
  - Dr. Stefano Moncada (Principal Investigator, University of Malta)
  - Ruth Gutierrez-Corley (Co-Principal Investigator, University of Malta)
- Research Title: "The Sustainability of Seaweed Aquaculture for Blue Growth and Climate Change Adaptation in Small Island Developing States: The Case of Belize"
- Research Location: Belize
- Validity: The permit is valid from 1 April 2023 to 1 April 2024, subject to conditions and compliance with the NICH Act.
- Conditions:
  - The research permit was granted under the NICH Act (Chapter 331, Section 71 and 72(a), Revised Edition 2003, Laws of Belize).
  - The Act mandates the Institute for Social and Cultural Research to review and approve all research involving human subjects in Belize.
- Authorized Date: March 31, 2023

- Authorized by: Mr. Rolando Cocom, Acting Director, ISCR, National Institute of Culture and History

This permit formally authorizes your research activities in Belize for a year. Figure 9.9 below is a screenshot of the letter showing approval to conduct social research in the case study of Belize SIDS.

| PERMIT TO CONDUCT SOCIAL RESEARCH                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Permit No. ISCR/ H/2/127                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <p><b>Grantee:</b><br/>This is to certify that Dr. Stefano Moncada (Principal Investigator of the University of Malta) and Ruth Gutierrez-Corley (Co-Principal Investigator of the University of Malta) have been granted permission to conduct social research in Belize.</p> <p><b>Research Title:</b><br/>"The Sustainability of Seaweed Aquaculture for Blue Growth and Climate Change Adaptation in Small Island Developing States: The Case of Belize"</p> <p><b>Research Location(s):</b><br/>Belize</p> <p><b>Validity:</b><br/>This permit shall remain valid from 1 April 2023 to 1 April 2024 and shall be subjected to conditions hereunder and to the compliance by the Grantee with the NICH Act.</p> <p><b>Conditions:</b><br/>Permission has been granted by the Institute for Social and Cultural Research under the auspices of the National Institute of Culture and History (NICH) as contained in the NICH Act Chapter 331, Section 71 and 72 (a) Revised Edition 2003, of the laws of Belize. The Act requires the Institute for Social and Cultural Research to review and approve all proposed research involving humans that is conducted in the country of Belize.</p> <p><b>Authorized:</b> March 31, 2023</p> <div style="text-align: center;"> <br/> <hr style="width: 100px; margin: 0 auto;"/> </div> <p>Mr. Rolando Cocom<br/>Acting Director<br/>Institute for Social and Cultural Research<br/>National Institute of Culture and History<br/>Tel: 822-3307</p> <div style="text-align: center;"> <br/>       national Institute of culture and history     </div> |

*Figure 9.9. Permit to Conduct Social Research in Belize issued by the local authority, Institute for Social and Cultural Research (ISCR) under the National Institute of Culture and History (NICH), Government of Belize.*

#### 9.4.3 Participants Information Sheet

The participants information sheet is a document provided to all participants in this study with key details about the research, ensuring they are fully informed before participating. Figure 9.10 below shows the Participant Information Sheet before each Semi-structured Interview Survey was conducted with the following key information:



**Participant Information Sheet – Semi-structured Interview Survey Instrument**

**Project Title: The Sustainability of Seaweed Aquaculture for Blue Growth and Climate Change Adaptation in Small Island Developing States: The Case of Belize**

**Project Summary:** This survey examines the perceptions of seaweed producers in Belize as it relates to the challenges, threats and risks along with their responses to improving seaweed mariculture activities in the Caribbean Sea. The study aims at critically understanding short and long-term adaptation employed by seaweed farmers in producing seaweed farms of the Caribbean. The principal investigator is Ruth Gutierrez-Corley (PhD Student, University of Malta), in cooperation with Dr. Stefano Moncada (Director, Islands and Small States Institute, University of Malta) and Professor Alan Deidun (Director, International Ocean Institute).

**How is the project being paid?** The project received funding from the Maltese Ministry for Foreign and European Affairs and Trade and the University of Malta.

**What will I be asked to do?** You are invited to participate in a semi-structure survey. The survey questions about the perceived threats, risks and challenges faced on seaweed farms in the Caribbean Sea. The survey intends to capture the response strategies to climate change adaptation employed by seaweed farmers on farming sites of their region.

Please answer the questions as best and as honestly as you can. There are no right or wrong answers.

**Salient participant characteristics (min-max participants, age, sex, other):** Minimum participants: 100 (no age or sex limitation)

**How much of my time will I need to give?** The survey will take approximately 30 to 45 minutes.

**What specific benefits will I receive for participating?** Your answers will provide useful information on the status of seaweed farming of one of the Caribbean Islands and Small States (ISSI), specifically in Belize. Publication will raise awareness of seaweed farmers' perceptions and recommendations for safeguarding the industry for long-term sustainability as a livelihood and climate adaptation strategy.

**Will participating in the project involve any discomfort for me?** There will be no discomfort to you in participating in the research study.

**How do you intend to publish the results?** Please be assured that only the researchers will have access to the raw data you provide. The information from these surveys will be analyzed in an aggregate manner – we will not use your names and your anonymity will be assured (no names on interviews). The findings of the research will be published in journals and theses that recommend actions to address the challenges faced on seaweed farms in the face of climate change in Caribbean ISSI. The seaweed farmers involved in this research study will be briefed about the outcomes.

**Can I withdraw from the study?** Participation is entirely voluntary and you are not obliged to be involved. If you do participate, you can withdraw at any time without giving a reason. If you do choose to withdraw, any information that you have supplied will not be used in the study.

**What if I require further information?** Please contact Ruth Gutierrez-Corley (+501-623-1504/+44-7788310137, [ruth.gutierrez-corley21@um.edu.mt](mailto:ruth.gutierrez-corley21@um.edu.mt)) or Dr. Stefano Moncada (+356-79098909, [stefano.moncada@um.edu.mt](mailto:stefano.moncada@um.edu.mt)) should you wish to discuss the research further before deciding whether or not to participate, or if you have questions about the study.

**What if I have a complaint?** This study has been approved by the University of Malta Research Ethics Committee. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Ethics Committee through the chairperson Prof. Patrick J. Schembri on Tel +356 2340 2789 or email [patrick.j.schembri@um.edu.mt](mailto:patrick.j.schembri@um.edu.mt). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome. If you agree to participate in this study, please sign the Participant Consent Form.

*Figure 9.10. Participant Information Sheet before each Semi-structured Interview Survey was conducted with the following key information.*

#### 9.4.4 Participants Consent Form

This consent form is designed to ensure that participants are fully informed and give their voluntary, informed consent to participate in the study. Consent forms were issued out at the same time as the information sheet and collected shortly after the principal researcher completed her introduction of this study's purpose. All forms of this study can be found [here](#). Figure 9.11 below shows a snapshot of the consent form:

**Participant Consent Form**

Project Title: "The Sustainability of Seaweed Aquaculture for Blue Growth and Climate Change Adaptation in Small Island Developing States: The Case of Belize".

I, \_\_\_\_\_ [your name] consent to participate in this project.

I acknowledge that:

I have read the participant information sheet and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.

The procedures required for the project and the time involved have been explained to me, and any questions I have about the project have been answered to my satisfaction.

I consent to completing the survey.

I understand that my involvement is confidential and that the information gained during the study may be published but no information about me will be used in any way that reveals my identity.

I understand that I can withdraw from the study at any time, without affecting my relationship with the researcher/s now or in the future.

Signature: \_\_\_\_\_ Date: \_\_\_\_\_

Address: \_\_\_\_\_

This study has been approved by the University of Malta Research Ethics Committee.

*Figure 9.11. Consent forms provided to each participant during primary data collection (including semi-structured interviews with seaweed farmers and elite interviews).*

## 9.5 APPENDIX E (Focus Group Discussions and CRiSTAL Toolkit)

The Community-based Risk Screening Tool - Adaptation and Livelihoods (CRiSTAL) was applied as a participatory framework to identify and analyze the climate-related vulnerabilities and adaptation responses of seaweed-farming communities in Belize. The toolkit served as both a diagnostic and dialogue instrument, enabling local seaweed farmers to articulate the environmental and socio-economic hazards as a hazard screening exercise that directly affect their livelihood assets, while also co-producing locally grounded adaptation measures.

CRiSTAL's structure, linking livelihood resources to climate risks and adaptation strategies, was particularly suited to this study's Sustainable Livelihoods Framework (SLF) orientation. The tool facilitated an integrated assessment of how human, natural, physical, social, financial, and cultural capitals are impacted by climate variability and non-climatic pressures, such as market access, policy uncertainty, and resource governance. The participatory nature of the toolkit ensured that adaptation options reflected both local knowledge and collective priorities, thereby strengthening the contextual relevance of findings.

Four Focus Group Discussions (FGDs) were conducted across major seaweed-farming hubs, each representing distinct geographical and institutional contexts:

- Focus Group 1 (Section 9.5.1 - 9.5.2) – *Belize Women Seaweed Farmers Association (BWSFA)*, Placencia Village
- Focus Group 2 (Section 9.5.3 - 9.5.4) – *Placencia Producers Cooperative Society Limited (PPCSL)*, Placencia Village
- Focus Group 3 (Section 9.5.5 - 9.5.6) – *Blue Waters Fishermen Association (BWFA)*, Riversdale Village
- Focus Group 4 (Section 9.5.7 - 9.5.8) – *Turneffe Seaweed Growers Association (TSGA)*, Belize City

Each FGD applied the CRiSTAL methodology to:

1. Identify key climate and non-climate hazards (e.g., ice-ice disease, sargassum influx, extreme weather events, theft, and market challenges).
2. Assess the sensitivity and exposure of different livelihood assets to these risks.
3. Document current coping and adaptive responses, such as freshwater rinsing, depth adjustments, and crop rotation.
4. Propose long-term adaptation strategies (e.g., improved site selection, diversification of value-added products, and policy advocacy for secure sea-space tenure).

The CRiSTAL results across the four sites reveal that climate variability, particularly sea-surface warming, storm intensity, and seasonal “box-send” wave action, continues to undermine seaweed productivity and infrastructure stability. However, collective organization through cooperatives and women's groups has enhanced social capital, fostering shared learning, informal monitoring systems, and advocacy for improved governance mechanisms.

Overall, the CRiSTAL Toolkit provided a systematic approach to linking community-level experiential knowledge with broader climate adaptation policy frameworks under Belize's Blue Economy and Mariculture Policy agendas. The summaries presented in Sections 9.5.2 (FDG #1), 9.5.4 (FDG #2), 9.5.6 (FDG #3), and 9.5.8 (FDG #4) synthesize the findings from each focus group discussions, highlighting site-specific challenges, adaptation measures, and

policy recommendations for strengthening the resilience and sustainability of seaweed-farming livelihoods in Belize.

#### 9.5.1 Focus Group Discussion 1: Placencia Village (Female Group)

A total of six participants attended the female focus group held on the 19th of June 2023. Ages ranged from 34 to 45 (mean age of 40). Participant occupations included: 1. tour guide (3); 2. entrepreneur (2); and 3. caretaker (1). The discussion commenced with the development of a map of the community and resources, supported by a facilitator (Figure 9.12.). The CRiSTAL toolkit guiding this discussion can be found in the next section of this appendix, 9.5.2 (FDG #1).



*Figure 9.12. Visual resource map with female focus group (Placencia Village) (Author's own elaboration).*

**Key points:** The map was used to relate the themes of the focus group discussion to identify important resources and hazards (Figure 9.12.). Participants engaged in discussions to determine where hazards originated in the surrounding environment where they lived and where their seaweed farms were located. This helped to foster a deeper understanding of the concepts being discussed in livelihood resources and hazards. Such impacts were highlighted as hazards originating from the mainland, where communities reside, along with policy and market structures.

The following resources were listed and prioritized:

*Livelihood Resources*

| <b>Livelihood Categories</b> | <b>Livelihood Resources</b>                                                                                          |
|------------------------------|----------------------------------------------------------------------------------------------------------------------|
| Human                        | Good health<br>Expertise in seaweed planting and harvesting practices                                                |
| Social                       | Formal and informal networks<br>Civil society support                                                                |
| Natural                      | Sea/ocean<br>Ocean weather<br>Freshwater                                                                             |
| Physical                     | Processing equipment and rack<br>Value-added product development infrastructure<br>Markets (local and international) |
| Financial                    | Grants<br>Income and personal savings                                                                                |
| Political                    | Governance of seaweed mariculture operations<br>Functioning of institutions                                          |
| Cultural                     | Sea landscape<br>Traditional knowledge of the use of seaweed                                                         |

*Table 9.15. Key livelihood resources identified from female focus group discussion in Placencia (Author's own elaboration).*

The following key points emerged in the discussion among male participants, about their livelihood resources:

In the discussions, human assets stood out as participants described their skills and knowledge working in the coastal and marine environment as well as in the tourism and fishing industries while transitioning into seaweed mariculture. All participants have received formal education, vocational training, technical skills, and experiential knowledge that have helped them to participate in seaweed farming livelihood activities. Participants shared that they are physically and mentally engaged in mariculture, but on a part-time basis.

At least one participant was involved in value-added seaweed products and worked as a seaweed-based trader full time. This was the only full-time individual in the group. Participants expressed a desire to continue improving their seaweed livelihoods and well-

being through the introduction of a healthy commodity in the local market. However, further human assets were discussed in the areas of conducting environmental monitoring such as water quality and cultivated seaweed species growth apart from individual participant observations on what is happening on the day of visiting seaweed farms for maintenance purposes in the past.

The participants expressed the importance of building formal and informal networks, friendship relationships, and social support systems within civil society to meet their social assets. Specifically, support from organizations like The Nature Conservancy (TNC), the Southern Environmental Association (SEA), the Placencia Village Council, and the Placencia Producers Cooperative Society Limited (PPCSL), which have provided technical assistance and networking opportunities. Participants highlighted how social media exposure has allowed them to build awareness, network, and conduct fundraising activities. For example, Facebook has enhanced the Belize Women Seaweed Farmers Association's (BWSFA) visibility of seaweed farming activities and attracted support from a wider audience, especially abroad. Limited input in technology use was reported to farm seaweed species.

Natural assets were seen as key as marine resources were readily available, and the health of the ocean environment directly affects seaweed farming sites, seawater, ocean currents, and marine biodiversity. The composition of the sea bottom was mentioned as having a balanced mix of seagrass and sand with corals nearby, and this was important for the successful cultivation of seaweed and the overall health of the marine ecosystem. While participants mentioned not farming on top of corals as part of their site selection criteria and good management practices (GMPs), the presence of coral reefs near farms can be an indication of a healthy ocean. Together with seaweed farming plots above the seabed floor, this can help to enhance the habitat for marine species, contribute to biodiversity, and support ecosystem services.

To support this, participants showed pictures of their seaweed farms and showed dried samples of marine creatures that lived within the thallus of seaweed on the cultivation lines as they were accidentally harvested and dried with the seaweed commodity. The participants showed how their seaweed farms provided a habitat and shelter from marine predators, such as marine creatures include juvenile lobsters, conch, and crabs, while other marine creatures, such as squids and fish (barracuda), used the area as feeding grounds, which contributed to the ecological balance and biodiversity of the marine ecosystem. Participants were expressing how much of a good candidate seaweed, particularly species like *Kappaphycus alvarezii*, played a great role in carbon sequestration, as it was observed to grow two times faster than *Eucheuma isiforme* and *Gracilaria crassissima* that were once the popular seaweed species to cultivate and now it's only *K. alvarezii*.

Physical assets were noted for being critical resources including cultivation materials (ropes and net bags, snorkeling gear, etc), processing equipment, and facilities for harvesting and processing raw seaweed on mainland Placencia Village. Sun-drying racks and processing spaces are essential physical assets for converting harvested seaweed into marketable products. Water resources such as VAT water catchments were used to capture rainwater to rinse the seawater from the wet seaweed and were important to the quality and cleanliness of the harvested seaweed. Alternative methods to fresh water, such as Ziplock bags to store seaweed until freshwater is accessed were identified. In addition, transportation infrastructure such as boats, nets, and other transportation equipment was necessary for transporting harvested seaweed from the farms to processing facilities on the mainland. Although participants did not have formal access to an official storage facility, they provided adequate storage facilities for seaweed at their homes in well-ventilated rooms, to preserve the quality of the harvested seaweed before processing and distribution. Participants provided descriptions of the requirements of the different local markets where they produced seaweed value-added products and the kind of quality and standards, they would like seaweed to continue having. This was a technique for different value-added products.

Participants highlighted that seaweed farming requires significant financial investments for infrastructure development and value-added product experimentation. There were some policy concerns about the current farming strategies employed on seaweed species. Participants lamented that the drafted mariculture policy had not engaged them, and they are concerned that this new regulation will marginalize them in favor of large companies. Clarification was needed on the mariculture policy and drafted blue economy bill currently being revised for Belize by consultants. Participants expressed a need to be informed of all the legislative changes. There was a lot of confusion around the terms and conditions of marine research permits issued by the Belize Fisheries Department to TNC Belize for seaweed farming operations in southern Belize with the women's group. Participants were not certain about whether seaweed could be sold under a research permit and believed that seaweed wasn't permitted to be sold to members of the BWSFA or local community.

Regarding cultural assets, seaweed resources have always been a part of the local food as a key ingredient to cook with porridges, smoothies/shakes and stews. There seemed to be no religious connection with seaweed but only the way the ocean is used daily for working and recreation. Even though each participant has traditionally used seaweed, there were participants who had no documentation of seaweed farming initiatives by different people in the farming groups. Scientific documentation and record keeping seems to be a concern that participants brought up as they identified it as a gap for them to step forward towards scaling up by keeping an up-to-date track record of farming operations and practices.

The identification of key livelihood resources, participants were asked to list the major hazards being faced by the seaweed farming community given in Table 9.16.

| <b>Hazard</b>                                   | <b>Frequency</b>     | <b>Duration</b> | <b>Intensity</b> | <b>Description of Direct/indirect impacts on Seaweed farms</b>           |
|-------------------------------------------------|----------------------|-----------------|------------------|--------------------------------------------------------------------------|
| Storms                                          | 4 – 6 times per year | 12 months       | High             | Income loss (↑)<br>Red seaweed escapees (↑)<br>Red seaweed disease (↑)   |
| Warming sea temperature                         | Twice per year       | 3 - 6 months    | High             | Wild red seaweed stocks (↓)<br>Income loss (↑)                           |
| Drought                                         | 2 times per year     | 2 - 4 months    | High             | Fresh water sources (↓)<br>Red seaweed processing and quality (↓)        |
| Theft                                           | 3 - 4 Times per year | 1 Day           | High             | Object and income loss (↑)                                               |
| Lack of diversity in cultivated seaweed species | Throughout the year  | 12 months       | High             | Red seaweed escapees (↑)<br>Nearby coral patch reef to seaweed farms (↓) |

|                                         |                     |           |      |                                                                |
|-----------------------------------------|---------------------|-----------|------|----------------------------------------------------------------|
|                                         |                     |           |      | Income loss (↑)                                                |
| Lack of support for small-scale farmers | Throughout the year | 12 months | High | Income loss (↑)<br>Small producers' displacement in market (↑) |

*Table 9.16. Key Hazards and Resources Impacted in First Focus Group Discussion in Placencia Village (Author's own elaboration).*

The following key points emerged during the discussion about hazards:

During the first focus group discussion, participants highlighted various climatic and non-climatic hazards and impacted resources associated with their current seaweed farming operations. Climatic hazards identified included storms, warming sea temperatures, and drought impacting the physical infrastructure, growth conditions, and water availability essential for successful cultivation. Emphasis was placed on severe storms, including tropical storms, hurricanes, and floods that have inflicted substantial damage on seaweed farm infrastructure by dismantling ropes and in many cases breaking off the seaweed crop from the cultivation ropes. High winds and heavy rainfall associated with storms have disrupted farming activities in the past leading to the need to repair and replace farming infrastructures in the ocean resulting in reduced time to plant and harvest during farm site visits. Storm surges and increased wave action during change of seasonal weather have damaged seaweed farms, impacting overall harvested seaweed crops. For example, participants shared that the aftermath of storms included equipment loss (ropes), work disruption (cancellation of farm visits/field work), and the displacement of cultivated red seaweed (break off from ropes), affecting both productivities.

Increased ocean temperatures were also a concern due to its negative impact on seaweed growth rates. Seaweed crops were not placed one to two feet from the sea water surface as they did before as participants perceived that this practice leads to thermal stress and reduced yields to seaweed crop by increased 'ice-ice' on the ends of the thallus. Plots were placed midwater ten feet above the seafloor. Although participants mentioned 'ice ice' seaweed disease outbreaks and this was not expressed to impact overall productivity as participants changed farming practice from 'raffia' to 'twist' ropes method at midrange of the water column. Higher sea temperatures had resulted in coral bleaching incidence around seaweed farms, and this is parallel with increased seaweed breakoffs to nearby patch reefs, thus impacting the quality of the harvested red seaweed due to transparent ends when it is dried.

Extended periods of drought have affected rainwater availability for rinsing off seawater from the harvested seaweed on mainland. Reduced rainfall and water scarcity during drought periods had posed difficulties in maintaining an adequate fresh water supply, especially on home-based processing of cultivated red seaweed. Drought-induced water stress has been perceived to reduce the quality of seaweed if other types of drying techniques have been imposed such as leaving seaweed in a Ziplock bag or under a tarp cover to dehydrate with the marine salt. Therefore, disruptions in processing activities of seaweed due to limited freshwater access for rinsing seaweed has led to lower quality of harvested red seaweed due to increased salt concentration of which is visible on the dried seaweed. One of the participants produced a mineral salt from the dried marine salt on the seaweed crop by shaking it after it had been dried for a few days. The cultural market's reluctance to accept red seaweed with sea salts had further impacted on the marketability of the crop.

The most important non-climatic hazards included theft, lack of seaweed genetic diversity and lack of support for small-scale farmers. Theft and security issues are major challenges to farms in the open ocean between islands. The current cultivation methods are aligned with the established good management practices including site selection using 'SMART siting' criteria

developed by The Nature Conservancy (TNC) and partners. Nevertheless, this location has been exposed to frequent theft that has led to a lack of trust among stakeholders. This has impacted the motivation in the industry and may lead to discontinuation in some instances. The loss of seaweed crop has led to no income from a harvesting cycle of which further exacerbates the financial strain on the women seaweed farmers in this focus group discussion.

Additionally, limited healthy seed bank nursery access and the increased in harvesting of wild red seaweed species, particularly *Eucheuma* sp., have contributed to the lack of seaweed diversity in farming operations as only one species, *Kappaphycus alvarezii* is being farmed at the time of this study. Moreover, the spread of the same propagated red seaweed species has led to the perception that without sufficient diversity, heavy reliance on a non-native macroalgae, *K. alvarezii*, could take over the wild seaweed species population. Participants shared that they have only been working with newly introduced seaweed species since 2019 due to limited seed access of wild *Eucheuma* sp. They expressed that farming only one type of seaweed species has limited their opportunities to enter niche markets as customers who work with cosmetics preferred *Eucheuma* sp. for their value-added products. Therefore, limited diversity of farmed seaweed crops further restricts the economic potential of seaweed farming.

Participants expressed that there is a lack of support for small-scale seaweed farmers from government which hinders their ability to thrive in the industry. Small-scale farmers may be displaced when larger companies enter industry as the government is currently promoting the seaweed farming business internationally for investment. Several challenges in this regard are being faced in accessing resources, technology, and markets that could enhance their productivity and profitability. Without adequate support, participants shared that they are already struggling and with larger companies invited to invest in Belize, they will be unable to compete with commercial seaweed farms, more established operations with advanced innovation in farming practices, leading to limited economic growth and displacement in the long term. Participants were included in the revision of updated mariculture policies and farming manuals and reaching out for help to address this issue to provide the necessary support to succeed.

#### *Hazards: Frequency, Duration, Intensity, Impacts, and Resources Impacted*

For each hazard and corresponding impact, Table 9.17 show the results of current coping strategies identified by participants. These coping mechanisms/ responses were assessed by the extent of their sustainability, and eventually proposed alternative strategies, assuming the availability of resources, that could be employed to cope more sustainably with those hazards identified previously (Table 9.16).

| Hazard | Current Responses                                                                                                                                                                                                                                                                                           | Long-Term Responses                                                                                                              |
|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Storms | <p>Change of seaweed mariculture techniques from floating rafts to submerged square rope plots with an appropriate anchor system.</p> <p>Dropping the cultivation lines to the sea bottom and holding it down with weights/additional anchors to prevent loss of seaweed crops during ocean turbulence.</p> | Develop a hurricane response and recovery plan and modify cultivation techniques as needed to secure seaweed farms in the ocean. |



|                                                   |                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                               |
|---------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Seawater temperature increase                     | Installation of buoy systems that can adjust to the sea depth where seaweed farms are growing. This allows seaweed farms to dwell in cooler areas.                                                                                                                                                                                                                   | Farming of red seaweed species that are more resilient to seawater temperature such as those non-native red seaweed species.                                                                                                                                                                                                                  |
| Extended periods of drought during the dry season | <p>Establishing water catchment systems by filling water tanks (recycled 55 gallons) from the mainland to take them to camping sites on islands.</p> <p>Traditionally freshwater was used to rinse seaweed as a freshness to maintain high quality crops but now seaweed is preserved by sealing it in a bag of salt water if it cannot be processed right away.</p> | <p>Monitoring of ocean weather and environmental conditions (i.e. Self-observation and temperature loggers).</p> <p>Use dehydration methods without depending on freshwater access on islands while maintaining high quality and standards. Show evidence of nutrient quality by doing consistent nutrient testing for the export market.</p> |
| Theft/security                                    | Consistent visits to red seaweed farming sites and regular harvest intervals between planting and farm maintenance.                                                                                                                                                                                                                                                  | Lobbying with international and local NGOs to co-create grant applications to access enforcement financing for the protection of seaweed farming sites.                                                                                                                                                                                       |
| Lack of diversity in cultivated seaweed species   | Currently red seaweed farms are acting as seed banks to expand production sites. Red seaweed species are propagated and placed on new cultivation lines.                                                                                                                                                                                                             | Informal social networks amongst seaweed farmers to share seeds for starting up of seaweed farms especially when a high amount of cultivated seaweed species was lost.                                                                                                                                                                        |
| Lack of support for small-scale farmers           | Liaising with regulatory agency about the concerns of government facilitating international companies/investors to visit farms as it may negatively impact small producers.                                                                                                                                                                                          | Legal protection of small-scale seaweed producers if investors are granted permission to have seaweed businesses in Belize.                                                                                                                                                                                                                   |

*Table 9.17. Main short and long-term responses coping strategies to the identified hazards (Author's own elaboration).*

The following key points emerged during the discussion about coping strategies:

In response to storms, short-term strategies included change of seaweed mariculture techniques from floating rafts with raffia to submerged square rope plots with seaweed twisted in between the ropes with an appropriate anchor system. The twisted rope technique holds the seaweed crop tighter on the cultivation lines especially during turbulence. Dropping the cultivation lines to the sea bottom and holding it down with weights/additional anchors to prevent loss of seaweed crops during ocean turbulence.

Long-term approaches focused on the creation of comprehensive hurricane response and recovery plans, involving modifications to farming techniques, updates to cultivation manuals, and improvements in overall management practices. In the future, seaweed farms could be relocated and installed in deeper zones where sunlight is still available but have reduced ocean turbulence. The participants mentioned being involved in a consultation of an ocean plan as part of the marine spatial plan for Belize. Participant revealed that they recommended not to include seaweed farms offshore as it is already difficult for them to access their farmers with only 10 miles from the shoreline on mainland. Moreover, the establishment of early warning systems, securing structures and equipment, and developing emergency response plans is a long-term plan of the participants to improve their response to storms in the area.

For warming sea temperatures, short-term measures involved introducing new farming practices during extreme weather, such as sinking farms deeper when temperatures increased. Long-term strategies included building the industry through healthy seed provision, researching heat-tolerant species, implementing breeding programs for resilience, and investing in water cooling systems or shading structures. Collaboration with scientists and marine experts was also emphasized to monitor and adapt farming practices in response to long-term climate trends.

Coping with drought involves short-term actions like establishing water catchment systems to transport water from the mainland to camping sites on islands. Long-term strategies included modifying farming techniques to adapt to changing water availability and ensuring sustainable water management practices for rinsing before drying treatment.

To address theft, short-term responses included consistent visits to farming sites, enhancing security measures, establishing community watch programs, and engaging with law enforcement. Long-term approaches involved improving communication within the farming community, forming partnerships with authorities and NGOs, implementing training programs for farmers, and advocating for policy changes and regulatory frameworks.

For the lack of diversity in cultivated seaweed species, short-term solutions focused on increasing the spread of propagated species among farmers. In the long term, establishing healthy seed bank nurseries was suggested to expand production sites and promote the farming of more resilient red seaweed species.

Short-term strategies for addressing the lack of support included involving participants in policy revisions and farming manual updates. Long-term responses included collaborating with authorities and organizations to secure funding, fostering informal social networks among participants, and co-creating grant applications for small-scale farmers.

This part of the focus group discussion allowed participants to express that seaweed farming faced many challenges in developing infrastructure, processing units, and value-added product development and what they plan to do differently. Existing strategies and policies need revision to stay informed of legislative changes and avoid discrepancies. Seaweed farming requires daily tools and gears, which were purchased through grants and personal investment. There is a lack of documentation and record keeping of seaweed farming operations, and there is limited use of technology for farming operations. Disaster reduction strategies are needed for seaweed farms. The Belize Women Seaweed Farmers Association (BWSFA) faces poor communication with government offices, and there is no clear understanding of marine research permit terms and conditions. Seaweed farms are vulnerable to breakage from wave action, and there is limited technical support. There is a need to establish seaweed raw quality and standards with the Belize Agriculture and Health Authority and the Belize Bureau of Standards. Seaweed farms provide environmental benefits, and there is a need for processing facilities and a niche market. Health and safety policies are needed for seaweed farmers, and a laboratory and training center should be established.

Participants made recommendations to develop a national macroalgae database with a list of seaweed species in Belize that are of economic value and to understand how they grow in the natural environment which can subsequently improve farming practices by these participants. An interest in continuing conducting environmentally friendly activities was expressed and a wish for more formal training with an emphasis on sustainable knowledge transfer, including trainers' training, reporting systems, seaweed farming site selection, and updating good management practices. Participants also recognized the necessity of training women's group association members in administrative tasks to better manage their seaweed farms. They advocated exchange programs, trade expos, and training opportunities to deepen their knowledge of seaweed farming and raise awareness of seaweed commodities.

Importantly, participants identified understanding the entire seaweed mariculture value chain as a crucial strategy for gaining market access and attracting investors. Exchange programs, trade expos, and training for women's farming groups were also highlighted as a need to learn more about seaweed farming and build awareness of seaweed commodities. Lastly, understanding the entire seaweed mariculture value chain was a crucial strategy voiced by the participants to gain market access and attract investors.

#### 9.5.2 CRiSTAL Toolkit: Seaweed Producers FDG #1 (Female Group)

The data presented in Table 9.18 and Table 9.19 provide baseline insights into the socio-economic characteristics, organizational composition, and spatial distribution of the seaweed farming community in Placencia, serving as the foundation for subsequent analysis of adaptation practices and livelihood assets.

|                         |                                                  |
|-------------------------|--------------------------------------------------|
| <b>Group Name:</b>      | Belize Women Seaweed Farmers Association (BWSFA) |
| <b>Location:</b>        | Placencia                                        |
| <b>Language spoken:</b> | English                                          |
| <b>Date:</b>            | 19 <sup>th</sup> June                            |
| <b>Start Time:</b>      | 09:15 AM                                         |
| <b>End Time:</b>        | 12:30 PM                                         |

Table 9.18. Description of first focus group (FDG #1).

|                                                                                         |                                                              |
|-----------------------------------------------------------------------------------------|--------------------------------------------------------------|
| <b>Number of seaweed producers (s):</b>                                                 | 6                                                            |
| <b>Name of registered seaweed cooperative (s)/ association (s)/community group (s):</b> | 5 Persons – Belize Woman Seaweed Farmers Association (BWSFA) |
| <b>Name of unregistered seaweed group (s):</b>                                          | 1 Independent seaweed farmer (Entrepreneur)                  |
| <b>Locations of seaweed farm (s)- (sketch it):</b>                                      | Placencia range and reef waters                              |
| <b>Number of years farming in the specified sites listed:</b>                           | 5 Years                                                      |
| <b>List of cultivated seaweed species on sites:</b>                                     | <i>Kappaphycus alvarezii</i> and <i>Eucheuma isiforme</i>    |

|                                                                                           |                                        |
|-------------------------------------------------------------------------------------------|----------------------------------------|
| <b>Estimated amount of seaweed farmed (in dry weight, pounds unit):</b>                   | 200 lbs Dry weight                     |
| <b>Historical land use prior to seaweed farming:</b>                                      | Boat channel and previous seaweed farm |
| <b>Site selection process for farming seaweed in the specific locations listed above:</b> | Reef waters with seagrass bottoms      |
| <b>If apply, reasons for site relocation:</b>                                             | No sites have been relocated as yet.   |

Table 9.19. Seaweed farming community profile (FDG #1).

Table 9.20 presents the business environment for farming seaweed, outlining the estimated financial investments, funding sources, household participation, and the involvement of government or E-NGOs in supporting seaweed farming activities.

|                                                                                                                              |                                                             |
|------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|
| <b>Investment needed to start a seaweed farm (US dollars):</b>                                                               | E-NGO grant Seeds capital and personal financing \$1000 USD |
| <b>Economic conditions for investing in seaweed farming: 1= Poor; 2= Satisfactory; Good; 4=Very Good; 5= Other (specify)</b> | 4 - Very good                                               |
| <b>No. of individuals/families working on seaweed farms:</b>                                                                 | 6 Individuals in BWSFA per trip to seaweed farms            |
| <b>Government &amp;/or NGO processes in accessing any resources or subsidies for farming seaweed:</b>                        | No.                                                         |

Table 9.20. Identification of seaweed farming resources and accessibility (FDG #1).

Table 9.21 presents the list of livelihoods capitals and associated resources identified during the focus group discussions with members of the BWSFA. These data provided a detailed overview of the diverse forms of human, social, natural, physical, financial, cultural, political, and informational capitals that underpin seaweed farming livelihoods in Placencia.

| <b>Capitals</b> | <b>Livelihood Resources</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Human</b>    | <ul style="list-style-type: none"> <li>• Good health</li> <li>• Swimming, breathing and diving skills</li> <li>• Good breathing skills (free diving, skin &amp; eye protection techniques and gears)</li> <li>• Protein-based nutrition (balanced diet)</li> <li>• Site selection skills for establishing seaweed farms</li> <li>• Expertise in seaweed planting and harvesting practices</li> <li>• Expertise in farming techniques such as tying methods</li> <li>• Ability to adapt to seaweed farming projects and changing environmental conditions</li> <li>• Expertise in rescue diving and first aid assistance</li> </ul> |
| <b>Social</b>   | <ul style="list-style-type: none"> <li>• Strong family support</li> <li>• Good community support</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

|                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                  | <ul style="list-style-type: none"> <li>• Individual support/peer-to-peer support (group/team support)</li> <li>• Teamwork support in farm management operations</li> <li>• Training capacity building programs and knowledge exchanges platforms</li> <li>• Partnerships with government agencies and NGOs such as with Belize Fisheries Department, Belize Ministry of Blue Economy and The Nature Conservancy (TNC)</li> <li>• Local NGO support managing nearby Marine Protected Areas (MPA) such as Southern Environmental Association (SEA)</li> <li>• Social media exposure (fundraising opportunities through virtual events)/membership awareness. For example, Facebook is a number one in the social network, especially for marketing.</li> </ul>                                                                                                                                                                                                                                       |
| <b>Natural</b>   | <ul style="list-style-type: none"> <li>• Healthy sea</li> <li>• Good ocean weather</li> <li>• Sea forest acting as shades to cool down the seawater temperature</li> <li>• Seagrass beds have few predators such as sea urchins</li> <li>• Sea forest provision acting like lobster shades</li> <li>• Carbon sequestration potential with seaweed breakoffs/escapees</li> <li>• Invasive seaweed species around seaweed farming sites such as sea urchins and wild seaweed species</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Physical</b>  | <ul style="list-style-type: none"> <li>• Processing equipment rack (processing house, water catchment, plastic cover)</li> <li>• Red seaweed value-added product development infrastructure such as processing house for packing, bottling and labeling of seaweed-based products.</li> <li>• Freshwater access to rinse seaweed</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Financial</b> | <ul style="list-style-type: none"> <li>• International NGO project grant investment in infrastructure, equipment, and labor wages (this is source of working capital for farm operations)</li> <li>• Access to credit and loans for business development</li> <li>• Government grant funding such as from Belize Trade and Investment Development Service (BELTRAIDE)</li> <li>• Standardization of seaweed crop cultivation and processing according to the standards of the Placencia Producers Cooperative Society Limited (PPCSL) for export.</li> <li>• High price with high seaweed commodity quality (locally approved for export).</li> <li>• Personal savings for maintenance of farm such as provision of food and personnel materials when visiting the farms</li> <li>• Microfinance access for women producing seaweed-based value-added products development through Micro, Small and Medium Enterprise (MSME) program</li> <li>• Fundraising (donations are made online)</li> </ul> |
| <b>Political</b> | <ul style="list-style-type: none"> <li>• Require a permit for seaweed farming, only marine research permit is accessible through International NGO grant support.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

|                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                    | <ul style="list-style-type: none"> <li>• Require protection for seaweed farms</li> <li>• Require official communication with the government office for seaweed commodity export permit/ commercial farming license.</li> <li>• Implementation of policy frameworks through cultivation guidelines (advice &amp; formulation of marine mariculture policy)</li> <li>• Technical support provided through NGO.</li> <li>• Strong awareness of seaweed mariculture guidelines during the launch of the blue economy ministry in Belize.</li> <li>• Seaweed seeds per farm are required through one time permit application</li> <li>• Lease seabeds permit required.</li> <li>• Require Belize Agriculture Health Authority (BAHA) seaweed commodity quality control and standards.</li> <li>• Require space for seaweed farming through marine spatial planning.</li> <li>• Seaweed farming zone sites.</li> <li>• Laws that protect each area in the marine zone. Boats are marked using color codes to use specific fishing zones. This is called Manage Access for the management of fisheries operations and marine protected area management.</li> </ul> |
| <b>Cultural</b>                    | <ul style="list-style-type: none"> <li>• Land &amp; sea harmony relationship</li> <li>• Seaweed has been traditionally used as the key ingredient in shake drinks such as those that were bought from Mr. Berry in the 1990s/early 2000.</li> <li>• Seaweed shakes have been traditionally used as a men drink believed to strengthen the sexual performance, hence it was famously consumed.</li> <li>• Seaweed porridge to help with malnutrition and would be ideal to include in school feeding programs.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Knowledge &amp; information</b> | <ul style="list-style-type: none"> <li>• Seawater temperature monitoring.</li> <li>• Self-observation on farming sites.</li> <li>• Association responsibility to monitor the weather.</li> <li>• Knowledge on farming techniques and strategies used to prepare for storms and warm sea water.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Innovation</b>                  | <ul style="list-style-type: none"> <li>• No technology requirement on boats (eg. radio and GPS)</li> <li>• Supporting civil society (ie. NGOs, students, researchers, etc) in data collection of ocean health and biodiversity such as installing sea water temperature loggers for monitoring of seawater temperature in seaweed farms and crabs.</li> <li>• Taking seaweed cover from the wild.</li> <li>• New farming practices and strategies introduced during extreme weather impacts such as sinking farms deeper when sea water temperature increases.</li> <li>• Building the seaweed industry through healthy seed provision for the national development of sustainable seaweed livelihoods and promoting value-added products to increase profitability</li> </ul>                                                                                                                                                                                                                                                                                                                                                                              |

|                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                        |
|--------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                    | and economic viability of cultivated seaweed commodity (“make more out of less”).                                                                                                                                                                                                                                                                                                                      |
| <b>Flexible forward-looking discussion making &amp; governance</b> | <ul style="list-style-type: none"> <li>• Formulate hurricane response and recovery plan.</li> <li>• Modify seaweed farming techniques and farming strategies.</li> <li>• Update manuals in seaweed cultivation better management practices.</li> <li>• Liaise with Belize Fisheries Department and BELTRAIDE about improving seaweed commodity quality for export market with BAHA support.</li> </ul> |

Table 9.21. List of seaweed farming resources (FDG #1).

Table 9.22 presented the major hazards affecting seaweed farms, including both climate-related and socio-economic hazards. The table summarized the frequency, duration, and intensity of these hazards, along with their direct and indirect impacts on seaweed farming operations in Placencia.

| <b>Hazards</b>                                             | <b>Frequency</b>     | <b>Duration</b>     | <b>Intensity</b> | <b>Description of Direct/indirect impacts on Seaweed farms</b>         |
|------------------------------------------------------------|----------------------|---------------------|------------------|------------------------------------------------------------------------|
| Theft                                                      | 3 - 4 Times per year | 1 Day               | High             | Object & income loss (↑)                                               |
| Cultivated red seaweed die-offs/break-offs                 | 4 – 6 times per year | Throughout the year | High             | Income loss (↑)<br>Red seaweed escapees (↑)<br>Red seaweed disease (↑) |
| Displacement of local seaweed farmers in the local economy |                      | All year-round      | High             |                                                                        |
| Scarcity of red seaweed seeds                              | Twice per year       | 3 - 6 months        | High             | Wild red seaweed stocks (↓)<br>Income loss (↑)                         |

Table 9.22. List of top three hazards to seaweed farms (FDG #1).

Following the identification of major hazards affecting seaweed farming (Table 9.22), Table 9.23 presented the list of formal and informal training initiatives attended by seaweed farmers. These training sessions focused on improving cultivation practices, environmental management, and cross-country knowledge exchange within the broader network of the Blue Economy and mariculture development.

|                                                     |
|-----------------------------------------------------|
| <b>Name of training (as labeled on certificate)</b> |
|-----------------------------------------------------|

|                                                          |                                                                              |                                                                                                                                                                                                    |
|----------------------------------------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| List of knowledge and skills acquired in training:       | List of environmental-related challenges addressed in training:              | Benefits received from training in a group set-up and knowledge exchange with seaweed farmers:                                                                                                     |
| Seaweed Mariculture Cultivation Training.                | Better Management Practices in Seaweed Farm Maintenance and Processing.      | Seaweed farmers have been able to establish pilot plots and develop relationships with other seaweed farmers in informal networks.                                                                 |
| Global South Exchange Program with Belize and Mauritius. | Exposure to better management seaweed farming practices in the Global South. | Seaweed farmers in the Belize Women Seaweed Farmers Association have the opportunity to learn from the fishing folks in Mauritius. This exchange program is still in the pipeline for 2024 events. |

Table 9.23. List of seaweed farming training (FDG #1).

Direct and indirect impacts from climate (Table 9.24) and non-climate related (Table 9.25) hazards are presented below.

| <b>Climate-related hazards: Hurricanes/storms/ floods, seawater temperature changes, and drought.</b> |                                                                                                       |                                                                                                                                          |                                                                                      |
|-------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Direct Impact                                                                                         | Indirect Impact                                                                                       | Other Causes of Impact                                                                                                                   | Impacted Resources                                                                   |
| Hurricanes/storms/ floods                                                                             | Unable to work                                                                                        | Loss of equipment to work                                                                                                                | Loss of red seaweed seeds                                                            |
| Seawater temperature increase                                                                         | Alteration of microbial communities in seaweed farms                                                  | Red seaweed disease outbreaks during summer                                                                                              | Reduction in harvested cultivated red seaweed                                        |
| Extended periods of drought during the dry season                                                     | Irregular harvesting schedule which leads to increased seaweed breakoffs (escapes) into the seafloor. | Inability to determine the weather conditions and preparedness for harvesting and processing in alternative sites for freshwater access. | Lower quality of harvested red seaweed due to salt concentration in dried commodity. |

Table 9.24. List of climatic hazards (FDG #1).

| <b>Non-Climate-related hazards: Theft/security, limited healthy seed bank nursery access, and limited awareness of seaweed commodity quality and standards.</b> |                 |                        |                    |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|------------------------|--------------------|
| Direct Impact                                                                                                                                                   | Indirect Impact | Other Causes of Impact | Impacted Resources |



|                                                              |                                                                                                                                                  |                                                                                                         |                                                                                                                                    |
|--------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| Theft/security                                               | Mistrusting relationships among fishers, tour guides and nearby island residents. It takes a fisherman to catch a fisherman in the act of theft. | Loss of Seaweed Farmers' motivation and discontinuation of seaweed farming maintenance.                 | Loss of income from harvested red seaweed and loss of farming infrastructure.                                                      |
| Limited healthy seed bank nursery access                     | Increase harvesting of wild red seaweed species.                                                                                                 | Increase the spread of the same propagated red seaweed species and more vulnerable to seaweed diseases. | Limited opportunities to enter niche markets with diseased seaweed crops.                                                          |
| Limited awareness of seaweed commodity quality and standards | High prices for approval in red seaweed value-added products development.                                                                        | Inability to expand seaweed value-added products and access international markets.                      | Loss of returns in value-added products investments due to lack of approved nutritional benefits on labels (eg. Patented products) |

Table 9.25. List of non-climatic hazards (FDG #1).

While Tables 9.23 and 9.24 outlined the range of climatic and non-climatic hazards affecting seaweed farms, Table 9.26 presents a more detailed analysis of the threats and the underlying reasons these challenges remain insufficiently addressed.

| List threats to seaweed farming:               | Reasons for not addressing threats:                                                                                                           | If threats are not impacting seaweed farms, describe risks:                                                                            |
|------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| Theft/security                                 | Poor communication amongst the seaweed farming community in the Placencia Peninsula.                                                          | Poor knowledge exchange and loss of indigenous knowledge.                                                                              |
| Scarcity of red seaweed seeds                  | Limited finance opportunities to establish a red seaweed species nursery site and farming production sites.                                   | The collapse of wild seaweed stocks in the reef may lead to longer distances to acquire seeds for restocking farming production sites. |
| Seaweed break-off & end up around seaweed farm | Lack of physical barrier infrastructure around seaweed farms to capture any seaweed that has broken off the parent crop on cultivation lines. | Loss of seaweed commodity income and lower productivity of farms (unable to see returns from investments).                             |
| Freshwater access on farming sites to rinse    | Limited access to finance to secure freshwater sources.                                                                                       | Loss of returns from seaweed farms. Culturally, the markets                                                                            |

|                                                                                                            |                                                                                                                                                                                                  |                                                                                                                                                                                                                                             |
|------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| seaweed before drying treatment                                                                            | Normally rainwater is captured but droughts during the dry season (ideal time for growing red seaweed) make it difficult to rinse seaweed on sites.                                              | may not be inclined to accept red seaweed with sea salts.                                                                                                                                                                                   |
| Grant dependency on red seaweed farming operations, processes and development of value-added products      | The traditional way of applying for grants needs to be written differently and allow part-time workers (eg. labor wages payment that is no more than 60% of the person's salary can be covered). | When grant cycles close or come to completion, the farm maintenance stops due to the high cost of logistics and transportation to farm sites.                                                                                               |
| Lack of trust in grassroots communities involved in red seaweed farming and donors                         | Poor communication amongst the seaweed farmers' community.                                                                                                                                       | Very limited outreach to seaweed farming communities with genuine interest to help seaweed farmers (eg. fishers/seaweed farmers can receive aid in conducting patrols for the enforcement of policies and reduce losses in seaweed farming. |
| Provision of farming operation expenses for logistics and transportation to and from seaweed farming sites | Seaweed farmers are currently changing their perception from farming in clusters to individual ventures into experimental farming.                                                               | Disconnection of seaweed farming activities for long periods due to lack of project manager.                                                                                                                                                |

Table 9.26. List of threats to seaweed farms (FDG #1).

Table 9.27 presents the analysis of hazards and the corresponding response strategies currently adopted by seaweed farmers, as well as proposed long-term responses to enhance seaweed mariculture activities in Placencia.

| Hazards                          | Current Responses                                                                                                                                  | Long-Term Responses                                                                                                            |
|----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| Hurricanes/storms/floods/runoffs | Short-term relocation of seaweed farms to deeper zones to prevent loss of seaweed during ocean turbulence.                                         | Change of seaweed mariculture techniques from floating rafts to submerged square rope plots with an appropriate anchor system. |
| Seawater temperature increase    | Installation of buoy systems that can adjust to the sea depth where seaweed farms are growing. This allows seaweed farms to dwell in cooler areas. | Farming of red seaweed species that are more resilient to seawater temperature such as those non-native red seaweed species.   |

|                                                   |                                                                                                                                                          |                                                                                                                                                                        |
|---------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Extended periods of drought during the dry season | Establishing water catchment systems by filling water tanks (recycled 55 gallons) from the mainland to take to camping sites on islands.                 | Monitoring of ocean weather and environmental conditions (ie. Self-observation and temperature loggers).                                                               |
| Theft/security                                    | Consistent visits to red seaweed farming sites and regular harvest intervals between planting and farm maintenance.                                      | Lobbying with international and local NGOs to co-create grant applications to access enforcement financing for the protection of seaweed farming sites.                |
| Healthy seed bank nursery access                  | Currently red seaweed farms are acting as seed banks to expand production sites. Red seaweed species are propagated and placed on new cultivation lines. | Informal social networks amongst seaweed farmers to share seeds for starting up of seaweed farms especially when a high amount of cultivated seaweed species are lost. |
| High red seaweed commodity quality and standards  | Red-cultivated seaweed has no quality standards as yet, but seaweed farmers are farming in pristine reef waters and maintaining high quality of crop.    | Consistent nutrient testing on red-cultivated seaweed species to maintain the high quality and standards of exported seaweed commodities.                              |

Table 9.27. Analysis of hazards and their current responses and long-term responses (FDG #1).

Table 9.28 presents the main external hazards and threats identified by seaweed farmers, highlighting institutional, economic, and operational challenges that influence the sustainability of seaweed mariculture in Placencia (FDG#1).

| External Hazards/Threats to Seaweed Farms |                                                                                                                                                                                                                                                               |
|-------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1                                         | Displacement of local seaweed farmers in the local economy: Interference of multimillionaire companies (25% Internationally - owned. 75% Belizean owned) in the seaweed mariculture industry.                                                                 |
| 2                                         | Complex legislation system governing seaweed mariculture activities: Inclusion of seaweed farmers for the revision of updated policies and farming manuals.                                                                                                   |
| 3                                         | Miscommunication in seaweed farming community: Poor knowledge and skills exchange opportunities to connect seaweed farmers.                                                                                                                                   |
| 4                                         | Red seaweed quality and standards: Belizean seaweed commodity by Food and Drug Administration (FDA) approval.                                                                                                                                                 |
| 5                                         | Poor enforcement for southern Belize: Need for partnerships with local NGOs, private island owners and the seaweed farming community on the ground for policing and island camping. Full-time security is required for seaweed farms (high operational cost). |

|   |                                                                                                                                                                                                        |
|---|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 6 | Misinterpretation of local adaptation strategies: Build awareness of Belize's national climate change adaptation through seaweed farmers' consultation.                                                |
| 7 | Ineligibility of seaweed farmers to access blue bond funding opportunities: Need for financing with marine NGO & Seaweed groups calls for proposal.                                                    |
| 8 | Inappropriate gears for farming: Seaweed farmers lack proper gears for working long hours in the sea under new climatic conditions such as skin protection gears against sun rays and epiphyte stings. |

Table 9.28. External hazards/threats to seaweed farms (FDG #1).

Table 9.29 presents the future perspectives of seaweed farmers regarding the sustainability and scaling up of seaweed farming operations in Placencia, with particular emphasis on infrastructural, financial, and policy-related needs identified during the focus group discussion.

|                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-----------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Current scale of operation</b><br>1=Very small;<br>2=Small;<br>3=Medium;<br>4=Mixed;<br>5= Large | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Resources needed to scale up farming operations</b>                                              | <ul style="list-style-type: none"> <li>• Seaweed farming finance opportunities for the further development of farming infrastructure and processing units for drying and value-added product development experimentation.</li> <li>• Revision of existing strategies and update of policies in seaweed mariculture in order for seaweed farmers to be informed of current legislative changes.</li> <li>• Require clarification of mariculture policy when it comes to the commercialization of red seaweed species at a large/industrial scale.</li> <li>• There is need for seaweed farming daily tools and gears. This can be purchased through grants and personal investment.</li> <li>• Growing and processing seaweed for specific markets may have different standards such as if shipped to the USA it will need to follow Food and Drug Administration (FDA) legal requirements.</li> <li>• There are no scientific documentation and record keeping of seaweed farming operations and indigenous knowledge. There needs to be accounts of what has been learnt so far from past initiatives. It is important to know this for scaling up.</li> <li>• Limited use of technology for management of farming operations, crop calendar cycles and monitoring of the environmental conditions such as radio, GPS, camera, seawater thermometer, etc.</li> </ul> |

|                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                               | <ul style="list-style-type: none"> <li>• There is need to develop disaster reduction strategies for seaweed farms such as ways to reduce debris entangling on the ropes, new tying techniques (tie-knot) and anchor systems on the base of floating rafts.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Challenges that may be faced in scaling up operations:</b> | <ul style="list-style-type: none"> <li>• Belize Women Seaweed Farmers Association (BWSFA) have experienced poor communication with government offices to understand the conditional offer in export permit and marine research permit.</li> <li>• Rules and regulations from government seem to be a blur as there is no solid program assigned to BWSFA. Belize Fisheries Department appears to have different rules depending on conditional offers to specific operations.</li> <li>• There is no clear understanding of the marine research permit terms and conditions. Seaweed farmers believe that they can't legally retail seaweed from the farms under the International NGO marine research permit.</li> <li>• There is no natural protection for the seaweed farms as it is located in an open channel between two Cayes (Little Water Caye and Ray Caye). This makes seaweed farms vulnerable to breakage from destructive impacts of wave action.</li> <li>• Limited technical support to seaweed farmers.</li> <li>• Strong policy duration with the blue economy but limited outreach on the ground.</li> <li>• Limited capacity for seaweed farmers to apply for seabed leasing.</li> <li>• Need to establish seaweed raw quality and standards with Belize Agriculture and Health Authority (BAHA) and Belize Bureau of Standards (BBS) especially for the local and export market.</li> <li>• Lack of space for seaweed farmers to share ideas and innovation in order to establish a culture of experimenting and research, especially where fishing/seaweed farming communities have developed deep relationships.</li> <li>• Monitoring and quantification of environmental benefits of seaweed farms. Seaweed acts as nurseries by providing seaweed shade in areas where there are only sandy bottoms habitats. Seaweed farms help to cool the sea floor for other marine creatives to live in such as the Caribbean Queen Conch.</li> <li>• Lack of processing facilities for drying processing and packaging of seaweed commodities. There is need for equipment and innovation such as creating controlled environments for dehydrating seaweed.</li> <li>• Limited access to a niche market with a high price for red seaweed commodities to use in cosmetics and pharmaceutical/nutraceuticals but require rebranding of high-quality cultivated red seaweed (eg. boutique farms).</li> <li>• There is a need to put in place Health and Safety policies for seaweed farmers, especially those who work in the field full</li> </ul> |

|                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                        | <p>time. There are limited efforts in skin and eye protection to avoid long term impacts. Sunglasses are not worn when seaweed farmers are out in the sea farming and doing farm maintenance activities.</p> <ul style="list-style-type: none"> <li>• There is a need to establish a laboratory and training to help seaweed farmers test water quality and seaweed species genetics. This will help to further development expertise in site selection and species selection for farming.</li> <li>• Consolidating and updating strategies used in the past and new strategies employed in farming sites.</li> <li>• Addressing the illegal fishing activities in the southern Belize is a big challenge that the government needs to invest in such as illegal fishing from Guatemala and Honduras. Enforcement needs to strengthen by paying the marine park rangers more and have one of the rangers work with BWSFA to secure the seaweed farms.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Training that may be needed for future employment in the seaweed farming sector</b> | <ul style="list-style-type: none"> <li>• There is need to develop formal training such as training of the trainers in order to have a sustainable transfer of knowledge to future generation</li> <li>• Developing a reporting system and getting trained to report hazards and incidents in the working environment to human health and safety such as accidents that may occur on the boats or in the farms.</li> <li>• Training on seaweed farming site selection based on ecological indicators and in accordance with marine spatial plan.</li> <li>• Training on better management practices in dealing with red seaweed escapees, especially when working with non-native species.</li> <li>• Seaweed farmers' cooperative/association training in red seaweed algae farm bookkeeping, administrative and finance operation of the clusters in the industry.</li> <li>• Organic exchange programs for planting and handling of red seaweed species to counterpart a support system for seaweed mariculture activities.</li> <li>• Seaweed mariculture trade expo with the international community to meet with potential investors and partners such as in Taiwan.</li> <li>• Need to train the women's farming group how to apply for the blue sustainable funds.</li> <li>• Training is needed to understand the entire seaweed mariculture value chain including all the permits that are needed to farm, develop value-added and market access.</li> </ul> |
| <b>Seaweed farming future policy direction</b>                                         | <ul style="list-style-type: none"> <li>• Community-based adaptation and ecosystem-based approach to new livelihood options that act as nature-based solutions to climate change in the marine environment. For example, it is important to link red seaweed mariculture to</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

|  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | <p>nature-based solutions in vulnerable coastal communities to climate change impacts.</p> <ul style="list-style-type: none"> <li>• Consistent seaweed sample testing for heavy metals and nutrients.</li> <li>• Development of a national database of seaweed species for farming opportunities including proper genetics testing results and precise species identification.</li> <li>• Opportunity to improve farming practices to further develop knowledge and value-added product development. This would help to motivate existing members in the women's group and spark new interest of other women.</li> </ul> |
|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

*Table 9.29. Future perspectives of seaweed farming sustainability (FDG #1).*

Table 9.30 provides the contact information of the lead seaweed farmer from the Belize Women Seaweed Farmers Association (BWSFA), identified during the focus group discussion for future communication and validation purposes.

| <b>Name</b> | <b>Position</b> | <b>Organization</b>                              | <b>Email</b>        |
|-------------|-----------------|--------------------------------------------------|---------------------|
| Jalima Gold | Secretary       | Belize Women Seaweed Farmers Association (BWSFA) | bwsfa2019@gmail.com |

*Table 9.30. Contact information of lead seaweed farmer (FDG #1).*

### 9.5.3 Focus Group Discussion 2: Placencia Village (Male Group)

A total of six participants attended the male focus group, with ages ranging from 32 to 63 (mean age of 47) on the 19th of June 2023. The occupation varied for the participants included: 1. tour guide (2); 2. caretaker (1); 3. construction worker (1); 4. boat captain (1) and researcher (1). The discussion commenced by mapping the boundaries of their community and resources, supported by a facilitator (Figure 9.13.). The CRiSTAL toolkit guiding this discussion can be found in the next section of this appendix, 9.5.4 (FDG #2).

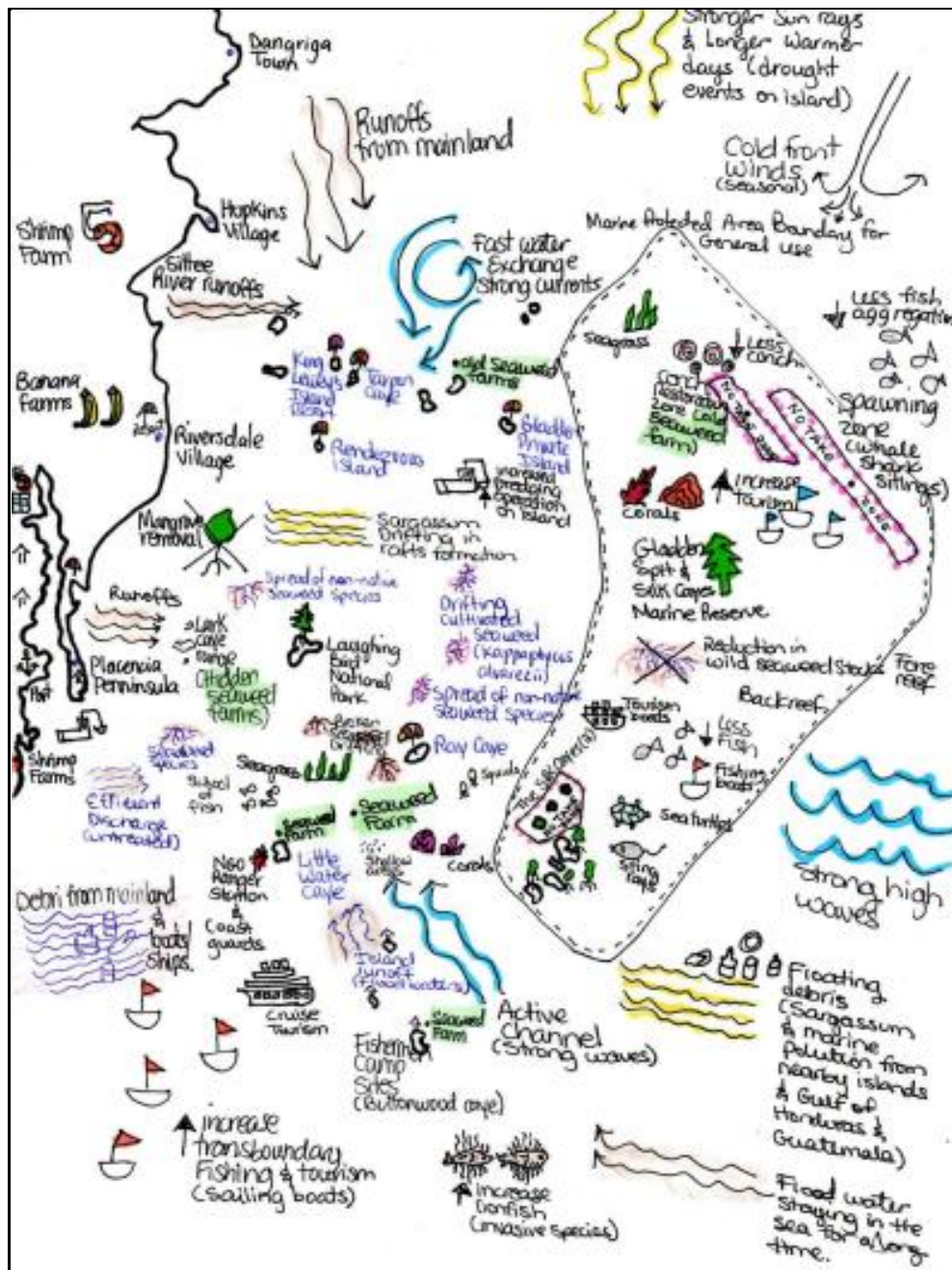


Figure 9.13. Visual Resource Map with male focus group (Placencia Village) (Author's own elaboration).

**Key points:** The map above (Figure 9.13) shows the Gladden and Split Cayes Marine Reserve in southern Belize where a group of seaweed farmers farm their red seaweed species in the vicinity of the Barrier Reef System. Participants identified both climatic and non-climatic



factors impacting their seaweed farms. As the seaweed crop was farmed 10 to 14 miles from the coastline, their seaweed was considered ‘reef waters’ seaweed.

The following livelihood resources were listed and prioritized in Table 9.31.

*Livelihood resources*

| <b>Livelihood Categories</b> | <b>Livelihood Resources</b>                                                                                                                                                                                  |
|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Social                       | <ul style="list-style-type: none"> <li>• Training programs for students and international participants in seaweed farming</li> <li>• Island owners, NGOs, and government authorities’ network</li> </ul>     |
| Natural                      | <ul style="list-style-type: none"> <li>• Healthy ocean environment</li> <li>• Healthy red seaweed seeds</li> </ul>                                                                                           |
| Physical                     | <ul style="list-style-type: none"> <li>• Freshwater</li> <li>• Transportation</li> <li>• Farming infrastructure and tools</li> <li>• Processing facilities and market</li> </ul>                             |
| Financial                    | <ul style="list-style-type: none"> <li>• Grant and personal investment</li> <li>• Consistent income from seaweed sales</li> <li>• Market</li> </ul>                                                          |
| Political                    | <ul style="list-style-type: none"> <li>• Permits and licenses</li> <li>• Institutional support</li> </ul>                                                                                                    |
| Cultural                     | <ul style="list-style-type: none"> <li>• Healthy spirituality when connected with the ocean (positive)</li> <li>• Family-bonding livelihood</li> <li>• Traditional seaweed-based food supplements</li> </ul> |

*Table 9.31. Key livelihood resources from focus group discussion 2 in Placencia (Author’s own elaboration).*

The following key points emerged in the discussion among male participants, about their livelihood resources:

The male focus group discussion on seaweed farming in southern Belize, revealed that the participants have extensive experience working with red seaweed species such as *Eucheuma isiforme*, *Gracilaria crassissima*, and *Kappaphycus alvarezii*. Each individual farmer focuses on farming one or two seaweed species. The participants identified essential skills such as construction skills and farming techniques employed depending on the location of the farms, the nature of the environment and seasonal weather patterns that were important in that area.

Training was received prior to engaging in seaweed farming where participants learnt how to set up and maintain farm infrastructure in the ocean. Mental stability and a positive attitude were identified as crucial for overcoming challenges like adverse weather and market fluctuations, emphasizing psychological resilience. Participants shared their health and safety skills, including cardiopulmonary resuscitation (CPR) and first aid, and experience with working with tourists or students.

Moreover, social assets highlighted by participants included their current collaboration with various stakeholders including students, E-NGO-led marine protected areas rangers, private island owners, and the Belize Fisheries Department (BDF). The diverse range of stakeholders brings together different perspectives, expertise, and resources, creating a robust support network that enhances the seaweed farmers' effort in building and expanding farms in the ocean. For example, participants discussed their experience in training programs for both students and international participants, as they expressed their strong commitment to knowledge sharing and capacity building. These training initiatives enhanced the skills of the farmers, promoted continuous learning, and cultivated a community of skilled workforce capable of engaging in seaweed farming practices. These short training courses also brought additional fundings and advocacy that have contributed to driving positive changes in the respective farms of the members in the Placencia Producers Cooperative Society Limited (PPCSL). Though not explicitly mentioned, participants revealed how their current engagements with the private sector, investors, and market partners have helped in accessing resources, expanding markets, and creating growth opportunities for the seaweed farming sector.

Natural assets play a pivotal role in supporting and influencing seaweed farming activities. They emphasized the importance of good environmental conditions, seaweed beds, and the importance of natural barriers provided by coral reef and mangroves resources for successful seaweed cultivation. Participants provided examples of how their farms require a healthy ocean environment with suitable water quality and conditions. Particularly, one participant shared how mangroves act as natural barriers crucial for capturing seaweed fragments broken off nearby seaweed farms and how their seaweed farms have provided other species a habitat, protection, and food source.

Regarding water quality, they shared how important full strength sea water (ie. 35 PPT in salinity) and good exchange of nutrients in the water column can impact seaweed growth and development. Additionally, this discussion addressed certain seaweed species' adaptability to nearshore brackish water conditions, but they understood the salinity tolerance for each and how this determines site selection and production optimization. Environmental concerns were shared as participants expressed the need for continuous environmental monitoring and protection of the seaweed farms from runoffs, land-derived pollution/debris drifting, coastal and island dredging, and all types of effluent discharge from the coastal areas including those from banana and shrimp farms especially during a flood. Participants understood how crucial it is for preserving natural resources and ecosystem health for sustaining their livelihood activity, displaying a heightened sense of environmental stewardship.

The importance of physical resources in supporting the infrastructure, equipment, and perceived optimal growing conditions necessary for cultivating seaweed was emphasized. They mentioned specific farming locations such as Little Water Caye and Lark Caye, where seaweed has been cultivated red seaweed species at least for the past decade. Proper infrastructure, including submerged anchors, rope-made square plots using tie-tie method, to enhance stability and security of seaweed crops where needed in some areas. Potential sites for establishment of seed bank sites were discussed which included locations like Laughing Bird Caye National Park. Additionally, participants mentioned the use of mangroves at Lark Caye as natural barriers to capture seaweed fragments and prevent them from reaching sensitive ecosystems such as coral reefs. Although not explicitly mentioned, essential equipment such as boats, harvesting tools, and monitoring devices were implied as critical for efficient seaweed farming operations.

Financial resources were deemed crucial for covering operational expenditures, investing in infrastructure and equipment, and ensuring overall economic viability. They emphasized market development for the *Kappaphycus* species, focusing on both export and local sales to generate revenue. The participants also addressed how important it is to diversify income

streams, especially during the transition from fishing to tourism-based businesses while still engaged in seaweed farming activities. Cost management was considered vital, with strategies like relocating farms closer to the mainland to reduce transportation expenses. Participants underscored challenges such as lack of financial support, theft, and market access, indicating the need for funding opportunities and supportive mechanisms. Effective pricing strategies for wet and dried seaweed products were discussed as essential for attracting buyers and maximizing profitability. Although not explicitly mentioned, investment in infrastructure and equipment was implied as necessary for enhancing productivity and efficiency in seaweed farming operations.

Lastly within the livelihood's assets, cultural resources play a vital role in preserving traditions, knowledge, and values integral to the community's identity and livelihood. Seaweed is an important part of traditional diet and food systems and has been used in dishes such as soups and stews. Seaweed shakes and gel are also part of this culinary practice, reflecting intergenerational knowledge. Participants shared personal anecdotes illustrated how seaweed farming was deeply rooted in their cultural identity, with knowledge and skills passed down through generations. Particularly, one participant shared their childhood memories of their father involved in wild harvesting seaweed for the local market and having to manually remove any debris from the thallus. This post harvesting processing technique was done with the entire family of which the wild seaweed was placed on top of tarps spread on the beach and left for sun drying. This was a type of community engagement in seaweed farming activities during the late nineteenth century to the early twentieth century and laid the foundation to fostering social cohesion and collective responsibility. The preservation of cultural heritage associated with seaweed farming, including traditional practices and culinary uses, was deemed essential.

#### *Hazards: Frequency, Duration, Intensity, Impacts, and Resources Impacted*

Participants engaged in discussions about the concerns and perceptions of the seaweed farming industry for the second focus group discussion with regard to the main hazards (Table 9.32.).

| <b>Hazards</b>       | <b>Frequency</b>     | <b>Duration</b> | <b>Intensity</b> | <b>Description of Direct/indirect impacts on seaweed farms</b>   |
|----------------------|----------------------|-----------------|------------------|------------------------------------------------------------------|
| Theft                | Ongoing              | Continuous      | High             | Object and income loss (↑)<br>Disruptions in farm operations (↑) |
| Debris/<br>Sargassum | Twice per year       | June – November | Medium to High   | Infrastructural damages (↑)<br>Ocean soil fertility (↓)          |
| Storms/Floods        | 1 - 3 times per year | June - November | Medium to High   | Infrastructural damages (↑)<br>Object and income loss (↑)        |

|                                                             |            |            |          |                                                            |
|-------------------------------------------------------------|------------|------------|----------|------------------------------------------------------------|
| Limited market channels and uncertainties in meeting demand | Periodic   | Variable   | Moderate | Income instability and financial uncertainties (↑)         |
| Regulatory Complexity Issues                                | Occasional | Short-term | Moderate | Administrative burdens and additional compliance costs (↑) |

*Table 9.32. Key hazards and resources identified in focus group discussion two (2) in Placencia Village (Author's own elaboration).*

The following were the key discussion points in the male focus group discussion:

In the second focus group discussion, participants highlighted several key hazards that directly impacted their farming operations. Theft emerged as a critical issue with a high intensity and continuous occurrence, raising concerns about the security and economic viability. Theft negatively affects market access and opportunities for the participants, thereby impacting sales and competitiveness. Participants shared that they had suspicion of individuals from the community that may be involved in theft which adds complexity to the situation, leading to fallouts between fishing/seaweed farming community, financial losses and disruptions in farm operations. Moreover, participants expressed how stolen seaweed does not only represent a loss of resources but also a forfeiture of cultivation efforts, further exacerbating economic strain on individual farmers and farming groups. The disruption of production schedules and farm operations due to theft leads to delays in harvesting and cultivation activities, impeding participants' capacity to meet market demands and fulfill orders. Additionally, the theft strains relationships and trust within the community, creating more social challenges which may have hindered collaboration among the fishing/seaweed farming community and neighboring villages. Participants raised alarms of stolen seaweed in the community as a security measure in sensitizing a local surveillance system like the neighborhood watch program out in the sea. Even though these theft reports have been reported to local authorities, police in mainland would be unable to do patrols and rely on the Coast Guards for improving security out in the sea but this does not involve patrolling around areas where seaweed farm resided.

Moreover, there were several environmental challenges identified as hazards, sometimes occurring on a seasonal basis like Sargassum and debris drifting (marine pollution), storms and floods that lead to runoffs of flooded rivers (high turbidity). Sargassum and debris drifting into seaweed farming areas emerged as a significant issue in environmental issues, with pollution impacts necessitating proper waste management practices and preventive measures to curb debris accumulation in the marine environment. Participants expressed how their previous farming method of floating rafts was not the best method during seasons with high influxes of Sargassum mixed with debris. Moreover, runoff from nearby rivers, such as the Sittee River and Mango Creek, was another concern, as this affected the water quality crucial for seaweed farming. Participants emphasized the importance of monitoring mainland runoff to seaweed farms, responsible pesticide and insecticide use, and measures to safeguard water quality. Incidence of flooded rivers occurred during heavy storm events, particularly hurricanes. However, participants pointed out how erosion from the islands near seaweed farms also contributed to magnifying the impacts of storms. Furthermore, the conservation of marine biodiversity was underscored, with participants advocating for the protection of wild seaweeds, coral reefs, mangroves, and other critical habitats through responsible farming practices and conservation efforts.

Participants highlighted limited market channels due to uncertainties in supplying seaweed to meet market demand which have significantly impacted seaweed farming operations in several ways. Restricted market access hindered participants' ability to sell dried seaweed crops due to the quantities available for sales, thus limiting revenue streams and business growth. This presented production planning challenges making it difficult to optimize cultivation and harvest schedules. Participants shared how these market limitations in meeting demand have reduced their opportunities for partnerships and product differentiation. To add, participants also shared how uncertainties in demand further impacted access to market information, trends, and consumer preferences, limiting participants' ability to adapt marketing strategies and capitalize on opportunities.

Regulatory complexity issues, though occasional and of moderate intensity, were recognized as hazards affecting the legal standing of seaweed farms operations due to lack of permits and compliance with regulatory authorities. Participants expressed how these regulatory complexities have created administrative burdens and additional compliance costs by having to hire expertise. Participants were very concern about potential dominance of external companies interested in farming seaweed in Belize being facilitated by the Belize Fisheries Department (BFD) and Lands Department. This added to the participants' uncertainties regarding land tenure and resource competition, of which participants felt the need for community advocacy to protect the interests of local seaweed farmers.

By recognizing and addressing these hazards, participants elaborated on ways they developed proactive response strategies for resilience-building measures to safeguard their seaweed farms in the ocean. Below expands on the coping strategies employed to each hazard.

#### *Coping strategies*

For each hazard, and correspondent impact, participants identified their current coping strategies, assessed the extent of their sustainability, and eventually proposed alternative strategies, assuming availability of resources, which could be employed to cope more sustainably with those hazards.

| <b>Hazard</b>         | <b>Current Responses</b>                                                                                                                                                   | <b>Long-Term Responses</b>                                                                                                                                                                             |
|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Theft                 | Consistent and longer stays on farming sites.                                                                                                                              | Hire security for seaweed farms to stay on site 24/7.                                                                                                                                                  |
| Ocean warming         | Buoy systems can adjust autonomously depending on the depth of red seaweed farms. It can adjust the location of farms from shallow to deeper areas with less human effort. | Farming of red seaweed in deeper waters where miscellaneous macroalgae growth on cultivation lines can slowly grow while preventing the spread of any water stress disease on the seaweed crop itself. |
| Storms/Floods/Runoffs | Don't lose everything. Move red seaweed into mangrove areas then move back to commercial areas.                                                                            | Install red seaweed farms near mangrove-rich areas.                                                                                                                                                    |

|                             |                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             |
|-----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                             | Sink red seaweed farms to deeper depths in natural holes in the seagrass meadows (including removal of buoy systems) and anchor to the sea floor to protect from ocean surface turbulence.                                                                                                    | Move red seaweed farms permanently to the mangrove range rather than reef water areas where ocean turbulence is higher during tropical storms or hurricanes.                                                                                                                                                                                |
| Strong winds                | Place a proper anchor system to hold cultivated and anchor lines onto the sea floor (steel and iron).                                                                                                                                                                                         | New red seaweed farming techniques such as submerged rope systems with buoy systems or tubular nets on the ocean floor.                                                                                                                                                                                                                     |
| Strong ocean waves/currents | Install an underwater barrier mesh net around the farms.                                                                                                                                                                                                                                      | Relocation of red seaweed farms to areas that have natural physical barriers that protect seaweed on cultivation lines from breaking off due to strong ocean currents.                                                                                                                                                                      |
| Market Fluctuations         | Diversified market channels, partnered with local vendors, and participated in industry events to boost visibility. They explored value-added products for niche markets, requiring ongoing effort.                                                                                           | Use of the cooperative marketing platform, supporting interests in market research, and developing long-term contracts with buyers to ensure stable market access and pricing, enhancing long-term sustainability.                                                                                                                          |
| Regulatory Issues           | Engaging with regulatory authorities, ensuring compliance with permit requirements, and seeking legal advice to navigate regulatory complexities. Some have formed advocacy groups to collectively address regulatory concerns. These efforts are essential but may require ongoing advocacy. | Ensure consistent and transparent communication channels with regulatory bodies, while reengaging interest in policy development, and advocating for streamlined permits. Also, promoting investing opportunities in capacity-building for compliance and fostering government partnerships could ensure sustainable regulatory management. |

*Table 9.33. Main Coping Strategies (short and long-term responses) to Hazards (Author's own elaboration).*

The following coping mechanisms were highlighted to each hazard:

The participants in the second focus group revealed theft as one of the major hazards. The participants responded to this hazard was to implement security measures such as increased local surveillance, community patrols, and securing farm equipment. Some of the participants have explored the idea of insurance options to cover potential losses from theft incidents. In the long term, participants have learnt to cope more sustainably with theft, participants

proposed investing in advanced security systems like hiring a security on site and encouraging a community watch program out at sea with other fishers and island owners. Establishing stronger community partnerships and engaging local authorities for increased monitoring and enforcement could enhance long-term security measures.

Moreover, participants identified four major climatic factors as hazards which include ocean warming, storms/floods, strong winds, and strong waves action directly impacting their seaweed farms in the ocean. Even though participants have actively engaged in monitoring environmental conditions in the past such as water quality, testing seaweed crop for nutrients and toxins, conducting regular clean-up efforts to remove debris, there is so much that funding can support for a long period of time of which these monitoring have stopped. Participants were only focused on reinforcing their farm structures in the ocean floor to withstand seasonal impacts. This is why they have shifted farming techniques over the past decade including shifting their interests in the type of seaweed species being farmed and choosing faster growing seaweed. With some of the student groups from abroad, some participants were able to implement water quality testing for wells on islands and erosion control measures to prevent runoffs from islands. Therefore, as long-term responses, participants have invested in more secure infrastructure designs, such as submerged farms and used natural protective barriers, to minimize the impact of environmental challenges and for seaweed to grow more naturally. Participants have also been using eco-friendly practices, like using biodegradable materials and promoting ecosystem restoration through their seaweed farms.

Furthermore, participants were able to diversify their market channels by establishing partnerships with local vendors and participating in industry events to increase market visibility. Some have also explored value-added product development to attract niche markets. As for long term responses participants have been able to address market access challenges in a very strategic way by using their cooperative marketing platform to collectively promote seaweed products, investing in market research to identify emerging trends, and developing long-term contracts with buyers to ensure stable market access and pricing.

Regarding regulatory issues, participants have been engaging with regulatory authorities, ensuring compliance with permit requirements, and seeking legal advice to navigate regulatory complexities. Some have formed advocacy groups to address regulatory concerns collectively. As for long term responses, participants have established consistent and transparent communication channels with regulatory bodies, participating in policy development processes, and advocating for streamlined permit procedures. Participants have also advocated for the need to invest in capacity-building for regulatory compliance and fostering partnerships with government agencies could lead to more sustainable management of regulatory issues.

Participants shared their concern of foreign investment in seaweed farming of which participants have already initiated dialogue with Belize Fisheries Department as to how ensure there is a fair playing field with external companies and possibility to negotiate fair partnerships. Participants proposed strengthening community ownership of seaweed farming initiatives, establishing clear land tenure agreements, and promoting inclusive decision-making processes. Developing social impact assessments and fostering partnerships with social organizations could enhance long-term resilience to social challenges.

By tackling these hazards and challenges with a mix of short-term actions and long-term responses, participants in the second focus group have shared their efforts to ensure the seaweed farming industry have a strong presence in their community to last longer in the years to come and for their children to adapt their practices and achieve overall success.

#### 9.5.4 CRiSTAL Toolkit: Seaweed Producers FDG #2 (Male Group)

Table 9.34 provides the description of second focus group (FDG #2) held with male seaweed producers from the Placencia Producers Cooperative Society Limited (PPCSL) in Placencia Village.

|                         |                                                         |
|-------------------------|---------------------------------------------------------|
| <b>Group Name:</b>      | Placencia Producers Cooperative Society Limited (PPCSL) |
| <b>Location:</b>        | Placencia                                               |
| <b>Language spoken:</b> | English                                                 |
| <b>Date:</b>            | 19 <sup>th</sup> June 2023                              |
| <b>Start Time:</b>      | 4:30 PM                                                 |
| <b>End Time:</b>        | 7:00 PM                                                 |

Table 9.34. Description of second focus group (FDG #2).

Table 9.35 summarizes the community profile of the seaweed producers from the Placencia Producers Cooperative Society Limited (PPCSL), outlining demographic, operational, and ecological aspects of the seaweed farming sites in southern Belize.

|                                                                                           |                                                                                             |
|-------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| <b>Number of seaweed producers (s):</b>                                                   | 5                                                                                           |
| <b>Name of registered seaweed cooperative (s)/ association (s)/community group (s):</b>   | Placencia Producers Cooperative Society Limited (PPCSL)                                     |
| <b>Name of unregistered seaweed group (s):</b>                                            | 3 independent seaweed farmers                                                               |
| <b>Locations of seaweed farm (s)- (sketch it):</b>                                        | Placencia range and surrounding area around Gladden Spit Silk Cayes Marine Reserve (GSSCMR) |
| <b>Number of years farming in the specified sites listed:</b>                             | 10+ Years                                                                                   |
| <b>List of cultivated seaweed species on sites:</b>                                       | <i>Kappaphycus alvarezii</i> and <i>Eucheuma isiforme</i>                                   |
| <b>Estimated amount of seaweed farmed (in dry weight, pounds unit):</b>                   | 1000 LBS Dry Weight                                                                         |
| <b>Historical land use prior to seaweed farming:</b>                                      | Fishermen/private owners and ranger's campsites                                             |
| <b>Site selection process for farming seaweed in the specific locations listed above:</b> | Mangrove habitat and active water current exchange                                          |



|                                               |                                                                                                               |
|-----------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| <b>If apply, reasons for site relocation:</b> | Relocated from Little Water Caye to Placencia range due to closer distance to land (more affordable for fuel) |
|-----------------------------------------------|---------------------------------------------------------------------------------------------------------------|

Table 9.35. Seaweed farming community profile (FDG #2).

Table 9.36 presents the business environment for seaweed farming, highlighting the initial investment required, economic conditions for investment, labor composition, and institutional support mechanisms among seaweed producers in Placencia.

|                                                                                                                              |                                                  |
|------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|
| <b>Investment needed to start a seaweed farm (US dollars):</b>                                                               | E-NGO Grant Seeds capital and personal financing |
| <b>Economic conditions for investing in seaweed farming: 1= Poor; 2= Satisfactory; Good; 4=Very Good; 5= Other (specify)</b> | 2= Satisfactory                                  |
| <b>No. of individuals/families working on seaweed farms:</b>                                                                 | 2 persons per farm sites                         |
| <b>Government &amp;/or NGO processes in accessing any resources or subsidies for farming seaweed:</b>                        | No                                               |

Table 9.36. Identification of seaweed farming resources and accessibility (FDG #2).

Table 9.37 presents the list of livelihood capitals and resources identified by male seaweed farmers during the second focus group discussion (FGD #2).

| <b>Capitals</b> | <b>Livelihood resources</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Human</b>    | <ul style="list-style-type: none"> <li>• Good health</li> <li>• Positive attitude and mentality</li> <li>• Good mental health</li> <li>• Good diet (Nutrition)</li> <li>• Boat and navigation skills</li> <li>• Survival and first aid skills (e.g. Cardiopulmonary resuscitation (CPR) skills)</li> <li>• Seaweed cultivation skills in installing farms and setting up sun drying tables (eg. Rope ties)</li> <li>• Swimming skills</li> <li>• Good work etiquette</li> <li>• Communication skills to sort out license applications for livelihood activities</li> <li>• Site selection expertise for seaweed farming on windward coast</li> <li>• Able to judge the weather conditions and now when to go farm, this is sea smart skills</li> </ul> |

|                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Social</b>   | <ul style="list-style-type: none"> <li>• Field students during summer breaks from universities</li> <li>• Listening to radio forecast from Meteorological Centre such as reliance on weather forecast for coastal conditions</li> <li>• Rangers from Marine Protected Areas (MPAs)</li> <li>• Seaweed tour guides from local tour guide operators in Placencia</li> <li>• Reciprocity, family and friends' exchanges</li> <li>• Marine NGO support in seaweed farming activities in Little Water Caye Rangers Station (eg. Southern Environmental Association)</li> <li>• Support from Island owner (eg. Resorts and family-based tourism businesses/fishermen campsites) to farm seaweed farms nearby privately owned islands</li> <li>• Good relationship with the government and regulatory agencies by keeping communication open</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Natural</b>  | <ul style="list-style-type: none"> <li>• Healthy ocean environment</li> <li>• Healthy seagrass beds</li> <li>• Good and rapid nutrient exchange</li> <li>• Moderate water current (not destructive impacts of wave action on seaweed crop on cultivated lines)</li> <li>• Good practices on island waste management for sewage and garbage disposal (eg. not throwing plastics in the ocean)</li> <li>• Mixed sea bottoms (white sand has higher reflection)</li> <li>• Good seawater temperature (around 86°F)</li> <li>• Healthy red seaweed seeds for replenishment of farms</li> <li>• There are 2 to 3 varieties of red seaweeds such as in red and yellow colorations (appearing as spaghetti-like yellow color).</li> <li>• Cultivated seaweed species include <i>Eucheuma isiforme</i> and <i>Kappaphycus alvarezii</i></li> <li>• <i>Gracilaria crassissima</i> is not cultivated as much compared to before.</li> <li>• <i>Chondrus crispus</i> is another potential seaweed species that is not farm but can be found in the wild on the rocks at the reef</li> <li>• Appropriate intensity of sunlight to help red seaweed to photosynthesize</li> <li>• Offshore reef protects the seaweed farms on the windward side of the islands</li> <li>• Wild seaweed stocks in Glovers Reef</li> </ul> |
| <b>Physical</b> | <ul style="list-style-type: none"> <li>• Farming practices include vegetable propagation (cuttings)</li> <li>• Clean fresh water to wash seaweed (eg. Rainwater)</li> <li>• Transportation fuel to and from seaweed farming sites (around 5-10 gallons round trip)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

|                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                  | <ul style="list-style-type: none"> <li>• Water VAT systems or 60 Gallon Drums to hold fresh water</li> <li>• Materials for farming infrastructure (eg. Ropes, anchors, buoys)</li> <li>• Swimming gears</li> <li>• Camping Gears (camping tent/ cooking equipment)</li> <li>• Food and drinking water supply during camping periods</li> <li>• Security phones and flashlight during camping on islands</li> <li>• Racks for sun drying seaweed and wheelbarrow from moving it from the farm site to the processing area</li> <li>• Global Positioning System (GPS) for identifying submerged seaweed farms</li> <li>• Infrastructure for seaweed cleaning and drying of red-cultivated seaweed species</li> <li>• Good sanitation</li> </ul>                                                                                |
| <b>Financial</b> | <ul style="list-style-type: none"> <li>• Grant (seed capital)</li> <li>• Fuel money</li> <li>• Labor wage</li> <li>• Rent gears</li> <li>• Boat maintenance</li> <li>• Buy seaweed/seeds</li> <li>• Food money</li> <li>• Camping gears such as tent</li> <li>• Private investment</li> <li>• Local Market</li> <li>• Small international market</li> <li>• Yearly fees for license application to conduct tourism and fishing livelihood activities</li> <li>• Yearly seagrass bed leasing application (\$100.00 BZ per acre) for commercial seaweed farm operations.</li> </ul>                                                                                                                                                                                                                                            |
| <b>Political</b> | <ul style="list-style-type: none"> <li>• Mariculture farmers permit to farm red seaweed species in the ocean</li> <li>• Gentle man agreement in ocean seabed access and use</li> <li>• Boat license for commercial and tourism with Port Authority</li> <li>• Fishermen license, shark license, and special fishing license with Belize Fisheries Department</li> <li>• Export license for seaweed from Belize Fisheries Department</li> <li>• Sea cucumber license</li> <li>• Tour guide license</li> <li>• Belize Tourism Boat License</li> <li>• Seaweed mariculture cultivation manuals provided by the Placencia Producers Cooperative Society Limited (PPCSL) and The Nature Conservancy (TNC)</li> <li>• Belize National Mariculture Policy</li> <li>• Belize Ocean Economy Plan and Manage Access Program</li> </ul> |

|                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Cultural</b>                                                             | <ul style="list-style-type: none"> <li>• Open and positive mentality when working in seaweed farming</li> <li>• Healthy spirituality when connected with the ocean</li> <li>• Wild seaweed harvesting encouraged family bonding in past</li> <li>• Hand-wash-hand mentality when working in the ocean</li> <li>• Seaweed is a part of the food culture in fishing communities</li> <li>• Seaweed has been traditionally used as porridge meals</li> <li>• Socialize on camping sites/bonding amongst seaweed farmers/fishers on sites</li> <li>• Traditional knowledge about when the seasons change and the wind direction such as south wind from October to June and east wind from June to September</li> <li>• Gel-making from red seaweed is the traditional way locals add to value-added of raw sundried seaweed</li> <li>• Creole dialect, English and Spanish language amongst seaweed farmers</li> </ul> |
| <b>Knowledge &amp; information</b>                                          | <ul style="list-style-type: none"> <li>• Weather forecasting-sea smart skills in determining weather conditions such as tides, trade winds, rain, etc.</li> <li>• Being a fisherman comes with a wealth of knowledge on the ocean through self-observation</li> <li>• Placencia historical fisheries industry and transition into red seaweed cultivation in the last 20+ years</li> <li>• Indigenous knowledge of seaweed resources and uses</li> <li>• Ecological observations of marine creatures living in seaweed farms</li> <li>• The first seaweed farming training was conducted by Dr. Allan Smith from Caribbean Natural Resources Institute (CANARI) in 2005 and the same farming practices from then are still done amongst the farmers in southern Belize.</li> <li>• Dr. Allan Smith taught the fishermen in southern Belize that seaweed should be in the mangroves.</li> </ul>                      |
| <b>Innovation</b>                                                           | <ul style="list-style-type: none"> <li>• Red seaweed farming installation with buoy and anchor systems such as new methods that create nursery habitats for marine creatures with high commercial value</li> <li>• Manual processing and packaging of red seaweed species for niche food, cosmetics and health and wellness markets</li> <li>• Red seaweed shipping services with ideal conditions to store dried seaweed for long periods during transportation from Belize to international markets</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Flexible forward-looking discussion (decision-making and governance)</b> | <ul style="list-style-type: none"> <li>• Solar systems and small inverters for electricity access on camping sites</li> <li>• Drying houses and clean sanitary areas for drying of red seaweed</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

|  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | <ul style="list-style-type: none"> <li>• Drone patrol for securing seaweed farms (prevention of theft)</li> <li>• Mainstreaming of seaweed farmers in Belize to be involved in the co-creation of policies such as the national climate change adaptation plan, blue economy policy and mariculture guidelines.</li> <li>• Red seaweed-based traditional food/drinks awareness along with nutritional benefits</li> <li>• Private sector, financial institutions and government collaboration are required to future establish local long-term strategies in financing.</li> <li>• Strengthen stakeholder relationship with the government by validating on the ground challenges faced by seaweed farmers by informing government authorities For example, fishermen are not being credited for informing authorities</li> <li>• Poor communication with the Government and seaweed farming and fishing community.</li> </ul> |
|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Table 9.37. List of seaweed farming resources (FDG #2).

Table 9.38 presents the top three hazards affecting seaweed farms identified during the second focus group discussion (FGD #2), including climate-related risks, their duration, frequency, intensity, and associated impacts on seaweed farms.

| Hazards           | Frequency                   | Duration        | Intensity      | Description of Direct/indirect impacts on seaweed farms           |
|-------------------|-----------------------------|-----------------|----------------|-------------------------------------------------------------------|
| Theft             | Four to Five times per year | 1 Day           | High           | Object & income loss (↑)<br>Cultivated seaweed loss (↑)           |
| Sargassum influx  | Throughout the year         | All year round  | Medium to High | Increased infrastructural damages (↑)<br>Ocean soil fertility (↓) |
| Storms and Floods | Three times per year        | June - November | Medium to High | Increased infrastructural damages (↑)<br>Object & income loss (↑) |

Table 9.38. List of top three hazards to seaweed farms (FDG #2).

Table 9.39 presents the list of seaweed farming training received by male seaweed farmers during the second focus group discussion (FGD #2), including the skills acquired,

environmental-related challenges addressed, and benefits gained through group knowledge exchange.

| Name of training (as labelled on certificate)       |                                                                                                    |                                                                                                                                    |
|-----------------------------------------------------|----------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| List of knowledge and skills acquired in training:  | List of environmental-related challenges addressed in training:                                    | Benefits received from training in a group set-up and knowledge exchange with seaweed farmers:                                     |
| Seaweed Mariculture Cultivation Training            | Better Management Practices in Seaweed Farm Maintenance and Processing.                            | Seaweed farmers have been able to establish pilot plots and develop relationships with other seaweed farmers in informal networks. |
| Fishermen exchange program with Colombia and Belize | Good fishing practices and use of sustainable innovation and technologies in the fishing industry. | Fishermen from Belize and Colombia established a long-term relationship in promoting good fishing practices in the Caribbean Sea.  |

Table 9.39. List of seaweed farming training (FDG #2).

Table 9.40 summarizes the climatic hazards (including climate-related risks) affecting seaweed farms, while Table 9.41 summarizes the non-climatic hazards, including their duration, frequency, intensity, and impacts on seaweed farms.

| Climate-related hazards: Increase seawater temperature, drought, debris and sargassum influx                      |                                                                                                      |                                                                                                                                                            |                                                                                     |
|-------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Direct Impact                                                                                                     | Indirect Impact                                                                                      | Other Causes of Impact                                                                                                                                     | Impacted Resources                                                                  |
| Increase seawater temperature (seawater warming) with light reflection from white sandy bottoms on seaweed farms. | Alteration of microbial communities in seaweed farms.                                                | Increase events of red seaweed die-offs (resembles the phenomenon of <i>ice-ice</i> seaweed disease) and breakoffs of cultivated red seaweed into the sea. | Reduction in harvested cultivated red seaweed.                                      |
| Extended periods of drought                                                                                       | High evaporation rate on the sea surface and perceived seawater salinity increases in farming sites. | Inability to rinse cultivated red seaweed with fresh water from the rain (drying process with sea salt).                                                   | Reduction of price on dried red seaweed due to high sea salt crystal concentration, |
| Increase drift logs, debris,                                                                                      | Sargassum influx passes over the surface if farms are submerged but end up                           | Increase of macroalgae species on cultivation ropes and                                                                                                    | Destruction of red seaweed farming infrastructure and                               |

|                      |                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                          |                                                             |
|----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|
| and Sargassum influx | in the mangroves. This is where the Sargassum settles at the bottom of the sea floor and decomposes. During this decomposition process, it creates an anoxic environment preventing anything to live and grow such as seagrass, juvenile fish and shellfish except. | anchors (unidentified macroalgae that are pulled off the farming infrastructure during maintenance operations and these hand-weeded macroalgae may have a market value, but this remains to be unknown). | reduction of equipment lifespan (eg. degradation of ropes). |
|----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|

Table 9.40. List of climatic hazards (FDG #2).

| <b>Non-Climate-related hazards: Unintentional non-compliance with existing policies and laws in seaweed mariculture, limited research and development (R&amp;D) and knowledge management and financial opportunities transfer to farmers to sustain seaweed farming operations.</b> |                                                                                                                                          |                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                     |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Direct Impact                                                                                                                                                                                                                                                                       | Indirect Impact                                                                                                                          | Other Causes of Impact                                                                                                                                                                                                          | Impacted Resources                                                                                                                                                                                                                                                                                                                                  |
| Lack of awareness or understanding of the policies and laws governing the red seaweed mariculture sector.                                                                                                                                                                           | Limited awareness may result in inadequate adherence to these standards, posing risks to the quality and safety of red seaweed products. | Limited awareness of international trade regulations and market standards may create barriers to market access for red seaweed products. Failure to meet regulatory requirements can restrict exports and market opportunities. | Increased investment uncertainty due to security related issues on farm sites. Access to seabed leasing permits creates uncertainty for investors looking to enter or support the red seaweed mariculture sector. This uncertainty may deter potential investments, hindering the industry's capacity for innovation and technological advancement. |
| Limited financial and marketing mechanisms for ongoing capacity-building training and farming operations                                                                                                                                                                            | Irregular visits to red seaweed farming sites for maintenance and shorter stays during camping.                                          | Loss of motivation and commitment of seaweed farmers to continue farming operations due to high fuel cost and inability to access markets due to lack of marketing skills.                                                      | Inconsistency in seaweed production and supply to the markets                                                                                                                                                                                                                                                                                       |

|                                                               |                                                                                                                                                                                             |                                                                                                                                                                   |                                                                                                                                     |
|---------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Limited research and development (R&D) in seaweed mariculture | Limited funds are available for R&D in red seaweed mariculture especially in value-added product development at an experimental stage.                                                      | Limited knowledge of red seaweed species in the wild and other valuable macroalgae species (limited opportunities for diversification in seaweed farming species) | Loss of indigenous knowledge on seaweed resources and poor marine biology/ science connection to onsite monitoring in seaweed farms |
| Loss of a seaweed leader/pioneer in the industry              | Increase involvement of supranational organizations which have led to the interference/ influence of seaweed farming practices and funding opportunities along the red seaweed value chain. | Limited knowledge and technology transfer opportunities.                                                                                                          | Figuring out how to continue supplying seaweed to local and international markets.                                                  |

Table 9.41. List of non-climatic hazards (FDG #2).

Table 9.42 presents the main hazards and threats to seaweed farms identified during the second focus group discussion (FGD #2), including the underlying reasons for not addressing these threats and the potential risks if they remain unresolved

| List hazards/threats to seaweed farming: | Reasons for not addressing threats:                                                                                                                                                                                                                                                                                                         | If threats are not impacting seaweed farms, describe risks:                                                                                                                                                                                                                                                                                                                                 |
|------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Theft/piracy                             | Camp for only a few days (3-5 days) near seaweed farms such as on islands managed by private owners (e.g. Resorts and family-based tourism businesses) and non-governmental organization rangers and field research stations. Seaweed farms are left unsupervised for a few days/weeks until the next visit for maintenance and harvesting. | Loss of income and materials: piracy of all seaweed resources including red seaweed seeds and farming infrastructure can lead to the collapse of individual seaweed farming plots. All materials can be lost gradually over a period or overnight such as the removal of all cultivating ropes and buoys from the sea. This requires the seaweed farmer to replant (starting from scratch). |



|                                                                                                                               |                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                 |
|-------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sea temperature increase                                                                                                      | Move red seaweed farms to deeper sites in the seagrass meadows.                                                                                                                                                                                    | Establish new farming techniques at the sea floor between 6 to 10 feet in depth where cool seawater thrives with enough sunlight penetration.                                                                                                                   |
| Drift log/debris/sargassum influxes                                                                                           | Manually remove debris/drift logs and sargassum from anchor ropes and buoys along with collecting seaweed breakoffs around the seaweed farm.                                                                                                       | Relocate seaweed farms near mangroves where natural barriers exist to keep away debris while submerging seaweed farms near these nutrient-rich areas.                                                                                                           |
| Disconnection of seaweed farmers in social networks: Seaweed farmers aren't active in the social development of the community | Some farmers assume that others might come in contact with them just to thief their supplies and ideas. This makes seaweed farmers prioritize their privacy and secure their data such as at the Cooperative Department headquarters.              | Capacity building in person and virtual events is becoming more frequent but tend to focus on specific groups in the country. However, Government should host an event annually for all farmers to come out and greet each other.                               |
| Shorter lifespan of ropes: Cultivating ropes is made from biodegradable material to prevent ghost fishing or marine pollution | Removal of ropes from farming sites so to prevent marine pollution. After 5 years, ropes are no longer useful to farmers.                                                                                                                          | Durable ropes for cultivation and anchor specialized for seaweed farming. Use softer ropes as cultivating lines so the ropes do not to cut the delicate seaweed thallus and prevent any breakoffs.                                                              |
| Middlemen entering the market                                                                                                 | The market is open to all. Chinese businessmen are entering the market as middlemen by purchasing seaweed from the locals and supplying international market. Middlemen have obtained export license but are not obligated to be a seaweed farmer. | The risk in this transaction is that a black market is created. Folks can supply middlemen seaweed without knowledge of where the seaweed is collected whether it is cultivated or from the wild. This also opens up markets for stolen seaweed from producers. |
| Mono-cultivation cultivated seaweed species may lower genetic diversity and increase susceptibility to diseases and pests.    | There are three common red seaweed species farmed in Belize. These include, <i>Eucheuma isiforme</i> , <i>Kappaphycus alvarezii</i> and <i>Gracilariia crassissima</i> . Normally a farmer would focus on farming one species                      | Participants believed that farms with multiple species may experience interbreeding. Seaweed species appear to look different than the first time when seaweed species were planted. The genetic pool of                                                        |

|                                                 |                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                             |
|-------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                 | if it is performing better in a specific environment. This leads to mono farming so any changes in water quality parameter would affect the productivity of the farm.                                                                                                                                        | seaweed species may be changing but in areas where mono farming is being practiced it may be more susceptible to <i>ice-ice</i> seaweed disease and epiphytes.                                                                                                              |
| <i>Eucheuma isiforme</i> is scarce in the wild. | There is no protection of seedlings sites to safeguard species from individuals wild harvest or stealing. For example, Tobacco Caye had a lot of wild <i>Eucheuma isiforme</i> but now it is extinct. This needs to be considered in the ongoing marine spatial plan for Belize. It is currently overlooked. | Scarcity of wild seaweed from different species especially <i>Eucheuma</i> is a threat to future expansion of the seaweed industry in Belize. Even though seaweed farmers have where to find their seedling, there is still needed to protect wild sites such as Twin Caye. |

Table 9.42. Hazards/threat to seaweed farms (FDG #2).

Table 9.43 presents the analysis of hazards and their current responses and long-term responses in the second focus group discussion (FDG #2).

| Hazards               | Current Responses                                                                                                                                                                          | Long-Term Responses                                                                                                                                                                                    |
|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Theft                 | Consistent and longer stays on farming sites.                                                                                                                                              | Hire security for seaweed farms to stay on site 24/7.                                                                                                                                                  |
| Ocean warming         | Buoy systems are able to adjust autonomously depending on the depth of red seaweed farms. It can adjust the location of farms from shallow to deeper areas with less human effort.         | Farming of red seaweed in deeper waters where miscellaneous macroalgae growth on cultivation lines can slowly grow while preventing the spread of any water stress disease on the seaweed crop itself. |
| Storms/Floods/Runoffs | Don't lose everything. Move red seaweed into mangrove areas then move back to commercial areas.                                                                                            | Install red seaweed farms near mangrove-rich areas.                                                                                                                                                    |
|                       | Sink red seaweed farms to deeper depths in natural holes in the seagrass meadows (including removal of buoy systems) and anchor to the sea floor to protect from ocean surface turbulence. | Move red seaweed farms permanently to the mangrove range rather than reef waters areas where ocean turbulence is higher during tropical storms or hurricanes.                                          |

|                             |                                                                                                       |                                                                                                                                                                                                        |
|-----------------------------|-------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Strong winds                | Place a proper anchor system to hold cultivated and anchor lines onto the sea floor (steel and iron). | New red seaweed farming techniques such as submerged rope systems with buoy systems or tubular nets on the ocean floor. This avoids extreme loss of seaweed due to destructive impacts of wave action. |
| Strong ocean waves/currents | Install an underwater barrier mesh net around the farms.                                              | Relocation of red seaweed farms to areas that have natural physical barriers that protect seaweeds on cultivation lines from breaking off due to strong ocean current                                  |

Table 9.43. Analysis of hazards and their current responses and long-term responses (FDG #2).

Table 9.44 presents analysis of external hazards/threats to seaweed farms.

| External Hazards/Threats to Seaweed Farms |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1                                         | Sewage waste runoffs to near-shore seaweed farms may pose a threat to the health of cultivated seaweed. The lack of sewage treatment systems in the Placencia Peninsula is a concern as sewage waste waters may seep into the sea and bioaccumulated in sea plants especially nearby-seaweed farms.                                                                                                                                                                                                                    |
| 2                                         | Brown seaweed waste on the seafloor may be a threat as Sargassum is perceived to create toxic environment where no life can live due to sunlight blockage and limited oxygen availability. The chemical changes in the water quality may influence the cultivated seaweed species but this remains unknown.                                                                                                                                                                                                            |
| 3                                         | Climate Change is a major threat along with the impacts of ocean warming and acidification ( $H_2CO_3$ ) on the marine environment and biodiversity such as ocean acidification affecting the shell of lobster and other shell species. It is unknown how ocean acidification and warming actually affected seaweed biology. So far pseudo data from the discussions with seaweed farmers have shared that seaweed species have shown to be robust especially with some seaweed species performing better than others. |
| 4                                         | Biodegradable farming infrastructure such as ropes used for cultivating and anchor lines may have a short life span (less than 5 years duration) in the ocean at full strength seawater (35 PPT). The biodegradable farming infrastructure may become a threat to marine life because it may break down into microplastics and contribute to marine pollution.                                                                                                                                                         |
| 5                                         | Indigenous knowledge of open ocean navigation along with seaweed resources and uses. For example, the loss of indigenous knowledge from the seaweed pioneers, such as Mr. Lowel 'Japs' Godfrey. His passing away in 2021 created a 'dent' in the farming activities in southern Belize that led to the loss of productivity on seaweed farms due to the fact that Japs was the main worker bee on site and stay 2 weeks camping near seaweed farming sites.                                                            |

|    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 6  | Poor enforcement of seaweed mariculture legislation: Weak institutional capacity and outreach to involve seaweed farmers in decision-making such as in the assemblage and implementation of national climate change adaptation policy, blue economy strategy plan and policy, mariculture policy and seaweed mariculture farming guidelines.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 7  | Debris destruction to seaweed farm infrastructure is becoming an increasing threat due to extreme weather events such as storms and hurricanes. Even the short-term responses to combat the impacts of destructive wave action such as physical barriers that are submerged may not work effectively and seaweed can still be broken off from the cultivation ropes and drift around seaweed farms.                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 8  | New entrants into the marketplace (ie. mega companies) is a major threat to the seaweed industry led from grassroots because locals won't be able to afford to compete especially if the seaweed-based products are cheaper than the grassroots seaweed farming projects. Moreover, local Belizean people are not able to afford permits so it would be different for them to be a part of the seaweed business if not supported by grants and government initiatives to subsidies different product and services.                                                                                                                                                                                                                                                                                                                 |
| 9  | Unsustainable practices of wild harvesting seaweed are a threat to future expansion of seaweed farms as these genetically rich wild seaweed stocks are traded cheaper and removed completely from the reef with their root system still attached to rocks and inability to regrow. Fishers and tour guides may wild harvest small quantities of seaweed to supply the local market demand based on sales order rather than for personal home use. These unsustainable efforts have increased over the past years by business opportunists to supply the local seaweed-based businesses that are eager to buy seaweed at a cheaper price while all the cultivated seaweed is exported international to fetch higher prices in niche markets thus leaving the local market without. This opens up the risks of a black mark as well. |
| 10 | Limited awareness of policies and laws in Red Seaweed Mariculture Industry. Even if Mariculture Policies exist along with laws in fisheries resources management and rights exist on paper, ineffective law enforcement can undermine their practical implementation. Insufficient resources, corruption, or lack of capacity in enforcing agencies can contribute to the inability to address theft incidents.                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 11 | Limited access to red seaweed commercial farming permits and export permits for international markets.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 12 | Increasing insecurity challenges in seaweed farming such as no legal rights to seabeds and unable to report theft events. The absence of a comprehensive regulatory framework for granting legal rights to seabeds and addressing theft events can exacerbate the problem. A clear and enforceable legal framework is essential to establish ownership rights and define penalties for                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 13 | Limited on-site support to seaweed farming operations hinders further development of social networks between NGOs, government and seaweed farmers. Policies may include guidelines for engaging with local communities, obtaining necessary permits, and respecting traditional practices. Limited awareness may strain relationships with local communities, leading to social conflicts and reputational risks.                                                                                                                                                                                                                                                                                                                                                                                                                  |

|    |                                                                                                                                                                                                                                                                                                                                                      |
|----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 14 | Limited Surveillance and Monitoring is a threat. Without adequate surveillance and monitoring mechanisms, it becomes challenging to detect and report theft events. Lack of technology, such as satellite monitoring or patrol systems, can make it easier for unauthorized activities to go unnoticed.                                              |
| 15 | Community Disempowerment is a threat to the sustainability of the industry especially in cases where local communities are not empowered or informed about their rights to the seabeds. Locals may face challenges in reporting theft incidents or asserting their legal claims. Empowering communities with knowledge and legal support is crucial. |

Table 9.44. Analysis of external hazards/threats to seaweed farms (FDG #2).

Table 9.45 provides a summary of the second seaweed producers' focus group sessions and their future perspectives of seaweed farming sustainability in Placencia Village.

|                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Current scale of operation</b><br>1=Very small;<br>2=Small;<br>3=Medium;<br>4=Mixed;<br>5= Large | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Resources needed to scale up farming operations</b>                                              | <ul style="list-style-type: none"> <li>• Finance and market penetration of red seaweed commodity.</li> <li>• Improving red seaweed quality through extended drying periods (needs to be longer for proper dehydration of cultivated seaweed)</li> <li>• Red seaweed-based value-added products development through experimentation such as Shake gels</li> <li>• Red seaweed innovation hub for improving better farming practices</li> <li>• Red seaweed food competition for awareness of nutritional benefits and use of seaweed commodities in local and international households</li> <li>• Develop a contingency plan for farmers to access when there is bad harvest. This can be a support financial package for loss of earnings and financial loss.</li> <li>• There is need to establish a seaweed hub to conduct screening and testing of seaweed commodity for export market such as conducting assessments for determining metals and nutrients content in seaweed. This would help to establish quality and standards.</li> <li>• Establish a strong market for cultivated seaweed species and prices to work on a patented formula to help the country of Belize to export metal-free sun-dried seaweed. For example, it is important for seaweed samples to be free of arsenic and cadmium when using freshwater well on islands that may be contaminated.</li> <li>• Resources are needed in expand markets for seaweed-based value added such as to the Mennonites communities in rural Belize that do livestock husbandry and are interested in</li> </ul> |

|                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|---------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                               | <p>experimenting seaweed as a key ingredient in the diets of cows. Another example mentioned was to tap into markets that are interested in using sargassum or <i>Kappaphycus alvarezii</i> in bioenergy production.</p> <ul style="list-style-type: none"> <li>• Grassroots need someone that they can trust both top down and bottom-up with superior interest and the grassroots people trust.</li> <li>• Participants expressed that that Lark Caye Range has the potential to be a seed bank for the country. The Sargassum that settles around this area settles near seaweed patches of which the seaweed grows good around decaying sargassum as a source of nutrients.</li> <li>• Seaweed species cultivated in Belize has different growth rate. For instance, <i>Kappaphycus alvarezii</i> grows five times faster than <i>Eucheuma isiforme</i>. Investment in expanding <i>Kappaphycus alvarezii</i> would be the best as it as shown to adapt to different temperatures of the ocean and has grown the fastest despite the increase wind and water turbulence over the past 10 years.</li> <li>• There is need to investment in field research to understand the crop calendar for seaweed commodity. Seaweed farmers expressed that good time to plant is September to November, but this depends on the location.</li> <li>• Seaweed farmers have expressed that they have the market but don't have the volume to supply the amount customers want. Seaweed farmers conduct their own private marketing operations to get their product on the market.</li> <li>• There is a strong dependency on foreign help (aid) and grants to develop seaweed farms, but the cost of operation is increasing such expenditures include; petrol cost to go out to the farms is correlated with the distant from mainland to the farm and labor wage to the people planting and doing maintenance. Currently, labor wages for seaweed farm workers are \$50.00 BZD per day with a meal.</li> </ul> |
| <b>Challenges that may be faced in scaling up operations:</b> | <ul style="list-style-type: none"> <li>• There is no clear communication channel available between the farmers, NGOs and government with updated information relating to the sea conditions and the climate and making this easier for farmers to access before they start planting.</li> <li>• Changes in seaweed mariculture progress in the formulation of policies and laws was a concern to participants as seaweed farmers were eager to learn more about ocean space legal access to safeguard their livelihood for long term benefit of the industry.</li> <li>• Ongoing development of a legal framework on the requirement seaweed farmers need to uphold with government in tenure agreements/ownership of seaweed farm and permits and licenses for wild harvest as seed stock</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

|  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | <p>replenish and carrying out seaweed cultivation activities in the ocean.</p> <ul style="list-style-type: none"> <li>• Need to create a sustainable commercial cultivation for the export of seaweed commodities to the international market.</li> <li>• Poor development of appropriate institutional systems for technical support of seaweed farms in the planning and responding to climate change impacts in the ocean environment.</li> <li>• High barriers and costs for market entry in the development of seaweed-based value-added products in the cosmetics and pharmaceuticals sector.</li> <li>• No access to credit or microfinance opportunities to invest into seaweed farmers especially in the expansion to sites closer to mainland in order to keep cost down.</li> <li>• No access to blue bond credit because seaweed farmers don't make the eligibility criteria that has been developed by Belize Sustainable Funds. TNC sits as the chair person in the board for the management of funds and blue credit.</li> <li>• Grant (seeds) dependency for the startup and operation of seaweed farms</li> <li>• Economic independence is lacking as the locals don't have the knowledge to design and manage their own seaweed business compared to the wealth of knowledge in environmental NGOs and funding that they have available for seaweed.</li> <li>• Lack of economic independence amongst seaweed farmers operating in clusters such as associations or cooperatives</li> <li>• Poor consultation regarding the creation of a commercial seaweed farming permit</li> <li>• Seaweed export license issued out to middlemen and not farmers which promotes piracy</li> <li>• Bribery and corruption that are conducted under-the-table transactions</li> <li>• Lack of economic incentives in seaweed farming discouraging investment in the seaweed mariculture industry.</li> <li>• Seaweed farmers' healthcare programs for long-term sustainability.</li> <li>• Nutrient-rich seaweed medicines require technological advances and investments.</li> <li>• Need proper marine radio for communication amongst seaweed farmers/fishers</li> <li>• High cost for the affordability of satellite phone and service fees</li> <li>• Blue economy policy is perceived as a strategy to take away livelihood options for coastal inhabitants and islanders.</li> <li>• Seaweed mariculture policy is not communicated to seaweed farmers.</li> </ul> |
|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

|                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                        | <ul style="list-style-type: none"> <li>• Seaweed preservative in bags (transparent and sealed/vacuum packed) that are FDA approved in the US is required.</li> <li>• Assessment of true realization of seaweed mariculture industry including investigation of FDA requirements</li> <li>• No regulation in selling seaweed.</li> <li>• No evidence of seaweed commodity source on the market which may require a sustainable harvested seaweed certification for the future.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Training that may be needed for future employment in the seaweed farming sector</b> | <ul style="list-style-type: none"> <li>• Training in seaweed farm protection for a proactive approach to ocean farmers' neighborhood watch program for seaweed farms in the vicinity of southern Belize.</li> <li>• Training in Natural Disasters (hurricanes, tropical storms, sea-level rise, ocean warming and acidification) Preparedness, Response and Recovery.</li> <li>• Training in the cultivation of red using recent seaweed better management practices (BMP) especially in the processing of red seaweed commodity for niche markets such as pharmaceuticals/nutraceuticals, cosmetics and the food/beverage sector. Train local communities to sell to seaweed cooperatives then export to international markets.</li> <li>• Training in the treatment of red seaweed disease (prevention and cure practices) especially during the summer.</li> <li>• Exchange program and training are needed to build capacity of seaweed farmers to adopt practices from other countries such as good management practices in red seaweed cultivation such as in the Caribbean Small Islands and Developing States.</li> <li>• Everyone must abide by the Belize Fisheries Resource Act, but the laws are not being executed in terms of enforcement and research (marketing and environment). A lot more training in this area of research and development is needed to strengthen the market and enhance the marine biodiversity through good management practices in seaweed farming.</li> <li>• There should be government-led initiatives that conduct research on the ground to provide technical support to farmers but even the Fisheries officer need to be trained to offer this service.</li> <li>• The Belizean seaweed farmers are very independent and creative with an ambitious mindset; however, they seek government assistance in training and consulting to strengthening branding and certification of products and services. Other training courses can be focused on sharing information on patenting, registering designs, trademarks, service marks and copyright as evidence of creation and protection.</li> </ul> |



|                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Seaweed farming future policy direction</b> | <ul style="list-style-type: none"> <li>• Formalizing Natural Disasters Preparedness, Response and Recovery Plan.</li> <li>• Red seaweed cultivation manuals with updated legislation and permit procedures for starting up and maintaining seaweed mariculture infrastructure and supplying good quality seaweed commodities.</li> <li>• If the government were meant to invest in the seaweed farming livelihood this could have double the output of seaweed production and it would allow seaweed commodity to the country's Gross Domestic Product (GDP).</li> <li>• Government-led initiatives could help to regulate the market price through the Bureau of Standards protocols by making it competitive. This may be a cause to increase seaweed production and have seaweed commodities readily available in the local market at a reasonable market price.</li> <li>• The reputation of Belizeans involved in the seaweed business is seen as a hobby rather than a business making opportunity. The expectation of the seaweed farming projects that are grant-led varies across the community. It is necessary to integrate business models into the planning of future seaweed farm expansions in traditional fishing and farming communities.</li> <li>• Cross government and sectoral collaboration in developing a policy to incentives the seaweed mariculture industry including clear procedures in ocean seabed permits for seaweed farmers to have ownership rights (lease agreement from Government) to use a specific area for red seaweed algae cultivation. A seaweed farmer mentioned that this cost \$100 Belize Dollars per acre but the cost of this still unclear.</li> </ul> |
|------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

*Table 9.45. Future Perspectives of seaweed farming sustainability (FDG #2).*

Table 9.46 provides future communication with lead seaweed farmers.

| <b>Name</b>  | <b>Position</b> | <b>Organization</b>                             | <b>Email</b>                         |
|--------------|-----------------|-------------------------------------------------|--------------------------------------|
| Wilbur Dubon | Manager         | Placencia Producers Cooperative Society Limited | wilbur.dubon@placencia-producers.com |

*Table 9.46. Future communication with seaweed farmers (FDG #2).*

### 9.5.5 Focus Group Discussion 3: Riversdale Village (Female Group)

A total of three participants attended the female focus group, with age ranging from 28 to 55 (mean age at 37) on the 28<sup>th</sup> of July 2023. The occupation varied for all participants, as follows: 1. fisherwoman (2); and 2. Landlord/businesswoman (1). The female participants started their discussion by plotting the boundaries of their community, supported by a facilitator, as shown in Figure 3. The CRiSTAL toolkit guiding this discussion can be found in the next section of this appendix, 9.5.6 (FDG #3).

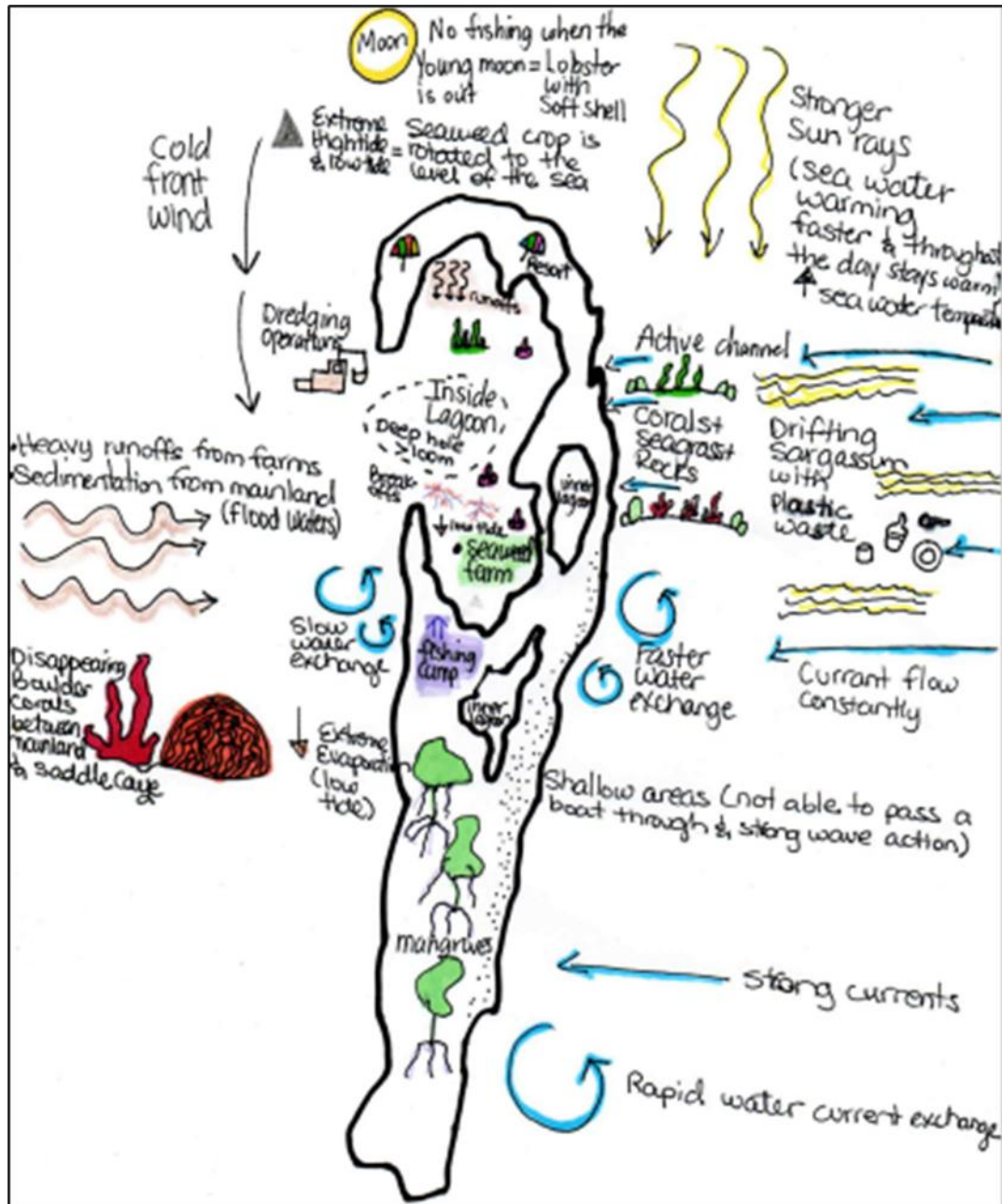


Figure 9.14. Visual resource map with female focus group (Riversdale Village) (Author's own elaboration).

**Key points:** Participants actively engaged in creating a visual resource map, depicting the environment they are currently conducting their seaweed farming activities. Female participants experienced enhanced understanding, visually highlighting crucial elements pertinent to seaweed farming. This representation deepened their comprehension of climatic factors that have impacted their natural resources and non-climatic factors such as island

developments for tourism that have added to challenges faced within their farming area. Through mapping their surroundings, participants identified and documented available resources for seaweed farming, including areas with suitable water conditions, access points, potential threats, and significant zones for their farming endeavors. Drawing the map was an enlightening experience for the participants as they were able to share their perspectives on how their community and livelihood activities have been operated under the current circumstances in Figure 3.

#### *Livelihood resources*

The visual resource mapping exercise engaged participants to further elaborate on the livelihood resources required for them to do their seaweed farming activities. The following resources were listed and prioritized (Table 9.47).

| <b>Livelihood Categories</b> | <b>Livelihood Resources</b>                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Human                        | <ul style="list-style-type: none"> <li>• Good health and nutrition</li> <li>• Safety skills such as CPR and boat navigation and basic maintenance</li> <li>• Practical skills for swimming</li> </ul>                                                                                                                                                                                                                                                                |
| Social                       | <ul style="list-style-type: none"> <li>• Family support</li> <li>• Fishing community support</li> <li>• Seasonal engagement with environmental research</li> <li>• Partnership and networking with environmental NGOs.</li> </ul>                                                                                                                                                                                                                                    |
| Natural                      | <ul style="list-style-type: none"> <li>• Identification of suitable areas for seaweed farming, considering factors like water conditions and access points</li> <li>• Wild seaweed stocks</li> <li>• Island facilities</li> </ul>                                                                                                                                                                                                                                    |
| Physical                     | <ul style="list-style-type: none"> <li>• Investment in boats and engines for transportation and farming activities</li> <li>• Startup commenced when ropes were bought from a family member</li> <li>• Net bags for seedlings</li> <li>• “Family House” on both Caye equipped with kitchen (gas stoves) and sleeping area</li> <li>• Space on the island for sun drying seaweed</li> <li>• Transportation by car for seafood deliveries to nearby resorts</li> </ul> |
| Financial                    | <ul style="list-style-type: none"> <li>• Personal funds for all investments including boats and engines for farming operations</li> <li>• Ownership of residential homes and family island</li> </ul>                                                                                                                                                                                                                                                                |
| Political                    | <ul style="list-style-type: none"> <li>• Engagement with consultants and policymakers for understanding legal requirements and policy direction for seaweed farming</li> <li>• Boat and fishing license</li> </ul>                                                                                                                                                                                                                                                   |
| Cultural                     | <ul style="list-style-type: none"> <li>• Passing down knowledge and stories about seaweed and fishing practices through generations (knowledge shared could be 4<sup>th</sup> generation by now).</li> <li>• Promoting a seaweed festival in Riversdale to celebrate the cultural significance of seaweed in their community</li> </ul>                                                                                                                              |

*Table 9.47. Key Livelihood Resources from Focus Group Discussion 3 in Riversdale (Author's own elaboration).*

The following livelihood resources were highlighted in the woman focus group discussion:

Participants indicated a desire for greater advancement of research and development in fully functioning small-scale seaweed farming in the inner lagoons of the islands where they reside. However, there were major concerns about the current seaweed farming project landscape, especially within the peninsula of Placencia in southern Belize.

In terms of human resources, participants emphasized the importance of maintaining good health and safety skills, including CPR, boat navigation, and swimming proficiency, to engage effectively in seaweed farming. These skills were deemed essential for ensuring the safety and efficiency of farming operations, underscoring the significance of personal health and practical abilities in sustaining livelihoods through seaweed cultivation.

Social resources played a crucial role in supporting individuals within their community and beyond. Family support and collaboration within the fishing community provided a strong foundation for participants engaging in seaweed farming. Additionally, partnerships and networking with environmental NGOs offered opportunities for knowledge exchange, resource access, and collective action, enhancing social capital and resilience among the participants.

Natural resources were fundamental to the success of seaweed farming ventures. Participants identified the importance of selecting suitable areas for farming, considering factors like water conditions and access points. Access to wild seaweed stocks and island facilities further contributed to the natural assets available for seaweed cultivation, highlighting the reliance on environmental resources for livelihood sustainability.

Physical resources encompassed the tangible assets and infrastructure necessary for seaweed farming activities. Investments in boats, engines, and equipment for transportation and farming operations were essential for mobility and productivity. The use of ropes, net bags for seedlings, and facilities like the "Family House" on the Cayes demonstrated the physical assets utilized in seaweed farming, emphasizing the importance of physical capital in livelihood development.

Financial resources played a critical role in initiating and sustaining seaweed farming initiatives. Participants mentioned the use of personal funds for investments in boats, engines, and other operational expenses. Ownership of residential homes and family islands also represented financial assets that supported livelihood activities, underscoring the role of financial stability and resources in the long-term viability of seaweed farming enterprises.

Political resources involved engagement with policymakers, consultants, and regulatory frameworks related to seaweed farming. Participants highlighted the importance of understanding legal requirements and policy directions for the industry. Possession of boat and fishing licenses signified compliance with regulatory processes, indicating the significance of political engagement and adherence to governance structures in navigating the seaweed farming sector.

Cultural resources encompassed the traditions, knowledge, and heritage associated with seaweed farming practices. Participants shared stories and passed down generational knowledge about seaweed cultivation and fishing practices, highlighting the cultural significance of these activities within their community. The promotion of a seaweed festival in Riversdale reflected efforts to celebrate and preserve cultural practices related to seaweed farming, emphasizing the cultural assets that contributed to livelihood sustainability.

These resources highlight the diverse range of assets and support systems that contribute to the sustainability and success of seaweed farming activities within the community.

*Hazards: frequency, duration, intensity, impacts, and resources impacted*

| <b>Hazard</b>             | <b>Frequency</b>     | <b>Duration</b>                                    | <b>Intensity</b> | <b>Description Of Direct/Indirect Impacts on Seaweed Farms</b> |
|---------------------------|----------------------|----------------------------------------------------|------------------|----------------------------------------------------------------|
| Sargassum Influx          | Throughout the year  | 12 months                                          | Medium to High   | Turbidity (↑)                                                  |
|                           | May - September      | 12 days                                            | Medium to High   | Release of hydrogen sulfide gas (↑)                            |
|                           | June - October       | 5 days                                             | High             | Entanglement of sargassum on cultivation lines (↑)             |
| Extreme High and Low Tide | Throughout the year  | 3 - 5 days intervals                               | Medium to High   | Calmness/very salty/very warm water (↑)                        |
| Ice-ice Seaweed Disease   | May - September      | Constant throughout the year but summers are worst | High             | 30% die off all seaweed stocks (↓)                             |
| Storms                    | June - November      | Three to four times per year                       | High             | Breakoff of cultivated seaweed (↑)                             |
| Floods                    | Once per year (rare) | 10 days                                            | Low              | Runoffs (↑)                                                    |
| Theft                     | Once a year (rarely) | One-time event (2 hours)                           | High             | Loss of cultivated seaweed and farming equipment (↑)           |

*Table 9.48. Key Hazards and Resources Impacted in Focus Group Discussion 3 in Riversdale (Author's own elaboration).*

*Key points:* The following key points emerged in the discussion among second group of female seaweed farmers. They pointed out that the influx of sargassum is a continuous challenge throughout the year with thick layers of sargassum settling in the base of red mangrove (*Rhizophora mangle*) roots near seaweed farmers. This natural phenomenon persists for twelve months and varies in intensity from medium to high. The presence of

sargassum results in increased water turbidity, the release of hydrogen sulfide gas, and the entanglement of sargassum on cultivation lines. These impacts can deteriorate the overall health of the seaweed farms by altering water quality and potentially damaging the infrastructure used for cultivation. The fluctuation between high and low tides presents a recurring hazard for participants, occurring at intervals of three to five days throughout the year. The varying conditions during these tidal changes, such as calmness, very salty water, and warm water, can impact the farming environment. These conditions may influence the growth and health of the seaweed crops and affect the working conditions for individuals tending to the farms.

The ‘ice-ice’ seaweed disease poses a significant risk to seaweed farms, particularly during the months of May to September, with the summer period being the most critical. This disease can result in a 30% die-off of all seaweed stocks, thereby impacting the productivity and sustainability of the farms. The high intensity of this hazard necessitates the implementation of preventive measures and management strategies by participants to minimize the loss of their seaweed crops. Storms, occurring between June and November three to four times a year, present a high-intensity hazard for seaweed farming operations. The strong winds and turbulent weather associated with storms can cause the breakage of cultivated seaweed, leading to potential damage to the farms and infrastructure. Participants must prepare for these weather events and develop contingency plans to mitigate the impacts of storms on their livelihoods.

Although rare, floods present a low intensity but impactful hazard for participants, typically occurring once a year for a duration of ten days. The runoff from floods can affect land quality and potentially disrupt farming activities. Participants need to be vigilant during flood events to assess and address any damage caused to their farms and take steps to restore the affected areas. Theft, though infrequent, poses a high-intensity risk to participants, typically occurring as a one-time event lasting for a short duration of two hours. The loss of cultivated seaweed and farming equipment due to theft can have significant financial and operational implications. Implementing security measures and protocols to prevent theft is crucial for safeguarding the assets and resources essential for seaweed farming operations. After identifying key livelihood resources, participants were asked to enumerate the major hazards affecting the seaweed farming community. The following list summarizes these hazards as shown in Table.

*Coping strategies:*

For each hazard, and correspondent impact, participants identified their current coping strategies, assessed the extent of their sustainability, and eventually proposed alternative strategies, assuming availability of resources, which could be employed to cope more sustainably with those hazards (Table 9.49).

| Hazards                   | Current Responses                                                                                                                                                             | Long-Term Responses                                                                                                                                   |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sargassum Influx          | Regularly clear sargassum manually to prevent entanglement                                                                                                                    | Change of farming locations during seasons of high Sargassum influxes.                                                                                |
| Extreme High and Low tide | Making observations on the changing water conditions, such as salinity and temperature and adjusting their farming practices to accommodate this variation. Farming in deeper | Investment in a strong rope-based submerged farming infrastructure that can withstand tidal fluctuations, and explore seaweed varieties that are more |

|                                |                                                                                                |                                                                                                            |
|--------------------------------|------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
|                                | areas or shallow areas depending on tide fluctuations.                                         | tolerant to varying water conditions                                                                       |
| <i>Ice-ice</i> Seaweed Disease | Well storage on boat to transfer seaweed seeds on ropes                                        | Water shock with freshwater                                                                                |
|                                | Break off white tips of seaweed on ropes                                                       | Plant to 15ft depth to avoid warm seawater                                                                 |
|                                | Harvest to time                                                                                | Crop rotation                                                                                              |
|                                | Farming in 4 ft depth                                                                          | Transfer farms to 10ft - 15ft depth                                                                        |
| Storms                         | Establish anchor systems                                                                       | Set up physical barrier to capture broken off seaweed                                                      |
| Floods                         | Improve land management practices to reduce soil erosion and waterlogging during flood events. | Advocate for mangrove protection as they are flood-resistant infrastructure and protect the seaweed farms. |
| Theft                          | Regular visits to farms                                                                        | Hire security                                                                                              |
|                                | Informally reporting with seaweed farmers                                                      | Report theft to Police and Fisheries Department                                                            |

Table 9.49. Main Coping Strategies (short and long-term responses) to Hazards (Author's own elaboration).

*Key finding:* Sargassum influxes have impacted their seaweed farms on a seasonal basis. They managed sargassum influxes by manually clearing the seaweed to prevent entanglement and relocating farming operations to different areas during periods of high sargassum presence. Long-term strategies included investing in robust, rope-based submerged farming infrastructure capable of withstanding tidal fluctuations and exploring the cultivation of seaweed varieties that were more tolerant to varying water conditions. In terms of extreme high and low tides, participants monitored changing water conditions and adjusted their farming practices, accordingly, shifting cultivation to deeper or shallower areas based on tidal fluctuations. Proposed long-term strategies involved investing in infrastructure that was resilient to tidal changes and researching seaweed varieties that were better adapted to different water conditions.

Moreover, *ice-ice* seaweed disease had been impacting on the health of the seaweed crop, but participants were unaware that this was a disease very common in red seaweed. Current strategies to combat ice-ice seaweed disease include using storage facilities on boats, applying

freshwater shocks to the seaweed, pruning affected white tips, planting at depths of 15 feet, timing harvests, practicing crop rotation, and cultivating seaweed at 4 feet depth. Long-term strategies included transferring farms to depths of 10-15 feet to avoid warm seawater conditions and implementing preventive measures to mitigate the spread of ice-ice disease. There were grazers like squids, conch, and juvenile fish observed as common around the seaweed farms.

Furthermore, during storm events such as hurricanes and tropical storms, participants had to establish anchor systems and physical barriers to capture seaweed that broke off during storms, thereby minimizing loss and damage. When storms occurred, they primarily relied on personal funds to recover. NGO funding was not mentioned as a source of funding. The farmers often split expenses among themselves after covering repair expenses and maintenance costs. They have requested donations for seaweed farms and technical support to visit and assess the farms, but this is still on its way.

As participants were closer to the mainland compared to other farms in southern Belize, they were more concerned about how floods impacted their farms and raised awareness of sedimentation and turbidity issues amongst local users in the area, such as a resort on a nearby island. They enhanced land management practices and advocated for the protection of mangroves to reduce soil erosion and waterlogging during flood events. Long-term responses included further improving land management practices and implementing sustainable flood mitigation measures to protect seaweed farms.

The growing hazard of theft and security issues had been brought up by other seaweed farmers in the vicinity, as participants were accused of stealing seaweed crops from another farm. Therefore, to address theft of their seaweed crops during the night, participants conducted regular farm visits, hired security personnel, engaged in informal reporting among community members, and reported incidents to the authorities. Long-term strategies might involve establishing community policing initiatives, neighborhood watch programs, and secure storage facilities to prevent theft and ensure the long-term security of seaweed farming operations. Participants learned seaweed farming from older fishermen within the community that were once farming seaweed but indicated the need for more training opportunities. Participants shared their experiences with various hazards impacting seaweed farming and discussed both immediate and long-term responses.

#### 9.5.6 CRiSTAL Toolkit: Seaweed Producers FDG #3 (Female Group)

Table 9.50 provides the description of the third focus group discussion (FGD #3) conducted with the Blue Waters Fisherman Association (BWFA) located in Riversdale, including key logistical details such as location, language spoken, date, and session duration.

|                         |                                                                       |
|-------------------------|-----------------------------------------------------------------------|
| <b>Group Name:</b>      | Blue Waters Fisherman Association (BWFA) (Riversdale Seaweed Farmers) |
| <b>Location:</b>        | Riversdale                                                            |
| <b>Language spoken:</b> | English                                                               |
| <b>Date:</b>            | July 28, 2023                                                         |
| <b>Start Time:</b>      | 2:20 PM                                                               |



|                  |          |
|------------------|----------|
| <b>End Time:</b> | 12:30 AM |
|------------------|----------|

Table 9.50. Description of third focus group (FGD #3).

Table 9.51 presents the seaweed farming community profile for the third focus group discussion (FGD #3) with the Blue Waters Fisherman Association (BWFA), detailing the number of producers, farm locations, cultivated species, production scale, and historical site characteristics.

|                                                                                           |                                                                                           |
|-------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| <b>Number of seaweed producers (s):</b>                                                   | 3                                                                                         |
| <b>Name of registered seaweed cooperative (s)/ association (s)/community group (s):</b>   | Blue Waters Fisherman Association (17 legally registered Fishers)                         |
| <b>Name of unregistered seaweed group (s):</b>                                            | Riversdale Women Seaweed Farmers Group under fishing association                          |
| <b>Locations of seaweed farm (s)- (sketch it):</b>                                        | Inner lagoons of Saddle Caye and Channel Caye                                             |
| <b>Number of years farming in the specified sites listed:</b>                             | 2                                                                                         |
| <b>List of cultivated seaweed species on sites:</b>                                       | <i>Eucheuma isiforme</i> , <i>Gracilaria crassissima</i> and <i>Kappaphycus alvarezii</i> |
| <b>Estimated amount of seaweed farmed (in dry weight, pounds unit):</b>                   | 120 dried weights                                                                         |
| <b>Historical land use prior to seaweed farming:</b>                                      | Fishing and Fishermen Camping Sites                                                       |
| <b>Site selection process for farming seaweed in the specific locations listed above:</b> | Homebase / Campsite                                                                       |
| <b>If apply, reasons for site relocation:</b>                                             | No relocation                                                                             |

Table 9.51. Seaweed farming community profile (FGD #3).

Table 9.52 outlines the business environment for seaweed farming as discussed in the third focus group (FGD #3), highlighting the initial investment requirements, prevailing economic conditions, household participation, and access to government or NGO support mechanisms.

|                                                                                                                              |                                                |
|------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|
| <b>Investment needed to start a seaweed farm (US dollars):</b>                                                               | Boat (\$10,000 BZD) and Machine (\$15,000 BZD) |
| <b>Economic conditions for investing in seaweed farming: 1= Poor; 2= Satisfactory; Good; 4=Very Good; 5= Other (specify)</b> | 2                                              |

|                                                                                                       |                                                                        |
|-------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| <b>No. of individuals/families working on seaweed farms:</b>                                          | 3 families (3 women seaweed farmers and helping husbands and children) |
| <b>Government &amp;/or NGO processes in accessing any resources or subsidies for farming seaweed:</b> | Nothing so far                                                         |

Table 9.52. Business environment for farming seaweed (FGD #3).

Table 9.53 presents the list of livelihood capitals and corresponding resources identified by participants during the third focus group discussion (FGD #3) with the Blue Waters Fisherman Association (BWFA) in Riversdale Village.

| <b>Capitals</b> | <b>Livelihood resources</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Human           | <ul style="list-style-type: none"> <li>• Good health</li> <li>• Balanced diet: Beans, Chicken, Lobster, Fish, Tortillas, Rice, Plantain, Lots of Water.</li> <li>• Safety skills such as CPR and boat navigation and basic maintenance</li> <li>• Practical skills for swimming and diving</li> <li>• Capacity building training and education programs for maximizing production and sustainable harvesting</li> </ul>                                                                                                                                                                                                                                                                                                 |
| Social          | <ul style="list-style-type: none"> <li>• Family support (seaweed farmers receive support from their husbands and children, who help with farming activities, especially during school breaks or when school is out)</li> <li>• Fishing community support</li> <li>• Seasonal engagement with shark researchers (Dr. Chapman).</li> <li>• Potential collaboration with other seaweed farmers for knowledge exchange and training opportunities</li> <li>• Partnership with Blue Ventures through their Blue Water Fisherman Association</li> <li>• Collaboration with organizations like The Nature Conservancy for mainstreaming women in seaweed farming and accessing investors and business opportunities</li> </ul> |
| Natural         | <ul style="list-style-type: none"> <li>• Healthy marine environment</li> <li>• Natural protection barrier for placing seaweed farms (eg. The presence of mangroves and reefs that protect the islands and minimize the impact of storms)</li> <li>• Clean ocean waters for farming, with consideration for the impact of climate change on water conditions</li> <li>• Healthy seeds for cultivation</li> <li>• The availability of wild seaweed patches for seed collection</li> </ul>                                                                                                                                                                                                                                 |
| Physical        | <ul style="list-style-type: none"> <li>• Boat and boat engine along with other gears for mobility in the sea</li> <li>• Startup commenced when ropes were bought from a family member</li> <li>• Net bags for seedlings</li> <li>• “Family House” on both Caye equipped with kitchen (gas stoves) and sleeping area.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                         |

|                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                         | <ul style="list-style-type: none"> <li>• Space on the island for sun drying seaweed</li> <li>• Transportation by car for seafood deliveries to nearby resorts</li> <li>• Infrastructure for seaweed farming operations, including facilities for cultivation equipment for growing and processing seaweed</li> <li>• The potential for infrastructure investment to support processing and value-added development</li> </ul>                                                                                                                                                                                                                 |
| Financial               | <ul style="list-style-type: none"> <li>• Infrastructure for seaweed farming operations, including facilities for processing seaweed</li> <li>• The use of personal funds for covering transportation costs for seaweed farming operations</li> <li>• Ownership of residential homes and family island</li> <li>• Financial resources and funding opportunities for seaweed farming projects</li> <li>• Local market access of whole sun-dried seaweed commodity</li> </ul>                                                                                                                                                                    |
| Political               | <ul style="list-style-type: none"> <li>• Consultation with Fisheries regarding marine research permit application (no follow up conducted)</li> <li>• Government structures in place for fishing license, marine research permit applications for seaweed farming operation and boat registration</li> <li>• Support for seaweed-based value-added products and product diversification</li> </ul>                                                                                                                                                                                                                                            |
| Cultural                | <ul style="list-style-type: none"> <li>• Local knowledge and stories passed down through generations related to seaweed and fishing practices (eg. knowledge shared could be 4<sup>th</sup> generation by now)</li> <li>• Potential for cultural festivities such as a seaweed festival in Riversdale, which has the potential for economic growth and attracting buyers from across the country (eg. Riversdale community wanting to put a historic market in Belize Crop Calendar Festivity)</li> <li>• The incorporation of seaweed into local knowledge and traditions, contributing to the cultural heritage of the community</li> </ul> |
| Knowledge & Information | <ul style="list-style-type: none"> <li>• Knowledge building amongst seaweed farming</li> <li>• Access to accurate information and proper guidance for sustainable harvesting and maximizing production</li> <li>• Access to information and guidance for seaweed farming grant applications and eligibility criteria for funds</li> </ul>                                                                                                                                                                                                                                                                                                     |
| Innovation              | <ul style="list-style-type: none"> <li>• Access to training and education programs for maximizing production and sustainable harvesting</li> <li>• Collaboration opportunities with organizations such as The Nature Conservancy for mainstreaming women in seaweed farming and accessing investors and business opportunities</li> <li>• Support for seaweed-based value-added products and product diversification</li> <li>• Access to accurate information and proper guidance for sustainable seaweed farming practices</li> </ul>                                                                                                       |

|                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                      | <ul style="list-style-type: none"> <li>• Potential participation in innovation challenges and accelerators focused on ocean-related challenges, including sustainable aquaculture and seaweed farming</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Flexible forward-looking discussion (decision-making and governance) | <ul style="list-style-type: none"> <li>• Access to information and guidance for seaweed farming applications and eligibility criteria</li> <li>• Financial resources and funding opportunities for seaweed farming projects.</li> <li>• Training and education programs for maximizing production and sustainable harvesting including exchange programs with other seaweed farmers in Belize and the Caribbean region.</li> <li>• Collaboration opportunities with organizations such as The Nature Conservancy for mainstreaming women in seaweed farming and accessing investors and business opportunities.</li> <li>• Access to accurate information and proper guidance for sustainable seaweed farming practices as participants expressed concerns about the government and seaweed mariculture policy framework, highlighting the need for clear policies and regulations to support their farming activities.</li> <li>• Support for seaweed-based value-added products and product diversification</li> <li>• Further engagement of rural community in national sustainable seaweed farming initiatives and boards. The women farmers have reached out to consultants and government entities to inquire about grants and policy developments related to seaweed farming, indicating their proactive approach to engaging with decision-makers and seeking support for their initiatives.</li> <li>• Joining existing initiatives have motivated the participants. While initially hesitant to join existing initiatives, the women farmers discussed concerns about the "trickle-down" benefits from such seaweed farming projects with gender mainstreaming and expressed interest in collaborating with organizations like The Nature Conservancy for training and knowledge exchange related to seaweed farming but rather to join the network than an association (legal requirements).</li> </ul> |

Table 9.53. List of seaweed farming resources (FGD #3).

Table 9.54 summarizes the key hazards and risks identified by the third focus group discussion (FGD #3) participants, including their frequency, duration, intensity, and the direct and indirect impacts on seaweed farms in Riversdale.

| Hazards | Frequency | Duration | Intensity | Description of Direct/indirect impacts on seaweed farms |
|---------|-----------|----------|-----------|---------------------------------------------------------|
|         |           |          |           |                                                         |

|                                       |                      |                                                    |                |                                                                                                                                                                                  |
|---------------------------------------|----------------------|----------------------------------------------------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sargassum influx                      | Throughout the year  | 12 months                                          | Medium to High | Reduced seaweed growth (↓)<br>Potential die-offs (↑)<br>Sunlight penetration (↓)<br>Slower water movement (↓)<br>Seawater Turbidity (↑)<br>Decaying rate of sargassum (↑)        |
|                                       | May - September      | 12 days                                            | Medium to High | Disturbance of hydrogen sulfide gas release from decaying sargassum (rotting egg smell) (↑)<br>Loss of objects due to oxidation process of any steel or iron on camping site (↑) |
|                                       | June - October       | 5 days                                             | High           | Entanglement of sargassum on cultivation lines (↑)                                                                                                                               |
| High and Low tide                     | Throughout the year  | 3 - 5 days intervals                               | Medium to High | Slower water movement/calmness (↓)<br>Extreme salinity levels/very warm water (↑)                                                                                                |
| Theft                                 | Once a year (rarely) | One time event (2 hours)                           | High           | Loss of cultivated seaweed and farming equipment (↓)                                                                                                                             |
| Ice-ice seaweed disease and epiphytes | May - September      | Constant throughout the year but summers are worst | Medium to High | 30% die off all seaweed stocks during heat waves (↓)<br>Health of seaweed farms (↑)<br>Productivity and yield quality of seaweed crops (↓)                                       |
| Storms and high tides                 | June - November      | Three to four times per year                       | High           | Loss of cultivated seaweed (breakoff due to wave action) (↑)<br>Growth seasons productivity (↓)<br>Damage to farming infrastructure (↑)                                          |
| Floods                                | Once per year (rare) | 10 days                                            | Low to Medium  | Heavy sedimentation (low runoff) (↑)<br>Discoloration of seawater (red to brown) (↑)                                                                                             |
| Dredging                              | For the past years   | Varies throughout the year                         | High           | Loss of biodiversity (↑)<br>Alterations in marine habitats (↑)                                                                                                                   |

Table 9.54. Summary of hazards (including climate-related risks) to seaweed farms (FGD #3).

Table 9.55 outlines the capacity-building and training programmes undertaken by members of the Blue Waters Fisherman Association (BWFA) during the third focus group discussion (FGD #3).

| <b>Name of training (as labeled on certificate)</b>  |                                                                                                                                                                                                                                     |                                                                                                                                                         |
|------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| List of knowledge and skills acquired in training:   | List of environmental-related challenges addressed in training:                                                                                                                                                                     | Benefits received from training in a group set up and knowledge exchange with seaweed farmer:                                                           |
| Cultivation of seaweed in ropes using twisted method | Review of farming techniques that can help them address environmental challenges such as the bad weather strategies in sinking seaweed farms away from sargassum influx, and cooler temperatures to reduce ice-ice seaweed disease. | Connect with other women seaweed farmers in the Placencia Peninsula to share lessons learnt in sustainable farming practices                            |
| Shark tagging training                               | Networking with scientist working in megafauna monitoring within the area. Working experience in conservation of shark species in Riversdale.                                                                                       | Exchanges of researchers and fisherfolk community to learn about the importance of environmental conservation and protection.                           |
| CPR training                                         | None                                                                                                                                                                                                                                | Survival skills training in the ocean environment especially during bad weather conditions. Building human resources to respond to medical emergencies. |

*Table 9.55. Summary of seaweed farming training programmes (FGD #3).*

Table 9.56 presents the analysis of climate-related hazards discussed by participants of the third focus group discussion (FGD #3), highlighting the direct and indirect impacts, underlying causes, and affected resources associated with sargassum influx, seawater warming, and storm events on seaweed farming operations.

| <b>Climate-related hazards: Sargassum influx, seawater warming and storms</b>                                                                    |                                                                                                                                                                                       |                                                                                                                                                                     |                                                                                                                                                                   |
|--------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Direct Impact                                                                                                                                    | Indirect Impact                                                                                                                                                                       | Other Causes of Impact                                                                                                                                              | Impacted Resources                                                                                                                                                |
| Depletion of wild seaweed stock and increased die-offs of seaweed crop (increase breakage)                                                       | Increasing seaweed species cloning on farming site and lower genetic reserves due to poor replenishments from the wild seaweed stocks                                                 | Seaweed Disease and epiphytes breakouts in seaweed farms hinder the productivity of farming operation (unable to work due to farmers getting stings from epiphytes) | Loss of seaweed crop due to susceptibility to seaweed diseases and pests. Decrease seaweed farming productivity (less hours of work) and increase economic losses |
| Damage to farm infrastructure (entanglement of cultivation lines and anchors) and disturbance from sargassum influx decaying near seaweed farms. | Disruption of marine ecosystem function. Very poor light penetration to submerged seaweed. It kills everything nothing can't grow. It is like a blanket. Look like the water is dark. | Reduced natural shades for marine environment and increased debris derived from farming infrastructure if damaged.                                                  | Additional costs for repairs and replacements and loss of cultivated seaweed.                                                                                     |
| Reduced productivity directly impacting seaweed growth and productivity (lower harvest).                                                         | Alterations to the natural habitat around seaweed farming areas may potentially affect the suitability of these locations for sustainable                                             | Reduced water quality conditions for seaweed growth. Changes in salinity, nutrient levels, and overall water conditions                                             | Reduced seaweed crop yields, crop loss due to breakage and overall economic losses.                                                                               |

|  |                      |                                                |  |
|--|----------------------|------------------------------------------------|--|
|  | seaweed cultivation. | impact the growth and health of seaweed crops. |  |
|--|----------------------|------------------------------------------------|--|

Table 9.56. Analysis of climate-related hazards impacting seaweed farms (FGD #3).

Table 9.57 summarizes the non-climate-related hazards identified by participants of the third focus group discussion (FGD #3), detailing the direct and indirect impacts, underlying causes, and affected resources associated with dredging activities, farm maintenance operations, and the challenges of meeting regulatory and legal requirements in seaweed mariculture.

| <b>Non-Climate-related hazards: Dredging, farm maintenance operations and meeting legal requirements of regulations</b>                                                                                       |                                                                                                                                                                                     |                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                              |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Direct Impact                                                                                                                                                                                                 | Indirect Impact                                                                                                                                                                     | Other Causes of Impact                                                                                                                                                                                                                                                    | Impacted Resources                                                                                                                                                                                                                                                                                                           |
| Sedimentation on seaweed farms (require more time to brush light white sediment off seaweed crop).                                                                                                            | Seaweed lost due to depth in dredging areas. When cultivated seaweed breaks off the farm, it goes in a 100-meter-deep hole                                                          | Reduced water quality conditions for seaweed growth. High turbidity reduces sunlight absorption rate.                                                                                                                                                                     | Profitability and economic viability of seaweed farming operations due to reduction of harvested cultivated seaweed.                                                                                                                                                                                                         |
| Changes in policies and regulations related to seaweed farming impact the legality of farming and market potentially leading to increased costs, reduced productivity, and other economic and social impacts. | Higher prices of cultivated seaweed competing with the lower price of wild harvested seaweed. Unclear regulations in sea space tenures are very discouraging to individual farmers. | Affordability of seaweed business is a concern. Adhering to consumer preference of seaweed quality in the local market are ad hoc and at a free cost in packaging compared to meeting the requirements for the export market and proof of sustainable farming operations. | Seaweed farming operations may impact fisheries resources, potentially leading to reduced fish populations, extinction of wild seaweed in the reef and economic losses for fishing communities. Concerns of a growing black market where wild seaweed is cheaper than cultivated seaweed which requires legal establishment. |



|                                                                                     |                                                                                                                                                                                                       |                                                                                                                                                                       |                                                                         |
|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| High expenses in seaweed farming operations reduce profitability and reinvestments. | Inflation is a concern. High investment cost in farming operations and maintenance increase the price of cultivated seaweed. Fuel prices are increasing and contributing to high operational expense. | Unclear legal requirements (eg. permits) requiring expertise knowledge to fill out application forms including environmental impact assessments and toxicology tests. | Reducing productivity and increasing costs, leading to economic losses. |
|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|

Table 9.57. Analysis of non-climate related hazards impacting seaweed farms (FDG #3).

Table 9.58 presents the major threats and risks to seaweed farming as identified by participants of the third focus group discussion (FDG #3), outlining the reasons for not addressing these threats and the potential risks if they remain unresolved.

| <b>List hazards/threats to seaweed farming:</b>                                                                                                  | <b>Reasons for not addressing threats:</b>                                                                                                                                                                          | <b>If threats are not impacting seaweed farms, describe risks:</b>                                                                                                                                                              |
|--------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| International E-NGO Monopoly in seaweed farming activities                                                                                       | Ongoing consultation with the Belize Women Seaweed Farmers Association.                                                                                                                                             | Monopoly of seaweed farming operations include attaining marine research permits to farm seaweed and not able to export under this type of permit.                                                                              |
| Bureaucratic process in attaining seagrass bed leasing                                                                                           | It's very costly. Currently using fishing license to farm seaweed (will need a seaweed farmer license in the future).                                                                                               | Local seaweed farmers will not be able to farm seaweed because of the high level of expertise required in filling out all applications for farming and leasing seagrass beds.                                                   |
| Lack of organizational structures for the management of physical assets and reinvestments opportunities in farming infrastructure and equipment. | Insufficient income is received from farmers labor in seaweed farmers. This makes it difficult for farmers to reinvest into improving infrastructure and durable equipment, especially for harsh weather condition. | Habitat degradation is a risk because of poor management of infrastructure in the ocean leading to spread of debris and contributing to marine pollution. This leads to changes in habitat structures and loss of biodiversity. |

|                                                                                                                                                                     |                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Government not providing open markets for local farmers.                                                                                                            | Seaweed farmers are not able to sustain their livelihood in seaweed farming alone. This means that individuals engaged in seaweed farming must take up part-time jobs because they are not making sufficient income from seaweed farming business. | By not having a local market, this opens the black market to sell illegally cultivated, wild harvested and Contraband seaweed. Unregulated markets with extreme price fluctuations affect the local law-abiding seaweed farmers.                                                                                                                                                                                                            |
| Loss of local knowledge exchange because of the lack of government-led initiatives and resources hubs to engage with farming communities.                           | Training and education provided by NGOs are not sufficient. Need better support from government to engage with individuals in seaweed farming business including both farming and wild harvesting of seaweed.                                      | Business isolation in rural communities is a risk as local seaweed farming communities don't want to be legally tied to associations formed by NGOs because of the policies and procedures involved. This acts as a hindrance in seaweed farming productivity and doesn't help the farming community engage with the open market. Seaweed farmers want to have sole control of their cultivated product with no ties to conditional offers. |
| Farmers do not see any initiative of government supporting seaweed livelihoods as a full-time job and not actively attracting new farmers for the seaweed industry. | Too many sanctions are placed on local seaweed farmers and local farmers rather have a dialogue with government.                                                                                                                                   | The risk is that there is no fair system in place, therefore farmers are not abiding by the existing laws or emerging new mariculture laws.                                                                                                                                                                                                                                                                                                 |

Table 9.58. Summary of hazards and threats to seaweed farming (FGD #3).

Table 9.59 summarizes the existing and long-term responses to major hazards and risks identified by participants of the third focus group discussion (FGD #3), including measures to address *ice-ice* seaweed disease, extreme weather events, theft, and sargassum influx affecting seaweed farming operations.

| Hazards                        | Current Responses                                       | Long-Term Responses                        |
|--------------------------------|---------------------------------------------------------|--------------------------------------------|
| <i>Ice-ice</i> seaweed disease | Well storage on boat to transfer seaweed seeds on ropes | Water shock with freshwater                |
|                                | Break off white tips of seaweed on ropes                | Plant to 15ft depth to avoid warm seawater |

|                                              |                                                                                                                                                                                                           |                                                                                                                                                                                              |
|----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                              | Harvest to time                                                                                                                                                                                           | Crop rotation                                                                                                                                                                                |
|                                              | Farming at 4ft depth                                                                                                                                                                                      | Transfer farms to 10ft - 15ft depth                                                                                                                                                          |
|                                              | Illegal wild harvest seed stock                                                                                                                                                                           | Establish microscale seed management to expand seaweed farms                                                                                                                                 |
| Extreme weather events (storms, wind, waves) | Establish anchor systems                                                                                                                                                                                  | Set up physical barrier to capture broken off seaweed and placing seaweed farms with natural protection such as around mangroves                                                             |
| Theft                                        | Regular visits to farms                                                                                                                                                                                   | Employing full-time security to prevent theft and vandalism                                                                                                                                  |
|                                              | Informally reporting with seaweed farmers                                                                                                                                                                 | Report on theft to Police and Fisheries Department                                                                                                                                           |
| Sargassum influx                             | Decomposition of sargassum increases turbidity, discoloration and increases the temperature of the sea water. Surrounding seaweed farms with mangroves to reduce sedimentation and improve water quality. | Developing and implementing sustainable farming practices to enhance the resilience of sargassum influx such as placing seaweed farm infrastructure 4 to 6 feet under the sea water surface. |
|                                              | Seeking out grants and funding opportunities to support disaster risk management around seaweed farming operations.                                                                                       | Collaborating with other seaweed farmers and organizations to share knowledge and expertise.                                                                                                 |

Table 9.59. Analysis of existing and long-term responses to hazards affecting seaweed farms (FGD #3).

Table 9.60 outlines the external risks and threats to seaweed farming identified by participants of the third focus group discussion (FGD #3), emphasizing the emerging challenges related to market competition, governance, and policy structures affecting local seaweed farmers and community-based operations.

| External hazards/threats to Seaweed Farms |                                                                                                                                                                                    |
|-------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1                                         | Cheaper priced seaweed in the open market from third party countries. Very limited protection in place to combat the importation of seaweed commodities from third party countries |

|   |                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2 | Government issuing out permits to external corporations to undergo seaweed farming operations in country. This can lead to displacement of local seaweed farming groups in traditional fishing communities who don't have the financial support to compete against big corporations.                                                                                                                                              |
| 3 | Increased social conflicts with government and local seaweed farming communities and their association. Consequently, trust is lost from both sides regardless of the efforts placed in the past to push seaweed farming livelihoods project due to rolling out of unfair policy and governance structures and actions over local farmers calls for support to build local economy and favor supporting big corporations instead. |

Table 9.60. External hazards/risks and threats to seaweed farms (FGD #3).

Table 9.61 presents a summary of the future perspectives of seaweed farming sustainability discussed by participants of the third focus group discussion (FGD #3).

|                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|--------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Current scale of operation</b><br><br><b>1=Very small;</b><br><b>2=Small;</b><br><b>3=Medium;</b><br><b>4=Mixed; 5=</b><br><b>Large</b> | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Resources needed to scale up farming operations</b>                                                                                     | <ul style="list-style-type: none"> <li>• Technical Support: Access to technical expertise and support for seaweed cultivation, including training in sustainable farming practices, disease management, and infrastructure development.</li> <li>• Financial Resources: Funding for infrastructure investment, such as processing facilities and value-added product development, as well as support for transportation and operational costs.</li> <li>• Legal and Regulatory Guidance: Assistance in navigating the legal and regulatory requirements for scaling up farming operations, including obtaining seabed leases and complying with mariculture policies.</li> <li>• Knowledge Exchange: Opportunities for knowledge sharing and collaboration with other seaweed farmers and organizations to learn from best practices and innovations in industry.</li> <li>• Policy Engagement: Support for engaging with policymakers and stakeholders to advocate for supportive policies and regulations that facilitate the sustainable growth of seaweed farming operations.</li> </ul> |

|                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|---------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                               | <ul style="list-style-type: none"> <li>• Access to Healthy Seeds: Ensuring access to healthy and diverse seaweed seeds from the wild to support the expansion of farming operations and genetic diversity.</li> <li>• By securing these resources, the women seaweed farmers can enhance the scalability, sustainability, and resilience of their farming operations, contributing to the long-term success of their endeavors and the well-being of their communities.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Challenges that may be faced in scaling up operations:</b> | <ul style="list-style-type: none"> <li>• Limited Access to Funding: Access to funding and financial resources may be limited, making it difficult to invest in infrastructure and expand operations.</li> <li>• Unclear Regulations and Policies: The regulatory environment for seaweed farming may be unclear or complex, making it difficult to navigate the legal requirements for scaling up operations.</li> <li>• Limited Technical Expertise: The women farmers may lack technical expertise in seaweed cultivation, disease management, and infrastructure development, making it difficult to scale up operations sustainably.</li> <li>• Climate-Related Risks: Climate-related risks, such as changes in water quality and extreme weather events, may impact on the productivity and sustainability of seaweed farming operations, making it difficult to scale up operations.</li> <li>• Limited Market Access: Access to markets for seaweed products may be limited, making it difficult to generate sufficient revenue to support the expansion of operations.</li> <li>• Limited Access to Healthy Seeds: Access to healthy and diverse seaweed seeds from the wild may be limited, making it difficult to expand farming operations and maintain genetic diversity.</li> <li>• Addressing these challenges will require a concerted effort from the women seaweed farmers, as well as support from policymakers, funders, and technical experts. By addressing these challenges, the women farmers can enhance the scalability, sustainability, and resilience of their farming operations, contributing to the long-term success of their endeavors and the well-being of their communities.</li> </ul> |
| <b>Training that may be needed for future employment in</b>   | <ul style="list-style-type: none"> <li>• Knowledge building opportunities such as CPR, navigation, boat maintenance, and diving skills.</li> <li>• Access to training programs for certification.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

|                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>seaweed farming sector</b>                  | <ul style="list-style-type: none"> <li>• Seaweed farmers are interested in gaining expertise in sustainable farming practices, pest and disease management, safety protocols, and environmental challenge mitigation.</li> <li>• Sustainable Farming Practices: Training in sustainable seaweed farming practices, including cultivation techniques, disease management, and environmental stewardship.</li> <li>• Infrastructure and Equipment Operation: Training in the operation and maintenance of farming equipment, boats, and processing facilities to support efficient and effective farming operations.</li> <li>• Business and Financial Management: Training in business planning, financial management, and access to funding to support the development and growth of seaweed farming enterprises.</li> <li>• Policy and Regulatory Compliance: Training in understanding and navigating the legal and regulatory requirements for seaweed farming, including obtaining permits and complying with industry standards.</li> <li>• Value-Added Product Development: Training in the development of value-added seaweed products, such as processing, packaging, and marketing, to enhance the economic potential of seaweed farming operations.</li> <li>• Climate Resilience and Risk Management: Training in climate resilience strategies, risk assessment, and adaptation measures to mitigate the impact of climate-related risks on farming operations.</li> <li>• By receiving these types of training, the women seaweed farmers can enhance their capacity to engage in sustainable and successful seaweed farming practices, contributing to their long-term employment and the overall development of the seaweed farming sector.</li> </ul> |
| <b>Seaweed farming future policy direction</b> | <ul style="list-style-type: none"> <li>• Government intervention to open new avenues or initiatives for helping local seaweed farmers to harvest their own seaweed crops for the open market.</li> <li>• Regulatory Clarity: Establishing clear and transparent regulations and policies governing seaweed farming, including licensing, permitting, and environmental standards, to provide a supportive framework for industry growth.</li> <li>• Access to Resources: Developing policies to facilitate access to resources such as funding, technical support, and</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

|  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|--|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | <p>healthy seeds to enable seaweed farmers to scale up their operations and adopt sustainable practices.</p> <ul style="list-style-type: none"> <li>• <b>Capacity Building:</b> Implementing policies to support capacity building initiatives, including training programs, knowledge exchange, and technical assistance, to enhance the skills and knowledge of seaweed farmers and industry stakeholders.</li> <li>• <b>Market Development:</b> Creating policies to support market development for seaweed products, including value-added products, domestic sales, and export opportunities, to enhance the economic viability of seaweed farming operations.</li> <li>• <b>Climate Resilience:</b> Integrating climate resilience strategies and risk management into policy frameworks to address the impact of climate-related risks on seaweed farming, such as Sargassum influx and changes in water quality.</li> <li>• <b>Gender Inclusivity:</b> Ensuring that future policies promote gender inclusivity and support the participation of women seaweed farmers, recognizing their contributions to the industry and addressing any gender-specific challenges they may face.</li> <li>• By addressing these policy directions, policymakers can create an enabling environment for the sustainable development of the seaweed farming sector, supporting the livelihoods of seaweed farmers and contributing to the economic and environmental sustainability of coastal communities.</li> </ul> |
|--|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

*Table 9.61. Future perspectives of seaweed farming sustainability (FGD #3).*

Table 9.62 provides future communication with lead seaweed farmers.

| <b>Name</b>    | <b>Mobile</b> | <b>Email</b>       | <b>Position</b>     |
|----------------|---------------|--------------------|---------------------|
| Isela Martinez | 6228715       | 95misela@gmail.com | Lead seaweed farmer |

*Table 9.62. Future communication with seaweed farmers (FDG #3).*

#### 9.5.7 Focus Group Discussion 4: Belize City/Turneffe Atoll Marine Reserve (Male Group)

A total of four (4) participants attended the male focus group, with ages ranging from 27 to 65 (mean age at 44) on the 3<sup>rd</sup> of August 2023. Their occupations varied as follows: 1. fisherman (2); 2. seaweed farmer (1) and freelancer (1). The participants started their discussion by plotting the boundaries of their community, supported by a facilitator, as shown by Figure 9.15. The CRiSTAL toolkit guiding this discussion can be found in the next section of this appendix, 9.5.8 (FDG #4).

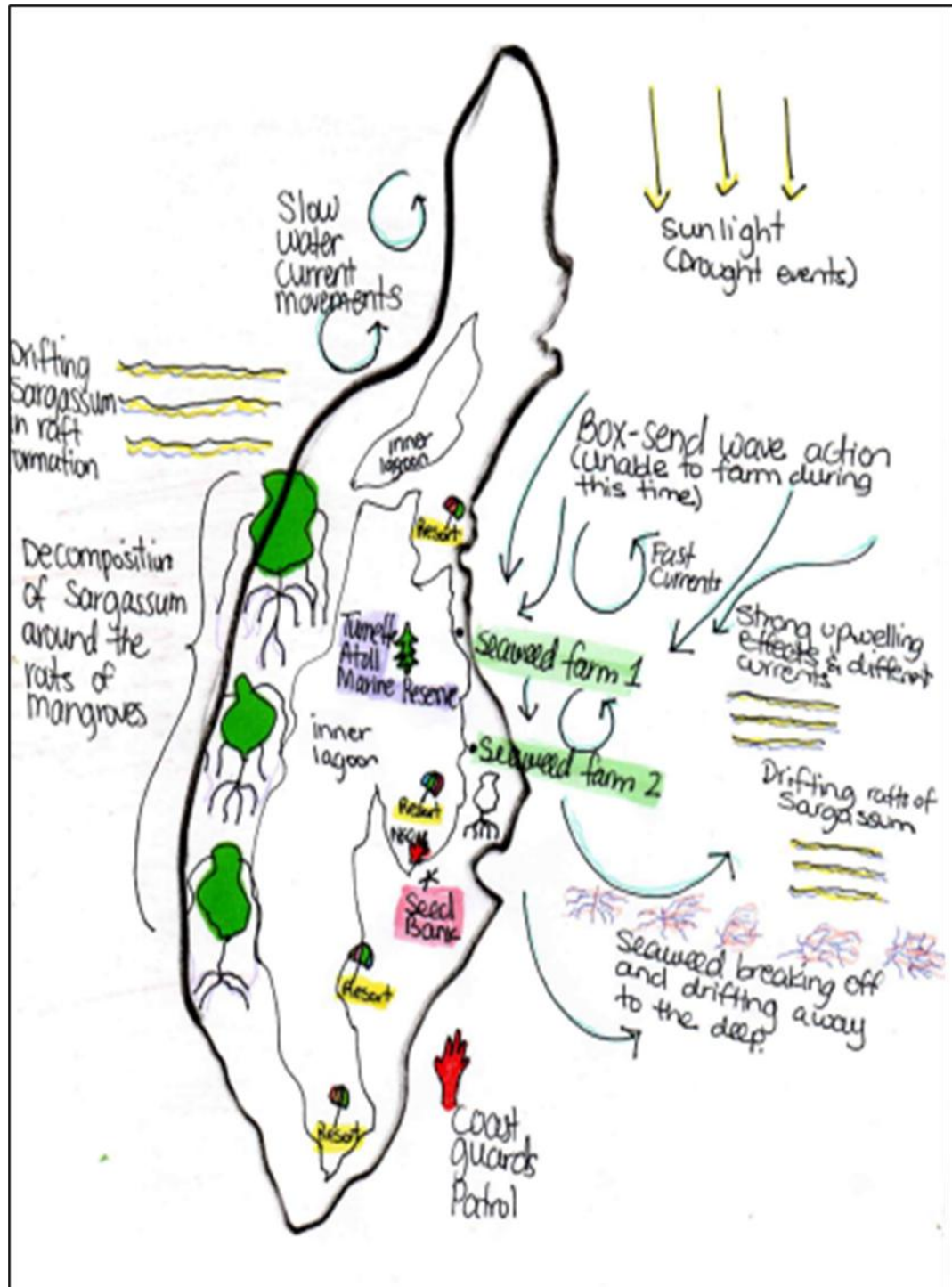




Figure 9.15. Visual resource map with male focus group (Belize City) (Author's own elaboration).

*Key points:* These group of male seaweed farmers described their farming sites as experimental production sites that were on the east side of Turneffe Atoll Marine Reserve. Initially experimental sites were on the East lagoons of the atoll but were moved to this new farming site since 2017. Farmers reported that their farming sites experience different currents throughout the year that are prone to sea level fluctuations and epiphytes.

#### *Livelihood resources*

The following resources were listed and prioritized Table 9.63.

| <b>Livelihood Categories</b> | <b>Livelihood Resources</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Social                       | <ul style="list-style-type: none"> <li>• NGO partnership with local seaweed farmers in the marine reserve through the protection of seed stocks at NGO headquarters</li> <li>• Informal communication with other seaweed farmers in the country</li> <li>• Consist of communication with authorities in the fishing industry</li> <li>• Promotion of seaweed gel with local resorts in Turneffe and tourists</li> </ul>                                                                                                                                                                                                  |
| Natural                      | <ul style="list-style-type: none"> <li>• Healthy reef waters to grow seaweed in</li> <li>• Access to areas in Turneffe that are not touristy sites or no take zones</li> <li>• Natural weather phenomenon occurring with the current water movement referred to as 'Box-in' where two wave actions are occurring at the same time in a particular area.</li> <li>• Tropical storms and hurricane alerts increasing</li> <li>• Increasing sargassum settling around mangrove areas</li> <li>• Rainwater access</li> </ul>                                                                                                 |
| Physical                     | <ul style="list-style-type: none"> <li>• Transportation and fuel (boat, engine, fuel and lube)</li> <li>• Farming infrastructures such as durable (nylon material) ropes</li> <li>• Anchors and buoys to submerge seaweed farms</li> <li>• Sandy areas to grow seaweed</li> <li>• Harvesting and drying infrastructure to process cultivated seaweed on camp sites and further processing in-land areas for the sale of commodity</li> <li>• Equipment for maintenance of seaweed farms</li> <li>• Weather protective gears for long hours under the sun</li> <li>• Freshwater access to rinse farmed seaweed</li> </ul> |
| Financial                    | <ul style="list-style-type: none"> <li>• Transportation-related expenses to visits to seaweed farms</li> <li>• Food-related expenses for camping around seaweed farms</li> <li>• Freshwater capture containers or VAT systems to filter captured water</li> <li>• Ropes for cultivating and anchoring seaweed farms</li> <li>• Labor wages for planters and harvesters</li> </ul>                                                                                                                                                                                                                                        |

|           |                                                                                                                                                           |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| Political | <ul style="list-style-type: none"> <li>• Permits and license</li> <li>• Working with NGOs and Fisheries department</li> </ul>                             |
| Cultural  | <ul style="list-style-type: none"> <li>• Indigenous knowledge of seaweed farming practices including ways of processing seaweed on camp sites.</li> </ul> |

*Table 9.63. Key Livelihood Resources from Focus Group Discussion 4 in Belize City (Author's own elaboration).*

The following livelihood resources were highlighted by the male focus group discussion in Turneffe Atoll:

The key resources identified by the participants for conducting their operations in Turneffe include human resources, social resources, natural resources, physical resources, financial resources, political resources, and cultural resources.

Human resources encompass various skills and supports essential for seaweed farming. Participants emphasized the importance of good health for physical well-being, survival skills for managing camping on seaweed farming sites, and swimming skills for water-related activities. Additionally, maintenance and security skills, along with knowledge of the area, were crucial. Family support played a significant role in building the seaweed business, while advocacy and communication skills with government officials and potential investors were also vital. Participants highlighted the need for sea navigation and weather prediction skills, as well as business and marketing skills derived from personal experiences.

Social resources included partnerships with E-NGOs for seed stock protection and informal communication with other participants in the country. Consistent communication with authorities in the fishing industry and the promotion of seaweed gel with local resorts in Turneffe and tourists were also identified as important social resources. Natural resources were critical for the success of seaweed farming. Participants noted the importance of healthy reef waters suitable for seaweed growth and access to areas in Turneffe conducive for farming. Understanding natural weather phenomena like 'Box-in' and dealing with tropical storms and increasing sargassum settling were essential. Rainwater access for various needs was also mentioned as a vital natural resource.

Physical resources included transportation and fuel for boats, durable ropes, anchors, and buoys for seaweed farms, and suitable sandy areas for seaweed cultivation. Infrastructure for harvesting, drying, and processing seaweed, along with maintenance equipment and protective gear, were also crucial. Freshwater access for rinsing seaweed was another important physical resource. Financial resources covered expenses related to transportation, food, and freshwater, as well as costs for ropes, labor wages, and equipment. Political resources involved obtaining permits, licenses, and collaborating with E-NGOs and government departments. Cultural resources encompassed indigenous knowledge of seaweed farming practices and processing techniques. These resources collectively supported the participants in Turneffe in effectively managing their operations and ensuring the sustainability of their seaweed farming activities.

*Hazards: Frequency, Duration, Intensity, Impacts and Resources Impacted*

| Hazard | Frequency | Duration | Intensity | Description of Direct/indirect |
|--------|-----------|----------|-----------|--------------------------------|
|        |           |          |           |                                |

|                                                                                |                       |                 |                | <b>impacts on seaweed farms</b>                               |
|--------------------------------------------------------------------------------|-----------------------|-----------------|----------------|---------------------------------------------------------------|
| Debris/ Sargassum                                                              | Twice per year        | June – November | Medium to High | Infrastructural damages (↑)<br><br>Ocean soil fertility (↓)   |
| Storms Changes/Strong Wind                                                     | 1 to 3 times per year | June - November | Medium to High | Infrastructural damages (↑)<br><br>Object and income loss (↑) |
| Uncertainty in government policies, permit issuance, and regulatory compliance | Ongoing               | Periodically    | Medium to High | Compliance challenges (↑)<br><br>Uncertainty in planning (↑)  |
| Fluctuations in market demand and pricing                                      | Ongoing               | Seasonal        | Medium to High | Sales volume and wholesale pricing (↓)<br><br>Income loss (↑) |

*Table 9.64. Key Hazards and Resources Impacted in Focus Group Discussion 4 in Belize City (Author's own elaboration).*

**Key points:** Guided by the CRiSTAL Toolkit, the male participants discussed several hazards impacting seaweed farming operations in area of Turneffe Atoll Marine Reserve, including their frequency, duration, intensity, and direct/indirect impacts. Participants revealed climate-related variables impacting their seaweed farming production as extreme weather events the loss of objects and income, and indirect impacts including increased security costs and potential disruptions to farming operations. One of the major environmental hazards occurring on a seasonal basis is debris with Sargassum drift. Debris and sargassum accumulation were noted to occur twice annually, typically between June and November, with medium to high intensity. Direct impacts included infrastructural damage, while indirect impacts encompassed reduced ocean soil fertility and challenges in maintaining the farms.

Participants also experienced other extreme weather events such as changes in seasons, storms, strong winds, and wave action happening one to three times per year from June to November, also presented medium to high intensity. The participants described a seasonal wave action coming in different directions into the seaweed farms as 'Box-Send' effect which normally erodes the beaches on the island coastline. The direct impacts were infrastructural damage and loss of objects, while indirect impacts included income loss and disruptions in farming activities due to the damage.

Uncertainty in government policies, permit issuance, and regulatory compliance was an ongoing hazard with medium to high intensity. Direct impacts involved compliance challenges, whereas indirect impacts included uncertainty in long-term planning and potential delays in operations due to regulatory uncertainties.

Fluctuations in market demand, pricing, and competition affecting seaweed sales were also discussed, occurring on an ongoing, seasonal basis with medium to high intensity. The direct impacts were fluctuations in sales volume and wholesale pricing, leading to income loss, while indirect impacts included increased competition, market uncertainty, and challenges in maintaining profitability.

These characteristics of the hazards and their impacts on the seaweed farms describe by the male participants brought understanding to the strategies used to cope with the challenges faced in their farming operations. After identifying major hazards affecting the seaweed farming community, the following current and long-term responses were elaborated as coping strategies to each hazard identified in Table 9.65.

#### *Coping strategies*

For each hazard, and correspondent impact, participants identified their current coping strategies, assessed the extent of their sustainability, and eventually proposed alternative strategies, assuming availability of resources, which could be employed to cope more sustainably with those hazards (Table 9.66).

| <b>Hazards</b>                                               | <b>Current Responses</b>                                                                                                                                             | <b>Long-Term Responses</b>                                                                                                                                                                                                                            |
|--------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Theft                                                        | Implementing security measures such as surveillance cameras and increased monitoring during vulnerable periods                                                       | Securing permits for farming seaweed and seabed leasing land tenures to report theft incidence to local coast guards for patrols.                                                                                                                     |
| Debris/ Sargassum                                            | Clearing debris regularly, repairing damaged infrastructure, and replacing farming infrastructures where necessary                                                   | Investing in higher-quality equipment with longer lifespans, implementing preventive maintenance schedules, and exploring alternative materials for ropes and buoys that are more durable                                                             |
| Storms<br>Changes/Strong<br>Wind/Strong Ocean<br>Wave Action | Maintain equipment regularly and replace worn-out components as needed and anchor farms to the seafloor properly especially just strong winds and wave action events | Investing in more resilient infrastructure, such as stronger anchoring systems and storm-resistant equipment. Developing a community early warning systems through word-a-mouth and preparing a disaster preparedness plan to extreme weather events. |

|                                                                                |                                                                                                                      |                                                                                                                                                                                                                            |
|--------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Uncertainty in government policies, permit issuance, and regulatory compliance | Seek to stay informed about regulatory changes and comply with existing requirements                                 | Engaging with policymakers to advocate for supportive regulations, participating in industry associations to influence policy decisions, and investing in capacity building to ensure compliance with evolving regulations |
| Fluctuations in market demand, and pricing                                     | Adjust pricing strategies or seek alternative markets during periods of market volatility (local consistent markets) | Establishing long-term contracts with buyers, and liaise closely with existing clients                                                                                                                                     |

*Table 9.66. Main Coping Strategies (short and long-term responses) to Hazards (Author's own elaboration).*

*Key findings:* The major hazards impacting seaweed farming operations in Turneffe, along with their current and long-term responses focused primarily on extreme weather events which include debris drifting and strong impacts of seasonal changes including storm events. Regarding debris and sargassum, participants regularly cleared debris, repaired damaged infrastructure, and replaced farming infrastructures where necessary. Long-term strategies involved investing in higher-quality equipment with longer lifespans, implementing preventive maintenance schedules, and exploring alternative materials for ropes and buoys that were more durable.

In response to storm changes, strong winds, and strong ocean wave action, participants-maintained equipment regularly, replaced worn-out components as needed, and properly anchored farms to the seafloor, especially during strong winds and wave action events. Long-term responses included investing in more resilient infrastructure, such as stronger anchoring systems and storm-resistant equipment. Additionally, they developed a community early warning system through word-of-mouth and prepared a disaster preparedness plan for extreme weather events.

To address uncertainty in government policies, permit issuance, and regulatory compliance, participants sought to stay informed about regulatory changes and complied with existing requirements. Long-term strategies involved engaging with policymakers to advocate for supportive regulations, participating in industry associations to influence policy decisions, and investing in capacity building to ensure compliance with evolving regulations.

For fluctuations in market demand and pricing, participants adjusted pricing strategies or sought alternative markets during periods of market volatility, focusing on local consistent markets. Long-term responses included establishing long-term contracts with buyers and liaising closely with existing clients to mitigate the impacts of market fluctuations.

These coping strategies, implemented by the participants in Turneffe Atoll Marine Reserve have enhanced their resilience to withstand the impacts from changes occurring in the environment, market and policy. Participants demonstrated ways they managed their farming operations in the face of various challenges as described in Table 9.67.

#### 9.5.8 CRiSTAL Toolkit: Seaweed Producers FDG #4 (Male Group)

Table 9.68 provides an overview of the fourth focus group discussion (FGD #4) conducted with the Turneffe Seaweed Growers Association (TSGA), summarizing key contextual details including the group's location, date, language spoken, and session duration.

|                         |                                             |
|-------------------------|---------------------------------------------|
| <b>Group Name:</b>      | Turneffe Seaweed Growers Association (TSGA) |
| <b>Location:</b>        | Belize City                                 |
| <b>Language spoken:</b> | English                                     |
| <b>Date:</b>            | 4 <sup>th</sup> August 2023                 |
| <b>Start Time:</b>      | 2:30 PM                                     |
| <b>End Time:</b>        | 6:30 PM                                     |

Table 9.68. Description of fourth focus group (FGD #4).

Table 9.69 outlines the seaweed farming community profile for the fourth focus group discussion (FGD #4) with the TSGA, detailing membership composition, farming locations, cultivated species, production capacity, and site selection considerations.

|                                                                                           |                                                                       |
|-------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| <b>Number of seaweed producers (s):</b>                                                   | 5                                                                     |
| <b>Name of registered seaweed cooperative (s)/ association (s)/community group (s):</b>   | Turneffe Seaweed Growers Association (TSGA)                           |
| <b>Name of unregistered seaweed group (s):</b>                                            | 1 independent seaweed farmers                                         |
| <b>Locations of seaweed farm (s)- (sketch it):</b>                                        | Southeast of Turneffe Atoll Marine Reserve near Turneffe Flats        |
| <b>Number of years farming in the specified sites listed:</b>                             | 2 Years                                                               |
| <b>List of cultivated seaweed species on sites:</b>                                       | <i>Kappaphycus alvarezii</i> and <i>Eucheuma isiforme</i>             |
| <b>Estimated amount of seaweed farmed (in dry weight, pounds unit):</b>                   | 1000 LBS Dry Weight                                                   |
| <b>Historical land use prior to seaweed farming:</b>                                      | Fishermen/private owners and ranger's campsites                       |
| <b>Site selection process for farming seaweed in the specific locations listed above:</b> | Upwelling of cold waters to the flat where seaweed farms are located. |
| <b>If apply, reasons for site relocation:</b>                                             | Relocated from the West part of Turneffe due to poor water exchange.  |

Table 9.69. Seaweed farming community profile (FGD #4).

Table 9.70 presents the business environment for seaweed farming as discussed by the TSGA during the fourth focus group discussion (FGD #4).

|                                                                                                                                |                                                  |
|--------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|
| <b>Investment needed to start a seaweed farm (US dollars):</b>                                                                 | E-NGO capital Grant and Seeds personal financing |
| <b>Economic conditions for investing in seaweed farming: 1= Poor; 2= Satisfactory; 3=Good; 4=Very Good; 5= Other (specify)</b> | 3=Good                                           |
| <b>No. of individuals/families working on seaweed farms:</b>                                                                   | 2 persons per farm sites                         |
| <b>Government &amp;/or NGO processes in accessing any resources or subsidies for farming seaweed:</b>                          | No                                               |

Table 9.70. Business environment for farming seaweed (FGD #4).

Table 9.71 presents the livelihood capitals and associated resources identified TSGA during the fourth focus group discussion (FGD #4). The table highlights the diverse range of human, social, natural, physical, financial, political, cultural, knowledge, and innovative assets that collectively contribute to the sustainability and governance of seaweed farming livelihoods within the Turneffe Atoll region.

| <b>Capital</b> | <b>Livelihood resources</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Human</b>   | <ul style="list-style-type: none"> <li>• Good health</li> <li>• Survival skills to manage camping on seaweed farming sites including CPR training</li> <li>• Swimming skills</li> <li>• Maintenance and security skills and knowledge of the area.</li> <li>• Family support to strive in building the seaweed business</li> <li>• Nutritious diet (fruits and vegetables along with rice, beans and chicken)</li> <li>• Captain and boat mechanical skills</li> <li>• Advocacy and communication skills with government officials and potential investors</li> <li>• Sea navigation and weather prediction skills</li> <li>• Good business and marketing skills based on past personal lessons</li> </ul> |
| <b>Social</b>  | <ul style="list-style-type: none"> <li>• Obtaining support and resources for seaweed farming</li> <li>• NGO partnership with local seaweed farmers in the marine reserve through the protection of seed stocks at NGO headquarters</li> <li>• Informal communication with other seaweed farmers in the country</li> <li>• Consist of communication with authorities in the fishing industry</li> <li>• Promotion of seaweed gel with local resorts in Turneffe and tourists</li> </ul>                                                                                                                                                                                                                     |
| <b>Natural</b> | <ul style="list-style-type: none"> <li>• Healthy reef waters to grow seaweed in</li> <li>• Access to areas in Turneffe that are not touristy sites or no take zones</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

|                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                  | <ul style="list-style-type: none"> <li>• Natural weather phenomenon occurring with the current water movement referred to as ‘Box-in’ where two wave actions are occurring at the same time in a particular area.</li> <li>• Tropical storms and hurricane alerts increasing</li> <li>• Increasing sargassum settling around mangrove areas</li> <li>• Rainwater access</li> </ul>                                                                                                                                                                                                                                                 |
| <b>Physical</b>  | <ul style="list-style-type: none"> <li>• Access to transportation and fuel (boat, engine, fuel and lube)</li> <li>• Farming infrastructures such as durable (nylon material) ropes</li> <li>• Anchors and buoys to submerge seaweed farms</li> <li>• Sandy areas to grow seaweed</li> <li>• Harvesting and drying infrastructure to process cultivated seaweed on camp sites and further processing in-land areas for the sale of commodity</li> <li>• Equipment for maintenance of seaweed farms</li> <li>• Weather protective gears for long hours under the sun</li> <li>• Freshwater access to rinse farmed seaweed</li> </ul> |
| <b>Financial</b> | <ul style="list-style-type: none"> <li>• Transportation-related expenses to visits to seaweed farms</li> <li>• Food-related expenses for camping around seaweed farms</li> <li>• Freshwater capture containers or VAT systems to filter captured water</li> <li>• Ropes for cultivating and anchoring seaweed farms</li> <li>• Labor wages for planters, harvesters and watchmen (security on seaweed farms)</li> <li>• Personal funds</li> </ul>                                                                                                                                                                                  |
| <b>Political</b> | <ul style="list-style-type: none"> <li>• Access to sea space (seagrass bed leasing permits and seaweed farming license)</li> <li>• Open door communication policy with NGOs and government department in seaweed farming projects with seaweed farmers</li> <li>• Support from policymakers to address challenges related to securing sea space tenures,</li> <li>• New rhythms of support and resources to further develop seaweed farming operations</li> <li>• Seaweed farmers and policymaker’s accountability in ensuring transparent and stakeholder-involved regulations and policies</li> </ul>                            |
| <b>Cultural</b>  | <ul style="list-style-type: none"> <li>• Preservation of traditional knowledge and practices related to seaweed farming</li> <li>• Traditional knowledge of seaweed farming practices including ways of processing seaweed on camp sites.</li> <li>• Informal communication between fishers referred to as the ‘fisherman code’</li> <li>• Historical knowledge of sea space uses and pioneers in seaweed farming</li> <li>• Close relationship with the sea as way therapy while making an income</li> <li>• Recognition of the cultural significance of seaweed farming within the community</li> </ul>                          |



|                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                             | <ul style="list-style-type: none"> <li>• Passing down knowledge from older seaweed farmers to younger generations, as well as the promotion of cultural practices that are integral to the farming process.</li> <li>• Engagement in seaweed farming activities promotes and support community cohesion and collaboration, as well as the celebration and promotion of the cultural heritage associated with seaweed farming in the region.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Knowledge &amp; information</b>                                          | <ul style="list-style-type: none"> <li>• Access to training and education in seaweed farming techniques</li> <li>• Information on environmental conditions and best practices to grow seaweed in specific areas for sustainable farming.</li> <li>• Knowledge sharing amongst seaweed farmers in the country through seaweed cultivation trainings and manuals with the support of an international NGO, The Nature Conservancy (TNC) and the Placencia Producers Cooperative Society Limited (PPCSL)</li> <li>• International NGO partnership with the Belize Blue Economy and Fisheries Department</li> <li>• Peer-to-peer knowledge transfer from experienced seaweed farmers to new farmers</li> <li>• Access to information on mariculture policies and regulations</li> <li>• Access to data collected by organizations such the TNC for onsite data collection is important for the farmers to make informed decisions about their farming practices</li> </ul> |
| <b>Innovation</b>                                                           | <ul style="list-style-type: none"> <li>• Access to technology and expertise for value-added product development, such as cosmetics, bioplastics, and agar production</li> <li>• On-site processing of seaweed crop using artisanal methods such as the hand-picked seaweed crop from the cultivated ropes, sun-dried seaweed crop on table with greenhouse mesh or tarp to dehydrate seaweed.</li> <li>• Handcrafted traditional seaweed gel and shakes for local market</li> <li>• Traditional users of seaweed as food have local knowledge on the quality standards in seaweed processing</li> <li>• Emerging value-added products showing the good quality of processed sun-dried seaweed and in gel formation to meet expectations of the consumer's taste.</li> </ul>                                                                                                                                                                                            |
| <b>Flexible forward-looking discussion (decision-making and governance)</b> | <ul style="list-style-type: none"> <li>• The early development of the livelihood resources needed for Turneffe Atoll Seaweed Farmers include access to sea space tenures through NGO partnerships, consistent communication with government departments, and obtaining support and resources for seaweed farming.</li> <li>• Establishing transparent and inclusive governance structures that involve the participation of the farmers in decision-making processes related to regulations, policies, and resource allocation.</li> <li>• Fostering collaboration between the farmers, government agencies, and relevant stakeholders can facilitate the development of effective governance mechanisms that</li> </ul>                                                                                                                                                                                                                                               |

|  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|--|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | <p>support the sustainable growth of the seaweed farming industry.</p> <ul style="list-style-type: none"> <li>• Advocating for the need to attain training to meet quality standards in seaweed processing, indicating a need for innovation in processing techniques and technology.</li> <li>• Open access to information on new farming techniques and innovative practices in seaweed farming is also important for the farmers to improve their productivity and sustainability.</li> <li>• Further development of human resources in farmers is required with a special focus on good health and training, including CPR training and extreme exposure to sun rays.</li> <li>• Fuel subsidence for seaweed farming are required for the industry to become carbon neutral as seaweed farming operations are solely dependent on fossil fuels for transportation, including boat engines that can consume fuel efficiently, to transport seaweed and other resources.</li> <li>• Seaweed farmers have expressed a desire for greater collaboration, transparency, and support for seaweed farming in Belize, indicating a need for political resources to advocate for their interests and address issues related to foreign involvement in seaweed farming and access to markets.</li> <li>• Seaweed farmers require a business mindset and business plan to effectively use available financial resources to cover the expenditures of farming, including hire of watchman, payment of permits and licenses rather than mismanaging personal funds to recover from shocks.</li> <li>• Promoting forward-looking discussions on innovation and technology adoption can enhance the resilience and productivity of the seaweed farming practices including exploring opportunities for access to new farming techniques and development of value-products within the country rather than only exporting raw product (diversifying the market opportunities for farmers and seaweed-based entrepreneurs).</li> <li>• Embracing a forward-looking approach to decision-making can also involve anticipating and addressing potential challenges, such as environmental changes and market dynamics, through proactive planning and adaptation strategies.</li> <li>• A flexible and forward-looking approach to decision-making and governance can empower the Turneffe Atoll Seaweed Farmers to navigate the complexities of the industry, foster sustainable practices, and contribute to the economic and cultural vitality of the community.</li> </ul> |
|--|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

*Table 9.71. Livelihood capitals and resources identified by seaweed farmers (FGD #4).*

Table 9.72 summarizes the key hazards (including climate-related risks), duration, frequency, intensity and impact on seaweed farms in the western areas of Turneffe Atoll Marine Reserve.

| Hazards                               | Frequency                                 | Duration        | Intensity      | Description Of Direct/Indirect Impacts on Seaweed Farms        |
|---------------------------------------|-------------------------------------------|-----------------|----------------|----------------------------------------------------------------|
| Natural events 'Box-send' wave action | Every year September, October, & November | 2 months        | High           | Loss of cultivated seaweed (↑)<br>Damage to infrastructure (↑) |
| Securing sea space tenures            | All year around                           | All year around | Medium to High | Financial losses (↑)<br>Object loss (↑)                        |
| Sargassum influx                      | All year around                           | All year around | Medium to High | Damage to infrastructure (↓)<br>Mobility in the ocean (↓)      |

Table 9.72. List of top three hazards to seaweed farms (including climate-related risks, duration, intensity, frequency, and impact on seaweed farms (FDG #4).

Table 9.73 outlines the training activities undertaken by the farmers of Turneffe Atoll during the fourth focus group discussion (FGD #4), including the knowledge and skills acquired, environmental challenges addressed, and the perceived benefits of training in fostering collaboration and knowledge exchange among seaweed farmers.

| Name of training (as labelled on certificate)                                                                                   |                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                |
|---------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| List of knowledge and skills acquired in training:                                                                              | List of environmental-related challenges addressed in training:                                                                                                                                                                                                            | Benefits received from training in a group set-up and knowledge exchange with seaweed farmers:                                                                                                                                                                 |
| Hazard Analysis and Critical Control Point (HACCP) training in processing seafood in fishing cooperative                        | Food safety and quality control in seafood processing such as finfish, lobster and conch. Understand how to keep the standards high in seafood quality based on the fishing cooperative procedures in Belize City. No environmental challenges addressed in this training. | This type of training wasn't specifically with seaweed, but it dealt with seafood such as conch, lobster and finfish. This training was conducted a very long time, but seaweed farmers have expressed a need for a training like this specifically on seaweed |
| Introduction to seaweed farming techniques in 2005 with Dr. Allan Smith from the Caribbean Natural Resources Institute (CANARI) | Learning how to use rope as cultivation of seaweed resources rather than wild harvesting. Livelihood diversification strategy for traditional fishermen who solely relied on fishing alone. No environmental challenges addressed in this training.                        | Training can also provide opportunities for farmers to learn about new farming techniques, value-added product development, and market opportunities, which can enhance their economic prospects.                                                              |

|                                                                                          |                                                                                                                                                                                                                                                      |                                                                                                                                    |
|------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| Good management practices of seaweed cultivation with TNC and seaweed producing entities | Training of best practices that work in cultivating specific seaweed species that is grown in Belize. Improved productivity, quality control, and sustainability of their farming practices. No environmental challenges addressed in this training. | Training foster collaboration and knowledge-sharing among farmers, which can contribute to the cultural vitality of the community. |
|------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|

Table 9.73. Training and knowledge exchange among seaweed farmers (FGD #4).

Table 9.74 presents the direct and indirect impacts from climate and non-climate related hazards of seaweed farmers in the fourth focus group discussion in Belize City.

| <b>Climate-related hazard: Severe weather events, such as hurricanes and storms</b> |                                                                                                                                                                                                     |                                                                                                                                          |                                                                                              |
|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|
| Direct Impact                                                                       | Indirect Impact                                                                                                                                                                                     | Other Causes of Impact                                                                                                                   | Impacted Resources                                                                           |
| Physical damage to infrastructure such as ropes and buoys.                          | Changes in the marine environment, such as erosion of beaches and changes in ocean currents, which can affect the suitability of farming locations and the overall health of the coastal ecosystem. | Debris deriving from destroyed infrastructure becomes marine pollution and settles on the seafloor and in mangroves/coastal environment. | Hinder the farmers' ability to work on the farms, leading to lost productivity and income.   |
| Changes in ocean currents and temperatures.                                         | Changes in marine ecosystem and affect the growth and quality of seaweed crops and reduce overall coastal environment health.                                                                       | Negative effect on farming infrastructure shelf-life such as ropes.                                                                      | Impact economic viability of the farming practices due to reduced working days on the farms. |
| "Box-send" effect, which occurs during specific months (September to November).     | Create challenges for accessing and maintaining seaweed farms, thus affecting farmer's productivity.                                                                                                | Rapid wave action cause entanglement of ropes with sargassum debris and hindrance of farming activities                                  | Loss of cultivated seaweed due to the force of the weather.                                  |

Table 9.74. Climate-related hazards and their impacts on seaweed farming (FDG #4).

Table 9.75 summarizes the non-climate-related hazards identified by the seaweed farmers in Turneffe Atoll Marine Reserve during the fourth focus group discussion (FGD #4), focusing on unregulated seaweed quality controls and market standards. The table highlights the direct, indirect, and underlying causes of these risks, as well as their associated impacts on the economic viability, infrastructure, and resource management of seaweed farming operations.

| <b>Non-climate-related Hazards: Unregulated seaweed quality controls and standards to local and international market</b>                                                                                                            |                                                                                                                                                                 |                                                                                                                                                                                                                                                                               |                                                                                                                              |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|
| Direct Impact                                                                                                                                                                                                                       | Indirect Impact                                                                                                                                                 | Other Causes of Impact                                                                                                                                                                                                                                                        | Impacted Resources                                                                                                           |
| Market demand and pricing: Fluctuations in market demand and pricing for seaweed products impact the profitability and economic viability.                                                                                          | Consumers may turn to wild harvested seaweed due to quicker demand and cheaper prices. This may reduce demand and affect pricing.                               | Unclear regulations and permit processes along with bureaucratic hurdles can create barriers to entry and limit the growth potential.                                                                                                                                         | Livelihood economic viability: Reduced income and financial resources                                                        |
| Competition and market access: Increased competition from other seaweed farmers, fishers and private companies in limited market access areas (rural).                                                                              | Inadequate infrastructure, technological support, and access to resources such as affordability of farming equipment and infrastructure to meet market demands. | Infrastructure and Transportation: Challenges related to transportation, such as a lack of reliable transportation options to harvest to time and infrastructure to process seaweed can hinder the timely and efficient supply of seaweed to local and international markets. | Financial Support and Investment: Market share and profitability of seaweed cultivation for local and international markets. |
| Quality Control and Standards: Adhering to quality control standards and meeting the requirements of international markets may pose challenges for seaweed farmers, impacting their ability to access and compete in these markets. | Reduction of seaweed quality to consumers due to changes in farming cultivation methods or processing practices.                                                | Regulatory Challenges: Unclear regulations, permit processes, and bureaucratic hurdles can create barriers to entry and limit the growth potential of the seaweed farming industry.                                                                                           | Poor access to high-quality seaweed seeds and a consistent supply may change seaweed appearance.                             |

*Table 9.75. Non-climate-related hazards and risks to seaweed farming (FGD #4).*

Table 9.76 outlines the main hazards and threats to seaweed farming identified by the Turneffe Seaweed Growers during the fourth focus group discussion (FGD #4). The table highlights the reasons why these threats remain unaddressed and describes the potential risks they pose to seaweed farms if left unmanaged, particularly regarding regulatory uncertainty, market access, infrastructure limitations, and environmental stressors.

| <b>List hazards/threats to seaweed farming:</b>                                                                                                                                                                                 | <b>Reasons for not addressing threats:</b>                                                                                                                                                                                                          | <b>If threats are not impacting seaweed farms, describe risks:</b>                                                                                                                                                                       |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Regulatory uncertainty and affordability of permits for local seaweed farmers limits the growth potential of the seaweed farming industry.                                                                                      | Need to understand how the current fisheries resources management laws and policies affect farmers who are currently engaged in farming operations or interested to enter.                                                                          | Unclear regulations and permit processes to attain sea space tenures may affect the security of farms and inability to report theft incidence. This may lead to more theft.                                                              |
| Market access and pricing fluctuations impacts the profitability and economic viability of seaweed cultivation for both local and international markets.                                                                        | Financial literacy and limited market information affect farmers ability to compete in an international market including having the financial investment for value-added products.                                                                  | The fluctuations in market demand and pricing for seaweed products can impact the price of sustainably harvested seaweed compared to wild harvest.                                                                                       |
| Infrastructure and transportation challenges directly threatens the economic viability of seaweed farms around islands and hinder the timely and efficient supply of seaweed to local and international markets.                | The availability of investment capital for seaweed farms is empirical for infrastructure improvement and expansion of operations to supply a local and international market consistently.                                                           | Issues related to transportation, such as a lack of reliable transportation options and infrastructure, can lead to irregular supply of seaweed farming products. Customers not relying on farmer's sustainably harvested products.      |
| Lack of in-country quality control and standards for export market is a threat to seaweed-based products deriving from Belize as some products may be good and some may not. This can lead to Belize seaweed being blacklisted. | Expertise in quality control and standards in red seaweed species grown in Belize. Need to understand the requirements of the international markets and affordability of certifications for seaweed farmers to access and compete in these markets. | Supplying poor quality seaweed commodity limits future market access opportunities due to poor adherence to the requirements of international markets.                                                                                   |
| Environmental factors such as extreme storms and changing environmental conditions is the most underlining threat to seaweed farms' productivity leading to damage, loss of crops and need for reinvestment (replanting).       | Lack of investment for early monitoring systems on farming sites. Site-specific data can help the farmers to make inform decisions about the seaweed crop cycle.                                                                                    | Climate change-related conditions may intensify and lead to further losses of the farmers resources. Farmers' limited knowledge of weather changes is a great risk to identifying adaptation strategies that can work on the farm sites. |

*Table 9.76. Key hazards, unaddressed threats, and potential risks to seaweed farming (FGD #4).*

Table 9.77 presents the current and long-term responses to the key risks and hazards identified by the Turneffe Seaweed Growers during the fourth focus group discussion (FGD #4). The table illustrates how farmers are presently addressing challenges related to regulatory uncertainty, market access, infrastructure, quality control, competition, and environmental change, while outlining their proposed long-term strategies to strengthen the resilience and sustainability of seaweed farming livelihoods.

| <b>Hazards</b>                               | <b>Current Responses</b>                                                                                                                                                                                                                                                                       | <b>Long-Term Responses</b>                                                                                                                                                                                                                                                                 |
|----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Regulatory Uncertainty                       | To advocate for clear regulations and policies specific to seaweed farming that provide clarity on permits, quality standards, and market access                                                                                                                                               | To work with government agencies and industry stakeholders to develop and implement clear regulations and policies that support the growth and competitiveness of the seaweed farming industry.                                                                                            |
| Market Access and Pricing Challenges         | To seek support from government agencies, NGOs, and industry stakeholders in developing and accessing markets, as well as providing market information and opportunities.                                                                                                                      | To develop and expand market opportunities, including exploring new markets and value-added products, to enhance the marketability and profitability of seaweed products.                                                                                                                  |
| Infrastructure and Transportation Challenges | To seek support for infrastructure development and access to resources such as ropes, buoys, and farming equipment                                                                                                                                                                             | To invest in infrastructure development and technological support to enhance the efficiency and sustainability of seaweed farming practices.                                                                                                                                               |
| Quality Control and Standards                | The current response to quality control and standards challenges is to adhere to quality control standards and meet the requirements of international markets.                                                                                                                                 | The long-term response is to invest in training and capacity building across the entire value chain, including farming techniques, quality control, and market access, to enhance the skills and knowledge of seaweed farmers and improve the quality and marketability of their products. |
| Competition and Market Access                | To engage in working groups, partnerships with relevant organizations, and collaboration with industry stakeholders to provide opportunities for knowledge sharing, market access, and collective action to address challenges and opportunities in supplying local and international markets. | To develop and expand market opportunities, including exploring new markets and value-added products, to enhance the marketability and profitability of seaweed products.                                                                                                                  |
| Environmental Factors                        | To environmental factors is to monitor and manage the impact of natural events like storms and changing environmental conditions on seaweed farms.                                                                                                                                             | To invest in research and development to enhance the resilience and sustainability of seaweed farming practices in the                                                                                                                                                                     |

|  |  |                                            |
|--|--|--------------------------------------------|
|  |  | face of changing environmental conditions. |
|--|--|--------------------------------------------|

Table 9.77. Current and long-term responses to identified risks and hazards in seaweed farming (FGD #4).

Table 9.78 summarizes the external hazards/threats to seaweed farming identified by the farmers in the fourth focus group discussion (FGD #4). These include regulatory uncertainty, market access and pricing fluctuations, infrastructure and transportation challenges, quality control standards, competition, and environmental factors that collectively affect the sustainability, productivity, and long-term economic viability of seaweed farming livelihoods in Belize.

| External Hazards/Threats to Seaweed Farms |                                                                                                                                                                                                                                                |
|-------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1                                         | Regulatory uncertainty: Unclear regulations and permit processes pose a risk to seaweed farms, potentially creating barriers to entry and limiting growth potential                                                                            |
| 2                                         | Market access and pricing: Fluctuations in market demand and pricing for seaweed products can impact the profitability and economic viability of seaweed cultivation for both local and international markets                                  |
| 3                                         | Infrastructure and transportation challenges: Issues related to transportation, such as a lack of reliable transportation options and infrastructure, can hinder the timely and efficient supply of seaweed to local and international markets |
| 4                                         | Quality control and standards: Adhering to quality control standards and meeting the requirements of international markets may pose challenges for seaweed farmers, impacting their ability to access and compete in these markets             |
| 5                                         | Competition and market access: Increased competition from other seaweed farmers and industries, as well as limited market access, can affect the market share and profitability of seaweed cultivation for local and international markets     |
| 6                                         | Environmental factors: Natural events like storms and changing environmental conditions can impact seaweed farms, leading to damage, loss of crops, and the need for replanting, affecting the productivity and resources of farmers           |

Table 9.78. External hazards/threats to seaweed farming (FDG #4).

Table 9.79 presents the current scale of operation, key resources needed for scaling up, challenges anticipated in expanding production, training requirements for future employment, and policy directions for the sustainable development of seaweed farming in Turneffe Atoll Marine Reserve.

|                                                                                                                              |   |
|------------------------------------------------------------------------------------------------------------------------------|---|
| <b>Current scale of operation</b><br><b>1=Very small;</b><br><b>2=Small;</b><br><b>3=Medium;</b><br><b>4=Mixed; 5= Large</b> | 2 |
|------------------------------------------------------------------------------------------------------------------------------|---|



|                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|---------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>Resources needed to scale up farming operations</b></p>       | <ul style="list-style-type: none"> <li>• Scaling up seaweed farming operations requires a comprehensive set of resources, including infrastructure, training and capacity building, research and development, market development, policy and regulation support, collaboration and partnership, and financial support to support the growth and competitiveness of the seaweed industry.</li> <li>• Investment in infrastructure such as transportation, storage facilities, processing plants, and pre-processing units on the island is crucial to support the scaling up of farming operations</li> <li>• Resources for training and capacity building across the entire value chain, including farming techniques, quality control, and market access, are essential to enhance the skills and knowledge of seaweed farmers and improve the quality and marketability of their products</li> <li>• Investment in research and development to enhance the resilience and sustainability of seaweed farming practices in the face of changing environmental conditions, such as climate change and natural disasters, is important for scaling up operations</li> <li>• Resources for market development, including market research, access to market information, and opportunities for value-added products, are needed to enhance the marketability and profitability of seaweed products</li> <li>• Support for the development and implementation of clear policies and regulations specific to seaweed farming is essential to provide clarity on permits, quality standards, and market access, supporting the growth and competitiveness of the seaweed farming industry</li> <li>• Resources for collaboration and partnership with government agencies, NGOs, industry stakeholders, and research institutions can provide opportunities for knowledge sharing, market access, and collective action to address challenges and opportunities in scaling up farming operations</li> <li>• Access to financial resources, including loans for investments in processing stations/plants on the island, working capital, and investment in technology and equipment, is crucial for scaling up seaweed farming operations</li> </ul> |
| <p><b>Challenges that may be faced in scaling up operations</b></p> | <ul style="list-style-type: none"> <li>• Collaboration with government agencies, NGOs, industry stakeholders, and research institutions is essential to develop long-term solutions that support the growth and sustainability of seaweed farming in the face of challenges in scaling up operations.</li> <li>• Addressing these challenges requires a multi-faceted approach including cross sectoral collaboration with the government structures and NGO partners along with seaweed farmers in order to foster an effective regulations framework.</li> <li>• Closing the gap between seaweed farmers and customers requires much more effort in awareness of nutritional</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

|                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                               | <p>benefits of seaweed products. This will help to develop a strong local and international market and room to scale up.</p> <ul style="list-style-type: none"> <li>• Investment capital to infrastructure improvement, quality control measures, and resilience-building strategies to mitigate the impact of environmental factors needs to be strengthened through impact investors and market.</li> <li>• Limited access to financial resources, including loans for investments in processing stations/plants on the island, working capital, and investment in technology and equipment, can hinder the ability to scale up operations.</li> <li>• Matching the supply and demand requires sophistication and market information to avoid flooding the market. For instance, scaling up operations means that more seaweed commodities will be available in the market and if there is poor market growth this seaweed commodity may go to a waste due to not being able to sell it.</li> <li>• Adhering to quality control standards and meeting the requirements of international markets may pose challenges for scaling up operations, impacting the ability to access and compete in these markets. For example, FDA requirements in the USA which is the closest international market to Belize.</li> <li>• Provision of site selection and monitoring of weather conditions is crucial as natural events like storms and changing environmental conditions can impact seaweed farms, leading to damage, loss of crops, and the need for replanting, affecting the productivity and resources of farmers, making it challenging to scale up operations.</li> </ul> |
| <p><b>Training that may be needed for future employment in the seaweed farming sector</b></p> | <ul style="list-style-type: none"> <li>• Future employment in the seaweed farming sector may require various types of training to develop the necessary skills and knowledge. The following types of training may be needed for future employment in the seaweed farming sector:</li> <li>• Farming Techniques: Training in seaweed farming techniques, including farm setup, maintenance, and cultivation practices, is essential for individuals seeking employment in the sector.</li> <li>• Quality Control and Processing: Training in quality control measures, processing techniques, and value-added product development can enhance the skills of individuals involved in seaweed processing and product development.</li> <li>• Environmental Resilience: Training in environmental resilience and adaptation strategies can prepare individuals to address challenges related to climate change, natural events, and environmental factors affecting seaweed farms.</li> <li>• Market Access and Business Skills: Training in market access, business management, and entrepreneurship can equip individuals with the skills needed to navigate market dynamics, develop business plans, and access financial resources for seaweed farming operations.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                  |

|                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                         | <ul style="list-style-type: none"> <li>• <b>Regulatory Compliance:</b> Training in regulatory compliance, including understanding permits, standards, and regulations specific to seaweed farming, is important for individuals involved in farm management and operations.</li> <li>• <b>Collaboration and Networking:</b> Training in collaboration, networking, and partnership development can enhance the ability of individuals to engage with government agencies, NGOs, industry stakeholders, and research institutions to address challenges and opportunities in the seaweed farming sector.</li> <li>• <b>Research and Development:</b> Training in research and development methodologies, including data collection, analysis, and innovation, can prepare individuals to contribute to the advancement of seaweed farming practices and technologies</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Seaweed farming future direction</b> | <ul style="list-style-type: none"> <li>• The enabling environment for the cultivation of red seaweed to supply local and international markets involves various factors that support and facilitate the sustainable growth of the seaweed farming industry.</li> <li>• <b>Clear Regulations and Policies:</b> Well-defined regulations and policies specific to seaweed farming that provide clarity on permits, quality standards, and market access can create a conducive environment for farmers to operate and access local and international markets.</li> <li>• <b>Market Development and Support:</b> Support from government agencies, NGOs, and industry stakeholders in developing and accessing markets, as well as providing market information and opportunities, can enhance the marketability of red seaweed products for local and international trade.</li> <li>• <b>Access to Seeds and Consistent Supply:</b> Ensuring access to high-quality seaweed seeds and a consistent supply is crucial for the sustainability and expansion of red seaweed cultivation to meet the demands of local and international markets.</li> <li>• <b>Training and Capacity Building:</b> Opportunities for training and capacity building across the entire value chain, including farming techniques, quality control, and market access, can enhance the skills and knowledge of seaweed farmers, making them more competitive in local and international markets.</li> <li>• <b>Infrastructure and Technology:</b> Adequate infrastructure, technological support, and access to resources such as ropes, buoys, and farming equipment are essential for efficient and sustainable red seaweed cultivation to meet market demands.</li> <li>• <b>Collaboration and Networking:</b> Engaging in working groups, partnerships with relevant organizations, and collaboration with industry stakeholders can provide opportunities for knowledge sharing, market access, and collective action to address challenges and opportunities in supplying local and international markets.</li> </ul> |

|  |                                                                                                                                                                                                                                                                                                                                                                    |
|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | <ul style="list-style-type: none"> <li>Financial Support and Investment: Access to financial resources, including loans for investments in processing stations/plants, as well as support for infrastructure development and quality control, can enable the growth and competitiveness of red seaweed cultivation for local and international markets.</li> </ul> |
|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

*Table 9.79. Current operations, scaling-up resources, challenges, training needs, and future policy directions for seaweed farming (FGD #4).*

Table 9.80 provides future communication with lead seaweed farmers.

| <b>Name</b>   | <b>Position</b> | <b>Organization</b>                  | <b>Email</b>              |
|---------------|-----------------|--------------------------------------|---------------------------|
| Alfonzo Marin | Lead            | Turneffe Seaweed Growers Association | alfonzomarin304@gmail.com |

*Table 9.80. Future communication with seaweed farmers (FDG #4).*

## 9.6 APPENDIX F (Elite Interview)

### 9.6.1 Data: Summary of Elite Interview Transcription

The Elite Interview Surveys were conducted to gather in-depth insights from key stakeholders and decision-makers involved in seaweed aquaculture, climate adaptation, and policy development in Belize. The interviews targeted individuals in influential positions across various sectors, including government, non-profit organizations, and international partners. The elite interviewees held roles such as Director, Senior Officer, Deputy Executive Director, and Executive Director within institutions ranging from government bodies to international environmental non-governmental organizations (E-NGOs) and regional partners. These interviews allowed for a comprehensive understanding of the policy landscape, institutional challenges, and strategic initiatives related to the sustainability of seaweed farming and its role in climate adaptation in Small Island Developing States (SIDS), specifically focusing on Belize. The diversity in gender, age, and institutional affiliation provided a multi-dimensional perspective on the issues being studied. The responses summarized below correspond to the seven guiding questions posed to elite interview participants. Each table presents a synthesized summary of responses from respondents (A–F) from Table 9.81 to Table 9.87.

1. Is there a Blue Economy Strategy Plan in Belize, and if yes can you summarize its objectives?

| Respondents | Responses                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A           | <p>Belize has outlined its Belize Blue Economy Development Policy, Strategy, and Implementation Plan 2022-2027 (BEDPS) with predefined actions geared towards development, though it acknowledges a significant challenge in the form of budget constraints. While the document provides a comprehensive legal framework for the broad blue economy context, encompassing 14 legislations, it notably lacks specific focus on mariculture. Instead, the BEDPS underscores the importance of growing sectors, often referencing them as aquaculture.</p> <p>Within the realm of mariculture, the plan recognizes a critical challenge—the need for regulations governing fisheries resources to ensure the sustainable development of mariculture. This alignment with mariculture policy, deep-sea fishing, and value chain development is emphasized. Additionally, the BEDPS underscores the imperative to institutionalize the implementation of both the national fisheries policy strategy and action plan, and the national mariculture policy.</p> <p>Guided by principles that prioritize governance, the BEDPS highlights seaweed as the "lowest hanging fruit" in terms of policy implementation, designating it as a sector ready for immediate action. The document also delves into incentive structures for economic growth and capacity building, pinpointing these as overarching priorities that directly intersect with seaweed cultivation.</p> <p>In essence, the BEDPS extensively covers existing sectors within the blue space, while also identifying emerging sectors for potential development. Notably, some of these emerging sectors lack explicit connections to climate change within the policy documents. Overall, the plan provides a comprehensive blueprint for Belize's blue economy, emphasizing</p> |

|   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|   | governance, regulatory frameworks, and strategic priorities for sustainable growth.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| B | Fisheries Policy Strategy and Action Plan, Belize National Mariculture Policy 2022, Belize Blue Economy Strategy and Implementation Plan 2022-2027 (important documents).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| C | <p>Blue economy is pretty new to the region; in terms of CRFM, we are just starting a project that would give us some plan for a regional plan and start with 5 countries: Panama, Barbados, Belize, Guyana, Jamaica, St Kitts and Nevis BE CLME+. For most people, the blue economy is new and emerging, and Belize is the only country in the region that has a blue economy plan or strategy.</p> <p>The initiative titled the “BE-CLME+: Promoting National Blue Economy Priorities Through Marine Spatial Planning in the Caribbean Large Marine Ecosystem Plus” project - US 48-million-dollar project to strengthen the foundation for blue economic growth and sustainable development of marine living resources by focusing on marine spatial planning, area-based management, and climate-smart sustainable seafood value chain development has commenced.</p> |
| D | <p>Belize Blue Economy Development Policy, Strategy and Implementation Plan 2022-2027 is the overarching document for blue economy in Belize.</p> <p>However, the Belize Funds follow the commitments Belize has made to conservation through the Blue Bond Agreement. It follows NBAP, NDC, UNFCCC, SDGs and GBF.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| E | <p>Belize Blue Maritime Economy Plan</p> <p><a href="https://assets.publishing.service.gov.uk/media/63e1244ee90e0762692b96cd/Belize_Maritime_Economy_Plan_August_2022.pdf">https://assets.publishing.service.gov.uk/media/63e1244ee90e0762692b96cd/Belize_Maritime_Economy_Plan_August_2022.pdf</a></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| F | Yes, see the Belize Blue Economy Development Policy, Strategy & Implementation Plan (2022-2027) HERE. See Strategic Objectives on page 20.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

*Table 9.81. Summarizes the responses from elite interview participants regarding the existence and objectives of Belize's Blue Economy Strategy Plan.*

2. Is there any legislative framework in place for safeguarding/understanding nature-based solutions (such as seaweed farming) in Belize's Blue Economy Plan?

| Respondents | Responses                                                                                                                                                                                                                                                                                                                                           |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A           | These benefits can be understood through research permits or legislative measures that aim to commercialize such activities. The Fisheries Act is mentioned as a source where these regulations or permits can be found. Additionally, the concept of mariculture is more extensively discussed in the economic plan compared to the strategy plan. |
| B           | According to the policy, an under a research permit speaks to supporting a conducive market, which can be interpreted as an international market. You can sell your seaweed under a marine research permit in accordance with the policy.                                                                                                           |

|   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| C | <p>Seaweed cultivation, considered a Nature-based Solution (NbS), faces significant challenges in its industry. The foremost issue lies in obtaining permission to utilize the seafloor, necessitating a research permit from entities like TNC and Tassa. Without guaranteed land tenure, expansion becomes difficult, hindering secure investments in seaweed production. Despite efforts since 2016-2017 to establish a policy framework for secure farming at sea, no conclusive agreement has been reached.</p> <p>Tenureship for 5 - 10 years = enough production in a long term<br/>TNC MCCAP project - TNC, lands, fisheries = policy framework /free range (farm the sea with some kind of security)</p> <p>Climate change compounds the industry's woes, as rising temperatures lead to diseases in sea moss. The heat, particularly at the water's surface, literally cooked the plants. To counter this, cultivation has shifted closer to the bottom and midwater. The reports highlight the emergence of ice-ice disease, notably in Turneffe, impacting the industry. While not immediately publicized, the disease's presence in the south remains unclear.</p> <p>Obtaining proper seeds presents another challenge. A promising farm in Turneffe, the northern region, faced setbacks when their supplies were stolen during a reef expedition. This incident marked the closest the industry came to successful production in the north.</p> <p>Further complicating matters is the invasion of sargassum, devastating coastal areas and straining financial resources. The affected farms lacked the funds for repeated reinvestment, exacerbating the industry's struggle.</p> |
| D | <p>We don't have Nature-based Solution (NbS) implicitly written anywhere, but of course we support sustainable use of our resources, so that must factor in NbS.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| E | <p>Belize Fisheries Resource Act<br/><a href="https://faolex.fao.org/docs/pdf/blz197105.pdf">https://faolex.fao.org/docs/pdf/blz197105.pdf</a></p> <p>Belize Mariculture Policy<br/><a href="https://static1.squarespace.com/static/64f79fffaa1a5c7f98a0a4b4/t/64f80b46f8781b13b60c522d/1693977414644/Final+National+Mariculture+Policy-2023-05-10.pdf">https://static1.squarespace.com/static/64f79fffaa1a5c7f98a0a4b4/t/64f80b46f8781b13b60c522d/1693977414644/Final+National+Mariculture+Policy-2023-05-10.pdf</a></p> <p>Department of Environment<br/><a href="https://faolex.fao.org/docs/pdf/blz5416.pdf">https://faolex.fao.org/docs/pdf/blz5416.pdf</a></p> <p>Lands Department<br/><a href="https://naturalresources.gov.bz/index.php/dock-application/">https://naturalresources.gov.bz/index.php/dock-application/</a></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| F | <p>Yes, a draft Blue Economy Bill has been elaborated, but it is currently at the stakeholder consultation phase.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

*Table 9.82. Elite interview participants' views on legislative frameworks safeguarding seaweed farming in Belize's Blue Economy Plan.*

3. To what extent are seaweed mariculture activities captured in the Belize Blue Economy Strategy Plan?

| Respondents | Responses                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A           | The strategy document does not mention a blue economy plan for scaling up seaweed farming in Belize, but the maritime economies policy emphasizes mariculture's importance. The ministry is working on legislation and governance frameworks, with mariculture policy being implemented to complement the blue economy approach.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| B           | Mariculture policy is ready, and regulations are in draft                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| C           | There have been no advancements in institutional aspects; we're still at stage 1, which is the policy framework.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| D           | <p>The growth of industry faces a significant challenge due to the absence of supporting legislation. For example, securing tenure for farms, particularly in the context of seabed leasing, lacks a structured framework. While efforts have been made by the BE to address this through legislation, recent inquiries reveal delays in the consultancy process. Despite an initial target for completion in August, the consultant's failure to deliver has necessitated the issuance of a new consultancy.</p> <p>In light of these legislative obstacles, the development of the industry remains hindered. However, recognizing the potential of blue business innovations, a thematic focus has been placed on funding projects such as mariculture. Although the market for seaweed in Belize may be limited, there is optimism about its scalability if the proper framework is established. A key challenge identified in this endeavor is the need for enhanced organizational capacity, financial management, structures, and business acumen.</p> <p>To address these challenges, proactive steps are being taken, including the exploration of partnerships to implement a capacity-building program. The program is specifically designed to benefit communities aspiring to develop blue businesses, aiming to equip them with the necessary skills and knowledge to stand independently in the industry.</p> |
| E           | Very minimal as Belize Maritime Plan is an overarching document and each sector can adopt it as they see fit.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| F           | Caribbean Seaweed as a high-value crop and its by-products represent a significant opportunity for sustainable economic diversification and growth, and with meaningful impact for stakeholders particularly vulnerable to climate change. There is tremendous potential to harness the power of knowledge transfer, MSME development, and SDG-oriented climate action opportunities as well as the opportunity to attract research tourism which has economic spin-offs. There is furthermore a unique chance to secure Geographical Indication designation for Belizean seaweed given the specie-specific features exhibited. In the case of Belize, which has made major debt for conservation commitments in the form of our pioneering Blue Bond, the seaweed aquaculture sector could have a prominent place and at scale (where appropriate), especially along Belize's southern coast. For this, however, much work needs to be undertaken from the policy                                                                                                                                                                                                                                                                                                                                                                                                                                                           |



|  |                                                                                                                           |
|--|---------------------------------------------------------------------------------------------------------------------------|
|  | and regulatory side to rationalize and simplify permitting processes through which to encourage investment in the sector. |
|--|---------------------------------------------------------------------------------------------------------------------------|

*Table 9.83. Elite interview participants' views on the extent to which seaweed mariculture activities are captured in the Belize Blue Economy Strategy Plan.*

4. How does the blue economy strategy plan capture the scaling up of seaweed farming activities in Belize through blue growth financial mechanisms/instruments? If not, is there any plan to do so?

| <b>Respondents</b> | <b>Responses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A                  | The strategy document doesn't speak to capturing the scaling up of seaweed farming activities in Belize through blue growth financial mechanisms/instruments but the maritime economy policy touches on it in terms of highlighting the importance and emergence of mariculture in its entirety, though not focused solely on seaweed but broadly. In terms of scaling up, from the blue economy's ministerial perspective, the ministry is working on blue economy legislation, and in developing the governance framework, one of the pre thematic areas that will be advancing is the mariculture policy which will be implemented. This will start with seaweed to fully complement the blue economy approach. This is intended to be advanced in national legislation.                                                                                                                                                                      |
| B                  | No formal license can be issued until regulations are in place                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| C                  | <p>In Belize, the challenge lies in the fundamental understanding of the importance of paperwork for small businesses, hindering investment and impact on livelihoods. Despite 20 years of funding, the lack of tangible results raises concerns.</p> <p>The country has a parametric insurance scheme through CCRIF, offering payouts within 1-2 weeks for events like category 1 hurricanes. However, the COAST insurance scheme for fisheries, piloted in St Lucia and another country, has yet to see successful claims. Securing insurance for fishing proves difficult and costly.</p> <p>Jamaica has a national fisherman insurance scheme where fishermen contribute and receive dividends based on damages. Unfortunately, Belize has not adopted such best practices, reflecting the presence of red flags from the past. The current situation aligns with historical concerns, making the challenges in the region unsurprising.</p> |
| D                  | Financial support is provided through funding given to the government, competitive grants award programs, and non-government support. The funding aims to achieve commitments such as expanding biodiversity protection zones, legislating revised Coastal Zone Management (CZM) Act and Integrated Coastal Zone Management (ICZM) plan, and reaching the goal of 30% oceans protected by 2026.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| E                  | There is room for improvement but overall, more research is needed and to look at the value chain including lending institutions. UNDP and TNC have placed funds on seaweed farming projects so far.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

|   |                                                                                                                                                                                                                                                                                  |
|---|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|   | The new business model needs to include private income from the seaweed farmer and a grant to match the total amount of money needed.                                                                                                                                            |
| F | Yes, as fish stocks decline, pressure is placed on fisherfolk for alternative livelihoods. Additionally, as demand and resources for climate change adaptation increases, the sector fills a gap where investment in this sector directly feeds into climate adaptation efforts. |

*Table 9.84. Elite interview participants' views on how the blue economy strategy plan captures the scaling up of seaweed farming activities in Belize through blue growth financial mechanisms or instruments.*

5. Do you think that seaweed farming, in this current status, is beneficial to sustain the livelihoods of those who work in it?

| Respondents | Responses                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A           | <p>Currently, there are two farms in Turneffe, namely Marin and Pebbles Farm, along with the TASA Seed bank. In Placencia, there are three entities - Placencia Coop, BWSFA, and Riversdale. The livelihoods of Marin and Pebbles Farm, benefiting only two individuals, remain unaffected and do not contribute to decreased well-being. Conversely, the cooperative in Placencia faces challenges with inconsistent contributions, highlighting a need for more sustained efforts. BWSFA distinguishes itself by adding significant value to its farming practices, positioning it favorably compared to others and enabling the production of a variety of products.</p> <p>However, attention is drawn to the need for information regarding the women of Riversdale. Currently, sustaining the livelihoods of those involved is not deemed beneficial, as the focus should be on research and development. It's crucial for people to comprehend that mariculture and aquaculture are not quick-fix solutions but rather long-term investments. While investments may take time to yield returns, emphasizing research and development in the present is essential for future prosperity.</p> |
| B           | Seaweed farming is seen as an alternative income generation activity for fishers - it is an attempt to reduce fishing effort to move away from the lobster and conch fishing industries. However, the cost of materials for the infrastructure of seaweed farms is a huge disincentive for anyone. The farms must be monitored regularly; if left alone, larceny can occur. Additionally, if we are going to extract the value-added products to make medicine etc. this would be more feasible but exporting the raw material will not make any sense because the volume being produced is too small, the return on investments would be small. Placencia persons aren't making a good living from this initiative currently.                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| C           | <p>Belize has not been able to develop a seed bank. If they want to compete with Asia, Belize needs to provide container loads of seeds to sell on the market. Belize has not produced anything near a 20-foot container. The industry is non-existent. There is nothing to report on the seaweed industry in the CRFM report but there is data for other countries.</p> <p>In short, it is a NbS option, but it is restricted by the heat, climate changes well as SST going up as high as 34 degrees.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

|   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|---|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| D | <p>The potential benefits of establishing a new mariculture market in Belize, particularly focusing on seaweed cultivation, have been explored by various groups over the years. Despite efforts by organizations like TNC, the industry remains small-scale and has faced challenges in turning profits. Capacity issues, both in terms of production and business model development, have hindered the sector's growth.</p> <p>While there is a concerted effort to expand the industry, the feasibility is questionable due to ongoing production and capacity costs. The transfer of successful approaches and techniques across Belize has been limited, contributing to the overall struggle for sustainability.</p> <p>In addressing these challenges, the emphasis is not solely on financial support but also on fostering initiatives that are genuinely sustainable. A key aspect involves overcoming the difficulty faced by women's groups in understanding the necessity for long-term sustainability beyond project support. The focus is on finding ways to support these initiatives comprehensively, ensuring they thrive and provide livelihoods in the long run.</p> |
| E | Profitability is key for anyone involved in seaweed business and there must be socio-economic benefit at minimal impact on the environment.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| F | See Belize Maritime Economy Plan attached.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

*Table 9.85. Elite interview participants' views on whether seaweed farming in its current status is beneficial for sustaining the livelihoods of those engaged in it.*

6. Do you think that there is a link between seaweed farming and climate change adaptation?

| Respondents | Responses                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A           | Seaweed can be incorporated into NDCs as a carbon sequestration adaptation. There is a carbon sequestration initiative involving kelp rotation, currently underway in the Asia/Pacific region. This unique approach advocates for a paradigm shift in the blue economy, emphasizing a continuous tradeoff rather than a straightforward "plant and reap" strategy. Notably, practitioners, such as the Turneffe individuals, incorporate a rotating system into their harvesting practices. This seamless integration of kelp rotation reflects a broader commitment to sustainable practices and aligns with the evolving principles of the blue economy. |
| B           | <p>There is nothing in the regulation that speaks about climate change adaptation and seaweed. It mainly discusses designating areas for mariculture.</p> <p>The use of seaweed farming to adapt to climate change is not necessarily the intention of the policy, it is really to diversify the fishing industry and provide alternative job. The reason why we are doing it is because it can be done in shallow water, low-intensive technology, the cost to establish a farm is low costing and you can harvest in relatively short period of time.</p>                                                                                                |
| C           | The pressing reality of climate change necessitates sustainable solutions for the future. However, the current outlook appears challenging, given the                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

|   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|   | untapped potential of seaweed, which is not only easily accessible close to shore but also holds promising benefits. To address this issue, substantial research and development efforts are required to identify seaweed species with heat resilience. Regrettably, concentrated research in this crucial area has been lacking, hindering progress in finding viable methodologies for combating climate change.                                                                                                                                                                                                                                                                                                                                                |
| D | To treat something as carbon storage, it has to be locked up. As for seaweed, it will be removed, and therefore carbon will be released.<br>Seaweed, while not considered a direct adaptation option, holds the potential to contribute as a Nature-based Solution (NbS) for fostering sustainable livelihoods. While seaweed farming may not specifically aid seagrass beds in adapting to climate change, it can enhance local water habitats and offer additional support to various organisms. The primary impact lies in the improvement of environmental health, particularly in regions facing nutrient enrichment. In essence, seaweed farming serves as a valuable NbS, promoting resilience and sustainability in the face of environmental challenges. |
| E | Seaweed traps carbon and provides shade (cools the sea). Seaweed farms are still fuel dependent.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| F | Not familiar.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

*Table 9.86. Elite interview participants' views on the link between seaweed farming and climate change adaptation.*

7. What space and development do you think seaweed aquaculture can have in Belize, and more general in the Caribbean region?

| Respondents | Responses                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A           | <p>The scope of marine spatial planning (MSP) raises questions about its extension, particularly into the Exclusive Economic Zone (EEZ). A crucial aspect to consider within this framework is the integration of mariculture, specifically seaweed cultivation, both in shallow/coastal areas and deep waters. An inquiry emerges regarding the rationale behind moving seaweed mariculture from shallow to deep waters, with a statement emphasizing the perceived lack of sense in such a shift.</p> <p>In exploring this transition, the discussion naturally extends to the incentives and subsidies contemplated to facilitate the relocation of seaweed mariculture. The skepticism towards deepwater mariculture prompts a further query about the considerations for moving traditional activities into the EEZ. This expansion necessitates a comprehensive examination of factors such as fuel costs, infrastructure, security personnel, as well as the requirements for enforcement and monitoring.</p> <p>As MSP unfolds, it becomes essential to analyze how this strategic planning will influence or potentially trigger adjustments in other resource mechanisms to support the proposed design. The challenge of persuading individuals engaged in traditional practices to embrace this shift to deep</p> |

|   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|---|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|   | waters is acknowledged, acknowledging the resistance that may arise due to associated challenges.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| B | There's an ongoing MSP project looking at suitable areas for mariculture; mariculture management areas (MMA).<br>Coastal waters are more appropriate for seaweed mariculture and are not far out in deep waters.<br>Seaweed farming areas currently are 'micro-farms'.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| C | Climate-based insurance scheme for fishers, which may consider compensation for damages and lost income due to postponement of fishing activities in extreme weather conditions, replace and repair fishing boats, gear, tools and infrastructure destroyed or damaged by storms, etc. This assessment will include the evaluation of relevant existing climate-based insurance schemes in the region.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| D | In a decade of development and capacity building, the seaweed industry is struggling to generate sustainable livelihoods independently. While supplemental profits are evident, the current stage is far from ideal. The missing elements crucial for progress are effective business models. Currently, the landscape is reactive, lacking a comprehensive national enabling framework encompassing permits, incentives, and structure.<br><br>Seaweed farms, although underdeveloped and primarily microscale, show promise. The current scale is not exhaustive, and there is no imminent threat of space depletion in the next 10 years. Challenges arise when considering deep-sea cultivation due to the difficulty of managing shallow water algae species in such environments. Safety concerns, including exposure to waves and currents, make deep-sea operations and snorkeling ventures perilous.<br><br>The optimal location for seaweed cultivation is within the reef. Abundant space within the reef allows for scalability. However, realizing this potential requires a national plan that facilitates zoning areas, providing a structured approach to the industry's growth. |
| E | Nearshore farming rather than inshore or offshore farming. Closer to the shore for seaweed farmers to access farms.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| F | While seaweed mariculture presents an exciting opportunity in terms of alternative livelihoods, significant work needs to be done to address and simplify the multiple, bureaucratic and ever-changing regulatory requirements and overly complicated and cost-prohibitive steps for obtaining a permit.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

*Table 9.87. Elite interview participants' views on the space and development potential of seaweed aquaculture in Belize and the wider Caribbean region.*

#### 9.6.2 Analysis: Elite Interviews Code Book

The purpose of the elite interview codebook is to comprehensively document the various topics, concerns, and valuable perspectives shared by individuals involved in the seaweed farming sector and climate adaption approaches in Belize. The purpose of this codebook is to categorize the data obtained from interviews into distinct and well-defined categories. Each category corresponds to a particular issue that is directly relevant to the growth,

administration, and difficulties associated with seaweed farming. The topics covered include ecosystem-based and innovative production methods, as well as measures to address environmental consequences such as climate change, marine biodiversity, and biosecurity. In addition, the codebook examines socio-economic aspects such as financial viability, market availability, and the involvement of community-based adaptation (CbA) and ecosystem-based adaptation (EbA) in seaweed mariculture. By utilizing these codes, the information gathered from interviews is methodically organized, creating a strong framework for examining the developing blue economy of Belize and the strategic importance of seaweed farming within it. The codebook in Table 9.88 below captures the main codes and subcodes in the elite interview discussions.

| Name                                                                                  | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ecosystem-based and innovative approaches                                             | This theme on ecosystem-based and innovative approaches encompasses advance cultivation and technological methods using ecosystem-based adaptation strategies to resolve issues related to climate change, marine pollution, and the impact of environmental factors on seaweed growth. Participants discussed the need for climate adaptation strategies, the role of seaweed in improving water quality, and the potential environmental impact of seaweed farming on marine ecosystems using scientific observation and data to improve cultivation methods for higher production. |
| Advanced Cultivation Methods                                                          | This highlights the advanced cultivation methods utilized by local seaweed farmers in Belize. It includes two successful forms of cultivation: raffia and submerged structures. The raffia method involves using lines to hold the seaweed, mimicking its floating in the ocean, while the submerged method utilizes tie-tie lines for cultivation beneath the water's surface in cooler areas.                                                                                                                                                                                       |
| Awareness of Seaweed Disease and Climate Adaptation                                   | This code highlights the lack of attention given to seaweed disease within existing policies and regulations, despite its potential impact on farming practices. It captures the characteristics of the disease, referred to as "ice seaweed disease," including its bacterial nature and susceptibility to environmental factors like water temperature and spacing on cultivation lines.                                                                                                                                                                                            |
| Belize Blue Economy Approach - Diversification and Sustainable Development Strategies | Explore strategies, financial support, technological advancements, and the blue economy approach in the context of diversification and sustainable development in fisheries. It examines efforts to reduce pressure on traditional fisheries, secure funding and loan criteria for diversification projects, integrate technology for improved efficiency and sustainability, and embrace a holistic perspective that considers sustainability and economic growth beyond traditional                                                                                                 |
| Biodiversity Support provided by Seaweed Farms                                        | It explores the potential ecological benefits of seaweed farming in enhancing biodiversity within marine ecosystems. It discusses the habitat value of seaweed farms as shelters and feeding grounds for various marine species, including trips, squids, octopus, juvenile lobsters, crabs, and others. It considers the indirect impacts of seaweed farming on increasing the production of commercially valuable species such as conch and lobster over time, although attributing this solely to seaweed farming is complex.                                                      |
| Biosecurity and zoning strategies                                                     | refers to the regulatory considerations and planning efforts aimed at mitigating risks associated with disease control, pest management, and environmental impact in seaweed mariculture. It encompasses the identification of suitable zones for mariculture, assessment of ecological and social capacities, and development of biosecurity measures. It includes discussions on disease control strategies, environmental clearance, and monitoring protocols for pathogens, pests, etc.                                                                                           |
| Carbon-Offsetting                                                                     | This explores sustainable industry practices and the imperative for economic diversification within marine sectors. The growing                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

|                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-----------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                       | industry of carbon offsetting through seaweed farming using crop rotation where carbon sequestration occurs continuously across different plots, while contributing to national efforts to reduce carbon emissions. It underscores the intersection between revenue generation and climate adaptation within the framework of the blue economy paradigm shift.                                                                                                                                                                        |
| Carbon-Sequestering                                                   | This explores the emergence of rotational seaweed farming as a significant industry for carbon offsetting. It outlines the practice of planting seaweed farms on a rotational basis, allowing for continuous carbon sequestration. By harvesting from one plot while leaving others to grow and sequester carbon, this method contributes to national efforts to reduce carbon emissions. It underscores the importance of the blue economy paradigm shift, which emphasizes purposeful planting and sustainable trade-offs.          |
| Climate Change Issue                                                  | It refers to the overarching challenge posed by climate change in the seaweed farming industry. This encompasses a range of climate-related impacts such as rising sea temperatures, ocean acidification, changes in precipitation patterns, and extreme weather events, all of which can affect seaweed growth, productivity, and sustainability. This code serves to categorize discussions, research findings, and strategies related to addressing the implications of climate change on seaweed cultivation and its association. |
| Cultivated Seaweed Yield                                              | This provides insights into the production trends and yields of seaweed species, a valuable aspect of the marine industry. This includes ratio conversion between wet to dried seaweed in pounds of commercial cultivated seaweed species such as Eucheuma and Kappaphycus. Any reference to yield in harvest and production loss is also captured in seaweed yield.                                                                                                                                                                  |
| Dry season challenge with temp, water flow and nutrient exchange      | It is used to encapsulate discussions and observations related to the difficulties faced during the dry season, particularly concerning temperature fluctuations, water flow alterations, and nutrient exchange limitations. It highlights the impact of seasonal variations on seaweed farming operations and encompasses discussions on strategies to mitigate the challenges posed by dry conditions, maintain optimal environmental conditions for seaweed cultivation, and ensure sustainable production during dry season.      |
| Expanding biodiversity protection zones to cover 20.5% of ocean space | It is focused on the efforts to increase the coverage of protected marine areas to encompass 30X30 Agenda for the management of the ocean space. This code encompasses conversations related to the establishment, management, and expansion of biodiversity protection zones, highlighting the significance of marine conservation efforts in safeguarding vulnerable ecosystems and biodiversity hotspots. It includes discussions on the ecological, social, and economic benefits of expanding protected areas.                   |
| Habitat Preservation Considerations During Harvest                    | It encompasses techniques aimed at preserving marine habitat and biodiversity within seaweed farms. This includes leaving portions of the farm untouched during harvesting to provide safe havens for juvenile marine species. Additionally, methods such as shaking harvested seaweed to remove attached creatures before removal from the water are employed to minimize ecological impact.                                                                                                                                         |
| Ice-Ice Issue                                                         | Ice-ice is a common disease that affects seaweed, particularly species like Kappaphycus and Eucheuma, which are commonly cultivated for commercial purposes. Ice-ice disease is characterized by the appearance of white, cottony tufts or patches on the seaweed thallus, leading to reduced growth, productivity, and quality of the seaweed crop. The disease is caused by various environmental stressors, including high light intensity, high water temperature, nutrient imbalances, and physical damage to the seaweed.       |
| Increase sea temperature                                              | It refers to the phenomenon of rising temperatures in ocean waters. It includes the impacts of increasing sea temperatures on various                                                                                                                                                                                                                                                                                                                                                                                                 |

|                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|--------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                        | aspects of marine ecosystems, including seaweed cultivation. It includes considerations of how higher temperatures affect seaweed growth, reproduction, and susceptibility to diseases or stressors. Additionally, discussions under this code explore the broader implications of rising sea temperatures on ocean health, biodiversity, and adaptation strategies.                                                                                                                                                              |
| Installation of Physical Barriers                      | Installation of physical structures in the ocean to act as barriers for <i>Kappaphycus alvarezii</i> spreading to other ecosystems. This seaweed species has been considered an invasive species, as not native to Belize. Due to its invasive nature, there is a need for containment structures to prevent its spread.                                                                                                                                                                                                          |
| Interventions in seaweed farming                       | Explores intervention from regulatory agencies and civil society collaboration involved in the improving the seaweed project landscape in Belize. This can include aim to develop site selection criteria for seaweed cultivation led by TNC. Seaweed farmers inform the development of site selection environmental criteria for placing seaweed farms indicating the variability of conditions across different sites despite meeting environmental criteria.                                                                   |
| Invasive species for local cultivation                 | It refers to discussions surrounding the introduction of invasive species for cultivation purposes within local ecosystems. It highlights risks and benefits associated with cultivating invasive species, including considerations of their impact on native biodiversity, ecosystem stability, and economic opportunities. It involves assessing the ecological and regulatory implications of introducing invasive species for cultivation as well as strategies for managing potential negative impacts on local environments |
| Juvenile Habitat Provision by Seaweed Farms            | It encapsulates discussions related to the role of seaweed farms in providing a habitat for juvenile marine species. This code captures how seaweed farms create safe havens and food sources for various juvenile organisms, including fish, crustaceans, and other marine life. It explores the ecological importance of seaweed farms as nursery habitats, as well as the potential benefits for fisheries and overall marine biodiversity. Therefore, optimizing the habitat provision for marine juvenile species.           |
| <i>Kappaphycus alvarezii</i> Breakoff Yield Assessment | The assessment of seaweed harvest yields highlights the field work experiences of harvest activities, such as the collection of fallen <i>Kappaphycus alvarezii</i> pieces, and estimating the quantification of harvest yields, with specific reference to weight measurements. It also captures methods used to assess seaweed harvest yields/seaweed production statistics, factors influencing yield variability, and implications for production planning and resource management in the seaweed farming industry.           |
| <i>Kappaphycus alvarezii</i> Fast Growth Rate          | Impacts of seaweed escapees from farms on benthic habitat (eg. seagrass, corals) such as the <i>Kappaphycus alvarezii</i> . It explores the potential environmental impact of seaweed species, particularly its fragmentation and spread in marine environments. It examines concerns regarding <i>Kappaphycus alvarezii</i> presence in seagrass beds and on coral reefs.                                                                                                                                                        |
| <i>Kappaphycus alvarezii</i> Invasive Nature           | <i>Kappaphycus</i> is considered non-native seaweed species or invasive species, not native to Belize. <i>K. alvarezii</i> is the main seaweed crop grown in ocean-based farms. Due to its invasive nature, there is a need for containment structures to prevent its spread in the open ocean environment and ecosystems such as corals.                                                                                                                                                                                         |
| Land runoffs deriving from Mangrove Coasts             | This code refers to the issue of land runoffs originating from mangrove coasts and their impact on seaweed farming and marine ecosystems. It elaborates on the discharge of sediments, pollutants, nutrients, and other substances from land-based activities such as agriculture, aquaculture, urban development, and deforestation.                                                                                                                                                                                             |
| Low-cost technology                                    | This code pertains to low-cost technology needed on seaweed farms. There are minimal resource requirements, highlighting the efficiency                                                                                                                                                                                                                                                                                                                                                                                           |



|                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                      | of the practice. It includes innovative farming methods, DIY solutions, locally sourced materials, and community-driven initiatives that reduce the financial barriers associated with seaweed farming and enhance the livelihoods of coastal communities.                                                                                                                                                                                                                                                                 |
| Marine pollution deriving from seaweed farms                         | This code encompasses the point of environmental repercussions of seaweed farming, particularly focusing on pollution stemming from farming operations. It includes disintegration of farming infrastructure into marine ecosystems, addressing pollution sources, quantification, mitigation strategies to prevent unattended farms in the ocean, and the sustainability of farming practices.                                                                                                                            |
| Marine Spatial Planning and Offshore Opportunity                     | It captures perceptions related to the integration of seaweed mariculture into Marine Spatial Planning (MSP) frameworks, particularly focusing on shallow/coastal and deep-water aspects. It highlights inquiries about the extent of marine spatial planning, its coverage of Exclusive Economic Zones (EEZ), and the incorporation of mariculture activities. It also raises questions about the feasibility of transitioning seaweed mariculture from shallow to deep waters, considering influencing economic factors. |
| Micro-environment conditions of Sargassum Impacts on Seaweed Growth  | This code captures the micro-environmental impacts of Sargassum on seaweed cultivation. It includes conversations about how Sargassum influences factors like light availability, water flow, nutrient exchange, and temperature regulation relevant to seaweed growth. The code covers challenges posed by Sargassum accumulation, mitigation strategies, and adaptations needed to optimize seaweed cultivation despite its presence.                                                                                    |
| Nature-based Solution debate                                         | This code focuses on seaweed farming as a nature-based solution for climate challenges. It encompasses discussions on its potential to mitigate climate impacts, like ocean acidification and sea-level rise, through carbon sequestration and coastal protection. It also includes talks on ecological benefits, biodiversity enhancement, and its role in climate adaptation and mitigation strategies.                                                                                                                  |
| Pre-harvest Cleaning Technique                                       | This code pertains to discussions about pre-harvest cleaning methods in seaweed farming, focusing on removing impurities and organisms from seaweed biomass before harvest. It includes equipment, procedures, frequency, effectiveness, environmental considerations, and quality assurance. Additionally, it highlights challenges, innovations, and best practices in pre-harvest cleaning techniques.                                                                                                                  |
| Provisional Ecosystem Services of Shade and Cool Waters by Mangroves | This code focuses on the ecosystem services of mangroves, particularly their role in providing shade and cooling coastal waters. It includes discussions on how mangroves regulate temperature, mitigate heat stress, and create microclimates for various species. It also covers the importance of mangroves in coastal ecosystems, their benefits for biodiversity, and the impacts of degradation or loss on ecosystem services. It explores management strategies for preserving and enhancing mangrove habitats.     |
| Removing mangroves and need to protect                               | This code encompasses the issue of the removal of mangroves and the necessity of their preservation. It discusses the vital role of mangrove ecosystems in coastal protection, biodiversity, and climate mitigation, emphasizing the need to minimize threats like deforestation. Strategies for conservation, including policies and community initiatives, are also considered.                                                                                                                                          |
| Seaweed absorbs excessive nutrients                                  | This code addresses seaweed's role in absorbing excess nutrients from water, enhancing water quality, and regulating nutrients in marine ecosystems. It discusses its ecological significance, such as mitigating eutrophication and promoting ecosystem health and biodiversity. It also explores seaweed farming as a nature-based solution for nutrient remediation in coastal regions.                                                                                                                                 |
| Seaweed as an indicator for monitoring                               | This code pertains to seaweed's role as a bioindicator for monitoring marine ecosystem health. It discusses how variations in seaweed populations and health reflect broader environmental conditions like                                                                                                                                                                                                                                                                                                                 |

|                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| environmental impacts                             | water quality and habitat degradation. It explores seaweed monitoring programs for assessing ecosystem health, identifying human impacts, and informing conservation efforts and policies.                                                                                                                                                                                                                                                                                                                                        |
| Seaweed improves water quality                    | This code addresses seaweed's role in enhancing water quality in marine environments. It includes discussions on how seaweed populations remove excess nutrients, pollutants, and sediments from the water through processes like nutrient uptake and filtration. It captures research findings on seaweed's impact on water clarity, oxygenation, and nutrient levels, informing conservation and management efforts.                                                                                                            |
| Seaweed Species and Uses                          | This explores seaweed varieties presence and utilization in different parts in Belize, mainly coastal communities. Also, it provides insights into the local knowledge in diversity of seaweed species present in Belize and their utilization in local seaweed farming practices. This can include shifts in seaweed preference such as locals' preferences for specific seaweed species because of its perceived potency, color, smell, and gelling texture.                                                                    |
| Seaweed Varietal Resilience                       | This highlights the varying resilience levels of different seaweed varieties. This can include perceived comparisons of seaweed species resilience and its adaptability to different environmental conditions. Also, the challenges associated with seaweed species growth range and rate can be captured to indicate potential constraints in its cultivation. This can be linked to climatic factors in the adaptation of seaweed species tolerance to salinity and temperature, its suitability for cultivation practices.     |
| Seaweed provides a habitat and nursery            | This code addresses the role of seaweeds as habitat and nurseries for marine species, particularly juveniles. It includes discussions on how seaweed beds create diverse ecosystems offering shelter and food, supporting biodiversity and promoting the growth of juvenile organisms. It captures research findings and insights into the ecological functions and management implications of seaweed nursery habitats.                                                                                                          |
| Sedimentation and Filtering Function of Mangroves | This code addresses the role of mangroves in filtering sediments and purifying coastal water. It includes discussions on how mangrove forests act as natural filtration systems, trapping sediments and pollutants from runoff and tidal waters. It captures research findings and insights into the ecological functions and ecosystem services provided by mangrove sediment filtration, such as shoreline protection and habitat provisioning.                                                                                 |
| Selective Harvesting Techniques                   | It refers to the deliberate methods employed during the harvesting process to minimize ecological impact and preserve habitat for juvenile marine organisms. It encompasses practices such as selectively harvesting portions of the farm to maintain habitat and shaking harvested seaweed to remove attached creatures before removal from the water.                                                                                                                                                                           |
| Smart Siting and Environmental Considerations     | pertains to discussions regarding the strategic selection of locations for seaweed farming operations with a focus on environmental sustainability. This code includes It makes references to practices such as water temperature logging and consideration of biodiversity impacts during site selection. It underscores the importance of assessing environmental factors like trampling on marine ecosystems, water temperature variations, and nutrient flow to ensure responsible and sustainable seaweed farming practices. |
| Unsustainable wild harvest practices              | This explores unsustainable practices such as in quality concerns with seaweed sourcing as ethical considerations are mainly appealing to consumer market. Seaweed-based products are promoted with sustainably produced seaweed. Seaweed that is packaged with rocks and dirt it is suggesting it may have been sourced from the wild and packaged without proper cleaning. This raises concerns about the                                                                                                                       |

|                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|----------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                | quality and sourcing practices of the seaweed used in public spaces such as cooking shows.                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Use of CBA and EBA approaches                                  | This code focuses on community-based and ecosystem-based adaptation approaches in Belize's seaweed farming. It includes discussions on historical practices, indigenous knowledge, and community-led initiatives to adapt to environmental changes. It covers topics like local ecological knowledge, traditional farming techniques, and challenges in the face of climate-related pressures and socio-economic dynamics.                                                                                                                |
| Financial and investment mechanisms                            | This theme addresses the financial and investment mechanisms used to resolve technical and operational issues faced by seaweed farmers. It includes issues in current seaweed farm projects under funding which are implementing advanced cultivation, biosecurity measures, organizational dynamics, and research and development. Participants discussed the need for innovative cultivation methods, improved maintenance practices, and capacity-building initiatives to address financial and investment challenges.                 |
| Blue Bond Grants Award Program to Government and civil society | This code refers to the funding initiatives aimed at supporting biodiversity conservation, sustainable livelihoods, and disaster resilience efforts in coastal communities. This code encompasses the allocation of grants to achieve commitments related to marine protected areas management, biodiversity protection zones, and sustainable livelihoods. It also includes considerations for disaster response and insurance schemes to address economic impacts of natural disasters, while focusing on strategic funding allocation. |
| Blue Business Innovation Funding Opportunities                 | It encompasses initiatives aimed at fostering innovation and entrepreneurship within the blue economy sector. It pertains to funding programs that support the development of new blue businesses, particularly in emerging areas such as aquaculture and seaweed-based value-added products. It involves collaboration with relevant entities to facilitate community innovation plans and provide technical support to aspiring entrepreneurs, with a focus on funding projects that align with strategic objectives.                   |
| Cluster Formations Funding Benefits & Challenges               | It focuses on the potential benefits of forming legally recognized entities such as associations for seaweed farmers, including increased accessibility to funding opportunities. This explores the feasibility and advantages of forming organization as clusters, as well as the challenges and opportunities associated with funding accessibility for small local cluster.                                                                                                                                                            |
| Financial sustainability issue                                 | It addresses the hurdles related to financial viability and business development in seaweed farming initiatives. This includes concerns about the affordability of materials for farm construction and ongoing monitoring, as well as the need for effective marketing strategies and the establishment of lending institutions to incentivize business establishment. It also touches upon the shift from reliance on handouts to fostering a culture of entrepreneurship among stakeholders.                                            |
| Foreign Investors Influencing Factors                          | It captures factors influencing the economics of seaweed farming, particularly it compares fuel price and low Labor wages in Belize. It captures perspectives around foreign investors such as the Mexicans, who have expressed interest to farm in Belize due to the attractiveness of the industry. Mexico's historical involvement in seaweed cultivation.                                                                                                                                                                             |
| Funder's technical support services                            | It refers to the assistance provided by funding organizations or agencies to support technical aspects of seaweed cultivation projects. It encompasses discussions related to the provision of expertise, resources, and guidance by funders to help seaweed farmers overcome technical challenges, enhance their cultivation practices, and improve overall project outcomes. It includes conversations on                                                                                                                               |

|                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                            | the types of technical support offered, such as training programs, equipment provision, research collaboration, etc.                                                                                                                                                                                                                                                                                                                                                                                                     |
| Lack of Financial Incentives and Subsidies                                                 | It captures the main concerns and gaps regarding seaweed farming development, providing insights into the challenges and areas needing attention in this sector. It includes inquiries about potential incentives for transitioning traditional activities to deep-sea seaweed farming. Concerns were also raised regarding the absence of traceability measures, indicating a need for transparency and accountability in the supply chain.                                                                             |
| Lack of funding due to the high costs associated with purchasing and maintaining equipment | It encapsulates the financial challenges of high costs associated with purchasing and maintaining equipment required for seaweed farming. It delves into the specific types of equipment needed for seaweed cultivation, such as harvesting tools, processing machinery, or monitoring devices, and the financial strain they impose on farmers. It explores potential strategies or initiatives aimed at alleviating the funding barrier, such as grants, subsidies, or collaborative partnerships to support farmers.  |
| Limitations of seaweed farmers capacity                                                    | Balancing business ownership with environmental compliance delves into the dual role of seaweed farmer as both business owners and stewards of environmental conservation. It emphasizes the limitation of balancing business interests with environmental regulations and compliance. This theme underscores the complexities and challenges faced by fishers in navigating the intersection of business ownership and environmental stewardship.                                                                       |
| National strategic funding for conservation commitments                                    | This code encompasses discussions on the early history of seaweed farming, detailing its inception, initial cultivation methods, and developmental journey. It covers the origins of seaweed farming, pioneering efforts, evolution of techniques, and factors influencing its growth into a global industry, incorporating traditional knowledge and innovation across regions.                                                                                                                                         |
| Power of financial resources                                                               | The interviewee reflects on their transition from an academic role to a position of influence as a funder. They emphasize the power of financial resources in driving decisions and influencing outcomes, particularly in the context of the blue economy unit.                                                                                                                                                                                                                                                          |
| Scaling Up Operations                                                                      | It delves into the strategies and plans for scaling up seaweed farming operations in Belize. It highlights the absence of specific provisions in the blue economy strategy plan for scaling up seaweed farming activities. However, it captures the importance of mariculture in general within the maritime economic plan. It captures interest in advancing seaweed farming as part of scaling up efforts, aligning with the broader blue economy approach.                                                            |
| Value-Added Seaweed Commodity Issue                                                        | It pertains to seaweed farming practices that involve adding value to harvested seaweed by processing it into various products such as food, gel, and creams. Entities like BWSFA (Belize Women's Seaweed Farmers Association) are highlighted for their approach of maximizing the utility of seaweed, leading to greater profitability compared to traditional farming methods.                                                                                                                                        |
| Working capital availability constraints                                                   | It pertains to discussions regarding the financial constraints faced by fishermen in pursuing certain activities or ventures within the fishing industry. Specifically highlights the lack of readily available funds among fishermen, indicating challenges associated with accessing financial resources for various purposes within the industry.                                                                                                                                                                     |
| Regulatory and policy frameworks                                                           | The regulatory and policy framework is the legislative framework governing seaweed farming activities. It highlights practices such as the alignment of national programs with blue economy policies, the status of multi-stakeholder approach, challenges in regulatory compliance, and the need for licensing provisions. Participants discussed the complexity of regulatory processes, the lack of specific regulations for seaweed mariculture, and the need for improved competence capacity to ensure compliance. |

|                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|--------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Advisory and Partnership Dynamics                                        | This is related to advice-giving, managerial partnerships, and operational challenges within the context of seaweed farming in Belize's blue economy. It includes offering guidance and warnings based on their experiences in the field of fisheries and aquaculture. Also, it can include roles of managing partners, administrative responsibilities, and the impact of external factors like hurricanes and piracy on seaweed farming operations.                                                                    |
| Alignment of National Program to BE Policy                               | This expands in environmental management, policy frameworks, and institutional arrangements governing marine and coastal resource utilization. It includes the importance of community-based and ecosystem-based adaptation approaches, the integration of monitoring and evaluation programs with national plans and policies, such as the blue economy strategy and coastal zone management plan. There is emphasis on the need for legislative changes to address overlapping mandates and regulatory frameworks.     |
| Aquaculture Operator's License Provision                                 | This relates to the provision for aquaculture operator's licenses under the Fisheries Act, Chapter 210, within the context of seaweed farming in Belize's blue economy. It focuses on explaining the commercial license required for aquaculture operators to engage in aquaculture activities, including the associated cost of \$1,000 Belize Dollars. It explores the criteria used, regulations, and considerations relevant to obtaining an aquaculture operator's license for seaweed farming operations.          |
| Bureaucratic administrative requirements                                 | This highlights the constraints faced by seaweed farmers to legally operating their seaweed farming business. This includes bureaucratic administrative requirements (applications and expertise), technical and financial constraints. It underscores one of the factors hindering the local seaweed farmers from having the same legal rights to develop livelihood opportunities.                                                                                                                                     |
| Business Management and Engagement Strategy                              | It underscores the role of good business management skills and engagement strategies which address issues such as the importance of proper business registration as a requirement in research permits application submission and the involvement of private entities in seaweed cultivation. It provides insights into engagement strategies for non-governmental individuals in the seaweed industry, emphasizing the need for clarity and legal compliance in business operation.                                      |
| Challenges in other Countries' Seaweed Industry                          | It pertains to the identification and analysis of obstacles, barriers, and difficulties faced by seaweed farming sectors in nations beyond Belize. This code encompasses various challenges such as regulatory hurdles, environmental factors, market limitations, technological constraints, or socio-economic issues that hinder the development and growth of seaweed cultivation in different geographical contexts.                                                                                                 |
| Co-managers' Involvement in Regulatory Authorities                       | It represents collaborative efforts between management, government entities, and NGOs to establish a regulatory framework conducive to sustainable resource management. It emphasizes the need for information sharing and cooperation among stakeholders to ensure effective enforcement of laws and regulations. Additionally, it underscores the role of co-managers in law enforcement and the importance of establishing clear criteria for grants and loans to promote accountability and prevent misuse of funds. |
| Communication Issue in Blue Economy Implementation and Policy Governance | This highlights communication issue as a hindrance in the implementation blue economy principles and policy framework monitoring and evaluation responsibility. Key points include questioning the effectiveness and necessity of blue bonds and related units, highlighting discrepancies in understanding between policymakers and industry experts, and emphasizing the importance of aligning financial decisions with conservation priorities. It explores communication challenges in regulatory implementation.   |

|                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Complex and expensive regulatory processes         | It describes the challenges associated with navigating intricate and costly regulatory procedures. This code is used to categorize discussions, observations, and analyses regarding the difficulties faced by stakeholders, particularly seaweed farmers, in complying with complex and expensive regulatory requirements imposed by governing bodies. It encompasses discussions on the bureaucratic hurdles, financial burdens, and administrative complexities encountered in obtaining permits, licenses, and approvals for   |
| Enforcement of Regulation Challenges               | It captures challenges around enforcement of regulation. Key points include observations on the lack of communication and understanding among stakeholders, challenges in policy implementation, and the need for commitment to uphold agreements and regulations. It includes issues such as the effectiveness of communication strategies, the role of governmental agencies in policy implementation, and the integration of conservation principles into economic decision-making processes within the blue economy framework. |
| Enhancing Transparency by Publishing               | It is used to represent discussions centered around the ecological significance of seaweed farming activities. It encompasses conversations related to how seaweed farms serve as habitats and provide shelter for various marine species, contribute to biodiversity conservation, enhance water quality, and promote ecosystem health. It includes discussions on the ecological benefits derived from seaweed cultivation practices, such as providing refuge for juvenile species, enhancing nutrient cycling, etc.            |
| Export Regulation & Compliance                     | This captures the current status of entities having met the legal requirement for trading seaweed commodity locally and abroad. It pertains to having seaweed-based sole trading entities upholding the rules and regulation of the Belize Fisheries Department. It also provides insights into compliance with trading seaweed commodity such as meeting certain criteria developed by the regulatory agency for exporting seaweed.                                                                                               |
| Geographic Indicator (GI) for Seaweed Commodity    | It refers to the designation and protection of a specific geographic location for the production of seaweed and related products. It encompasses discussions related to the legal and regulatory frameworks surrounding the recognition and branding of seaweed cultivated in a particular region, emphasizing its unique qualities, characteristics, and production methods. It includes considerations of the economic, cultural, and environmental significance of establishing a Geographic Indicator (GI) for seaweed.        |
| Knowledge Transfer and International Collaboration | It refers to discussions regarding the exchange of techniques, approaches, and experiences in seaweed mariculture both within Belize and internationally. This code highlights efforts to facilitate knowledge transfer through initiatives such as symposiums, where representatives from different countries share insights and experiences. It underscores the importance of collaboration and learning from diverse perspectives to enhance the development and advancement of seaweed farming.                                |
| Lack of Data Collection and Documentation          | It highlights the absence of systematic data collection and documentation in the management of seaweed farming activities. It underscores the importance of gathering empirical data and obtaining permits to substantiate information instead of relying solely on anecdotal evidence. It addresses the need for structured questionnaires, recording of conversations, and comprehensive analysis to inform decision-making and reporting. It acknowledges the existing opportunities for improvement in data management.        |
| Lack Seaweed Mariculture Regulation                | This code pertains to the absence of regulatory frameworks governing seaweed mariculture activities. It highlights implications of the lack of specific regulations for managing seaweed farming operations, including issues related to environmental protection, resource                                                                                                                                                                                                                                                        |

|                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                            | management, licensing, and industry standards. It includes calls for the development or enhancement of regulatory frameworks tailored to the unique characteristics and needs of the seaweed mariculture sector.                                                                                                                                                                                                                                                                                                               |
| Legal and Policy Framework Development Issues                              | It explores the technicalities of understanding governance of seaweed aquaculture operations in Belize. It delves into issues such as the interpretation and application of international conventions like UNCLOS, the development of specific policies for mariculture, and the inclusion of seaweed as a component of broader economic strategies and their efforts in improving policy development and institutional arrangements by understanding the role of stakeholders, capacity-building initiatives, adaptation etc. |
| Legalities of Aquaculture Operators License Application                    | This is related to the application process for aquaculture operator licenses within the context of seaweed farming in Belize's blue economy. It focuses on the requirement for aquaculture operator licenses as stipulated by law and explores opinions and perspectives regarding the effectiveness and feasibility of obtaining such licenses for seaweed farming operations. It includes addressing considerations, challenges, and potential outcomes associated with the application process for the license.             |
| Legislative Framework Status and Policy Development                        | It includes legislative framework and policy development surrounding seaweed farming such as the Fisheries Resources Act of 2020, which outlines provisions for mariculture but lacks specific regulations. It captures the process of ongoing efforts by organizations to draft regulations for the mariculture sector, guided by national mariculture policies, & importance of policy development for sectoral growth, and the integration of nature-based activities into the blue economy through legislative measures.   |
| Limitation in stakeholder consultation in regulation framework formulation | It highlights concerns regarding the selection of consultants for regulatory tasks, such as the formulation of the mariculture regulation development in Belize. It shares sentiments of dissatisfaction with the consultant selection process, emphasizing the roles and capabilities of individuals involved, and emphasizes the need for proper stakeholder consultation. The implications of contractor selection decisions on regulatory development processes in the mariculture sector of Belize.                       |
| Limitation in Technology and Infrastructure Transfer                       | The limited capacity of fishers or seaweed farmers stakeholders in managing their income generating activities in the ocean as a business. It provides examples of ways technology and infrastructure transfer are limited in building local capacity through collaborations with organizations like BELTRAIDE. This limitation emphasizes initiatives aimed at empowering locals with the knowledge and skills needed to effectively manage their operations as sustainable businesses.                                       |
| Limitation to Human Capacity in R&D and innovation                         | This emphasizes the necessity for individuals with specific skills to engage in activities related to seaweed farming and marine conservation. It underscores the importance of recruiting more students or volunteers to participate actively in these initiatives and contribute to driving positive change within the sector. Additionally, it highlights the relevance of technological advancements not only for fishers but also for broader applications in marine activities.                                          |
| Limitation to Insurance Schemes and Risks Management                       | It highlights the efforts to establish insurance schemes for fishers and processing workers to mitigate the financial impacts of such risks and the interactions with stakeholders involved in insurance scheme development, including government agencies and financial institutions. The need for comprehensive insurance coverage tailored to the specific needs of fishers and other stakeholders in the seaweed farming sector, as well as the challenges and opportunities associated with implementing such schemes.    |

|                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|-------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Limitation to R&D in invasive seaweed, seaweed diseases and pests | This highlights the difficulties associated with Ice-ice seaweed disease conditions in the context of seaweed farming or related activities. Both references indicate challenges and discomfort linked to ice conditions, suggesting potential obstacles or adverse impacts on operations. Further exploration may reveal insights into the specific impacts of ice conditions and strategies to mitigate associated challenges.                                                                                  |
| Maintenance Requirements for Seaweed Farms                        | It involves discussions regarding the considerable maintenance demands associated with seaweed farming. This reference underscores the necessity for ongoing upkeep and care required to ensure the optimal functioning and productivity of seaweed farms.                                                                                                                                                                                                                                                        |
| Mariculture Management Areas (MMAs) Definition                    | Participants discuss the process of defining MMAs, which involves Marine Special Planning to identify suitable areas for mariculture. This theme highlights the strategic planning involved in the development of mariculture zones.                                                                                                                                                                                                                                                                              |
| No Respect for Regulatory Authority                               | It highlights concerns about perceived disrespect for authority, particularly within the Fisheries authority. It delves into the dynamics between stakeholders and the Fisheries administrator, emphasizing the importance of compliance and communication with designated authorities. It underscores the necessity of upholding the law, especially in relation to criteria and regulations governing the conch fishery and other aspects of the sector.                                                        |
| Non-legal business practices                                      | It captures non-legal business practices and the presence of a potential black market within the seaweed industry. Despite efforts to conduct business in a legitimate manner, there may still be instances of illicit trade or activities occurring. These challenges highlighted related to regulating the seaweed trade and the potential impact of unregulated practices on the market, concerns about the influx of seaweed from external markets into Belize and the lack of regulation governing its sale. |
| Policy Development Process                                        | This code relates to discussions concerning policies governing seaweed farming in Belize, covering their formulation, implementation, and evaluation. It includes topics like stakeholder engagement, regulatory frameworks, and decision-making mechanisms. Additionally, it captures aspects of policy objectives, legal mandates, coherence, consultation, advocacy, capacity building, and monitoring. Reflections on challenges, opportunities, and lessons learned are also included.                       |
| Pre-Legislation Preparatory Measures                              | It signifies the proactive approach taken to addressing issues and encourage compliance with forthcoming legislation. It underscores the importance of collaboration among stakeholders, including management, government entities, and NGOs, to foster constructive engagement and avoid potential conflicts. Additionally, it highlights the role of co-managers in law enforcement and the need for clarity regarding their discretion under new legislation.                                                  |
| Pre-requisite criteria for engaging in farming initiatives        | This code encompasses discussions on the prerequisites for engaging in seaweed farming, including knowledge, skills, resources, permits, regulations, funding, and community support. It covers identification of requirements, challenges in meeting them, strategies for overcoming barriers, and ensuring inclusive and sustainable participation in farming initiatives.                                                                                                                                      |
| Recommendations in Blue Economy Development                       | Emphasizes the importance of adopting a scientific approach, conducting pre-feasibility studies, and implementing regulatory measures to facilitate the transition to environmentally friendly practices such as electric transportation. The need for national direction, highlighting the role of legislation and criteria establishment for funding. Addresses the importance of infrastructure development, stakeholder cooperation, and the exploration of emerging sectors like deep-sea minerals.          |



|                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|--------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Regulation Compliance & Competence Capacity                  | This encompasses the challenges related to regulatory compliance and the need for capacity building within the context of seaweed farming in Belize. It highlights issues such as the absence of proper permits and licenses required for operations, as well as the lack of scientific and administrative capacity among stakeholders. It emphasizes the importance of establishing regulatory frameworks and building capacity to ensure sustainable and legally compliant practices within the industry.              |
| Regulation of Internal Seaweed Trade                         | It encompasses discussions related to the need for regulatory frameworks governing the domestic trade of seaweed. This code highlights considerations regarding the current absence or limitations of regulations overseeing internal seaweed commerce, suggesting a potential area for policy development or enhancement to ensure orderly and transparent trade practices within the seaweed industry.                                                                                                                 |
| Regulatory Compliance & Licensing Issue                      | It encompasses the challenges and discrepancies related to regulatory compliance and licensing within the context of seaweed farming in the small island developing state of Belize. It highlights the absence of inadequacy of legal permissions and permits required for engaging in research and development (R&D) activities, as well as for export operations. It underscores the need for adherence to regulatory frameworks, including environmental impact assessments (EIA) and export permits.                 |
| Research Permit Compliance and Capacity Assessment           | It highlights the seaweed farmers stakeholders' lack of research permits, challenges related to seaweed farming commercialization, and uncertainties regarding research objectives. It captures concerns about capacity issues and trustworthiness, particularly regarding the handling of grant funds and research outcomes by seaweed farming leaders. To a lesser extent it recognizes the need for clear communication and proper documentation in research activities.                                              |
| Sargassum influx delay crop cycle activities                 | This code covers discussions on the disruption of crop cycle activities due to Sargassum seaweed influx. It addresses challenges for farmers, including planting and harvesting delays, caused by Sargassum accumulation. It highlights ecological impacts, economic losses, and potential adaptation strategies to mitigate Sargassum impacts on crop cycles.                                                                                                                                                           |
| Seabed leasing cost for mariculture                          | It encompasses the costs associated with obtaining seabed permits for mariculture activities. It highlights the lack of a standardized rate for seabed permits, reaffirms the high cost of acquiring seabed permits, particularly for designating areas for mariculture. The discrepancy in the estimated cost per acre underscores the financial burden faced by farmers due to the high costs associated with seabed permits for mariculture activities.                                                               |
| Seaweed Farming as a Key Action in International Commitments | It denotes the integration of seaweed aquaculture initiatives with overarching national and international policies. This includes blue economy strategy, coastal zone management plan, and the National Biodiversity Strategy and Action Plan (NBSAP), as well as global initiatives such as the Global Biodiversity Framework (GBF) and Sustainable Development Goals (SDGs). It encompasses the consideration of internationally recognized frameworks like the UNFCCC and nationally determined contributions (NDCs). |
| Seaweed Production Reporting Challenges                      | This pertains to challenges in accurately reporting seaweed production in Belize. It highlights the issues faced such as discrepancies between reported export and domestic sales figures, highlighting the need for improved accuracy and reliability in data collection and reporting processes.                                                                                                                                                                                                                       |
| Sovereign Rights in the Exclusive Economic Zone (EEZ)        | It pertains to discussions regarding Belize's jurisdiction and authority over its EEZ, particularly in the context of foreign affairs and diplomatic representation. This code captures insights related to the recognition and protection of Belize's rights within its EEZ,                                                                                                                                                                                                                                            |

|                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|----------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                | emphasizing the importance of public understanding and awareness regarding sovereignty issues in maritime territories.                                                                                                                                                                                                                                                                                                                                                                                                       |
| Striving for quality and standards                             | This captures any importance of producing high-quality products that meet minimum standards by consumers in the seaweed industry. It underscores the significance of striving for quality and standardization in product production. It includes expressions of the necessity of adhering to standards to ensure the viability and competitiveness of their products in the market. This theme emphasizes the commitment to meeting quality benchmarks to enhance product value and marketability.                           |
| Theft and Security Measures                                    | It examines issues related to theft and security concerns in seaweed farming operations in Belize. It emphasizes the importance of implementing security measures at farming sites to prevent piracy and safeguard investments.                                                                                                                                                                                                                                                                                              |
| Traceability opportunity                                       | It encompasses discussions related to the economic aspects and regulatory requirements of seaweed farming. This code includes references to economic indicators such as GDP and exports, as well as regulatory considerations such as traceability and compliance with phytosanitary certification requirements from BAH (Belize Agricultural Health Authority). It highlights the importance of understanding and adhering to regulations while considering the economic implications of seaweed farming activities.        |
| Socio-economic and community-based approaches                  | This theme focuses on the socio-economic and community-based approaches currently employed in seaweed farming. activities encompasses accessibility issues, economic viability concerns, financial sustainability challenges, and market-related issues. Participants highlighted the importance of alternative income sources, financial incentives, and subsidies to support seaweed farmers. Additionally, they discussed the role of women in the industry and the need for improved market accessibility and viability. |
| Accessibility for women                                        | Women's involvement in agricultural initiatives is characterized by both accessibility to resources and persistent obstacles. Efforts by organizations aim to support women's groups yet challenges in establishing sustainable business models remain. Emphasis is placed on developing income-generating activities beyond grant cycles through skill development and value-added production.                                                                                                                              |
| Alternative Income Source and Fisheries Management Strategy    | It encompasses perspectives on utilizing seaweed farming as an alternative income source for fishers, aiming to mitigate overfishing pressure on traditional marine stocks. It highlights the need for diversification in the fishing industry, promoting sustainable livelihoods and reducing dependence on finite resources. It explores the potential role of seaweed farming in ecosystem resilience and climate adaptation, emphasizing its value in sustainable economic growth and addressing the challenges.         |
| Challenges and Frictions in Organizational Dynamics            | It comprises of challenges encountered within the organizational framework, including issues related to leadership transitions and internal conflicts. It links to the need to have the efficiency of existing regulations and the need for clearer guidelines. These challenges are not solely confined to managerial levels within the organization but also extend to stakeholder interactions and broader policy and legislative contexts.                                                                               |
| Community-Based Ecosystems Cultivation Approach by Marine NGOs | It represents the collaborative efforts undertaken by marine non-governmental organizations (NGOs) to implement community-based approaches for cultivating ecosystems, particularly focused on seaweed farming. This code is used to categorize discussions, initiatives, and projects related to the involvement of NGOs in supporting communities to cultivate seaweed and other marine resources in a sustainable manner, with an emphasis on community engagement, empowerment, and environmental stewardship.           |

|                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-----------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Cooperative Management and Resource Sharing         | This captures the management practices and resource sharing within cooperatives involved in seaweed farming. Key points include concerns about the management of farms within the cooperative, issues surrounding the equitable distribution of funds, and observations regarding individual efforts versus collective responsibilities. It explores the challenges in cooperative governance, the impact of individual contributions on overall success, and the need for transparent and fair resource allocation mechanisms.  |
| Cultural Perceptions and Accountability             | This delves into the cultural perceptions and accountability regarding resource management and governmental involvement. It highlights the need for deeper understanding and accountability among stakeholders, suggesting a disconnect between perceived responsibility and actual action. This prompts reflection on societal attitudes towards resource management and calls for a more nuanced approach to addressing environmental challenges.                                                                              |
| Early History and Evolution of Seaweed Farming      | This code captures discussions on the early history and evolution of seaweed farming, exploring its inception, pioneering efforts, and developmental trajectory. It encompasses points on the origins of seaweed cultivation, adoption of traditional and innovative techniques, and factors contributing to its growth as an industry.                                                                                                                                                                                          |
| Economic viability characteristics                  | Seaweed farming is an attractive option due to its low-intensive technology and suitability for shallow waters. The establishment costs are relatively low, and the product has a quick reproduction cycle, allowing for short harvest periods. While there is a market for seaweed products, challenges remain regarding volume and pricing control. Currently, focus is primarily on local markets, with limited exploration of international or regional markets. Value-added products have not been widely considered.       |
| Expanding Interest in Seaweed Cultivation           | It encapsulates discussions related to the growing attention and enthusiasm surrounding seaweed farming and cultivation practices. It highlights increasing interest from various stakeholders, including farmers, communities, and government agencies, in exploring seaweed as a viable economic opportunity and sustainable livelihood option. It elaborates on the potential benefits, challenges, and opportunities associated with expanding seaweed cultivation efforts.                                                  |
| Family Support                                      | It focuses on the involvement of family members in seaweed farming operations within the blue economy context of Belize. It highlights instances where multiple family members actively participate in farming activities. It explores the dynamics of family support in farming operations, including the distribution of tasks and responsibilities among family members, as well as the potential impacts of familial involvement on the sustainability and success of seaweed farming initiatives.                           |
| Integration of Seaweed Farming in Economic Planning | It examines the extent to which seaweed aquaculture activities are incorporated into economic planning strategies. It focuses on whether discussions surrounding seaweed aquaculture are included in broader economic plans, such as maritime economist plans, as opposed to being directly addressed in policy strategy and implementation plans. Discussions within this category may explore the implications of the integration (or lack thereof) of seaweed aquaculture in economic planning processes for the development. |
| Lack of access to high-quality seeds                | It represents discussions related to the difficulty or inability of seaweed farmers to access high-quality seeds for cultivation. This code highlights difficulty in obtaining reliable and genetically diverse seaweed seeds for their farms. It explores the implications of seed accessibility challenges on the productivity, sustainability, and growth of the seaweed farming industry. Additionally, considerations of potential strategies or interventions to improve access to high-quality seeds.                     |

|                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|----------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Lack of land papers for business                               | It encapsulates discussions surrounding the challenges associated with the lack of proper land documentation or ownership papers for seaweed farming businesses. It explores the implications of insecure land tenure on the ability of farmers to invest in and expand their operations. It includes difficulties in accessing financing or investment opportunities, concerns about land tenure conflicts or disputes, and potential strategies for resolving or mitigating these challenges, such as land regularization. |
| Lack of Secure Tenure for Seafloor Use                         | This code refers to the absence of inadequacy of secure tenure arrangements for the use of seafloor areas in seaweed farming activities. The implications of not having clear and legally recognized rights or permissions to access, use, and manage marine spaces for seaweed cultivation. It concerns land ownership, leasing arrangements, permit requirements, tenure security, and the impact of insecure tenure on investment, expansion, and sustainable development of the seaweed farming industry.                |
| Market Accessibility Issues and Regulatory Compliance          | The accessibility of the market for seaweed products and the regulatory framework governing their sale and factors influencing the pricing and availability of seaweed products in the market, as well as regulations pertaining to their sale and distribution. The challenges and opportunities related to market access for seaweed farmers, as well as the implications of regulatory policies on the commercialization of seaweed farming operations within the blue economy context of Belize.                         |
| Market Viability                                               | This code highlights the economic dimensions of seaweed farming, emphasizing its market viability. It includes conversations on product demand, market trends, pricing, potential buyers, export prospects, value-added products, and strategies for market penetration. It encompasses market research, development initiatives, marketing strategies, and collaborations across the seaweed industry supply chain.                                                                                                         |
| MSME development and SDG-oriented climate action opportunities | This code covers fostering Micro, Small, and Medium-sized Enterprises (MSMEs) to advance Sustainable Development Goal (SDG)-oriented climate action. It includes conversations about supporting MSMEs in initiatives like renewable energy adoption, climate-resilient agriculture, sustainable tourism, and green technologies to meet SDG targets. This includes funding mechanisms, capacity building, policy frameworks, and collaborations empowering MSMEs for climate change adaptation while promoting SDGs.         |
| Partnership and Collaboration Opportunity                      | It pertains to expressions made regarding partnerships and collaborations opportunities such as interest in exploring new partnerships, potentially indicating a shift in existing affiliations. It indicates a collaborative effort between the interviewee and another entity to work on a publication, suggesting a proactive approach to fostering partnerships for mutual benefit.                                                                                                                                      |
| Personal Empowerment & Professional Identity                   | It captures statements made by the interviewee regarding their personal motivations, professional identity, and commitment to their work within the context of the fisheries sector. It reflects the personal motive to prioritize their security and autonomy, highlighting their self-reliance and expertise. Also, it captures positive position within the interviewee's professional network, personal passion for their work, genuine desire to assist others within the industry.                                     |
| Pricing issue                                                  | This code covers discussions on pricing within the seaweed farming industry, including challenges, strategies, and considerations. It includes topics such as determining fair market prices, competitiveness, fluctuations, structures, negotiation strategies, affordability, impacts on profitability, and market access. It also involves exploring factors influencing pricing decisions, addressing barriers, and assessing pricing implications on the sector.                                                        |

|                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Proximity to shore                                 | This code explores the positioning of seaweed farms near coastlines. It includes discussions on proximity, accessibility, advantages (like farmer access) and challenges (like environmental impact). Strategies for optimizing farm placement for maximum benefit with minimal coastal impact are also discussed.                                                                                                                                                                                                                                              |
| Reluctance in Cluster Formation                    | Convincing individual farmers from different regions in Belize to partner in joint seaweed mariculture business ventures lies in the pervasive reluctance among stakeholders to engage in collaborative efforts. This reluctance manifests as a significant barrier to effective cooperation and partnership formation within the industry. The prevailing sentiment of disinterest or unwillingness to collaborate undermines the potential for synergy and collective advancement within the seaweed mariculture sector                                       |
| Seaweed capacity in ecological resilience          | This code addresses seaweed's role in bolstering ecological resilience within marine ecosystems. It encompasses discussions on seaweed's contribution to ecosystem stability, adaptability, and recovery amidst environmental stressors like climate change and pollution. It captures insights into seaweed's capacity to maintain ecosystem functions, support biodiversity, and mitigate disturbances, informing conservation and management strategies.                                                                                                     |
| Stakeholder Agenda Bias Issue                      | It represents the influence of stakeholder agendas, particularly from NGOs, on decision-making processes within regulatory frameworks. This can include development of agreements by one party only. It highlights challenges arising from conflicting interests and emphasizes the need for transparency and alignment of objectives to overcome potential biases and ensure fair and equitable governance.                                                                                                                                                    |
| Stakeholder Consultation and Authority Dynamics    | It highlights issues related to stakeholder consultation processes and dynamics of authority within the context of seaweed farming regulations. It includes issues going over the timeline for regulatory development and the absence of a draft, payment for consultancy services. It emphasizes the absence of requisite stakeholder consultations as a significant disparity in the regulatory process.                                                                                                                                                      |
| Stakeholder Management and Transparency Challenges | Stakeholder management focus on issues surrounding global entities impacting local management decisions, challenges in policy enforcement and permit issuance, and the role of different stakeholders such as cooperatives and businesses in the export of seaweed. It captures issues around transparency in export operations, the involvement of foreign entities in local seaweed trade, and the need for effective stakeholder engagement and regulatory frameworks to address challenges in the industry.                                                 |
| Stakeholder Relation and Reputation                | The importance of avoiding guilt by association and maintaining careful communication. They emphasize the significance of public perception and assertiveness in professional interactions. Also, it addresses the loss of trust in certain individuals within the farming cluster organizations and government sectors. It highlights the need for effective communication and collaboration among stakeholders, including cooperative members and external organizations. Stakeholder engagement and encourages participation in seaweed livelihood projects. |
| Traditional ways and Transition Challenges         | It captures fisheries management practices and the cultural significance of fishing activities within the local community. It highlights the allowance by fisheries authorities for layman fishermen to sell their catch in the local market, acknowledging the cultural importance of these practices. It also emphasizes the need for improved management strategies within the fisheries sector. It delves into the challenges associated with transitioning traditional fishing practices towards deeper waters.                                            |
| Training and Endorsement                           | It focuses on training opportunities provided by entities like the Placencia Cooperative, TNC (The Nature Conservancy), and TASA (Turneffe Atoll Sustainability Association) in Belize. It also                                                                                                                                                                                                                                                                                                                                                                 |

|                              |                                                                                                                                                                                                                                                                                                                                                                                           |
|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                              | highlights concerns regarding the endorsement of training programs, particularly questioning the legitimacy of training fees charged by certain individuals or organizations.                                                                                                                                                                                                             |
| Viable Livelihood Challenges | It explores perspectives on the impact of seaweed farming on the livelihoods of those involved in the activity in Belize. It examines the balance between investment and returns, considering factors such as farm locations and the number of farms operating. It highlights the subjective nature of assessing the benefits and drawbacks of seaweed farming on individual livelihoods. |

*Table 9.88. Elite interview codebook at policy-level perspectives of seaweed farming as a climate change adaptation and blue growth in Belize.*

#### 9.6.2.1 Word Frequencies Analysis

The word cloud in the elite interviews reveals a strong emphasis on governance, development, cooperation, and sustainability in the context of seaweed farming and mariculture. The term "legislation" is prominent, indicating discussions around laws and regulations. The term "government" is also prominent, suggesting that government roles, actions, and policies were a major focus of the discussions. The term "development" emphasizes growth, expansion, and strategic planning in the context of seaweed farming. The term "cooperative" suggests a significant focus on cooperative management, collaboration, and resource sharing among stakeholders. The discussions were heavily centered on the practices of cultivating marine organisms, with specific attention to the policies, challenges, and opportunities within these fields. Incentives were also mentioned, possibly in relation to encouraging sustainable practices or investment in the sector. The term "stakeholders" reflects the involvement and importance of various groups and individuals in the seaweed farming industry, emphasizing the need for inclusive approaches. The term "sustainable" underlines the focus on long-term environmental and economic sustainability, which is crucial for the success of seaweed farming. Regulations were a significant concern for the interviewees. The specific mention of the seaweed species *Kappaphycus* indicates that it was a key topic of discussion.

The word frequency query setup involved configuring the NVivo software's criteria to identify and count words in the selected data. The query displayed the 1000 most frequent words, emphasizing the most commonly occurring ones. A minimum word length of 10 characters was specified, excluding common shorter words that may not contribute significant thematic value. This approach focused on more specific, content-rich terms, ensuring a thorough analysis. The tables below show the prevalence of the four main themes identified in elite interviews.



In the Regulatory and Policy Frameworks section (top-left, grey), the theme emerged as a dominant area of discussion. The largest blocks within this category included "Legal and Policy Framework Development," "Research Permit Compliance," and "Limitation to R&D in Seaweed," indicating that these were the most frequently mentioned sub-themes. Smaller blocks, such as "Theft and Security Measures" and "Alignment of National Program to Policy," represented less frequently discussed but still relevant issues.

The Ecosystem-based and Innovative Approaches section (bottom-left, blue) was represented by several large blocks, indicating significant discussion around topics such as "Belize Blue Economy Approach," "Seaweed Species and Uses," and "Marine Spatial Planning and Offshore Opportunity." Other notable sub-themes included "*Kappaphycus alvarezii* Invasive Nature" and "Carbon-Sequestering," reflecting the attention given to environmental sustainability and innovation in the sector. Smaller blocks indicated sub-themes that were mentioned less frequently, such as "Installation of Physical Barriers" and "Increased Sea Temperature."

In the Socio-economic and Community-based Approaches (including Cultural Practices) section (top-right, yellow), the focus was on socio-economic factors and community involvement in seaweed farming. Large blocks like "Viable Livelihood Challenges," "Stakeholder Consultation and Authority Dynamics," and "Stakeholder Management and Transparency Challenges" indicated that these were significant concerns for the interviewees. The presence of smaller blocks, such as "Pricing Issues" and "Integration of Seaweed Farming in Economic Plans," suggested that while important, these topics were less central to the discussions.

The Financial and Investment Mechanisms (including Cultural Practices) section (bottom-right, orange) was the smallest in terms of block size, indicating that these issues were discussed less frequently compared to the other themes. The largest blocks in this section, "Limitations of Seaweed Farmers' Capacity" and "Value-Added Seaweed Commodity Issues," showed that these were the most prominent financial concerns. Smaller blocks, such as "Blue Business Innovation Funding Opportunities" and "Working Capital Availability Constraints," represented sub-themes that received limited attention.

Overall, the tree map visualization revealed that Regulatory and Policy Frameworks and Ecosystem-based and Innovative Approaches were the most frequently discussed themes, with multiple sub-themes receiving significant attention. Socio-economic and Community-based Approaches were also important, with a strong focus on livelihood challenges and stakeholder dynamics. Financial and Investment Mechanisms were discussed the least, indicating that financial issues, while relevant, were not the primary focus of the interviews. This visualization effectively illustrates the relative importance of various sub-themes within the broader context of seaweed farming as discussed in the elite interviews. The tree map provides a comprehensive visualization of the main themes and subthemes, however, to further understand the sub-themes, the figure below provides a breakdown of the tree map by main theme.



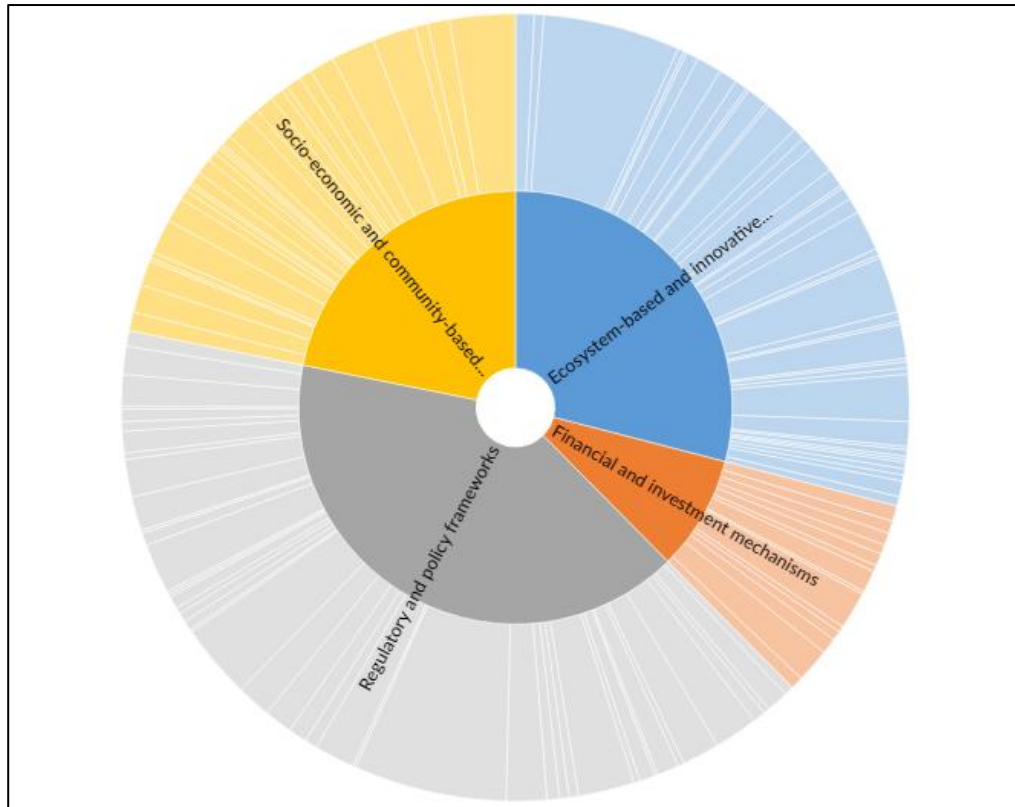


*Figure 9.17. Tree map of Themes and Subthemes in the Elite Interviews (Author's own elaboration).*

Key insights: The text highlights the challenges faced by seaweed farmers in Belize, including regulatory limitations, livelihood challenges, and export issues. It also discusses the importance of dedicated legislation, stakeholder collaboration, and sustainable practices. The text also highlights the diversity of seaweed species and ecosystems, species management, and infrastructure. It also discusses adaptation opportunities, such as alternative financing and blue bond initiatives, and the need for marine spatial planning and resource integration. It also discusses knowledge sharing, adaptation strategies, conservation integration, business management practices, profitability, and sustainability. The text also highlights the need for adaptation strategies in emerging business opportunities, conservation integration, business management practices, and sustainability. The text concludes by emphasizing the need for sustainable practices and strategic partnerships in the seaweed farming industry, traceability and certification.

## 9.7 APPENDIX G (PESTEL dataset and codebook)

### 9.7.1 Data: Legislative Frameworks

Table 9.89 below presents a comprehensive overview of Belize's legal frameworks and policies, categorizing them into binding or non-binding, including seaweed, information type, precautionary level, and adaptation strategies. Key aspects include framework type, information type, and precautionary level. Frameworks involving conservation, climate adaptation, and environmental protection generally show higher precaution. Adaptation approaches, such as Ecosystem-based Adaptation (EbA), Community-based Adaptation (CbA), or Hybrid Approaches, are used, with seaweed farming often blending ecosystem-based and community-based strategies. This comprehensive overview provides a comprehensive understanding of how these strategies are integrated into Belize's policy landscape.

The figure shows the distribution of legal frameworks and policies in Belize, categorized into three groups: Binding, Non-Binding, and International Agreements. Binding frameworks dominate, accounting for 41 of these, followed by 21 non-binding frameworks and the smallest international agreement. These frameworks govern sectors like seaweed farming, environmental management, and climate adaptation, emphasizing the regulatory and legal focus of the country's policy landscape. The figure also highlights that international agreements constitute the smallest category, with only four frameworks. Overall, the majority of legal frameworks and policies in Belize are legally binding as outlined below.

| No. | Framework                                         | Force of Framework | Inclusion of Seaweed | Information Type Used             | Use of Precaution | Use of CbA/EbA/Hybrid Approaches |
|-----|---------------------------------------------------|--------------------|----------------------|-----------------------------------|-------------------|----------------------------------|
| 1   | Trade and Investment Development Service Act 2000 | Binding            | No                   | Regulatory                        | Low               | None                             |
| 2   | Tourism Board Act Substantive Law 2000            | Binding            | No                   | Regulatory                        | Low               | None                             |
| 3   | Tourism Board Act Subsidiary Law 2003             | Binding            | No                   | Regulatory                        | Low               | None                             |
| 4   | Standards Act 2000                                | Binding            | Indirect             | Standards and regulations         | Medium            | None                             |
| 5   | Protected Areas System Act 2020                   | Binding            | Indirect             | Conservation and protection rules | High              | EbA                              |
| 6   | Prevention of Crimes Act Substantive Law 2011     | Binding            | No                   | Legal/Regulatory                  | Low               | None                             |

|    |                                                             |         |          |                                   |        |        |
|----|-------------------------------------------------------------|---------|----------|-----------------------------------|--------|--------|
| 7  | Port Authority Act 2003 Substantive Laws                    | Binding | No       | Regulatory                        | Medium | None   |
| 8  | Port Authority Act 2003 Subsidiary Laws                     | Binding | No       | Regulatory                        | Medium | None   |
| 9  | Police Act Substantive Law 2000                             | Binding | No       | Legal/Regulatory                  | Low    | None   |
| 10 | Patents Act 2011                                            | Binding | No       | Intellectual property regulations | Low    | None   |
| 11 | National Lands Act                                          | Binding | Indirect | Land use and management           | Medium | None   |
| 12 | Maritime Areas Act Substantive Laws 2020                    | Binding | Indirect | Marine regulations                | High   | EbA    |
| 13 | Maritime Areas Act                                          | Binding | Indirect | Marine regulations                | High   | EbA    |
| 14 | Food and Drugs Act 2000                                     | Binding | No       | Health regulations                | Medium | None   |
| 15 | Fisheries Resources Act                                     | Binding | Yes      | Regulatory/Conservation           | High   | Hybrid |
| 16 | Fisheries Development Authority Act                         | Binding | Yes      | Regulatory/Development            | High   | Hybrid |
| 17 | Environmental Protection Act 2020                           | Binding | Indirect | Environmental regulations         | High   | EbA    |
| 18 | Disaster Preparedness and Response Act Substantive Law 2000 | Binding | No       | Emergency preparedness            | High   | None   |
| 19 | Disaster Preparedness and Response Act Subsidiary Law 2003  | Binding | No       | Emergency preparedness            | High   | None   |

|    |                                                                     |         |          |                           |        |        |
|----|---------------------------------------------------------------------|---------|----------|---------------------------|--------|--------|
| 20 | Designated Processing Areas Act 2018                                | Binding | No       | Regulatory                | Low    | None   |
| 21 | Criminal Code Act Substantive Laws 2011                             | Binding | No       | Legal/Regulatory          | Low    | None   |
| 22 | Coastal Zone Management Act                                         | Binding | Yes      | Environmental management  | High   | EbA    |
| 23 | Coast Guard Act Substantive Law 2020                                | Binding | No       | Regulatory                | Medium | None   |
| 24 | Chamber of Commerce and Industry Act 2011                           | Binding | No       | Regulatory                | Low    | None   |
| 25 | Belize Solid Waste Management Authority Act 2011                    | Binding | Indirect | Waste management          | Medium | None   |
| 26 | Belize Port Authority Act 2000                                      | Binding | No       | Regulatory                | Medium | None   |
| 27 | Aquaculture Development Act                                         | Binding | Yes      | Regulatory/Development    | High   | Hybrid |
| 28 | Agricultural Health Authority Act Substantive Law 2011              | Binding | Indirect | Health regulations        | Medium | None   |
| 29 | Fiscal-Incentives 2023                                              | Binding | No       | Economic regulations      | Low    | None   |
| 30 | Environmental Protection (Pollution from Plastics) Regulations 2020 | Binding | Indirect | Environmental regulations | High   | EbA    |
| 31 | Environmental Protection (Pollution from Plastics)                  | Binding | Indirect | Environmental regulations | High   | EbA    |

|    |                                                                                        |         |          |                      |        |      |
|----|----------------------------------------------------------------------------------------|---------|----------|----------------------|--------|------|
|    | Regulation 2022                                                                        |         |          |                      |        |      |
| 32 | Forests Protection of Mangroves Regulation 2018                                        | Binding | Indirect | Conservation rules   | High   | EbA  |
| 33 | Climate Change and Carbon Market Initiatives Bill 2023                                 | Binding | Indirect | Climate policies     | High   | EbA  |
| 34 | Agricultural Health Authority (Food Processing Plants) Regulations                     | Binding | Indirect | Health regulations   | Medium | None |
| 35 | Agricultural Health Authority (Fish and Fisheries Product Inspection) Regulations 2002 | Binding | Yes      | Health regulations   | Medium | None |
| 36 | Agricultural Health Authority (Fish and Fisheries Product Inspection) Regulations 2000 | Binding | Yes      | Health regulations   | Medium | None |
| 37 | Agricultural Health Authority (Service Fees) Regulations                               | Binding | No       | Economic regulations | Low    | None |

|    |                                                                                               |             |          |                            |        |        |
|----|-----------------------------------------------------------------------------------------------|-------------|----------|----------------------------|--------|--------|
| 38 | Agricultural Health Authority (Quarantine Inspection and Certification Fees) Regulations 2001 | Binding     | No       | Health regulations         | Medium | None   |
| 39 | Agricultural Health Authority (Prevention of Plant and Animal Diseases OIRSA) Regulations     | Binding     | No       | Health regulations         | Medium | None   |
| 40 | Agricultural Health Authority (Inspection in a Foreign Country) Regulation, 2004              | Binding     | No       | Health regulations         | Medium | None   |
| 41 | Agricultural Health Authority (Food Safety) Regulations                                       | Binding     | Indirect | Health regulations         | Medium | None   |
| 42 | National Strategy for the Development of Statistics                                           | Non-Binding | No       | Data collection strategies | Low    | None   |
| 43 | National MSME Strategy and RoadMap for Belize 2022                                            | Non-Binding | No       | Strategic guidelines       | Low    | None   |
| 44 | National Hazard Mitigation Policy                                                             | Non-Binding | Indirect | Risk management            | High   | Hybrid |
| 45 | National Food and Agriculture Policy                                                          | Non-Binding | Indirect | Strategic guidelines       | Medium | None   |
| 46 | Mariculture Policy                                                                            | Non-Binding | Yes      | Strategic guidelines       | High   | Hybrid |

|    |                                                                                                      |             |          |                                       |        |        |
|----|------------------------------------------------------------------------------------------------------|-------------|----------|---------------------------------------|--------|--------|
| 47 | Growth and Sustainable Development Strategy 2016-2019                                                | Non-Binding | Indirect | Development plans                     | Medium | None   |
| 48 | Climate Finance Strategy Plan                                                                        | Non-Binding | No       | Financial planning                    | Medium | None   |
| 49 | Blue Economy Development Policy, Strategy and Implementation Plan 2022-2027                          | Non-Binding | Yes      | Strategic plans, economic assessments | Medium | Hybrid |
| 50 | Belize National Development Strategy 2022 -2026                                                      | Non-Binding | Indirect | Development plans                     | Medium | None   |
| 51 | Nationally Determined Contribution                                                                   | Non-Binding | Indirect | Climate commitments                   | High   | EbA    |
| 52 | Maritime Economy Plan                                                                                | Non-Binding | Yes      | Strategic guidelines                  | Medium | Hybrid |
| 53 | Horizon 2030 National Development Framework for Belize                                               | Non-Binding | Indirect | Long-term development framework       | Medium | None   |
| 54 | Culturally Appropriate Participation Plan Marine Conservation and Climate Adaptation Project (MCCAP) | Non-Binding | Indirect | Community engagement strategies       | Medium | CbA    |
| 55 | Belize National Sustainable Development Report                                                       | Non-Binding | Indirect | Sustainable development report        | Medium | None   |
| 56 | Belize National Climate Resilience Investment Plan                                                   | Non-Binding | Indirect | Climate resilience strategies         | High   | EbA    |

|    |                                                                          |                         |          |                                        |        |        |
|----|--------------------------------------------------------------------------|-------------------------|----------|----------------------------------------|--------|--------|
| 57 | Belize NAP to address climate change in the agriculture sector in Belize | Non-Binding             | Indirect | Adaptation strategies                  | High   | EbA    |
| 58 | Belize Marine Conservation and Climate Adaptation Project (MCCAP)        | Non-Binding             | Indirect | Conservation and adaptation strategies | High   | EbA    |
| 59 | Advancing Disaster Risk Finance in Belize                                | Non-Binding             | Indirect | Risk finance strategies                | Medium | None   |
| 60 | National Climate Change Policy, Strategy and Action Plan                 | Non-Binding             | Indirect | Climate policy and strategy            | High   | EbA    |
| 61 | National Biodiversity Strategy and Action Plan (2016-2020)               | Non-Binding             | Indirect | Biodiversity management                | High   | EbA    |
| 62 | Fisheries Policy, Strategy & Action Plan 2020-2024                       | Non-Binding             | Yes      | Strategic guidelines                   | High   | Hybrid |
| 63 | UNFCCC National Adaptation Plan                                          | International Agreement | Indirect | Climate adaptation strategies          | High   | EbA    |
| 64 | UN Convention on the Law of the Sea                                      | International Agreement | Indirect | Marine governance guidelines           | High   | None   |
| 65 | Convention on Biological Diversity 1992                                  | International Agreement | Indirect | Biodiversity conservation guidelines   | High   | EbA    |



|    |                                                                                    |                         |     |                      |        |        |
|----|------------------------------------------------------------------------------------|-------------------------|-----|----------------------|--------|--------|
| 66 | Ocean Economy and Trade Strategy on Belize Marine Fisheries and Seafood Processing | International Agreement | Yes | Strategic guidelines | Medium | Hybrid |
|----|------------------------------------------------------------------------------------|-------------------------|-----|----------------------|--------|--------|

*Table 9.89. Inventory of Policy and Legal Instruments Relevant to Seaweed Mariculture in Belize: Classification by Legal Force, Seaweed Specificity, Information Type, Precaution Level, and Adaptation Approach (Author's own elaboration).*

### 9.7.2 Analysis: PESTEL Codebook

A PESTEL framework was used to analyze the external factors that affect policy formation and execution in the mariculture and related sectors in Belize. The PESTEL study, acronym for Political, Economic, Social, Technological, Environmental, and Legal elements, offers a complete perspective to comprehend the policy landscape. The PESTEL framework was dissected into several thematic codes and sub-codes, which were thoroughly examined to comprehend the intricacies of how these elements interrelate with and impact mariculture regulations.

The analytical results indicated different degrees of influence within the six categories. The Legal elements were found to be the most significant, with 46 codes and 1,532 mentions, indicating the crucial role of regulatory frameworks and legal structures in influencing the mariculture sector. The presence of environmental elements was significant, with 32 codes and 413 mentions, indicating the crucial importance of environmental sustainability and ecological considerations in policy deliberations. The analysis revealed that political variables, represented by 31 codes and mentioned 317 times, and economic elements, likewise represented by 31 codes but mentioned 383 times, highlighted the significance of governance, institutional structures, and economic incentives in the growth of mariculture. The social variables, which were identified by 27 codes and mentioned 155 times, emphasized the importance of community involvement, fairness in society, and public knowledge. Finally, the Technological aspects, consisting of 13 codes and mentioned 66 times, emphasized the growing significance of technology and innovation in promoting sustainable mariculture practices.

The following codebook in Table 9.90 presents the categorization and analysis that offer a precise comprehension of the external aspects that need to be taken into account when developing and executing successful mariculture strategies in Belize. The categories and their corresponding theme codes provide useful insights into the difficulties and opportunities in the industry, helping policymakers build well-informed, balanced, and sustainable development strategies.

| Name                                | Description                                                                                                                                                                                                     |
|-------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Economic                            | Evaluation of the economic trends such as inflation rates, exchange rates, economic growth, and unemployment rates that could impact Belize Seaweed Aquaculture Development.                                    |
| 1. Funding and Financial Strategies | This code covers a range of financial planning and management codes that are critical to supporting sustainable development and resilience, especially in the context of environmental and economic challenges. |

|                                                                                                                                                                        |                                                                                                                                                                                                                                              |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A dedicated fund ensures that financial resources are available to address environmental emergencies                                                                   | This refers to the establishment of a specific financial reserve that can be quickly accessed in the event of environmental disasters or emergencies, ensuring a rapid and effective response.                                               |
| Advancing Disaster Risk Finance in Belize                                                                                                                              | This code focuses on improving and implementing financial strategies that specifically address the risks associated with natural disasters in Belize, possibly including insurance mechanisms, contingency funds, and other financial tools. |
| Financial Management and Fiscal Impact for Economic Losses and Contingent Liabilities                                                                                  | This code deals with the financial planning needed to manage the economic impact of unexpected events or liabilities, ensuring that the financial system can absorb shocks without severe consequences.                                      |
| Mobilizing finance, public capital investment, and accessing and managing climate finance                                                                              | This describes efforts to gather and allocate financial resources, particularly from public sources and climate-related funds, to invest in projects that mitigate or adapt to climate change.                                               |
| Climate Finance Strategy Plan                                                                                                                                          | A sub-point under mobilizing finance, this likely involves developing a strategic plan specifically for accessing and utilizing funds aimed at climate change mitigation and adaptation.                                                     |
| Need for sustainable financial resources to promote sector development strategies                                                                                      | This emphasizes the importance of having long-term, sustainable financial support to ensure the continued growth and development of key economic sectors.                                                                                    |
| Need to strengthen legal frameworks and enforcement mechanisms to reduce corruption, thereby fostering a more conducive environment for economic growth and investment | This point stresses the importance of legal and institutional reforms to ensure transparency and reduce corruption, which is crucial for the effective use of financial resources.                                                           |
| Practice of budgeting and resource mobilization in National Fisheries Policy, Strategy & Action                                                                        | This involves applying budgeting and financial resource mobilization strategies specifically within the context of national fisheries, ensuring that these sectors are well-funded and strategically managed.                                |
| Resource Mobilization and Investment Strategies                                                                                                                        | This code refers to strategies for attracting and utilizing investments and resources to support various development initiatives.                                                                                                            |
| The need to reduce administrative costs, regulatory delays, and investment risks                                                                                       | This highlights the necessity of streamlining administrative processes and reducing bureaucratic inefficiencies and risks that could hinder investment and financial operations.                                                             |
| 2. Economic Development and Diversification                                                                                                                            | This code focuses on initiatives and strategies aimed at broadening the economic base, particularly in sectors like aquaculture and mariculture, which are crucial for sustainable development in regions like Belize.                       |
| Aquaculture development in inception stage in Belize                                                                                                                   | This refers to the early stages of establishing aquaculture as a viable economic sector in Belize, which involves foundational planning and initial investments.                                                                             |

|                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|---------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Foreign Exchange Earnings in Aquaculture (only for shrimp)                            | This sub-code discusses the contribution of shrimp farming to Belize's foreign exchange reserves, highlighting the economic significance of this specific aquaculture product.                                                                                                                                                                                                                                                                                                                                       |
| Coastal zone economic significance and potential for growth (human resources and GDP) | This code focuses on the economic importance of coastal areas, particularly their potential for growth in terms of human resources and contributions to Gross Domestic Product (GDP).                                                                                                                                                                                                                                                                                                                                |
| Critical role of blue economy initiatives in economic development                     | This code emphasizes the importance of the blue economy, which includes all economic activities related to oceans, seas, and coasts, in driving economic growth and sustainability.                                                                                                                                                                                                                                                                                                                                  |
| Economic diversification as an economic benefit to sustainable mariculture            | This code refers to diversifying economic activities, particularly through mariculture (the cultivation of marine organisms), which can provide economic benefits and contribute to sustainability.                                                                                                                                                                                                                                                                                                                  |
| Economic support and development initiatives in [sustainable] mariculture             | This code refers to specific initiatives aimed at supporting and developing mariculture in a sustainable manner, ensuring long-term economic viability.                                                                                                                                                                                                                                                                                                                                                              |
| Belize Chamber of Commerce and Industry Act                                           | The Belize Chamber of Commerce and Industry Act, Chapter 308, Revised Edition 2011, establishes the organization's structure, governance, objectives, powers, divisions, and legal proceedings. It supports Micro, Small, and Medium Enterprises (MSMEs) through various committees, including the Business Development Committee, which promotes business development in domestic and international markets, and the Membership Development and Services Committee, which reviews membership criteria and services. |
| Economic viability and pilot projects in mariculture development                      | This code captures the importance of assessing economic viability through pilot projects in mariculture, which can demonstrate the potential success and scalability of these ventures.                                                                                                                                                                                                                                                                                                                              |
| Fiscal incentives for mariculture development                                         | It captures the economic implications of the Fiscal Incentives Act 2003 (Revised Edition 2011), which includes mariculture as an eligible activity for tax holidays and duty exemptions. This highlights the potential financial benefits and economic support available for mariculture development in Belize, encouraging investment and growth in the sector.                                                                                                                                                     |
| Designated Processing Areas Act                                                       | The Fiscal Incentives Act, 2023 of Belize aims to improve the fiscal incentive program, streamline it, and offer new incentives for Micro, Small, and Medium Enterprises (MSMEs). It provides detailed provisions on application processes, eligibility criteria, types of incentives, duration, requirements, reporting obligations, penalties, and administrative fees. The act promotes MSMEs development by supporting approved activities while restricting certain ones.                                       |
| Fiscal Incentive Act                                                                  | The Fiscal Incentives Act, 2023 of Belize aims to improve the fiscal incentive program, streamline it, and offer new incentives for Micro, Small, and Medium Enterprises (MSMEs). It provides detailed provisions on application processes, eligibility criteria, types of incentives, duration, requirements, reporting obligations, penalties, and administrative fees. The act promotes MSMEs development by supporting approved activities while restricting certain ones.                                       |

|                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Incentives for Sustainable Investment                                                                            | This code highlights the importance of providing incentives to encourage investments that are not only profitable but also environmentally and socially sustainable.                                                                                                                                                                                                                                                                                                                      |
| Investment Confidence                                                                                            | This code stresses the need for creating a stable and attractive environment for investors, which is crucial for economic growth and diversification.                                                                                                                                                                                                                                                                                                                                     |
| The Belize National Coast Guard Service Act (2011)                                                               | The Belize Coast Guard Act establishes a legal framework for maritime security, including protecting investments in the blue economy and mariculture. It outlines the establishment, duties, functions, and command of the Coast Guard, enforcing maritime laws, maintaining territorial integrity, and preventing maritime crime. The Act also prevents conflicts of interest but involving the Coast Guard's role in supporting such mariculture activities would need to be consulted. |
| No tax incentive schemes developed that include supportive fiscal regulation for sustainable seaweed mariculture | This points out the lack of tax incentives or supportive fiscal policies specifically targeting sustainable seaweed mariculture, suggesting an area for potential policy development.                                                                                                                                                                                                                                                                                                     |
| Statistics aid in setting economic goals, targets, and strategies for sustainable development                    | This emphasizes the role of statistical data in formulating realistic economic goals and strategies, which is essential for planning sustainable development.                                                                                                                                                                                                                                                                                                                             |
| Value chain development and diversification in mariculture                                                       | This refers to efforts to enhance and diversify the value chain in mariculture, ensuring that all stages from production to market are optimized and sustainable.                                                                                                                                                                                                                                                                                                                         |
| 3. Market Development and Competitiveness                                                                        | This code focuses on capturing the strategies and frameworks necessary to enhance the market presence and competitiveness of mariculture products. It emphasizes the importance of certification, economic considerations, and standards in developing a robust and competitive market for these products.                                                                                                                                                                                |
| Awareness of certification schemes impact market access and competitiveness for mariculture products             | This code highlights the role of certification schemes in ensuring market access and enhancing the competitiveness of mariculture products. Certification can serve as a quality assurance mechanism that makes products more attractive in both domestic and international markets.                                                                                                                                                                                                      |
| “Responsible Aquaculture Program” of the Global Aquaculture Alliance (GAA)                                       | This program provides standards and certification for responsible aquaculture practices, focusing on environmental and social responsibility.                                                                                                                                                                                                                                                                                                                                             |
| Global GAP                                                                                                       | Refers to the Global Good Agricultural Practices certification, which sets international standards for safe and sustainable farming practices. This indicates the direction that Belize intends go while continuing to sustain their leadership in biodiversity protection and environmental stewardship. Preliminary discussion around this matter has commenced in seaweed farming and value addition.                                                                                  |
| Hazard Analysis Critical Control Point (HACCP) Certification                                                     | A systematic preventive approach to food safety that identifies, evaluates, and controls hazards which are significant for food safety.                                                                                                                                                                                                                                                                                                                                                   |
| International Federation of Organic                                                                              | This standard relates to organic agriculture, ensuring that products are produced sustainably without synthetic inputs.                                                                                                                                                                                                                                                                                                                                                                   |

|                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Agriculture Movements Basic Standards (IFOAM)                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Marine Stewardship Council (MSC)                                                                                                                            | An eco-label and fishery certification program that ensures seafood is sourced from sustainable fisheries.                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Economic considerations in stakeholder feedback to shape mariculture policies                                                                               | This point refers to the importance of incorporating economic factors when gathering stakeholder input to shape policies in mariculture, ensuring that these policies are both effective and financially sustainable.                                                                                                                                                                                                                                                                                                           |
| Market development and economic growth provided by mariculture development                                                                                  | This code emphasizes how the development of mariculture can drive market growth and contribute to broader economic development, suggesting that investment in mariculture can yield significant economic benefits.                                                                                                                                                                                                                                                                                                              |
| Belize Marketing Development Corporation to Support for Aquaculture Marketing                                                                               | Refers to the role of the Belize Marketing Development Corporation in facilitating the marketing and promotion of aquaculture products, helping to enhance market access and competitiveness.                                                                                                                                                                                                                                                                                                                                   |
| Provision of compulsory standards for market regulation and quality assurance                                                                               | This highlights the need for mandatory standards that regulate the market and ensure the quality of mariculture products, which is crucial for maintaining consumer trust and market stability.                                                                                                                                                                                                                                                                                                                                 |
| Standards Act                                                                                                                                               | The Standards Act of 1992, also known as S. I. 67 of 1992, enforces mandatory standards for various products, including mariculture, to ensure quality and safety. The act defines "article" as goods involved in manufacturing, testing, preparation, processing, packaging, storage, or sale, and "activity" as any process or practice deemed a compulsory standard. The Belize Bureau of Standards establishes these standards, while the Standards Advisory Council implements them. No standards for seaweed commodities. |
| 4. Resource Utilization and Value Addition                                                                                                                  | This code focuses on strategies and frameworks aimed at maximizing the efficient use of natural resources and enhancing their economic value, particularly in the context of biodiversity, fisheries, and mariculture.                                                                                                                                                                                                                                                                                                          |
| Biological diversity and genetic materials definition according to CBD                                                                                      | This refers to the guidelines and definitions provided by the Convention on Biological Diversity (CBD) for managing and utilizing biological diversity and genetic materials. It emphasizes the importance of biodiversity in sustainable development.                                                                                                                                                                                                                                                                          |
| Blue economy strategies (i.e. Biotrade) maximizing value-added from fisheries resource production and facilitating private sector leadership in development | This point discusses strategies within the blue economy framework that focus on adding value to fisheries resources through Biotrade, promoting sustainable practices, and encouraging private sector involvement in development initiatives.                                                                                                                                                                                                                                                                                   |
| Development of management frameworks for locally consumed fisheries including seaweed for food security                                                     | This involves creating management plans and frameworks to ensure that locally consumed fisheries, including seaweed, are sustainably managed to support food security.                                                                                                                                                                                                                                                                                                                                                          |

|                                                                                                      |                                                                                                                                                                                                                                                                    |
|------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Economic implications of environmental liabilities and penalties                                     | This code explores the economic consequences of environmental liabilities and the potential penalties that can arise from non-compliance with environmental regulations, stressing the importance of sustainable practices.                                        |
| Fisheries resources as Biotrade and GDP contributor                                                  | This highlights the role of fisheries resources, particularly when used in Biotrade, as significant contributors to the Gross Domestic Product (GDP), reflecting their economic importance.                                                                        |
| High fuel, food and logistics costs increase operational burden and necessitate policy interventions | This code identifies the challenges posed by rising operational costs, such as fuel, food, and logistics, and suggests the need for policy measures to reduce these financial burdens.                                                                             |
| Petroleum Act (Revised 2020)                                                                         | refers to legislative revisions that address fuel-related issues, which are critical for managing the costs in sectors like fisheries and mariculture.                                                                                                             |
| Plan Belize Medium-term Development Strategy 2022-2026                                               | This refers to a strategic plan that likely includes policy measures aimed at addressing operational challenges and promoting sustainable economic growth.                                                                                                         |
| Impact on mariculture development and economic value of carrageenan and agar extracts from seaweed   | This code captures the economic value of extracts like carrageenan and agar, derived from seaweed, in the context of mariculture development, emphasizing their significance in the industry.                                                                      |
| Regional economic integration organization definition by CBD                                         | This code refers to the role of regional economic integration organizations as defined by the Convention on Biological Diversity (CBD), emphasizing the importance of regional cooperation in managing biodiversity and resources.                                 |
| Seaweed resources as Biotrade products                                                               | This code captures on the use of seaweed as a Biotrade product, highlighting its potential for adding economic value within the blue economy.                                                                                                                      |
| United Nations Convention on Biological Diversity                                                    | Refers to the international legal framework that supports the sustainable use of biodiversity, including seaweed resources, as part of global Biotrade initiatives.                                                                                                |
| Versatile uses of seaweed                                                                            | This code captures the various applications of seaweed, which range from food and health products to industrial uses, underscoring its versatility and potential for value addition.                                                                               |
| 5. Trade and Investment Policies                                                                     | This code focuses on the regulatory and strategic frameworks that govern trade and investment activities, with an emphasis on enhancing economic growth, operational efficiency, and sustainable practices.                                                        |
| Belize can enhance its trade-mark protection regime, thereby supporting economic growth              | This code suggests that by improving its trademark protection laws and enforcement, Belize can create a more secure environment for businesses, which in turn would foster economic growth by encouraging innovation and attracting investment.                    |
| Maritime Trade and Economic Activities                                                               | This code refers to the broad range of activities related to maritime trade, including shipping, logistics, and port operations, which are vital to Belize's economy. Enhancing these activities could improve the country's trade efficiency and economic output. |
| The Registration of Merchant Ship Act (Revised 2020)                                                 | A sub-point under maritime trade, this likely involves updated regulations for the registration of merchant ships, ensuring that Belize's shipping industry is compliant with international standards and capable of supporting robust maritime trade.             |

|                                                                                                                |                                                                                                                                                                                                                                                                                         |
|----------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Operational Efficiency through Asset Utilization under Port Authority                                          | This point focuses on improving the efficiency of operations at ports, possibly by optimizing the use of assets managed by the Port Authority. Enhanced efficiency at ports can reduce costs and delays, boosting trade competitiveness.                                                |
| Permit required for importation of restricted products such as bottle caps                                     | This code refers to the regulatory requirement that certain restricted products, like bottle caps, need special permits for importation. Such regulations are typically in place to ensure product safety, compliance with environmental standards, or other regulatory goals.          |
| Provision of permit for the importation of biodegradable products (restricted products)                        | This code points out the importance of regulating the importation of biodegradable products. The requirement for permits ensures that these products meet specific environmental and safety standards before entering the market.                                                       |
| Trade Facilitation for Economic Growth through Ports                                                           | This code highlights the role of ports in facilitating trade and economic growth. By improving the infrastructure, management, and regulatory frameworks associated with ports, Belize can enhance its trade efficiency, attract more business, and stimulate economic development.     |
| 6. Sustainability and Environmental Protection                                                                 | This code focuses on initiatives and strategies aimed at promoting environmental sustainability, protecting ecosystems, and supporting economic activities that are aligned with these goals.                                                                                           |
| Blue carbon initiatives directly address environmental concerns by leveraging carbon markets                   | This code refers to efforts that utilize blue carbon ecosystems (like mangroves, seagrasses, and salt marshes) to capture and store carbon dioxide, thereby reducing greenhouse gas emissions. These initiatives leverage carbon markets to fund conservation and restoration projects. |
| Call for development of risk-sharing schemes for mariculture                                                   | This emphasizes the need to create financial mechanisms, such as insurance schemes, that distribute the financial risks associated with mariculture, particularly in the face of climate-related events.                                                                                |
| Apply the framework for climate-risk insurance or other parametric insurance policies developed in Mariculture | This involves applying insurance models that are specifically designed to cover risks related to climate change impacts in mariculture, such as parametric insurance, which pays out based on predefined conditions rather than actual loss assessments.                                |
| Cross-cutting commodity insurance (not specifically seaweed)                                                   | This code highlights the need for insurance products that cover a range of commodities, providing broader financial protection across different sectors, however, it does not capture seaweed commodity. Preliminary discussions have gone on at policy-level.                          |
| Need for Addressing Natural Disaster Risks in Mariculture Investments (gap)                                    | This highlights the existing gap in addressing the risks posed by natural disasters to mariculture investments, calling for tailored solutions.                                                                                                                                         |
| Proposed Insurance Schemes for Risk Management in Mariculture (i.e. COAST mechanism)                           | This refers to specific insurance proposals, such as the Caribbean Oceans and Aquaculture Sustainability Facility (COAST), designed to provide financial protection against risks in the mariculture sector.                                                                            |

|                                                                                                                            |                                                                                                                                                                                                                                                                        |
|----------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Carbon credit markets for trading through offsetting and carbon dioxide equivalent                                         | This involves the creation and participation in carbon credit markets, where entities can trade carbon offsets, essentially paying for projects that reduce carbon emissions to compensate for their own emissions.                                                    |
| Ensuring biosecurity and environmental protection through a structured fee system for various agricultural health services | This code suggests implementing a fee-based system to fund biosecurity measures and environmental protection services, particularly those related to agriculture and mariculture.                                                                                      |
| Importance of developing adaptation strategies that ensure sustainability in NDCs                                          | This emphasizes the need to develop and implement adaptation strategies within the framework of Nationally Determined Contributions (NDCs) under the Paris Agreement, ensuring long-term sustainability.                                                               |
| Prohibited single use plastic products including plastic bottles                                                           | This code highlights the efforts to ban single-use plastic products, such as plastic bottles, to reduce environmental pollution and protect ecosystems.                                                                                                                |
| Promotion of sustainable tourism practices that support the economic stability of coastal communities                      | This refers to the encouragement of tourism practices that are environmentally sustainable and economically beneficial to coastal communities, ensuring that tourism contributes to, rather than detracts from, the health of these areas.                             |
| Belize Tourism Board Act (2020)                                                                                            | A sub-code indicating legislative measures, such as the Belize Tourism Board Act, that might provide a regulatory framework for promoting sustainable tourism practices.                                                                                               |
| Sustainable Livelihoods and Economic Viability                                                                             | This code highlights the focus on ensuring that livelihoods, particularly in coastal and agricultural communities, are both sustainable and economically viable, balancing environmental protection with economic needs.                                               |
| Timely investments in the continuing of climate adaptation strategies in the environment and society                       | This captures the importance of making timely investments in climate adaptation efforts to address the ongoing and future impacts of climate change on both the environment and human societies.                                                                       |
| Tourism as a related sector promoting practices that protect these shared ecosystems                                       | Promotion of sustainable tourism practices that support the economic stability of coastal communities, including those involved in seaweed farming.                                                                                                                    |
| 7. Production and Innovation in Mariculture                                                                                | This thematic code focuses on enhancing mariculture practices, fostering innovation, and ensuring sustainable production in the industry.                                                                                                                              |
| Economic empowerment through gender-balanced mariculture                                                                   | This code emphasizes the importance of ensuring gender balance in the mariculture industry. By empowering both men and women equally, the industry can benefit from diverse perspectives and contributions, leading to greater innovation and economic sustainability. |
| Historical development of aquaculture in Belize                                                                            | This code refers to the chronological development of aquaculture practices in Belize, highlighting key milestones, challenges, and successes in the industry.                                                                                                          |
| Dominance of Pacific White Leg Shrimp Farming                                                                              | This sub-point likely focuses on the significant role that Pacific White Leg Shrimp farming has played in Belize's aquaculture industry, possibly being the leading species farmed in the region.                                                                      |
| Freshwater culture of Grey Tilapia                                                                                         | This refers to the farming of Grey Tilapia in freshwater environments, an important species in Belize's aquaculture due to its adaptability and market demand.                                                                                                         |



|                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Grow out cages of Cobia                                                                                                                                                   | This refers to the use of grow out cages for farming Cobia, a species known for its fast growth and high-quality meat, indicating efforts to diversify the species farmed in Belize.                                                                                                                                                           |
| Grow-out trial of Red Drum                                                                                                                                                | This code mentions experimental or pilot programs aimed at determining the viability of mariculture sector. This code captures interventions in Red Drum as a farmed species in Belize.                                                                                                                                                        |
| Hatchery and grow out of Nile Tilapia                                                                                                                                     | This code describes the process of hatching and growing Nile Tilapia, another widely farmed species, highlighting its significance in Belize's aquaculture sector.                                                                                                                                                                             |
| Hatchery trials with Florida pompano                                                                                                                                      | This code refers to experimental hatchery trials with Florida pompano, assessing its potential as a new species for cultivation.                                                                                                                                                                                                               |
| Seaweed cultivation of Eucheuma sp. and Gracilaria sp.                                                                                                                    | This code refers to the cultivation of specific types of seaweed that are locally found in Belize's waters. These include red seaweed species such as Eucheuma isiforme and Gracilaria crassissima, which are important for their economic and ecological value in mariculture.                                                                |
| Increasing seafood demand                                                                                                                                                 | This code highlights the growing global and local demand for seafood, which drives the need for expanded and sustainable mariculture production.                                                                                                                                                                                               |
| Aquaculture policy impact on cultivated species economic development                                                                                                      | This sub-code captures how policies related to aquaculture influence the economic viability and development of species being farmed, ensuring that policy frameworks support sustainable and profitable aquaculture.                                                                                                                           |
| Mariculture (including IMTA) as a key contributor to Belize's Blue Economy and Food Security                                                                              | This code highlights the role of mariculture, including Integrated Multi-Trophic Aquaculture (IMTA), in supporting Belize's Blue Economy. This type of mariculture is highly promoted and hope that it be a part of Belize's future sustainable ocean economy and ensuring food security by providing a reliable source of nutritious seafood. |
| Need to use ecological objectives as well as economic and political ones to establish catch quotas and carrying capacity                                                  | This code emphasizes the importance of incorporating ecological considerations into the decision-making process for setting catch quotas and determining the carrying capacity of mariculture systems, ensuring long-term sustainability.                                                                                                      |
| Targeted capacity building for mariculture industry growth                                                                                                                | This code focuses on the need for specific training and development programs aimed at building the capacity of individuals and organizations within the mariculture industry, ensuring that they have the skills and knowledge required to support industry growth and innovation.                                                             |
| 8. Economic development, stimulation, investment and support                                                                                                              | This thematic code focuses on strategies and legislative frameworks designed to promote trade, stimulate economic growth, and support businesses, particularly small and medium enterprises (SMEs).                                                                                                                                            |
| Belize Trade and Investment Development Service Act promoting trade and investment, supporting economic development and facilitating the implementation of trade policies | This code refers to a legislative act designed to enhance trade and investment in Belize. It focuses on creating a conducive environment for economic development by supporting trade activities, attracting investment, and ensuring the effective implementation of trade policies.                                                          |
| The Big Push approach for micro, small and                                                                                                                                | This code refers to an economic strategy or initiative aimed at significantly boosting the growth of micro, small, and medium enterprises (MSMEs). The "Big Push" approach typically                                                                                                                                                           |

|                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| medium enterprises (MSME)                                                                                        | involves concentrated efforts, possibly through financial incentives, infrastructure development, or policy support, to accelerate the growth and sustainability of MSMEs, recognizing their crucial role in economic development.                                                                                                                                                                                                                                                                        |
| Environment                                                                                                      | This contains several thematic codes that are essential for understanding the environmental factors influencing mariculture, particularly in the context of sustainable development, conservation, and climate change adaptation. Evaluation of environmental issues such as climate change, sustainability, and environmental regulations that could affect the Belize Seaweed Aquaculture Development including seaweed mariculture sector in fisheries.                                                |
| 1. Alignment of Mariculture Policy with Sustainable Development Goals                                            | This thematic code emphasizes the integration of the SDGs into the development and implementation of mariculture policies. The SDGs are a set of 17 global goals established by the United Nations in 2015, aimed at addressing various global challenges, including poverty, inequality, climate change, environmental degradation, peace, and justice.                                                                                                                                                  |
| Sustainable Development Goals (SDGs) in mariculture policy                                                       | Embedding SDGs into mariculture policy frameworks has been identified as crucial, which involves integrating sustainability indicators, aligning policies with national and international SDG-related policies, and fostering cross-sectoral coordination among agriculture, fisheries, and environmental protection to support sustainable holistic development.                                                                                                                                         |
| 10. National Environmental Monitoring and Evaluation                                                             | This thematic code focuses on systematic observation, assessment, and analysis of environmental conditions and impacts, particularly related to mariculture activities. This monitoring and evaluation are crucial for ensuring that environmental standards are met, identifying areas for improvement, and supporting sustainable practices.                                                                                                                                                            |
| Environmental monitoring and evaluation (i.e. spatial data collection and performance indicators) in mariculture | This sub-code emphasizes the importance of collecting spatial data and using performance indicators to monitor and evaluate the environmental impacts of mariculture. Spatial data collection involves gathering information on the geographic distribution of mariculture activities, environmental conditions, and resource use. Performance indicators are used to measure the success of mariculture practices in terms of sustainability, environmental protection, and compliance with regulations. |
| 11. Protection of Biodiversity and Ecosystem Health                                                              | This thematic code focuses on the preservation and enhancement of biodiversity and the overall health of ecosystems, particularly in the context of marine and coastal environments. This code underscores the importance of maintaining ecological balance and protecting species diversity, which are critical for the sustainability of natural resources and human livelihoods.                                                                                                                       |
| Belize's 2016–2020 National Biodiversity Strategy and Action Plan                                                | This sub-code refers to Belize's strategic framework aimed at conserving and sustainably using its biological resources. The National Biodiversity Strategy and Action Plan (NBSAP) for 2016–2020 outlines the country's priorities and actions to protect biodiversity, recognizing its importance to the environment, economy, and society.                                                                                                                                                             |
| Biodiversity loss and marine ecosystem damage implications                                                       | This sub-code highlights the consequences of biodiversity loss and damage to marine ecosystems. It emphasizes the need to address the factors contributing to the degradation of marine habitats and species, as these losses can have far-reaching implications for ecosystem services, food security, and climate resilience.                                                                                                                                                                           |

|                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                 |
|-------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ecosystem diversity and species conservation                                                                      | This sub-code focuses on the importance of preserving ecosystem diversity and protecting species from extinction. It involves implementing conservation measures to maintain the variety of life forms within ecosystems, which is essential for ecological stability and resilience.                                                                                           |
| Ecosystem protection and financing                                                                                | This sub-code deals with the financial aspects of ecosystem protection, including funding mechanisms and economic strategies to support conservation efforts. It recognizes that adequate financing is crucial for implementing effective conservation projects and sustaining long-term environmental protection.                                                              |
| Maritime Economy Plan of Belize                                                                                   | This sub-sub-code refers to Belize's plan to integrate sustainable maritime practices into its economy. The plan likely includes initiatives to balance economic activities, such as fishing and tourism, with the need to protect marine ecosystems and biodiversity.                                                                                                          |
| Protected Areas System Act 2020 and PACT Act 2020                                                                 | These legislative frameworks are critical for the management and protection of Belize's protected areas. The Protected Areas System Act and the Protected Areas Conservation Trust (PACT) Act provide the legal basis for conserving biodiversity, regulating activities within protected areas, and ensuring sustainable use of natural resources.                             |
| Ensuring biosecurity through stringent inspection and certification processes, vital for environmental protection | This sub-code emphasizes the importance of biosecurity measures in protecting biodiversity. Stringent inspection and certification processes help prevent the introduction and spread of invasive species, pests, and diseases that could threaten native ecosystems and species.                                                                                               |
| Environmental Protection through Mangroves Protection Regulation                                                  | This sub-code highlights the role of mangrove ecosystems in environmental protection. Mangroves are vital for coastal protection, carbon sequestration, and supporting marine biodiversity. Regulations that protect mangroves are essential for preserving these critical ecosystems.                                                                                          |
| Protecting and preserving the environmental goods and services provided by coastal ecosystems                     | This sub-code focuses on the value of the goods and services provided by coastal ecosystems, such as fisheries, tourism, and climate regulation. Protecting these services is essential for sustaining the livelihoods of coastal communities and maintaining ecological balance.                                                                                               |
| Seaweed farming is not captured as a key resource in carbon credits through blue carbon sequestration             | This sub-code addresses the potential of seaweed farming to contribute to carbon sequestration, which is not yet fully recognized in carbon credit markets. Seaweed farming has significant potential to sequester carbon dioxide and should be integrated into blue carbon initiatives to enhance its role in climate change mitigation.                                       |
| 12. Species Conservation and Habitat Protection Efforts                                                           | The thematic code focuses on initiatives and strategies aimed at conserving species and protecting their habitats, particularly in marine and coastal environments. This code highlights the importance of preserving biodiversity and maintaining the health of ecosystems that support various species, including those critical for mariculture and other marine activities. |
| Does not identify the target cover of protected mangroves, especially near seaweed farms                          | The sub-code highlights a gap in mangrove conservation efforts, especially near seaweed farms, due to the lack of defined targets and objectives. Mangroves are vital for ecosystem balance, marine species nursery, and coastal protection.                                                                                                                                    |
| 13. Sustainable Practices and Resource Efficiency Considerations in Mariculture                                   | This thematic code emphasizes the importance of implementing sustainable and resource-efficient practices in mariculture to minimize environmental impacts and maximize benefits for both the environment and society. This code includes various strategies and approaches that aim to make                                                                                    |

|                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                      |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                     | mariculture more sustainable by focusing on best practices, environmental adaptation, and the promotion of eco-friendly products.                                                                                                                                                                                    |
| Climate adaptation as an environmental benefit of sustainable mariculture                                                                           | This sub-code highlights the role of mariculture in adapting to climate change, presenting it as an environmental benefit. It focuses on how sustainable mariculture practices can contribute to resilience against climate impacts.                                                                                 |
| Aquaculture adaptation measures in Belize NAP to climate change in agriculture                                                                      | This sub-sub-code refers to specific adaptation measures outlined in Belize's National Adaptation Plan (NAP) that address climate change challenges in agriculture, including mariculture. It emphasizes the integration of these measures into mariculture practices.                                               |
| Cultivation Manual for Seaweed Mariculture Best Management Practices                                                                                | This sub-code focuses on the development and use of cultivation manuals that provide best management practices for seaweed mariculture. These manuals are essential for guiding sustainable farming techniques that minimize environmental impacts and enhance productivity.                                         |
| Cultivation of Eucheuma isiforme and Gracilaria sp. in Seaweed Farming                                                                              | This sub-code highlights the cultivation of specific seaweed species, Eucheuma isiforme and Gracilaria sp., which are commonly farmed for their commercial value. The focus is on sustainable farming practices that ensure these species are cultivated in an environmentally friendly manner.                      |
| Encourage the use of trade-marks that signify compliance with environmental standards and promote blue product such as seaweed value-added products | This sub-code advocates the use of trade-marks and certifications that indicate compliance with environmental standards. Promoting products that meet these standards, particularly value-added seaweed products, helps consumers identify and support sustainable mariculture practices.                            |
| Encouragement of bio-based products for environmentally friendly practices                                                                          | This sub-code emphasizes the promotion of bio-based products, which are derived from renewable biological resources. These products are considered more environmentally friendly compared to traditional products made from fossil fuels or other non-renewable resources.                                           |
| Environmental Benefits of Inclusive Mariculture Practices                                                                                           | This sub-code focuses on the environmental benefits of adopting inclusive mariculture practices, which consider the needs of diverse stakeholders, including small-scale farmers and local communities. Inclusive practices help ensure that mariculture is both environmentally sustainable and socially equitable. |
| Low environmental impact as environmental benefits of sustainable mariculture offers l                                                              | This sub-code highlights the low environmental impact associated with sustainable mariculture practices. It emphasizes that adopting sustainable practices can reduce the negative impacts of mariculture on ecosystems and biodiversity.                                                                            |
| Natural resources definition                                                                                                                        | This sub-code addresses the importance of clearly defining "natural resources" within the context of mariculture and environmental management. A clear definition is crucial for the effective management and conservation of these resources.                                                                       |
| Need to establish a comprehensive sustainability framework for mariculture that addresses environmental and societal impacts                        | This sub-code advocates for the development of a comprehensive sustainability framework specifically for mariculture. Such a framework would address both environmental and societal impacts, ensuring that mariculture practices contribute positively to sustainable development.                                  |

|                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                  |
|------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Provision of ecosystem services as an ecological benefit of sustainable mariculture                                                | This sub-code emphasizes the role of mariculture in providing ecosystem services, such as carbon sequestration, habitat creation, and water purification. Recognizing these services as ecological benefits underscores the value of sustainable mariculture practices.                                                                                                          |
| Seaweed resources may be included in exploring markets for blue carbons but do not specify                                         | This sub-code suggests that seaweed resources could play a role in emerging markets for blue carbon credits, which are credits earned by protecting or restoring marine and coastal ecosystems that capture and store carbon. However, it notes that specifics are not yet fully defined.                                                                                        |
| Seaweed species used for cultivation                                                                                               | This sub-code highlights the different seaweed species that are cultivated in mariculture. Understanding the species used is important for developing species-specific best practices that ensure sustainability.                                                                                                                                                                |
| Small open economy with high debt levels                                                                                           | This sub-code considers the economic context of Belize, noting that its small, open economy with high debt levels presents unique challenges and opportunities for sustainable mariculture. It emphasizes the need for mariculture practices that are economically viable and contribute to national economic resilience.                                                        |
| Special consideration for seaweed mariculture initiative as it's a less harmful type of mariculture                                | This sub-code recognizes that seaweed mariculture is generally considered less harmful to the environment compared to other types of mariculture, such as fish farming. It advocates special consideration and support for seaweed farming initiatives due to their lower environmental impact.                                                                                  |
| Sustainable mariculture practices and environmental protection supporting community livelihoods (including IMTA and best practice) | This sub-code emphasizes the importance of sustainable mariculture practices that not only protect the environment but also support community livelihoods. It includes Integrated Multi-Trophic Aquaculture (IMTA) as an example of a best practice that integrates different species in a way that mimics natural ecosystems, enhancing sustainability.                         |
| 2. Conservation and World Heritage Initiatives                                                                                     | This thematic code focuses on efforts to protect and preserve natural and cultural heritage sites, particularly those designated as World Heritage Sites, as well as broader conservation initiatives aimed at safeguarding marine biodiversity and ecosystems.                                                                                                                  |
| Conservation and World Heritage Site status                                                                                        | This sub-code highlights the importance of maintaining and enhancing the status of sites recognized as World Heritage Sites by UNESCO. These sites are of outstanding universal value, and their conservation is crucial for preserving global natural and cultural heritage.                                                                                                    |
| Establishment of a National Protected Areas Advisory Council                                                                       | This sub-code refers to the creation of a National Protected Areas Advisory Council, which would play a key role in advising on the management and conservation of protected areas, including those with World Heritage status.                                                                                                                                                  |
| Marine biodiversity and protected areas                                                                                            | This sub-code focuses on the conservation of marine biodiversity through the establishment and management of protected areas. These areas are critical for preserving marine ecosystems, species, and habitats that are essential for the health of the ocean and the sustainability of mariculture activities.                                                                  |
| 3. Ecosystem-based Management and Conservation                                                                                     | This thematic code focuses on applying an ecosystem-based approach to the management and conservation of natural resources, particularly in the context of mariculture and environmental protection. This approach emphasizes the interconnectedness of ecosystems and the need to manage natural resources in a way that maintains ecosystem health, integrity, and resilience. |

|                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                       |
|----------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Biological corridors                                                                                                                         | Biological corridors are vital for maintaining biodiversity by connecting fragmented habitats. This sub-code emphasizes the importance of establishing and managing biological corridors to allow species migration, genetic exchange, and ecosystem connectivity, which are crucial for the long-term sustainability of both terrestrial and marine ecosystems.                                      |
| Criteria for re-classification of protected areas as part of adaptive management measures                                                    | This code emphasizes the importance of adaptive management in the re-classification of protected areas. By considering socio-economic aspects, environmental conditions, and potential impacts, Belize can ensure that its protected areas are managed effectively to support sustainable development and resilience within the Blue Economy, including seaweed farming and other related activities. |
| Assessment of potential impacts or impacts of concern that may affect the protected area                                                     | This involves evaluating the potential environmental impacts or threats that could necessitate the re-classification of a protected area, ensuring that protective measures are updated and effective.                                                                                                                                                                                                |
| Environmental conditions of ecosystems and species of concern                                                                                | Monitoring and assessing the health and conditions of ecosystems and species within protected areas to determine whether existing classifications remain appropriate or need adjustment.                                                                                                                                                                                                              |
| Socio-economic impacts on local communities and stakeholders                                                                                 | Considering the socio-economic implications of protected area management, including how changes in classification might affect local communities and stakeholders, ensuring that conservation efforts are balanced with human needs and livelihoods.                                                                                                                                                  |
| Definition of ecosystem                                                                                                                      | This sub-code involves clearly defining what constitutes an ecosystem within the context of mariculture and environmental management. It includes understanding the complex interactions between living organisms (plants, animals, and microorganisms) and their physical environment, which are fundamental to implementing ecosystem-based management.                                             |
| Environmental protection through fisheries management (ecosystem integrity, habitat management, stock replenishment, and climate adaptation) | This sub-code focuses on integrating ecosystem considerations into fisheries management to maintain ecosystem integrity. It emphasizes ensuring fisheries practices do not harm ecosystem health, protecting crucial habitats, and implementing measures to sustain fish stocks at sustainable levels, ensuring long-term ecological balance.                                                         |
| Habitat creation and nursery benefits of sustainable seaweed farming                                                                         | This sub-code highlights the role of sustainable seaweed farming in creating habitats and providing nursery grounds for various marine species. It emphasizes the ecological benefits of seaweed farms, which can enhance biodiversity and support the life cycles of many marine organisms.                                                                                                          |
| Land Use Management including reserving land for conservation purposes including seaweed farms                                               | This sub-code addresses the need for strategic land use management that includes setting aside areas for conservation, including those designated for seaweed farming. It involves balancing land use between conservation needs and sustainable mariculture development.                                                                                                                             |
| Types of carbon sources                                                                                                                      | This sub-code addresses the understanding and management of carbon sources within ecosystems, including black carbon from fossil fuels, blue carbon sequestered by marine vegetation, and green carbon present in land biomass and soil, alongside greenhouse gas emissions from these sources, including organic waste decay.                                                                        |

|                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Use of ecosystem approach in aquatic resource management                                                                            | This sub-code emphasizes the adoption of an ecosystem approach in managing aquatic resources, ensuring that all aspects of the ecosystem are considered in decision-making. This approach seeks to maintain ecological balance while supporting sustainable resource use, including in mariculture practices. "Ecological balance" means the various conditions required for the survival and development of persons and other living organisms.                                                       |
| Use of MPA's for seaweed farming initiatives                                                                                        | This sub-code highlights the role of Marine Protected Areas (MPAs) in promoting sustainable seaweed farming, which supports conservation and economic goals. Recent initiatives at Gladden Spit, Silk Caye, and Turneffe Atoll Marine Reserves illustrate this. The Integrated Coastal Zone Management Plan 2016 offers a baseline for mariculture development using Marine Spatial Planning (MSP).                                                                                                    |
| Various categories of protected areas                                                                                               | This sub-code emphasizes the importance of recognizing and managing various categories of protected areas, each with distinct conservation objectives and protection levels. Understanding these classifications is essential for effective conservation strategies and ensuring mariculture practices align with conservation goals. Protected areas, including private lands, are managed to achieve specific conservation outcomes, with legal and fiscal incentives supporting their preservation. |
| 4. Environmental Pollution and Waste Management                                                                                     | This thematic code addresses the issues related to pollution and the management of waste in environmental contexts, particularly focusing on practices that protect natural ecosystems, including marine environments, from degradation. This code includes several sub-codes that highlight different aspects of pollution control, public participation, regulatory measures, and waste management strategies.                                                                                       |
| Effluent discharge negative impact on mangroves and seaweed resources but not being monitored (no penalties issued for destruction) | This sub-code highlights the harmful impact of effluent discharge from aquaculture facilities on sensitive ecosystems like mangroves and seaweed. It emphasizes the lack of monitoring, enforcement, and penalties for such pollution, revealing significant gaps in environmental protection efforts. Effluent includes aquatic, liquid, and chemical wastes from facility operations.                                                                                                                |
| Encourages public participation in environmental protection by incentivizing reporting                                              | This sub-code emphasizes the role of public participation in environmental protection by incentivizing the reporting of violations, such as illegal dumping or pollution. It details the investigation process, potential legal actions, and rewards for informants. Penalties include fines and imprisonment for offenses like causing environmental damage, misleading reports, or obstructing enforcement.                                                                                          |
| Environmental pollution definition                                                                                                  | This sub-code focuses on establishing a clear definition of environmental pollution within regulations, crucial for setting legal standards and consistent enforcement. "Environmental pollution" refers to the presence of harmful pollutants, solid, liquid, or gaseous, that endanger human health, environmental integrity, or disrupt ecological balance. The definition includes pollutants like noise, vibrations, and chemical changes.                                                        |
| Environmental Protection (Pollution from Plastics and Permit Application Updates) (Amendment) Regulations 2022                      | This sub-code refers to specific regulatory updates aimed at reducing pollution from plastics. It highlights the importance of updating permit applications and other regulatory frameworks to address new environmental challenges, particularly those related to plastic waste.                                                                                                                                                                                                                      |

|                                                                                                          |                                                                                                                                                                                                                                                                                                                                      |
|----------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Environmental protection through regulatory measures                                                     | This sub-code addresses the role of regulations in protecting the environment. It involves implementing and enforcing legal measures to control pollution, manage waste, and ensure that industrial and commercial activities do not harm natural ecosystems.                                                                        |
| Environmental Protection through Seabed Leasing and Compliance                                           | This sub-code focuses on the environmental implications of leasing seabed areas for various uses, including mariculture. It emphasizes the need for strict compliance with environmental regulations to prevent degradation of marine habitats and ensure sustainable use of seabed resources.                                       |
| Food Safety and Water Quality Standards                                                                  | This sub-code highlights the importance of maintaining food safety and water quality standards, particularly in the context of mariculture and other aquatic resource management activities. Ensuring that these standards are met is essential for protecting public health and the environment.                                    |
| BAHA Food Processing Plan and Portable Water) minimum standards regulation                               | A sub-point under food safety, this refers to specific regulations set by the Belize Agricultural Health Authority (BAHA) regarding food processing and water quality standards, ensuring that mariculture products are safe for consumption.                                                                                        |
| Plant Pest and Animal Disease Prevention Regulations                                                     | This sub-code deals with regulations aimed at preventing the spread of plant pests and animal diseases, which can have significant impacts on agriculture, mariculture, and the broader environment. Effective prevention measures are crucial for protecting biodiversity and maintaining ecosystem health.                         |
| Prohibition of depositing garbage or hazardous waste in the sea that damages flora and fauna             | This sub-code focuses on the prohibition of dumping garbage or hazardous waste into the sea, which can cause severe harm to marine life and ecosystems. It underscores the need for strict enforcement of anti-dumping laws to protect ocean health.                                                                                 |
| Proper solid waste management for reduction of environmental pollution                                   | This sub-code emphasizes the importance of effective solid waste management practices to reduce environmental pollution. Proper waste management is critical for minimizing the impact of human activities on land and marine environments.                                                                                          |
| Restriction on importation of plastics and promotion of biodegradable packaging for value-added products | This sub-code addresses the need to restrict the importation of plastic materials and promote the use of biodegradable packaging, particularly for value-added products. This is an important step in reducing plastic pollution and supporting sustainable production practices.                                                    |
| Strict regulations on hazardous materials and environmental protection in the sea                        | This sub-code highlights the necessity of strict regulations governing the use and disposal of hazardous materials, especially in marine environments. These regulations are crucial for preventing contamination and protecting marine ecosystems from harmful substances.                                                          |
| 5. Environmental Risks in Mariculture                                                                    | The thematic code focuses on the various environmental challenges and risks associated with mariculture, particularly unsustainable practices. This code encompasses a range of specific risks that could negatively impact marine ecosystems, biodiversity, and the long-term sustainability of mariculture operations.             |
| Climate Change Impacts on Pests                                                                          | This sub-code addresses the potential impact of climate change on pest populations within mariculture environments. Changes in temperature, salinity, and other environmental conditions can lead to shifts in pest behavior, potentially increasing the vulnerability of mariculture operations to infestations and related losses. |



|                                                                                                        |                                                                                                                                                                                                                                                                                                           |
|--------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Economic vulnerability is primarily driven by its high dependence on marine natural resources          | This sub-code highlights the economic risks associated with heavy reliance on marine natural resources for mariculture. Overdependence can lead to economic instability if those resources become depleted or if environmental conditions change, affecting the availability and health of the resources. |
| Environmental damage definition                                                                        | This sub-code focuses on defining what constitutes environmental damage in the context of mariculture. A clear definition is essential for establishing regulatory frameworks, assessing the impacts of mariculture activities, and implementing appropriate mitigation measures.                         |
| Environmental Risks of Unsustainable Mariculture                                                       | This sub-code examines the specific environmental risks associated with unsustainable mariculture practices, including:                                                                                                                                                                                   |
| Risks in the displacement of bird populations by scary devices to discourage predation of farmed fish  | The use of scary devices to prevent predation on farmed fish can inadvertently displace bird populations, disrupting local ecosystems.                                                                                                                                                                    |
| Risks in the release of antifouling chemicals and antibiotics                                          | The use of chemicals and antibiotics in mariculture can lead to pollution of surrounding waters, impacting non-target species and contributing to the development of resistant pathogens.                                                                                                                 |
| Risks of dependency on commercial catches of wild stock to replenish mariculture                       | Relying on wild fish stocks to sustain mariculture operations can deplete those stocks, leading to broader ecological and economic consequences.                                                                                                                                                          |
| Risks of escapees from farms and impact on wild stocks                                                 | Farmed species escaping into the wild can disrupt local ecosystems, outcompete native species, and lead to genetic dilution of wild populations.                                                                                                                                                          |
| Risks of eutrophication from mariculture effluents                                                     | The discharge of nutrient-rich effluents from mariculture operations can lead to eutrophication, causing harmful algal blooms and oxygen depletion in surrounding waters.                                                                                                                                 |
| Risks of invasive or exotic species unsustainable practices                                            | The introduction of non-native species through mariculture can lead to the establishment of invasive species, which may outcompete native species and disrupt local ecosystems.                                                                                                                           |
| Risks of the transfer of parasites and diseases and genetic interaction between escaped farmed species | Farmed species may carry parasites and diseases that could spread to wild populations, while genetic interactions between escaped farmed species and wild populations could compromise the genetic integrity of the latter.                                                                               |
| Hazardous substance definition                                                                         | This sub-code focuses on defining hazardous substances within the context of mariculture. Clear definitions are critical for regulating the use of chemicals and other potentially harmful substances in mariculture operations to protect the environment and human health.                              |
| Historical seaweed cultivation and                                                                     | This sub-code examines the history of seaweed cultivation in the Caribbean and the factors that have led to its depletion. Understanding these historical trends is important for                                                                                                                         |

|                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                |
|-------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| depletion in the Caribbean                                                                                                                | developing sustainable practices and preventing further degradation of seaweed resources.                                                                                                                                                                                                                                      |
| Impact of over-exploitation on fisheries                                                                                                  | This sub-code addresses the negative impacts of over-exploitation of marine resources on fisheries. Overfishing can lead to the collapse of fish populations, disrupting food webs and the livelihoods of communities dependent on fishing.                                                                                    |
| Limited access to fishing gears with no measures in place to remove destructive fishing gears such as gill nets used as physical barriers | This sub-code highlights the problem of limited access to sustainable fishing gears and the continued use of destructive gears, such as gill nets. These practices can cause significant damage to marine ecosystems and non-target species.                                                                                   |
| Potential for ecosystem degradation                                                                                                       | This sub-code underscores the potential for mariculture activities to contribute to the degradation of marine ecosystems if not managed sustainably. This includes habitat destruction, pollution, and loss of biodiversity.                                                                                                   |
| Resource degradation                                                                                                                      | This sub-code refers to the depletion and degradation of natural resources due to unsustainable mariculture practices. It emphasizes the need for resource management strategies that protect and conserve marine resources for future generations.                                                                            |
| Resource efficiency and long-term economic viability                                                                                      | This sub-code focuses on the importance of improving resource efficiency in mariculture to ensure long-term economic viability. Efficient use of resources reduces waste, minimizes environmental impact, and supports the sustainability of mariculture operations.                                                           |
| Use of precautionary approach in fisheries management                                                                                     | This sub-code advocates for the application of a precautionary approach in fisheries management, particularly in the context of mariculture. This approach involves taking proactive measures to prevent environmental harm even in the absence of complete scientific certainty.                                              |
| 6. Integrated Ecosystem Management and Planning                                                                                           | The thematic code focuses on the holistic approach to managing ecosystems, particularly in relation to mariculture and broader environmental protection efforts. It emphasizes the integration of various management strategies, planning processes, and principles to ensure sustainable use of marine and coastal resources. |
| Biomass Definition and Implications                                                                                                       | This sub-code deals with the definition of biomass within the context of ecosystem management and its implications for sustainable resource use. Understanding what constitutes biomass is crucial for planning and managing natural resources, particularly in mariculture where biomass production is a key component.       |
| Definition of environment                                                                                                                 | This sub-code emphasizes the importance of clearly defining "environment" in policies and regulations. A comprehensive definition ensures that all elements of the natural world, including air, water, soil, and living organisms, are considered in management and planning processes.                                       |
| Ecosystem approach and adaptive management to administer sustainable management systems                                                   | This sub-code focuses on the application of the ecosystem approach and adaptive management in administering sustainable management systems. It highlights the need for flexible and responsive management strategies that can adjust to changing environmental conditions and new information.                                 |
| Ecosystem-based management principles incorporated into the MSP and mariculture development process                                       | This sub-code involves incorporating ecosystem-based management (EBM) principles into Marine Spatial Planning (MSP) and the mariculture development process. EBM considers the entire ecosystem, including human activities, ensuring that mariculture practices are sustainable and do not harm the environment.              |

|                                                                                                                 |                                                                                                                                                                                                                                                                                                                            |
|-----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ecosystems Approach and the Precautionary Principle governing all marine resource management interventions      | This sub-code highlights the importance of applying both the ecosystem approach and the precautionary principle in all marine resource management interventions. The precautionary principle advocates caution in decision-making, especially when scientific knowledge is incomplete, to prevent environmental harm.      |
| Environmental impact assessment in policy review of the mariculture sector                                      | This sub-code emphasizes the necessity of conducting Environmental Impact Assessments (EIA) during the policy review of the mariculture sector. EIAs help identify potential environmental impacts of mariculture activities, allowing for the development of strategies to mitigate negative impacts.                     |
| Financing mechanisms for integration of climate change measures for environmental protection and planning       | This sub-code addresses the need for financing mechanisms that support the integration of climate change adaptation and mitigation measures into environmental protection and planning efforts. Adequate funding is essential for implementing sustainable practices in mariculture and other sectors.                     |
| Implementation of precautionary plans in special areas                                                          | This sub-code focuses on the implementation of precautionary plans in special areas that are particularly sensitive or vulnerable to environmental impacts. It involves taking proactive measures to protect these areas from potential harm due to human activities or natural events.                                    |
| Integrated management approaches to encourage sustainable tourism practices that reduce environmental pressures | This sub-code emphasizes the use of integrated management approaches to promote sustainable tourism practices that minimize environmental pressures. It highlights the need to balance tourism development with environmental conservation, ensuring that tourism activities do not degrade marine and coastal ecosystems. |
| Management of Natural Resources and Environmental Issues                                                        | This sub-code covers the broader management of natural resources and environmental issues, ensuring that they are addressed in a coordinated and sustainable manner. Effective management is key to preserving ecosystem services and maintaining biodiversity.                                                            |
| Multifaceted approach of the priority areas in Sustainable Fisheries Management including mariculture           | This sub-code advocates for a multifaceted approach to managing priority areas in sustainable fisheries management, including mariculture. It suggests that various strategies and tools should be employed to address the complex challenges associated with sustainable resource use.                                    |
| NDCs actions may include seaweed ecosystems in zoning scheme but does not specify                               | This sub-code notes that Nationally Determined Contributions (NDCs) under the Paris Agreement may include seaweed ecosystems in zoning schemes, although specific details are not provided. Incorporating seaweed ecosystems into NDCs can enhance their role in climate change mitigation and adaptation.                 |
| Need to establish sustainable and climate-ready management in fisheries sector including seaweed farming        | This sub-code notes that Nationally Determined Contributions (NDCs) under the Paris Agreement may include seaweed ecosystems in zoning schemes, although specific details are not provided. Incorporating seaweed ecosystems into NDCs can enhance their role in climate change mitigation and adaptation.                 |
| Scenario-based zoning scheme using MSP approach for mariculture                                                 | This sub-code involves the use of scenario-based zoning schemes within the framework of Marine Spatial Planning (MSP) to guide mariculture development. Scenario-based planning allows for the consideration of various future possibilities, helping to optimize the location and intensity of mariculture activities.    |

|                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|--------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Special consideration for ecosystem-based adaptation (EbA) measures                                                | This sub-code highlights the importance of incorporating Ecosystem-based Adaptation (EbA) measures into management and planning processes. EbA uses biodiversity and ecosystem services to help communities adapt to the adverse impacts of climate change, making it a critical component of sustainable development.                                                                                                                                                |
| 7. National and International Climate Commitments                                                                  | This thematic code focuses on the obligations and strategies adopted by nations, including Belize, to address climate change both domestically and in line with international agreements. It emphasizes the importance of reducing emissions, adapting to climate impacts, and supporting sustainable practices.                                                                                                                                                      |
| Belize commitment to reducing emission and adaptation strategies while providing support for sustainable practices | This sub-code highlights Belize's commitment to mitigating climate change by reducing greenhouse gas emissions and implementing adaptation strategies. It underscores the importance of integrating sustainable practices into these efforts to ensure long-term environmental and economic benefits.                                                                                                                                                                 |
| UN Climate Change Convention                                                                                       | This refers to Belize's adherence to the United Nations Framework Convention on Climate Change (UNFCCC), which sets the framework for global efforts to combat climate change. It includes commitments under the Paris Agreement and other international climate accords.                                                                                                                                                                                             |
| Climate change projections                                                                                         | This sub-code involves the use of climate change projections to inform national and international climate commitments. Understanding potential future climate scenarios helps countries like Belize develop effective mitigation and adaptation strategies, ensuring they are prepared for anticipated changes in climate patterns.                                                                                                                                   |
| Definition of Adaptation to Climate Change                                                                         | This sub-code focuses on the definition and understanding of "adaptation to climate change." Adaptation involves adjusting systems, practices, and policies to minimize the negative impacts of climate change while taking advantage of any potential opportunities. This definition of "adaptation" provides a clear understanding of the concept within the context of climate change and its implications for sustainable development, including seaweed farming. |
| 8. National Climate Change Adaptation Projects                                                                     | The thematic code focuses on the specific initiatives, strategies, and frameworks implemented at the national level to address and adapt to the impacts of climate change. These projects are critical for building resilience, reducing vulnerabilities, and ensuring sustainable development in the face of climate change.                                                                                                                                         |
| Belize Marine Climate Change and Adaptation Project (MCCAP)                                                        | This sub-code refers to the Belize Marine Climate Change and Adaptation Project (MCCAP), which is a key initiative aimed at enhancing the resilience of Belize's marine ecosystems and coastal communities to climate change. The project focuses on protecting marine biodiversity, improving the adaptive capacity of local communities, and promoting sustainable resource management practices.                                                                   |
| Climate Change Vulnerabilities and Government Response                                                             | This sub-code addresses the identification of climate change vulnerabilities in Belize and the corresponding government response strategies. It highlights the importance of understanding the specific risks posed by climate change in various sectors and regions and the need for targeted governmental interventions.                                                                                                                                            |
| National Climate Change Policy, Strategy, and Action Plan                                                          | This sub-code covers the strategic framework for climate change adaptation and mitigation from 2021 to 2025. It sets out more comprehensive and long-term goals for integrating climate resilience into national development planning.                                                                                                                                                                                                                                |

|                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (NCCPSAP)<br>2015-2020                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| National Climate Resilience Investment Plan                   | This sub-code involves the financial and investment strategies necessary to support Belize's climate resilience goals. It focuses on securing funding for projects that enhance infrastructure, protect ecosystems, and support vulnerable communities in adapting to climate change.                                                                                                                                                                                                                                             |
| Nationally Determined Contributions (NDC) revision            | This sub-code refers to the periodic revision of Belize's Nationally Determined Contributions (NDCs) under the Paris Agreement. The NDCs represent Belize's commitment to reducing greenhouse gas emissions and adapting to climate change impacts, with updates reflecting the country's evolving climate priorities.                                                                                                                                                                                                            |
| Policy framework for climate change adaptation in mariculture | This sub-code emphasizes the need for a specific policy framework to guide climate change adaptation within the mariculture sector. Such a framework would provide the necessary guidelines and regulations to ensure that mariculture practices are resilient to climate impacts, thereby protecting both the industry and the ecosystems it relies on.                                                                                                                                                                          |
| Reduce local climate vulnerability and economic impact        | This sub-code focuses on strategies and projects aimed at reducing the local vulnerabilities to climate change, particularly in terms of economic impact. It highlights the importance of targeted interventions to protect livelihoods, infrastructure, and economic stability in communities that are most at risk from climate change impacts.                                                                                                                                                                                 |
| 9. National Disaster Preparedness and Response                | This thematic code focuses on the strategies and measures that Belize implements to prepare for and respond to natural disasters. It emphasizes the importance of proactive planning and resilience-building to mitigate the impacts of disasters, particularly in the context of Belize's geographic and environmental vulnerabilities.                                                                                                                                                                                          |
| Caribbean Vulnerability to hazards                            | This sub-code addresses the broader context of the Caribbean region's vulnerability to various natural hazards, such as hurricanes, earthquakes, and floods. The Caribbean's geographic location makes it particularly susceptible to these events, which can have devastating impacts on infrastructure, economies, and communities. This sub-code emphasizes the need for regional cooperation, knowledge sharing, and the development of comprehensive disaster risk reduction strategies to enhance resilience.               |
| Climate and Natural Disaster Risks in Belize's Mariculture    | This sub-code specifically focuses on the risks posed by climate change and natural disasters to Belize's mariculture industry. Mariculture, or the cultivation of marine organisms in their natural habitats, is highly vulnerable to extreme weather events such as hurricanes, storm surges, and rising sea levels. This sub-code highlights the importance of incorporating disaster risk management into mariculture practices, including the development of resilient infrastructure, the use of early warning systems, etc |
| Legal                                                         | Legal factors govern environmental, economic, and social activities, ensuring effective law enforcement, resource protection, public health promotion, and sustainable development. Understanding the legal environment including laws, regulations, and legal risks that could impact Belize Seaweed Aquaculture Development. Compliance with national and international laws promotes environmental sustainability and social equity.                                                                                           |
| 1. Community and Social Regulations                           | This thematic code encompasses laws, policies, and practices that influence social structures, community well-being, and cultural rights, particularly in relation to environmental                                                                                                                                                                                                                                                                                                                                               |

|                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|---------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                         | management and conservation. This code is essential for ensuring that community interests are protected and that social equity is upheld within broader environmental and economic frameworks.                                                                                                                                                                                                                                                                                                          |
| Human right approach with protection for fundamental rights to indigenous people in marine conservation | The sub-code emphasizes the significance of a human rights-based approach in marine conservation, focusing on indigenous peoples' rights, cultural heritage, land rights, and traditional knowledge, empowering them in decision-making processes.                                                                                                                                                                                                                                                      |
| Tourism-related tours promoted by Belize Tourism Board Act                                              | The Belize Tourism Board Act, Cap. 275 (Revised 2020) provides for the establishment of the Belize Tourism Board (BTB), with the primary function to develop all aspects of the tourist industry of Belize including sustainable development practices and eco-tours. Establishment of the BTB is to develop and promote the efficiency of the tourism industry. BTB aims to balance the promotion of tourism with the need to protect natural resources, cultural heritage, and community livelihoods. |
| 11. National Disaster Preparedness and Response                                                         | The thematic code focuses on the legal and policy frameworks that guide a nation's efforts to prepare for, respond to, and mitigate the impacts of natural and human-made disasters. This code is crucial for ensuring that there are clear, actionable strategies in place to protect lives, property, and infrastructure during emergencies.                                                                                                                                                          |
| Legal framework that governs disaster preparedness and response                                         | This sub-code encompasses the overarching legal structures that dictate how disaster preparedness and response activities are managed at the national level. These frameworks establish the responsibilities of various government agencies, outline the procedures for emergency management, and set the standards for coordination and communication during disasters.                                                                                                                                |
| Disaster Preparedness and Response Act                                                                  | This sub-sub-code refers to a specific piece of legislation that formalizes the processes and structures for disaster preparedness and response. The act typically includes provisions for creating disaster management plans, establishing emergency response agencies, and defining the roles of national and local governments in disaster situations.                                                                                                                                               |
| National Hazard Mitigation Policy                                                                       | This sub-sub-code focuses on policies aimed at reducing the risk and impact of natural hazards, such as hurricanes, floods, and earthquakes. The policy likely includes strategies for risk assessment, land-use planning, infrastructure resilience, and public education. The goal of hazard mitigation is to minimize the long-term risks associated with natural disasters by implementing preventative measures and promoting sustainable development practices.                                   |
| 12. Property and Resource Management Laws                                                               | This thematic code pertains to the legal frameworks that regulate the ownership, use, and management of land and natural resources. This code is crucial for ensuring that land and resources are used sustainably and in accordance with the law, particularly in contexts like mariculture, where access to coastal and seabed areas is essential.                                                                                                                                                    |
| Form of Application for a Grant of National Land including seabed leasing application                   | This sub-code refers to the legal procedures and forms required to apply for the use of national land, including the leasing of seabed areas for activities such as mariculture. It outlines the process by which individuals or companies can legally obtain rights to use or develop national land and seabed areas.                                                                                                                                                                                  |
| National lands laws including seabed access for mariculture                                             | This sub-code covers the specific laws that govern the use of national lands, including seabed areas, particularly for mariculture purposes. It includes legal provisions that regulate                                                                                                                                                                                                                                                                                                                 |

|                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                | how access to these areas is granted, ensuring that such activities are conducted within the legal framework.                                                                                                                                                                                                                                                                                                                                                                                                    |
| National Lands Act                                                                                                                             | This sub-sub-code refers to the primary legislation governing the use and management of national lands in Belize. The act provides the legal basis for the allocation, leasing, and use of national lands, including the seabed, and outlines the rights and responsibilities of landholders.                                                                                                                                                                                                                    |
| National Lands Act 2003 (Revised Edition 2011)                                                                                                 | This sub-sub-code represents the updated version of the National Lands Act, reflecting revisions and amendments made to the original act. It includes the most current legal guidelines and regulations for the management of national lands. This Act highlights the definition of "national lands" to include the seabed. This has direct implications for mariculture activities seeking access and use of the seabed, emphasizing the regulatory requirements and permissions necessary for such activities. |
| Provision provides clear legal guidelines and penalties for unauthorized occupation, reducing ambiguity and ensuring compliance with land laws | This sub-code emphasizes the importance of clear legal guidelines and penalties for the unauthorized occupation of land. It aims to reduce ambiguity in land use regulations and ensure strict compliance with the law, thereby preventing illegal occupation and ensuring orderly land management.                                                                                                                                                                                                              |
| Requirement to obtain a license and conditions from the Fisheries Administrator (including mariculture)                                        | This sub-code specifies the legal requirement for obtaining a license from the Fisheries Administrator to engage in activities such as mariculture. It outlines the conditions under which such licenses are granted, ensuring that mariculture operations are regulated and conducted sustainably.                                                                                                                                                                                                              |
| The provisions on company under alien control and the prohibition against aliens holding national land including seabed leasing                | This sub-code addresses the legal restrictions placed on foreign entities (companies under alien control) in relation to holding national land or leasing seabed areas. It includes provisions that prohibit or limit the ownership and control of national land by non-citizens, ensuring that such resources remain under the control of Belizean nationals.                                                                                                                                                   |
| 13. Regulatory Framework and Compliance                                                                                                        | This thematic code refers to the legal structures, procedures, and compliance mechanisms that govern the development and operations of mariculture, ensuring that the industry aligns with environmental, economic, and social objectives. These frameworks help in setting standards, licensing requirements, and compliance measures to facilitate sustainable mariculture practices.                                                                                                                          |
| Addressing Regulatory Uncertainty in Mariculture Development                                                                                   | This sub-code focuses on the need to address the lack of clear and consistent regulations governing mariculture development. Regulatory uncertainty can hinder investments and growth in the sector, and addressing this issue involves creating well-defined rules and procedures to streamline mariculture activities.                                                                                                                                                                                         |
| Cumbersome nature of the current administrative process required to start a mariculture venture                                                | This sub-code highlights the challenges associated with the complex administrative procedures that individuals and businesses face when starting mariculture ventures. It emphasizes the need to simplify the process, reducing bureaucratic hurdles to encourage more participation in the sector.                                                                                                                                                                                                              |
| Current lack of legal provisions for mariculture-specific                                                                                      | This sub-code points out the absence of specific legal frameworks that regulate mariculture in Belize. This gap highlights the need to develop laws that address the unique                                                                                                                                                                                                                                                                                                                                      |

|                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|--------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| regulation in Belize (gap)                                                                       | needs and challenges of mariculture, such as seabed leasing, licensing, and environmental impact assessments.                                                                                                                                                                                                                                                                                                                                                   |
| Legal framework for the issuance of aquaculture licenses and the regulation of export businesses | This sub-code covers the legal provisions related to the issuance of licenses for aquaculture businesses, including mariculture, and the regulation of export businesses. It ensures that companies engaged in mariculture meet specific regulatory standards to operate both domestically and internationally.                                                                                                                                                 |
| Regulatory and licensing issues in mariculture                                                   | This code captures the legal aspects addressed in the survey, such as siting of mariculture operations, access to the seabed, licensing, quality control, and certification. These regulatory factors are critical for the proper governance and legal compliance of mariculture activities. This sub-code reveals the various regulatory and licensing issues related to mariculture, ensuring that all operators comply with national and international laws. |
| Aquaculture licenses and regulatory regime for export business                                   | This sub-sub-code refers to the regulatory framework that governs the licensing of aquaculture businesses, particularly those involved in exporting products. It ensures that export-oriented businesses meet all the necessary legal and environmental requirements.                                                                                                                                                                                           |
| Environmental Impact Assessment on seaweed mariculture development requirement                   | This sub-sub-code emphasizes the requirement for environmental impact assessments (EIAs) to be conducted before any seaweed mariculture development can proceed. EIAs help to identify potential environmental risks and ensure that projects are sustainable.                                                                                                                                                                                                  |
| Mariculture license and regulatory conditional offers                                            | This sub-sub-code deals with the specific conditions that must be met for the issuance of mariculture licenses. These conditions ensure that businesses operate sustainably and comply with all legal requirements.                                                                                                                                                                                                                                             |
| Permit requirement to import restricted products such as plastic bottle covers                   | This sub-sub-code refers to the need for permits to import certain restricted products, including those used in mariculture operations, such as plastic bottle covers. These restrictions help manage the environmental impact of mariculture.                                                                                                                                                                                                                  |
| Tour operator and tour guide license requirements for seaweed farm ecotours                      | This sub-sub-code focuses on the licensing requirements for tour operators and guides who run ecotours related to seaweed farms, ensuring that they comply with regulatory standards for tourism and environmental protection.                                                                                                                                                                                                                                  |
| Regulatory and procedural framework for mariculture development                                  | This sub-code refers to the overall regulatory and procedural structure that governs mariculture development, including the standards and processes that must be followed for successful and compliant operations.                                                                                                                                                                                                                                              |
| Belize Marine Fisheries and Seafood Processing Trade Strategy including seaweed mariculture      | This sub-sub-code highlights Belize's strategic framework for marine fisheries and seafood processing, which includes seaweed mariculture. It provides guidance on how the industry can grow sustainably while contributing to the national economy.                                                                                                                                                                                                            |
| Overarching Guiding Principles of the National Mariculture,                                      | This sub-sub-code refers to the key principles that guide the development of mariculture and fisheries within Belize's broader blue economy policy. These principles focus on sustainable development, environmental stewardship, and economic resilience.                                                                                                                                                                                                      |



|                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Fisheries & Blue Economy Policy                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Sustainable fisheries development initiatives including provision of license and permit for the seaweed mariculture industry | This sub-code refers to initiatives aimed at promoting sustainable fisheries development, including the licensing and permitting processes for seaweed mariculture. These initiatives ensure that mariculture businesses operate within sustainable guidelines and contribute to the overall health of the marine ecosystem.                                                                                                                               |
| The need for legal frameworks that facilitate mariculture as a community livelihood                                          | This code highlights the legal aspects of ensuring community livelihoods through mariculture. It captures the need for legal frameworks that facilitate community access to mariculture opportunities, protect community interests, and promote fair and equitable involvement in the sector. This sub-code focuses on the importance of establishing legal frameworks that support mariculture as a viable livelihood for local communities.              |
| 14. Ecosystem-based Management and Conservation                                                                              | This thematic code focuses on the holistic approach to managing ecosystems in a way that conserves natural resources while supporting sustainable development. This approach integrates environmental, economic, and social considerations to ensure that ecosystems are managed sustainably for current and future generations.                                                                                                                           |
| Growth and Sustainable Development Strategy                                                                                  | This sub-code refers to Belize's strategic plan that aims to balance economic growth with sustainable development. The Growth and Sustainable Development Strategy (GSDS) outlines policies and actions that integrate ecosystem-based management into the country's broader development goals. The strategy emphasizes the importance of conserving natural resources while promoting economic activities that are sustainable and beneficial to society. |
| Horizon 2030 National Development Framework for Belize                                                                       | Belize's Horizon 2030 is a long-term national development framework focusing on sustainable development and resource protection. It incorporates ecosystem-based management principles and serves as a guided document for national policies.                                                                                                                                                                                                              |
| 2. Criminal Civil Law Enforcement                                                                                            | This thematic code focuses on the legal frameworks and enforcement mechanisms that aim to prevent and address criminal activities, particularly in relation to the protection of natural resources and maintaining public order. This code is essential for creating a safe and lawful environment, ensuring compliance with the law, and protecting both individuals and natural resources from criminal activities.                                      |
| Create a legal environment that discourages theft and encourages the reporting of suspicious activities                      | This sub-code emphasizes the importance of establishing a legal environment that actively discourages theft and promotes the reporting of suspicious activities. It highlights the role of legal provisions and public awareness in preventing crimes such as theft, particularly in vulnerable areas like marine reserves.                                                                                                                                |
| Police Act                                                                                                                   | This sub-sub-code refers to the legal framework provided by the Police Act, which governs the operation of the police force. The act outlines the powers and responsibilities of the police in preventing and responding to crimes, including theft. It also includes provisions that encourage public cooperation with law enforcement through the reporting of criminal activities.                                                                      |
| Legal framework for crime prevention and law enforcement                                                                     | This sub-code covers the overarching legal structures that guide crime prevention and law enforcement efforts. It includes specific acts and regulations that provide the basis for criminal justice procedures and ensure that crimes are effectively prevented and addressed.                                                                                                                                                                            |

|                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Criminal Code Act                                                                                                                                                                                  | This sub-sub-code refers to the Criminal Code, which is the primary legal document outlining criminal offenses and their corresponding penalties. It serves as the foundation for crime prevention and the administration of justice, defining what constitutes criminal behavior and how it should be punished.                                                                                                                                                                                                                |
| Prevention of Crimes Act                                                                                                                                                                           | This sub-sub-code highlights the Prevention of Crimes Act, which includes specific measures aimed at deterring criminal activities. This act may include provisions for surveillance, community policing, and other preventive strategies to reduce crime rates.                                                                                                                                                                                                                                                                |
| Offences and Penalties within Marine and Inland Water Reserves (including wild harvest of seaweed resources)                                                                                       | This sub-code focuses on the specific offenses and penalties related to activities within marine and inland water reserves, particularly those involving the illegal harvest of natural resources such as seaweed. It underscores the importance of protecting these areas from exploitation and ensuring that penalties are in place to deter illegal activities.                                                                                                                                                              |
| Police Act provides a general legal framework for addressing crimes, specific legal provisions and regulatory measures may be necessary to explicitly cover and protect seaweed farming activities | This sub-code reiterates the role of the Police Act in providing a comprehensive legal framework for addressing a wide range of crimes. It includes specific legal provisions and regulatory measures that are designed to maintain public order, protect property, and ensure the safety and security of communities. The act serves as a guide for law enforcement agencies in carrying out their duties effectively.                                                                                                         |
| 3. Economic and Trade Policies                                                                                                                                                                     | This thematic code focuses on the legislative and policy frameworks that guide economic activities and trade practices in Belize, particularly in the context of the blue economy, climate change, and the support of micro, small, and medium enterprises (MSMEs). These policies are crucial for fostering economic growth, sustainable development, and global competitiveness.                                                                                                                                              |
| Belize Blue Economy Bill in Draft                                                                                                                                                                  | This sub-code refers to the draft legislation aimed at establishing a comprehensive legal framework for Belize's blue economy. The blue economy encompasses sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystems. This bill would set the foundation for policies that promote sustainable marine and coastal resource management, integrate marine-based economic activities, and ensure environmental protection.                           |
| Climate change and carbon market initiatives bill in draft                                                                                                                                         | This sub-code highlights a draft bill focused on climate change mitigation and the development of carbon markets in Belize. The bill would aim to regulate carbon emissions, promote carbon trading, and establish mechanisms for Belize to participate in global carbon markets. This initiative reflects Belize's commitment to addressing climate change while leveraging economic opportunities from carbon trading to support sustainable development goals.                                                               |
| MSME strategy and roadmap for Belize involves simplifying registration, protecting intellectual property, and improving contract enforcement                                                       | This sub-code outlines the strategic initiatives and policy roadmap designed to support the growth of micro, small, and medium enterprises (MSMEs) in Belize. The strategy includes simplifying the business registration process to make it easier for MSMEs to start and operate legally, enhancing the protection of intellectual property to encourage innovation, and improving contract enforcement to ensure that business agreements are honored. These measures are intended to create a more enabling environment for |

|                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 4. Environmental and Biosecurity Laws                                        | This thematic code focuses on the legal frameworks governing environmental protection and biosecurity, particularly in mariculture and seaweed aquaculture. Sub-codes include biosecurity policies, co-management of protected areas, enforcement of environmental laws, maritime safety regulations, and penalties for environmental damage, ensuring sustainable and safe mariculture practices.                                                                           |
| Biosecurity policy and framework in relation to seaweed aquaculture          | This focuses on the development and implementation of biosecurity measures specifically for seaweed aquaculture. It encompasses policies that aim to prevent the introduction and spread of harmful organisms and diseases within seaweed farming operations, ensuring the health and sustainability of aquaculture practices.                                                                                                                                               |
| Biosecurity policy                                                           | This sub-sub-code likely refers to the specific guidelines and regulations that form part of this framework, outlining the standards and procedures that must be followed to maintain biosecurity in seaweed aquaculture.                                                                                                                                                                                                                                                    |
| Co-management of public protected areas                                      | This sub-code emphasizes the shared governance of protected areas by various stakeholders, including government agencies, local communities, and NGOs. Co-management is crucial for balancing conservation efforts with the sustainable use of natural resources within protected areas.                                                                                                                                                                                     |
| Enforcement Notices for Environmental Law Violations                         | This sub-code deals with the mechanisms for issuing enforcement notices to individuals or entities that violate environmental laws. Such notices are a key tool in ensuring compliance with environmental regulations and deterring harmful practices.                                                                                                                                                                                                                       |
| Environmental laws and regulations governing mariculture                     | This thematic code focuses on the legal framework that regulates mariculture activities, ensuring they are conducted in an environmentally responsible manner. These regulations are crucial for protecting marine ecosystems, maintaining water quality, and mitigating the environmental impacts associated with mariculture.                                                                                                                                              |
| Effluent Limitations Regulations 2009                                        | Control and monitoring of effluent discharges into inland waters or the marine environment, applicable to mariculture development.                                                                                                                                                                                                                                                                                                                                           |
| Environmental Impact Assessments Regulations 2003 & Amended Regulations 2007 | Requirement for all aquaculture activities to undergo an Environmental Impact Assessment (EIA) or a Limited Level Environmental Study, as determined by the Department of Environment. EIAs help in identifying and addressing risks to the environment, including impacts on biodiversity, water quality, and habitat integrity.                                                                                                                                            |
| Environmental Protection Act 2000 (Revised Edition 2011)                     | The sub-code references Belize's Environmental Protection Act, a legal framework for environmental protection, including mariculture activities. It outlines responsibilities for operators in pollution prevention, resource conservation, and environmental standards. The 2011 revised edition addresses emerging environmental challenges.                                                                                                                               |
| Environmental protection through the pollution from plastics regulation      | This sub-code highlights regulations aimed at reducing pollution from plastics, which are particularly relevant in mariculture where plastic materials are often used. These regulations may include restrictions on the use of certain types of plastics, requirements for proper disposal, and measures to prevent plastic waste from entering the marine environment. The goal is to mitigate the harmful impacts of plastic pollution on marine ecosystems and wildlife. |
| Fisheries Ordinance and Regulations                                          | This sub-code involves the legal framework that governs fisheries management, including regulations that pertain to mariculture. The fisheries ordinance may include rules on                                                                                                                                                                                                                                                                                                |

|                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|---------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                           | harvesting practices, resource allocation, and environmental protection.                                                                                                                                                                                                                                                                                                                                                                         |
| Legal frameworks must define and regulate actions related to hazard management                                            | This sub-code underscores the need for clear legal definitions and regulations regarding hazard management in mariculture. This includes managing risks associated with environmental hazards, such as pollution or natural disasters.                                                                                                                                                                                                           |
| Legal structure for agricultural health, biosecurity, and the operational governance including seaweed crops              | This sub-code focuses on the legal structures that govern agricultural health and biosecurity. It ensures that operational practices align with biosecurity standards to prevent the spread of diseases and pests. This code includes the procedures and requirements necessary to ensure that seaweed cultivation and trade are conducted safely and in compliance with national and international standards.                                   |
| Board of directors of BAHA                                                                                                | This sub-code refers to the governance structure within the Belize Agricultural Health Authority (BAHA), which oversees agricultural health and biosecurity measures, including those related to seaweed crops. The board of directors is responsible for setting policies, ensuring compliance with regulations, and guiding the overall strategy for maintaining agricultural health and biosecurity in Belize.                                |
| Provision of importation and exportation permit accompanied by a phytosanitary certification for plants including seaweed | This sub-code highlights the need to obtain proper permits for the importation and exportation of plants, including seaweed. These permits must be accompanied by a phytosanitary certification, which verifies that the plants meet the necessary health standards and are free from pests and diseases. This ensures that the trade of seaweed is conducted safely, protecting both local and international ecosystems.                        |
| Requirement of Quarantine Procedures for Plant Importation                                                                | This sub-code addresses the mandatory quarantine procedures that must be followed when importing plants, including seaweed, into the country. These procedures are designed to prevent the introduction of pests, diseases, or invasive species that could harm local ecosystems or agricultural sectors. Quarantine measures ensure that imported plants are thoroughly inspected and treated before being allowed into the local environment.  |
| Maritime Act                                                                                                              | This sub-code pertains to the legal provisions under the Maritime Act, which may include regulations related to maritime safety, environmental protection, and the management of marine resources in the context of mariculture.                                                                                                                                                                                                                 |
| Maritime safety regulations for mariculture operations                                                                    | This sub-code addresses the safety regulations that apply to mariculture operations conducted in maritime environments. These regulations ensure that mariculture activities do not pose risks to human safety or the marine ecosystem. Importance for Blue Economy development, particularly in relation to the EEZ (Exclusive Economic Zone).                                                                                                  |
| Belize Port Authority Act 2003 (Revised Edition 2011)                                                                     | This sub-code relates to the legal framework provided by the Belize Port Authority Act, which governs the management and operation of ports in Belize. This includes provisions for safe navigation within Belizean waters. It emphasizes the importance of siting mariculture operations to avoid obstruction of maritime traffic lanes and ensuring visibility and lighting of mariculture infrastructure to maintain overall maritime safety. |
| Need to develop and enforce laws related to food safety, land use and practices including seaweed crop                    | This sub-code highlights the necessity of developing and enforcing laws that govern food safety, land use, and mariculture practices. Ensuring compliance with these laws is critical for maintaining the quality and safety of seaweed products.                                                                                                                                                                                                |

|                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| National Agriculture and Food Policy of Belize and its principles                                                                                                     | This sub-code refers to the overarching national policy that governs agriculture and food safety in Belize. The policy outlines principles and guidelines for ensuring that agricultural practices, including those related to seaweed cultivation, are conducted in a manner that is safe, sustainable, and beneficial to the country's food security and economy. It is crucial for shaping laws and regulations that pertain to food safety, land use, and agricultural practices. |
| Penalties for Environmental Damage                                                                                                                                    | This sub-code refers to the penalties imposed for causing environmental damage, particularly in the context of mariculture. These penalties serve as a deterrent against harmful practices and reinforce the importance of environmental protection.                                                                                                                                                                                                                                  |
| Regulatory compliance and environmental sustainability, highlighting the importance of adhering to health standards and protecting marine resources including seaweed | This sub-code emphasizes the role of regulatory compliance in achieving environmental sustainability. It underscores the importance of adhering to health standards to ensure that mariculture practices do not compromise human or environmental health.                                                                                                                                                                                                                             |
| Regulatory requirements for agricultural health including seaweed                                                                                                     | This sub-code outlines the regulatory requirements that govern agricultural health in mariculture, particularly in relation to seaweed crops. These requirements are designed to ensure that seaweed farming practices do not introduce or spread harmful organisms.                                                                                                                                                                                                                  |
| 5. Environmental and Resource Management                                                                                                                              | The thematic code "Environmental and Resource Management" focuses on the regulatory and management aspects essential for sustainable environmental practices and resource management, particularly within the context of mariculture and fisheries in Belize. This code encompasses various regulations, policies, and frameworks designed to ensure the effective management of natural resources and the environment.                                                               |
| Climate change adaptation in mariculture regulatory requirements and frameworks                                                                                       | This sub-code emphasizes the need to incorporate climate change adaptation measures into the regulatory frameworks governing mariculture. This includes adapting regulations to ensure the resilience of mariculture practices in the face of changing climate conditions.                                                                                                                                                                                                            |
| Establishment of the Solid Waste Management Authority                                                                                                                 | Focuses on the creation and role of the Solid Waste Management Authority in managing waste, which is crucial for minimizing environmental pollution and maintaining the sustainability of mariculture and other related industries.                                                                                                                                                                                                                                                   |
| Fisheries Management Plans including in Co-management                                                                                                                 | Highlights the importance of developing and implementing fisheries management plans that incorporate co-management practices. This ensures that local communities and stakeholders are involved in the sustainable management of fisheries resources.                                                                                                                                                                                                                                 |
| The need to develop a seaweed resources Biotrade strategy plan                                                                                                        | Stresses the necessity of creating a strategic plan for the Biotrade of seaweed resources to optimize their sustainable use and market potential.                                                                                                                                                                                                                                                                                                                                     |
| The need to do a wild seaweed stock management plan                                                                                                                   | Calls for the development of a management plan focused on wild seaweed stocks to ensure their sustainable harvesting and conservation.                                                                                                                                                                                                                                                                                                                                                |

|                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                           |
|---------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Importance for BE development, particularly in relation to the EEZ              | This sub-code focuses on the significance of Blue Economy (BE) development, particularly within Belize's Exclusive Economic Zone (EEZ), to promote sustainable use and management of marine resources. The Maritime Areas Act 1992 (and as amended in 2019) is (Revised 2020) crucial for the development of BE in Belize, and particularly as relates to the EEZ.                                        |
| Management and development plans for different fisheries (except seaweed)       | Emphasizes the need for comprehensive management and development plans for various fisheries sectors, excluding seaweed, to ensure sustainable practices and resource conservation.                                                                                                                                                                                                                       |
| Mariculture provisions in governance and regulatory frameworks                  | This thematic code focuses on the legal and policy measures necessary to govern and regulate the mariculture industry in Belize. The sub-codes highlight the importance of establishing a comprehensive legal framework, adopting best practices, and ensuring that mariculture activities contribute to sustainable economic development while protecting the marine environment.                        |
| Absence of Blue Economy Act                                                     | This sub-code highlights the current gap in Belize's legal framework, specifically the lack of a dedicated Blue Economy Act. Such an act would provide a comprehensive legal basis for promoting and managing Blue Economy initiatives, including mariculture. Lack of a comprehensive legal framework for BE development and implementation.                                                             |
| Best practice guidelines for seaweed cultivation                                | Emphasizes the need for establishing and adhering to best practice guidelines in seaweed cultivation. These guidelines would ensure that seaweed farming is conducted in a manner that maximizes efficiency, sustainability, and environmental protection.                                                                                                                                                |
| Blue Economy Policy & Strategy Implementation Plan (2022-27)                    | Refers to the strategic document outlining Belize's approach to implementing its Blue Economy policy from 2022 to 2027. This plan would guide the development of mariculture and other marine-based industries, focusing on sustainable practices and economic growth.                                                                                                                                    |
| Fisheries Resources Act 2020                                                    | A significant legislative framework that governs the management, conservation, and sustainable use of fisheries resources in Belize. The act is vital for ensuring that mariculture activities align with broader fisheries management objectives. This Act details the specific requirements for licensing, species type, facility setup, zoning, and other regulatory measures tailored to mariculture. |
| Forests (Protection of Mangroves) Regulations 2018                              | This regulation protects mangrove forests, which are crucial for maintaining healthy marine ecosystems that support mariculture. The regulation plays a critical role in preventing the degradation of mangroves due to mariculture activities.                                                                                                                                                           |
| National Fisheries Policy, Strategy & Action Plan 2020-2024                     | A comprehensive policy document that outlines Belize's strategy for managing its fisheries resources over a four-year period. This plan includes provisions for developing the mariculture sector sustainably and responsibly.                                                                                                                                                                            |
| National Fisheries Policy, Strategy and Action Plan (2020-2024) for Mariculture | Specifically focuses on the mariculture sector, providing a strategic framework for its development. It ensures that mariculture practices are aligned with national fisheries policies and sustainability goals.                                                                                                                                                                                         |
| National Mariculture Policy 2021                                                | A policy dedicated to the development and management of the mariculture sector in Belize. It outlines the regulatory and operational frameworks necessary for promoting sustainable mariculture practices.                                                                                                                                                                                                |

|                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                         |
|--------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| The Maritime Areas Act 1992                                                                            | Governs Belize's maritime areas, providing the legal framework for the use and management of marine resources, including those related to mariculture. This act is fundamental for defining the boundaries and legalities of mariculture operations within Belize's territorial waters.                                                                                                 |
| Sustaining Livelihoods Dependent on Fisheries (including seaweed)                                      | Emphasizes the need to support and sustain livelihoods that depend on fisheries and mariculture, including those involved in seaweed farming, through effective management and resource conservation.                                                                                                                                                                                   |
| Territorial Use Rights for Fishing (TURFs) through managed access areas                                | Discusses the implementation of TURFs as a management strategy that grants exclusive fishing rights to local communities within designated areas, promoting sustainable resource use and community stewardship.                                                                                                                                                                         |
| 6. Food Safety and Health Standards                                                                    | This thematic code pertains to the regulatory and policy frameworks that ensure the safety, quality, and health standards of food products, particularly those derived from mariculture and other coastal activities in Belize. It involves various legal, sanitary, and procedural standards that govern the production, inspection, and export of fishery and seaweed-based products. |
| Agricultural Health Authority (Fish and Fisheries Product Inspection) Regulations                      | Focuses on the regulations established by the Agricultural Health Authority for inspecting fish and fisheries products, including those derived from mariculture. These regulations ensure that products meet safety and health standards before entering the market.                                                                                                                   |
| Aquaculture representation in coastal management                                                       | This sub-code examines the involvement of aquaculture in coastal management practices, including key legislative acts such as:                                                                                                                                                                                                                                                          |
| Aquaculture Development Act 2011                                                                       | Governs the development and regulation of aquaculture activities in Belize                                                                                                                                                                                                                                                                                                              |
| Coastal Zone Management Act 2000                                                                       | Ensures aquaculture representation in governance and planning for coastal zone management, emphasizing the integration of aquaculture into broader coastal management strategies. This Act provides a framework for managing Belize's coastal zones, including regulations that affect aquaculture.                                                                                     |
| Fisheries Resource Act 2020                                                                            | Regulations on mariculture operations to ensure compliance with specific conditions and requirements, including location, species cultivated, construction, disease prevention, and facility inspections. Regulates the management of fisheries resources, impacting aquaculture practices.                                                                                             |
| Integrated Coastal Zone Management Plan (ICZMP)                                                        | A strategic plan for managing coastal resources, including provisions for sustainable aquaculture development.                                                                                                                                                                                                                                                                          |
| Compliance with HACCP is often required for exporting food products to international markets           | Highlights the importance of Hazard Analysis and Critical Control Points (HACCP) compliance for ensuring that food products, including those from mariculture, meet international safety standards necessary for export.                                                                                                                                                                |
| Development and utilization of coastal zone resources, advising on policies, and implementing programs | This sub-code addresses the strategic use of coastal resources for mariculture, involving advisory roles, policy development, and the implementation of relevant programs.                                                                                                                                                                                                              |
| HACCP Official Registration and                                                                        | Focuses on the formal registration and adherence to HACCP protocols, which are critical for maintaining food safety standards in mariculture and fisheries products.                                                                                                                                                                                                                    |

|                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                |
|------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Compliance for Food Safety                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                |
| Legal Requirements for Training and Supervision in Food Safety                                       | Highlights the legal mandates for proper training and supervision in the food safety sector, ensuring that all personnel involved in mariculture and fisheries adhere to high safety standards.                                                                                                                                                                                                |
| Legal Standards for Fish and Fishery Products Inspection including seaweed-based products            | Covers the specific legal standards and procedures for inspecting fish and seaweed-based products to ensure they meet health and safety requirements before reaching consumers.                                                                                                                                                                                                                |
| Multi-disciplinary nature of mariculture (various sectors in policymaking and regulation)            | Recognizes the need for a multidisciplinary approach in mariculture policymaking and regulation, involving various sectors to address the complex nature of food safety and health standards.                                                                                                                                                                                                  |
| Regulatory Standards for Food Establishments at a high cost                                          | Highlights the high costs associated with meeting regulatory standards for food establishments, including those involved in mariculture, which may impact the economic viability of small-scale operations.                                                                                                                                                                                    |
| Regulatory support for high-quality and safe aquaculture products                                    | This sub-code emphasizes the importance of regulatory frameworks that support the production of high-quality, safe aquaculture products, including those derived from seaweed.                                                                                                                                                                                                                 |
| National Food and Agriculture Policy                                                                 | Highlights the national policies guiding food and agriculture practices in Belize, which include standards relevant to mariculture and its products.                                                                                                                                                                                                                                           |
| Sanitary, phytosanitary, and processing area regulations for mariculture                             | Focuses on the regulations governing the sanitary and phytosanitary conditions of mariculture, ensuring that processing areas meet the required standards.                                                                                                                                                                                                                                     |
| Belize Agricultural Health Authority Act 2000 Revised Edition 2011                                   | Provisions for the regulation of sanitary and phytosanitary certificates and procedures for carrying out risk analysis for plants and animals. Govern agricultural health and safety standards, impacting mariculture.                                                                                                                                                                         |
| Designated Processing Areas Regulations (DPA) 2019                                                   | Establishes the standards for processing areas to ensure food safety.                                                                                                                                                                                                                                                                                                                          |
| Standards Act 2000 Revised Edition 2011                                                              | Provides the overarching legal framework for maintaining standards in food safety.                                                                                                                                                                                                                                                                                                             |
| 7. Institutional Support and Enforcement                                                             | This thematic code relates to the structures, legal frameworks, and institutional roles that underpin the effective governance, compliance, and enforcement of regulations in mariculture and related sectors in Belize. This theme emphasizes the need for robust institutional mechanisms to support mariculture development while ensuring regulatory compliance and sustainable practices. |
| Advisory function of the standards advisory council but does not streamline seaweed quality controls | This sub-code focuses on the role of the standard's advisory council, particularly its advisory capacity. However, it points out that despite the council's role, it does not effectively streamline quality control measures for seaweed production.                                                                                                                                          |
| Call for Regulatory adjustments and institutional strengthening                                      | Highlights the necessity for revising existing regulations and strengthening institutions to better support and manage mariculture activities, ensuring they align with best practices and sustainability goals.                                                                                                                                                                               |



|                                                                                                              |                                                                                                                                                                                                                                          |
|--------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Key legal enablers and compliance requirement managed by various institutions (does not specify mariculture) | This sub-code lists the key institutions responsible for legal enforcement and compliance across various sectors, which indirectly affect mariculture:                                                                                   |
| Aquaculture Authority                                                                                        | Oversee the regulation and development of aquaculture activities. This sub-code lists the key institutions responsible for legal enforcement and compliance across various sectors, which indirectly affect mariculture:                 |
| Belize Agricultural Health Authority                                                                         | Manages agricultural health and safety, impacting mariculture through regulations on fish and seaweed products.                                                                                                                          |
| Bureau of Standards                                                                                          | Sets and enforces standards across industries, including mariculture.                                                                                                                                                                    |
| Coastal Zone Management Authority and Advisory Council                                                       | Development and utilization of coastal zone resources, advising on policies, and implementing sustainable development programs. Regulates the use of coastal resources, including those used in mariculture.                             |
| Customs and Excise Department                                                                                | Manages import and export regulations, which affect mariculture trade.                                                                                                                                                                   |
| Department of Environment                                                                                    | Enforces environmental regulations to ensure mariculture activities do not harm ecosystems.                                                                                                                                              |
| Fisheries Department and Advisory Council                                                                    | Directly involved in the management and regulation of fisheries and mariculture                                                                                                                                                          |
| National Coast Guard Service                                                                                 | Enforces maritime laws, indirectly impacting mariculture operations.                                                                                                                                                                     |
| Police Department                                                                                            | Ensures the enforcement of laws and regulations, including supporting those related to environmental crimes.                                                                                                                             |
| Port Authority                                                                                               | Manage port operations, crucial for the import/export of products.                                                                                                                                                                       |
| Prioritization of law enforcement, prosecution, and adherence to legal protocols                             | Emphasizes the importance of prioritizing law enforcement in mariculture to ensure adherence to legal protocols, thus protecting the industry from illegal activities and ensuring compliance with national and international standards. |
| Regulatory framework for cooperation and partnerships (coordination, planning, and implementation)           | Focuses on the need for a regulatory framework that fosters cooperation and partnerships among various stakeholders in mariculture. This includes:                                                                                       |
| #PLAN BELIZE Development Strategy 2022-26                                                                    | A strategic plan that includes provisions for sustainable development, which may influence mariculture.                                                                                                                                  |
| Belize Fisheries Resources Act 2020                                                                          | A legislative framework that governs the management of fisheries resources, including mariculture.                                                                                                                                       |
| Growth and Sustainable Development Strategy 2016-2019                                                        | A strategy that provides a holistic approach to sustainable development in Belize, impacting the mariculture sector.                                                                                                                     |
| Requirement to obtain tour guide and tour operator license for                                               | This sub-code highlights the regulatory requirement for obtaining licenses for tour guides and operators who conduct eco-tours of seaweed farms. This ensures that the tours are                                                         |

|                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| seaweed farms eco-tour                                                                                                                                                                            | conducted legally and that guides are properly trained and certified.                                                                                                                                                                                                                                                                                                                                                              |
| 8. Intellectual Property and Innovation                                                                                                                                                           | This thematic code focuses on the legal and strategic frameworks necessary to protect and promote intellectual property rights and innovation in Belize. This includes ensuring that the country's policies and regulations align with global standards and adequately support both the creation and protection of new ideas and products.                                                                                         |
| Intellectual Property Rights for the Protection of Inventions and Innovations                                                                                                                     | This sub-code emphasizes the importance of having strong intellectual property rights to safeguard inventions and innovations. It highlights the role of legal protections, such as patents, in encouraging creativity and technological advancement.                                                                                                                                                                              |
| Patent Act                                                                                                                                                                                        | Specifically refers to the legislation that governs the granting and enforcement of patents in Belize, which is crucial for protecting inventors' rights and fostering innovation.                                                                                                                                                                                                                                                 |
| Legal framework for trade-marks must be robust to provide effective protection and enforcement                                                                                                    | This sub-code underlines the necessity for a comprehensive legal framework to protect trademarks effectively. A robust system ensures that businesses and individuals can protect their brands, thereby promoting fair competition and consumer trust.                                                                                                                                                                             |
| National Climate Change Policy, Strategy, and Action Plan provide a strategic framework for integrating climate change adaptation into seaweed mariculture but does not specify to sector context | This sub-code indicates the integration of climate change considerations into intellectual property and innovation policies. The framework aims to support innovations that address climate change challenges, thereby aligning intellectual property strategies with broader environmental goals.                                                                                                                                 |
| Patent Cooperation Treaty, ensures that Belize aligns with global standards in industrial property rights                                                                                         | This sub-code discusses Belize's adherence to international agreements, such as the Patent Cooperation Treaty (PCT), which facilitates the protection of patent rights across multiple countries. Aligning with global standards helps Belize protect its innovators' rights internationally and attract foreign investments.                                                                                                      |
| 9. International and Regional Legal Frameworks and Agreements                                                                                                                                     | This thematic code pertains to the global and regional legal structures that Belize must adhere to in the management and conservation of its natural resources, particularly in the areas of fisheries and mariculture, as well as the protection of the Barrier Reef. It highlights Belize's commitment to complying with international standards and agreements that promote sustainable practices and environmental protection. |
| Access to Genetic Resources according to CBD definition                                                                                                                                           | This sub-code relates to the Convention on Biological Diversity (CBD) and the regulations regarding access to genetic resources. It ensures that Belize's legal frameworks are aligned with CBD definitions, which govern the use of genetic resources in a way that supports conservation, sustainable use, and equitable sharing of benefits arising from their utilization.                                                     |
| International conservation standards and legal frameworks for Barrier Reef protection                                                                                                             | This sub-code refers to Belize's commitment to international conservation standards, particularly those aimed at protecting the Barrier Reef. It underscores the importance of following global legal frameworks designed to preserve such critical ecosystems, ensuring their resilience and health for future generations.                                                                                                       |
| International legal framework on sustainable fisheries                                                                                                                                            | This thematic code and its sub-codes encapsulate Belize's integration into a network of international and regional legal frameworks that guide and regulate sustainable fisheries and                                                                                                                                                                                                                                              |

|                                                                                                                                              |                                                                                                                                                                                             |
|----------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| management including mariculture                                                                                                             | mariculture, ensuring that practices align with global conservation and trade standards.                                                                                                    |
| African, Caribbean, and Pacific Group of States (ACP)                                                                                        | The ACP group works on sustainable development issues, including fisheries and mariculture, across its member states, impacting Belize's practices and policies.                            |
| Bilateral relation with Mexico                                                                                                               | This sub-code refers to agreements and collaborations between Belize and Mexico that might impact fisheries and mariculture, including trade and environmental management.                  |
| Caribbean Community (CARICOM)                                                                                                                | CARICOM promotes economic integration and cooperation among Caribbean nations, including in the management of marine resources and mariculture.                                             |
| CARIFORUM-European Union Economic Partnership Agreement (EPA)                                                                                | Similar to the UK EPA, this agreement facilitates trade between Caribbean countries and the European Union, influencing mariculture practices and trade.                                    |
| CARIFORUM-United Kingdom EPA                                                                                                                 | The Economic Partnership Agreement between CARIFORUM and the UK includes provisions relevant to fisheries and mariculture, impacting Belize's trade and environmental practices.            |
| Central American Integration System (Sistema de Integración Centroamericana, SICA)                                                           | SICA promotes regional cooperation and integration, including sustainable fisheries management, impacting Belize's policies and practices.                                                  |
| Convention on Wetlands of International Importance Especially as Waterfowl Habitat                                                           | This convention, also known as the Ramsar Convention, focuses on the conservation and sustainable use of wetlands, which are critical for healthy marine ecosystems supporting mariculture. |
| The Caribbean Regional Fisheries Mechanism (CRFM)                                                                                            | CRFM supports the sustainable management of marine resources in the Caribbean, directly influencing Belize's fisheries and mariculture practices.                                           |
| The Central American Fisheries and Aquaculture Organization (Organización del Sector Pesquero y Acuicola del Istmo Centroamericano (OSPESCA) | This organization promotes the sustainable development of fisheries and aquaculture in Central America, which includes Belize.                                                              |
| The Convention on International Trade of Endangered Species (CITES)                                                                          | This sub-code is about CITES, which regulates the international trade of endangered species, including marine species that might be affected by mariculture.                                |
| The Latin American Organization for                                                                                                          | This organization focuses on cooperation among Latin American countries to develop and manage fisheries sustainably, impacting Belize's policies.                                           |

|                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Fisheries Development (Organización Latinoamericana de Desarrollo Pesquero - OLDEPESCA) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| The Organization of African, Caribbean and Pacific States (OACPS)                       | This sub-code refers to the OACPS, which supports sustainable development and management of natural resources, including fisheries and mariculture, in member states like Belize.                                                                                                                                                                                                                                                                                                           |
| The Western Central Atlantic Fishery Commission                                         | This sub-code pertains to regional cooperation in managing fishery resources in the Western Central Atlantic, directly influencing Belize's fisheries management practices.                                                                                                                                                                                                                                                                                                                 |
| UN Convention on the Law of the Sea                                                     | This convention is vital for governing all activities in the oceans and seas, including mariculture, ensuring that practices are legal, sustainable, and equitable.                                                                                                                                                                                                                                                                                                                         |
| UN Climate Change Convention                                                            | This sub-code relates to the UNFCCC, under which Belize commits to reducing greenhouse gas emissions, including those related to fisheries and mariculture.                                                                                                                                                                                                                                                                                                                                 |
| UN Convention on Biological Diversity                                                   | The CBD is crucial for setting global biodiversity targets, including the sustainable management of marine resources, which directly impacts Belize's mariculture practices.                                                                                                                                                                                                                                                                                                                |
| UN Convention to Combat Desertification                                                 | This sub-code emphasizes the relevance of the UNCCD in addressing land degradation, which indirectly impacts marine ecosystems and the sustainability of fisheries and mariculture.                                                                                                                                                                                                                                                                                                         |
| UNCTAD                                                                                  | The United Nations Conference on Trade and Development (UNCTAD) plays a role in promoting development-friendly integration of developing countries into the world economy, including aspects related to sustainable fisheries and mariculture.                                                                                                                                                                                                                                              |
| UNESCO World Heritage Convention                                                        | This convention protects sites of outstanding universal value, including marine environments that might be linked to mariculture activities. It ensures these areas are conserved for future generations.                                                                                                                                                                                                                                                                                   |
| World Trade Organization (WTO)                                                          | The WTO sets global rules for trade, including those affecting fisheries and mariculture. It helps ensure fair competition and addresses trade barriers that might impact on the export and import of marine products.                                                                                                                                                                                                                                                                      |
| Political                                                                               | The political factors captured in this framework encompass various dimensions of policymaking, governance, and international cooperation that are crucial for the development and regulation of the mariculture sector. These political factors collectively indicate the intention to ensure that the development of the mariculture sector is well-coordinated, legally compliant, environmentally sustainable, and aligned with both national and international goals at a policy-level. |
| 1. National Policy Frameworks and Strategies                                            | This thematic code and its sub-codes focus on the strategic direction and policy frameworks that guide national development, particularly in relation to mariculture and sustainable development. These codes collectively outline the various strategic and policy-oriented dimensions that guide Belize's approach to sustainable development, particularly in the mariculture sector, ensuring alignment with national goals and international commitments.                              |
| A balanced approach will help Belize meet social needs and                              | This sub-code emphasizes the importance of developing policies that strike a balance between social, economic, and                                                                                                                                                                                                                                                                                                                                                                          |

|                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| conserve its natural resource base, ensuring long-term sustainability and resilience                                                                  | environmental needs to promote sustainability and resilience in Belize.                                                                                                                                                                                                                                                                                                                                                                     |
| Alignment and integration of national and sector policies with local and international commitments and national development in the mariculture sector | This sub-code highlights the need to align national policies with both local and international commitments to ensure cohesive and comprehensive development, particularly in the mariculture sector.                                                                                                                                                                                                                                        |
| Bilateral, Regional, and Multilateral Cooperation                                                                                                     | This sub-code emphasizes the importance of collaboration at various levels bilateral, regional, and multilateral to ensure that Belize's policies are consistent with international commitments and benefit from shared expertise and resources.                                                                                                                                                                                            |
| National Fisheries Policy, Strategy, & Action Plan 2020-2024                                                                                          | This sub-code refers to the specific strategic framework and action plan that guides the development and management of fisheries in Belize, ensuring alignment with both national goals and international standards from 2020 to 2024.                                                                                                                                                                                                      |
| Belize Climate Action and Sustainable Development (BCASD)                                                                                             | This sub-code refers to specific policies or initiatives under the BCASD framework that are aimed at addressing climate action while promoting sustainable development.                                                                                                                                                                                                                                                                     |
| Blue Economy and Mariculture Principles                                                                                                               | This sub-code captures the principles guiding the Blue Economy, which includes mariculture, emphasizing sustainable use of marine resources.                                                                                                                                                                                                                                                                                                |
| Blue economy definition                                                                                                                               | This sub-code focuses on the specific definition of the Blue Economy, likely within the context of national policy, to ensure clarity and consistency in its application.                                                                                                                                                                                                                                                                   |
| Definition and Evolution of the Blue Economy                                                                                                          | This sub-code addresses how the concept of the Blue Economy has been defined and evolved over time, shaping current policy directions.                                                                                                                                                                                                                                                                                                      |
| Establishment of the Climate Finance Working Group under the Belize National Climate Change Committee (BNCCC)                                         | This sub-code involves the creation of a working group dedicated to climate finance, which supports national climate change initiatives.                                                                                                                                                                                                                                                                                                    |
| Identification of physical and non-physical intervention areas posed by climate variability                                                           | This sub-code identifies areas (both tangible and intangible) where interventions are necessary to address challenges posed by climate variability.                                                                                                                                                                                                                                                                                         |
| National Adaptation Plans (NAPs)                                                                                                                      | This sub-code pertains to the development and implementation of National Adaptation Plans, which guide the country's response to climate change impacts.                                                                                                                                                                                                                                                                                    |
| UNFCCC policy formulation and implementation support for NAPs                                                                                         | This sub-code highlights the role of the United Nations Framework Convention on Climate Change (UNFCCC) in providing guidance and assistance to countries like Belize in formulating and implementing their National Adaptation Plans. These plans are crucial for adapting to the impacts of climate change and ensuring that national strategies are in line with international frameworks and support mechanisms provided by the UNFCCC. |
| National Development Framework and Policy Direction                                                                                                   | This sub-code relates to the overarching framework that guides national development, including strategic policy directions across sectors.                                                                                                                                                                                                                                                                                                  |

|                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                         |
|-----------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Horizon 2030 National Development Framework                                                               | This sub-code refers to a comprehensive plan that outlines Belize's vision and goals for national development by the year 2030, focusing on sustainability and resilience.                                                                                                                                                                                              |
| National Climate Resilience Investment Plan (NCRIP)                                                       | This sub-code highlights Belize's strategy for investing in infrastructure and programs that enhance the country's resilience to climate change, particularly in vulnerable sectors.                                                                                                                                                                                    |
| Water Policy                                                                                              | This sub-code covers the policies and regulations that manage and protect water resources in Belize, ensuring sustainable use and addressing challenges such as water scarcity and quality in the context of national development.                                                                                                                                      |
| National Fisheries Policy & Strategy Vision Mission and Goal                                              | This sub-code captures the vision, mission, and goals of the National Fisheries Policy & Strategy, which would include mariculture.                                                                                                                                                                                                                                     |
| National Food and Agriculture Policy advocacy for high-quality and safe products                          | This sub-code emphasizes the advocacy efforts within the National Food and Agriculture Policy to ensure that products are of high quality and safe for consumption.                                                                                                                                                                                                     |
| Policy framework for climate change adaptation in mariculture                                             | This sub-code ensures that the mariculture sector develops in a sustainable manner, balancing economic growth with environmental protection.                                                                                                                                                                                                                            |
| A National Adaptation Strategy to Address Climate Change in the Agriculture Sector in Belize              | This sub-code refers to a comprehensive strategy specifically designed to help Belize's agriculture sector, including mariculture, adapt to the impacts of climate change. It likely outlines the necessary measures, guidelines, and interventions to ensure resilience in these sectors.                                                                              |
| Belize Fisheries Act 2020                                                                                 | This sub-code pertains to the legal framework established by the Fisheries Act of 2020, which includes provisions for managing and regulating fisheries, including mariculture, in the context of climate change. This act likely incorporates climate adaptation strategies into the governance of the fisheries sector to ensure sustainable and resilient practices. |
| Policy framework for ensuring sustainable development of the mariculture sector                           | This sub-code ensures that the mariculture sector develops in a sustainable manner, balancing economic growth with environmental protection.                                                                                                                                                                                                                            |
| Policy Priority Areas and Institutional Arrangements                                                      | This sub-code identifies key areas of focus and the institutional arrangements necessary to implement policies effectively.                                                                                                                                                                                                                                             |
| Develop and promote the use of IMTA systems based on the ecosystem carrying capacity of mariculture areas | This sub-code focuses on implementing Integrated Multi-Trophic Aquaculture (IMTA) systems, which utilize the ecosystem's natural carrying capacity, ensuring environmentally sustainable mariculture practices.                                                                                                                                                         |
| Developing Regulations under the Fisheries Resources Act 2020 for Mariculture                             | This code captures the legal dimension of developing specific regulations under the Fisheries Resources Act 2020 to address the needs of the mariculture sector. It emphasizes the importance of tailored regulations to ensure effective governance and sustainable development.                                                                                       |

|                                                                                                 |                                                                                                                                                                                                                                                                                                           |
|-------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Development and Adoption of Mariculture Certification and Traceability Guidelines               | This sub-code highlights the importance of establishing certification and traceability systems for mariculture products, ensuring quality, sustainability, and market access.                                                                                                                             |
| Enforcement of Best Practice Guidelines in mariculture development                              | This emphasizes the need for strict enforcement of guidelines that define best practices in mariculture, promoting sustainable development.                                                                                                                                                               |
| Establishment of a Multi-Agency National Mariculture Task Force                                 | This involves creating a task force that includes multiple agencies to oversee and coordinate mariculture activities, ensuring alignment with national policies and sustainability goals.                                                                                                                 |
| Establishment of Mariculture Allocated Zones (MAZs) in Coastal Spatial Planning                 | This code captures the political dimension of establishing Mariculture Allocated Zones (MAZs) as part of coastal spatial planning in Belize. It emphasizes the need for policy support and coordination to prioritize mariculture activities in designated zones and minimize conflicts with other users. |
| Establishment of Mariculture Standards and Market Access Committee                              | This focuses on forming a committee responsible for setting standards and facilitating market access for mariculture products, ensuring they meet international benchmarks.                                                                                                                               |
| Institutionalized Capacity Building through Public-Private Initiatives and Government Alliances | This sub-code highlights the need for ongoing capacity building in the mariculture sector, facilitated through partnerships between public and private entities.                                                                                                                                          |
| Leasing of the Seabed and Environmental Compliance in Mariculture                               | This involves establishing clear policies for seabed leasing and ensuring environmental compliance in mariculture operations.                                                                                                                                                                             |
| Liabilities, Fines, and Penalties for Environmental Harm in Mariculture                         | This code captures the legal aspect of defining liabilities, fines, and penalties for major environmental harm or damage caused by mariculture activities. It emphasizes the need for clear legal consequences to ensure accountability and compliance with environmental regulations.                    |
| Standards assessment and extension service in mariculture                                       | This focuses on the continuous assessment of standards and the provision of extension services to support mariculture development and compliance with best practices.                                                                                                                                     |
| Political aspect of the sustainable development strategy in mariculture                         | This sub-code captures the political considerations and dynamics that influence the development and implementation of sustainable strategies in mariculture.                                                                                                                                              |
| Political commitment of National Fisheries Policy & Blue Economy Initiatives for Mariculture    | This sub-code refers to the level of political commitment to supporting initiatives under the National Fisheries Policy and Blue Economy, particularly for mariculture.                                                                                                                                   |
| Sustainable Development Definition                                                              | This sub-code provides a specific definition of sustainable development as it applies to national policy frameworks, ensuring consistency in its application.                                                                                                                                             |

|                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| The coordination with the NDC implementation plan under the Paris Agreement                                                                                        | This sub-code emphasizes the importance of coordinating national policies with the Nationally Determined Contributions (NDCs) under the Paris Agreement to meet climate goals.                                                                                                                                                                                                                                                                                                                                            |
| 2. Governance and Institutional Arrangements                                                                                                                       | This thematic code focuses on the organizational structures, roles, and frameworks essential for managing and overseeing various environmental and mariculture activities in Belize. This theme highlights the importance of coordination, leadership, and regulatory development to ensure effective governance.                                                                                                                                                                                                         |
| Advisory council for coastal zone resources management                                                                                                             | Establishes the role of advisory bodies in managing coastal resources, ensuring sustainable use and conservation.                                                                                                                                                                                                                                                                                                                                                                                                         |
| Advisory role of the Fisheries Council (does not capture seaweed)                                                                                                  | This emphasizes the need to include seaweed in the advisory scope of the Fisheries Council, which currently overlooks this aspect.                                                                                                                                                                                                                                                                                                                                                                                        |
| Establishment of an Agriculture Sector Coordination Group will ensure effective oversight and coordination of these efforts, leading to successful policy outcomes | Aims to ensure effective oversight and coordination of agricultural activities, including those impacting on mariculture.                                                                                                                                                                                                                                                                                                                                                                                                 |
| Funding for the development of legal framework for BE development (not implementation)                                                                             | Highlights the necessity of financial support for creating comprehensive legal frameworks to support Blue Economy initiatives, though these are not yet implemented.                                                                                                                                                                                                                                                                                                                                                      |
| Governance structures and frameworks impacting local policy implementation and regulatory frameworks                                                               | Addresses the influence of governance on the execution of local policies and regulatory adherence, crucial for effective management.                                                                                                                                                                                                                                                                                                                                                                                      |
| Government Prioritization of New Areas and Initiatives                                                                                                             | This code highlights the government's role in identifying and prioritizing new areas and initiatives that require focus and resources, which could include innovative approaches to marine and coastal management.                                                                                                                                                                                                                                                                                                        |
| Ministry of Blue Economy & Civil Aviation                                                                                                                          | This code highlights the role of the Ministry of Blue Economy & Civil Aviation in prioritizing new areas and initiatives related to the Blue Economy. The ministry is responsible for overseeing and promoting sustainable economic activities that rely on ocean and coastal resources, as well as managing civil aviation matters. Its focus is on integrating these sectors into national development strategies, with an emphasis on sustainability and economic growth.                                              |
| Ministry of Sustainable Development, Climate Change & Disaster Risk Management                                                                                     | : This code refers to the ministry responsible for driving initiatives related to sustainable development, climate change adaptation and mitigation, and disaster risk management. The ministry prioritizes efforts that address the impacts of climate change and enhance the country's resilience to natural disasters, while also promoting sustainable practices across various sectors. This includes integrating climate and disaster risk considerations into policy and planning processes at the national level. |
| Institutional Framework for Climate Change through the                                                                                                             | This code refers to the need for a formal institutional framework, such as a dedicated department, to manage climate                                                                                                                                                                                                                                                                                                                                                                                                      |



|                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| proposed establishment of a climate change department                     | change initiatives effectively, ensuring that climate-related policies and strategies are implemented systematically.                                                                                                                                                                                                                                                                                                                                                                                                           |
| Institutional Support and Financing                                       | This code underlines the importance of institutional backing and the provision of financial resources to support the development and sustainability of various initiatives, including those related to the Blue Economy and climate change.                                                                                                                                                                                                                                                                                     |
| MBECA & associates (ministry portfolios and E-NGOs)                       | This code refers to the collaboration between the Ministry of Blue Economy and Civil Aviation (MBECA) and various associated entities, including ministry portfolios and Environmental Non-Governmental Organizations (E-NGOs). These collaborations are essential for providing institutional support and securing financing for initiatives related to environmental sustainability, the blue economy, and aviation sectors. The partnerships with E-NGOs are particularly important for leveraging expertise, resources, and |
| PACT (Amendment) Act, 2017 (Revised 2020)                                 | This code refers to the Protected Areas Conservation Trust (PACT) Amendment Act of 2017, which was revised in 2020. PACT is a statutory body in Belize responsible for generating and allocating financial resources for the management of protected areas in Belize. The amendment and its revision are aimed at enhancing the capacity of PACT to support conservation efforts, including providing financial resources for the maintenance and development of protected areas. This act is critical for ensuring sustainable |
| Leadership and governance by MBECA, BFD, & The Nature Conservancy (TNC)   | This code focuses on the leadership roles of key organizations like the Ministry of Blue Economy and Civil Aviation (MBECA), Belize Fisheries Department (BFD), and The Nature Conservancy (TNC) in governance and policy development for marine conservation and sustainable development.                                                                                                                                                                                                                                      |
| Maritime Security and Governance                                          | This code concerns the importance of securing maritime areas and managing them effectively, including preventing illegal activities and ensuring that maritime resources are used sustainably and protected.                                                                                                                                                                                                                                                                                                                    |
| National Coast Guard Service Act (2011)                                   | The Belize National Coast Guard Service Act, Cap 131.01, ensures maritime security throughout Belize's blue space, fostering investment confidence in Blue Economy development by granting law enforcement powers and establishing a governing board for policy and operational oversight.                                                                                                                                                                                                                                      |
| Ministerial duties and governance                                         | This code refers to the responsibilities of ministers and government officials in managing and governing sectors related to the Blue Economy, ensuring that policies are enforced, and objectives are met.                                                                                                                                                                                                                                                                                                                      |
| Ensuring Belize's compliance with international environmental conventions | This code refers to the ministerial responsibility of ensuring that Belize adheres to and fulfills its obligations under various international environmental agreements and treaties. This involves aligning national policies with global standards and reporting compliance as required.                                                                                                                                                                                                                                      |
| Promotion of national pride and stewardship                               | This code highlights the role of ministers in fostering a sense of national pride and encouraging stewardship among citizens. This includes initiatives that promote the protection and sustainable use of natural resources as a matter of national identity and pride.                                                                                                                                                                                                                                                        |
| Safeguarding natural heritage                                             | This code pertains to the responsibility of ministers to protect and preserve Belize's natural heritage. This includes the conservation of biodiversity, ecosystems, and landscapes that                                                                                                                                                                                                                                                                                                                                        |

|                                                                                                                                      |                                                                                                                                                                                                                                                                                              |
|--------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                      | are of cultural, historical, and environmental significance to the country.                                                                                                                                                                                                                  |
| Port operations, including those for aquaculture export, are under government control, promoting structured oversight and governance | This code highlights the government's control over port operations, particularly those related to aquaculture exports, ensuring that there are structured oversight and regulation to support sustainable practices.                                                                         |
| Belize Port Authority Act                                                                                                            | The Belize Port Authority Act, Chapter 233, outlines the establishment, roles, and responsibilities of the Belize Port Authority, including governance, regulations, and oversight of port operations and maritime activities.                                                               |
| Proposed establishment of the Belize National Climate Change Council for improved climate change governance                          | This code suggests the creation of a national council to better govern and coordinate climate change efforts in Belize, enhancing the country's ability to respond to climate challenges.                                                                                                    |
| Proposed Monitoring and Tracking Climate Change Initiatives                                                                          | This code emphasizes the need for a system to monitor and track the progress of climate change initiatives, ensuring that efforts are effective and aligned with national goals.                                                                                                             |
| Proposed Transparency and Accountability in Climate Change Initiatives                                                               | This code advocates transparency and accountability in climate change initiatives, ensuring that actions taken are open to public scrutiny and that responsibilities are clearly defined and fulfilled.                                                                                      |
| Recommendations for the formulation of a comprehensive disaster risk finance strategy                                                | This code refers to the need for a strategy to finance disaster risk management, ensuring that Belize can effectively respond to and recover from natural disasters, which are increasingly influenced by climate change.                                                                    |
| The need for comprehensive oversight and cross cutting across sectors)                                                               | This code highlights the necessity of integrated oversight that spans multiple sectors, ensuring that policies and initiatives are well-coordinated and that sectoral silos do not hinder progress.                                                                                          |
| Accountability and compensation                                                                                                      | This refers to the need for mechanisms to ensure that those responsible for damages or losses in the sector are held accountable and that affected parties are compensated appropriately. Mechanisms for infractions and unintended harm.                                                    |
| Environmental impact                                                                                                                 | This code addresses the potential negative impacts of mariculture and related activities on the environment, emphasizing the need for monitoring and mitigation strategies. Chemical, physical, and ecological impacts on wild species and habitats, including pollution and eutrophication. |
| Escaped species                                                                                                                      | This involves concerns about non-native or farmed species escaping into the wild, which can disrupt local ecosystems and biodiversity. Impact of escaped fish or other cultured species.                                                                                                     |
| Mariculture site or location regulation                                                                                              | This code highlights the importance of regulating the sites where mariculture activities are conducted to ensure they are environmentally suitable and do not conflict with other uses. Access to suitable sites, habitat and ecosystem sensitivity, and competing uses of space.            |
| Quality control                                                                                                                      | This relates to the standards and procedures that need to be in place to maintain the quality of products from mariculture operations, ensuring they are safe and meet market requirements. Requirements demanded by target markets.                                                         |
| Resource exploitation                                                                                                                | This code addresses the sustainable use of natural resources in mariculture, ensuring that activities do not lead to over-                                                                                                                                                                   |

|                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                     | exploitation or depletion of critical resources. Sanctioned exploitation of marine resources for feed.                                                                                                                                                                                                                                                                                                                             |
| Safety concerns                                                                                                                                                     | This involves ensuring the safety of workers, communities, and the general public in relation to mariculture activities, including operational safety and the handling of potentially hazardous materials. Possible obstruction to maritime traffic.                                                                                                                                                                               |
| Species of health and biosecurity                                                                                                                                   | This code refers to the measures needed to protect the health of farmed species and prevent the spread of diseases, which is critical for maintaining a sustainable and productive mariculture sector. Health of cultured species for human consumption and disease impacts.                                                                                                                                                       |
| The need for integrated marine spatial planning (i.e. an institutional tool for SDGs)                                                                               | This code captures the essence of the political aspect of ensuring sustainable development in mariculture, emphasizing the need for integrated marine spatial planning that takes into account the diverse and potentially competing interests of different economic sectors active in the coastal zone. This involves governmental and policy efforts to regulate and harmonize these activities to achieve sustainable outcomes. |
| There are a policy and institutional framework for sustainable development in place but harmonization of regulations in seaweed mariculture has not yet taken place | This code indicates that while there is a framework for sustainable development, better harmonization of regulations across different sectors and levels of governance is needed to ensure effectiveness.                                                                                                                                                                                                                          |
| Urgent need for strong political commitment to support, follow-up, and implement the National Strategy for the Development of Statistics                            | This code underscores the necessity for political will and commitment to ensure that the National Strategy for the Development of Statistics (NSDS) is implemented effectively, supporting data-driven decision-making across sectors.                                                                                                                                                                                             |
| 3. Legal and Regulatory Frameworks                                                                                                                                  | This thematic code focuses on the legal structures and regulations necessary for effective governance, compliance, and sustainability in Belize's mariculture and environmental management sectors.                                                                                                                                                                                                                                |
| Consideration of the need for regulatory enforcement, legal compliance, and government accountability.                                                              | This sub-code emphasizes the importance of ensuring that laws and regulations are not only in place but are effectively enforced and that government entities are held accountable for their implementation.                                                                                                                                                                                                                       |
| Disaster Risk Management and Legislative Updates                                                                                                                    | This sub-code addresses the legislative updates needed to manage disaster risks effectively, highlighting the importance of modernizing laws to reflect current challenges.                                                                                                                                                                                                                                                        |
| Disaster Preparedness and Response Act                                                                                                                              | A specific legislative act focused on preparing for and responding to disasters, ensuring that the legal framework supports adequate and timely responses to natural and human-made hazards.                                                                                                                                                                                                                                       |
| Legal requirements have been approved to support hazards reduction but do not capture productive sectors such as seaweed mariculture                                | This sub-code highlights a gap in existing legislation, where current legal frameworks support hazard reduction but fail to adequately address the needs of productive sectors like seaweed mariculture, suggesting the need for more inclusive legal provisions.                                                                                                                                                                  |
| Legislative Framework for Climate Change                                                                                                                            | Focuses on the creation and implementation of laws that specifically target climate change mitigation and sustainable                                                                                                                                                                                                                                                                                                              |

|                                                                                                                                                                                 |                                                                                                                                                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| and Sustainable Development                                                                                                                                                     | development, ensuring that Belize's development is both environmentally sustainable and resilient to climate impacts.                                                                                                                                   |
| Legislative framework for fisheries resource management needs to embrace ecosystem-based approaches and focus on biodiversity and social and economic needs of fishing          | Suggests that fisheries management laws should adopt ecosystem-based management practices that balance biodiversity conservation with the social and economic needs of local communities.                                                               |
| Need to implement and enforce anti-corruption laws rigorously to build trust in government institutions and the judiciary                                                       | Stresses the importance of strong anti-corruption measures to enhance public trust in governance, particularly in sectors critical to environmental management and mariculture.                                                                         |
| Proposed enforcement and penalties for enforcement and compliance with climate change regulations                                                                               | Recommends the development and implementation of penalties to ensure compliance with climate change regulations, highlighting the need for a robust enforcement mechanism to support climate-related laws.                                              |
| 4. International and Regional Cooperation                                                                                                                                       | This thematic code focuses on Belize's involvement in global and regional frameworks and initiatives that enhance its environmental management, disaster risk reduction, and sustainable development.                                                   |
| Advocacy and International Engagement                                                                                                                                           | This sub-code highlights Belize's active participation and advocacy in international platforms, aiming to influence global environmental policies and secure international support for its sustainability goals.                                        |
| Belize involvement in multilateral agreements and initiatives aimed at sustainable development across various primary economic sectors but does not specify seaweed mariculture | Focuses on Belize's participation in international treaties, agreements, and initiatives that promote global cooperation in environmental conservation, climate change mitigation, and sustainable development.                                         |
| Harmonization and cooperation in fisheries management through arrangements or agreements                                                                                        | Emphasizes the need for coordinated efforts between Belize and other countries or regions in managing fisheries resources sustainably. This includes adopting shared best practices and regulations to protect marine biodiversity.                     |
| Involvement of multilateral and bilateral financing, along with the exploration of new funding opportunities (may include seaweed)                                              | Recognizes the importance of securing financial and technical support from international partners to fund projects related to environmental conservation, climate change adaptation, and disaster risk management.                                      |
| Regional programs for local risk management including advanced risk management techniques                                                                                       | Refers to Belize's participation in regional initiatives that aim to build local capacity for disaster risk reduction, climate adaptation, and sustainable resource management, ensuring that regional strategies are aligned with national priorities. |

|                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                               |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 5. Sector-specific Policy Integration                                                                                                                                                                         | The thematic code "Sector-specific Policy Integration" focuses on the integration and alignment of policies specifically related to the mariculture sector in Belize. The sub-codes explore various aspects necessary for effective policy implementation and development within this sector: |
| Current challenges and opportunities in Belize mariculture development                                                                                                                                        | Identifies existing obstacles and potential areas for growth in the mariculture sector, helping to shape future policy directions.                                                                                                                                                            |
| High political commitment is crucial for mobilizing resources, fostering inter-ministerial coordination, and ensuring sustained attention to statistical development especially to capture seaweed production | Emphasizes the importance of political will in driving policy integration and resource allocation, ensuring cohesive and sustained sectoral development.                                                                                                                                      |
| Integrating non-export-oriented fisheries into coastal and oceans management plans                                                                                                                            | Focuses on the inclusion of small-scale or local fisheries in broader marine management frameworks, ensuring that they are not overlooked in favor of export-driven industries.                                                                                                               |
| Integration of global best practices in mariculture policy                                                                                                                                                    | Encourages the adoption of international standards and successful strategies to enhance the sustainability and productivity of Belize's mariculture industry.                                                                                                                                 |
| Interchangeable use of sustainable mariculture, responsible mariculture, and mariculture & need to differentiate (gap)                                                                                        | Addresses the need for clear definitions and distinctions between different types of mariculture to avoid confusion and ensure accurate policy implementation.                                                                                                                                |
| Inter-Ministerial Coordination and integration of sector policies                                                                                                                                             | Highlights the need for collaboration across various government ministries to ensure that sector-specific policies are harmonized and effectively implemented.                                                                                                                                |
| Intra and inter-ministerial coordination require political leadership to foster collaboration and streamline processes                                                                                        | Stresses the importance of leadership in promoting cooperation among ministries, which is crucial for efficient policy integration.                                                                                                                                                           |
| Need to strengthen the technical capacity of the Belize Fisheries Department and Council in the governance of the seaweed sector                                                                              | Calls for capacity building within key governmental bodies to ensure they can effectively govern and support the development of the seaweed mariculture industry.                                                                                                                             |
| Policy formulation and oversight for mariculture development through stakeholder engagements                                                                                                                  | Advocates for inclusive policy-making processes that involve stakeholders at all levels, ensuring that policies are well-informed and widely supported.                                                                                                                                       |

|                                                                                                                                                              |                                                                                                                                                                                                                         |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Policy fragmentation and inefficiency in harmonization                                                                                                       | Points out issues where existing policies may be disjointed or poorly coordinated, leading to inefficiencies and challenges in implementation.                                                                          |
| Policy supports for community livelihoods in mariculture                                                                                                     | Emphasizes the importance of policies that support the livelihoods of local communities involved in mariculture, ensuring that development is both sustainable and equitable.                                           |
| The first mariculture policy in 2021                                                                                                                         | References the development of a recent policy by The Nature Conservancy (TNC) and the Belize Fisheries Department (BFD), indicating an ongoing effort to update and improve sectoral governance.                        |
| The need for cohesive policies and strategic planning for the development of the mariculture sector                                                          | Stresses the importance of a unified approach to policy and strategic planning, essential for the successful and sustainable development of the mariculture sector in Belize.                                           |
| 6. Economic and Trade Policies and Market Promotion                                                                                                          | This thematic code focuses on the policies and strategies aimed at enhancing economic growth and trade, particularly within the context of seaweed mariculture and broader agricultural sectors.                        |
| Geopolitical location and potential trade relationship with bordering nations                                                                                | his sub-code emphasizes the strategic importance of Belize's geographical position in fostering trade relationships with neighboring countries, potentially boosting economic opportunities for the mariculture sector. |
| Proposals to enhance data sharing and develop more robust and affordable agricultural insurance products for smallholder farmers but do not capture seaweed. | This sub-code highlights the need for improved data sharing mechanisms and the development of agricultural insurance products that can mitigate risks for farmers and investors in the mariculture industry.            |
| Trade and Investment Policy to attract and retain investment including in seaweed mariculture                                                                | This sub-code focuses on the policies designed to make Belize an attractive destination for investments, particularly in the seaweed mariculture sector, ensuring long-term economic growth and stability.              |
| Belize Trade and Investment Development Service Act                                                                                                          | Refers to specific legislation aimed at facilitating trade and investment, which could be leveraged to support the development and expansion of the mariculture industry.                                               |
| National Trade Policy 2019-2030                                                                                                                              | This policy outlines the long-term strategic goals for trade in Belize, including provisions that could directly impact the mariculture sector, helping to align national trade objectives with sectoral development.   |
| 7. Environmental and Resource Management                                                                                                                     | This thematic code focuses on the policies and practices that govern the sustainable use and management of natural resources, particularly in the context of mariculture and related activities.                        |
| Environmental and Natural Resource Management                                                                                                                | This sub-code covers the broad strategies and policies aimed at managing natural resources in an environmentally sustainable manner. It emphasizes the balance between resource use and conservation.                   |
| Government Ownership and Control in Land and Resource Management including seabed leasing for seaweed farms                                                  | This sub-code addresses the role of the government in owning and controlling land and other resources. It also involves specific policies regarding the leasing of seabed areas for activities like seaweed farming.    |

|                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|--------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Definition of national lands                                                                           | This further elaborates on what constitutes national lands, providing a legal framework for their management and use, especially in the context of mariculture.                                                                                                                                                                                                                                                                                                                                                   |
| Policy implementation for environmental accountability in mariculture                                  | This sub-code focuses on the enforcement of policies that hold mariculture operations accountable for their environmental impacts, ensuring that these activities are conducted sustainably.                                                                                                                                                                                                                                                                                                                      |
| Policy integration of ecosystem-based adaptation in mariculture                                        | This code addresses the political aspect of incorporating EbA measures into mariculture policies, emphasizing the role of governance and policymaking in building climate resilience and reducing local vulnerabilities. Therefore, it highlights the importance of implementing EbA measures to enhance resilience to climate change and ensure the sustainable development of the mariculture sector.                                                                                                           |
| Promoting efficient management of maritime resources and infrastructure through port limits regulation | This sub-code pertains to the management of maritime resources and infrastructure, particularly through regulations that define and enforce port limits. These regulations are crucial for maintaining order and sustainability in maritime activities, including mariculture. These sub-codes collectively emphasize the need for a structured and sustain                                                                                                                                                       |
| 8. Stakeholder Engagement and Coordination                                                             | This thematic code emphasizes the importance of involving various stakeholders in the development and implementation of mariculture policies. This theme recognizes that effective and sustainable mariculture practices require the active participation and cooperation of all relevant parties, including the government, local communities, and specific demographic groups.                                                                                                                                  |
| Commitment by the government to mitigate hazards and improve disaster response                         | This sub-code highlights the government's role in engaging stakeholders to ensure that mariculture practices are resilient to hazards and that there are effective disaster response strategies in place.                                                                                                                                                                                                                                                                                                         |
| Policy supports for gender equality in mariculture                                                     | This sub-code focuses on the need for policies that promote gender equality within the mariculture sector, ensuring that both men and women have equal opportunities and are equally represented in decision-making processes.                                                                                                                                                                                                                                                                                    |
| Stakeholder mapping and engagement in the development of mariculture policy                            | This sub-code emphasizes the importance of identifying and involving all relevant stakeholders in the policy development process for mariculture. This includes recognizing the roles of different groups and ensuring that their interests and concerns are addressed.                                                                                                                                                                                                                                           |
| The need for culturally appropriate policies and support mechanisms with indigenous groups             | This sub-code underscores the necessity of developing policies that are sensitive to the cultural practices and needs of indigenous groups, ensuring that mariculture development respects and integrates these considerations.                                                                                                                                                                                                                                                                                   |
| Use of bottom-up approach emphasizes participatory governance into strategic planning process          | This sub-code advocates for a participatory governance model, where stakeholders at all levels, particularly local communities, are actively involved in the strategic planning process for mariculture. This approach ensures that policies are not only top-down but also incorporate input from those directly affected.                                                                                                                                                                                       |
| Social                                                                                                 | Understanding the social dynamics including demographic trends, cultural attitudes, and population growth that can impact Belize Seaweed Aquaculture Development. The thematic codes under the "Social" category capture various aspects of societal considerations that influence and are influenced by mariculture and related activities. These codes emphasize the importance of understanding and integrating social dynamics into the development and implementation of mariculture policies and practices. |

|                                                                                                                          |                                                                                                                                                                                                                                                                                                                                               |
|--------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Community Engagement and Participation                                                                                | This code highlights the necessity of involving local communities in decision-making processes related to mariculture. It stresses the importance of grassroots involvement to ensure that mariculture practices align with local needs and values.                                                                                           |
| A bottom-up approach enhances social cohesion by involving citizens and local communities in the decision-making process | This sub-code highlights the significance of grassroots involvement, ensuring that decision-making processes are inclusive and reflective of community needs and values.                                                                                                                                                                      |
| Collective capacity of a community to adapt (including CbA)                                                              | This focuses on the ability of communities to collectively respond and adapt to changes or challenges, including those posed by climate change and other environmental pressures.                                                                                                                                                             |
| Community engagement, education, research and capacity building for sustainable mariculture development                  | This sub-code emphasizes the importance of educating and empowering communities through research and capacity-building initiatives to support sustainable mariculture.                                                                                                                                                                        |
| Community participation, partnerships and addressing issues on conservation and management of fishers' reactions         | This nested sub-code highlights the role of partnerships and addresses the concerns of fishers in community participation and conservation efforts.                                                                                                                                                                                           |
| Community-level development for socio-economic and ecological benefits of mariculture                                    | This underscores the focus on community development that provides both socio-economic benefits and ecological sustainability.                                                                                                                                                                                                                 |
| International and local E-NGOs involvement in technical assistance                                                       | This code reveals how E-NGOs play an important role in the Belize Fisheries Sector, providing technical assistance, capacity building, sustainable practices, and ecosystem-based management. Their collaboration enhances fisheries management effectiveness, promotes sustainable development, and aligns strategies with global standards. |
| Cultural sensitivity and inclusivity in community participation for Blue Economy initiatives                             | Ensure that all community members, regardless of background, are included in discussions and decisions related to the Blue Economy.                                                                                                                                                                                                           |
| Definition of persons as stakeholders                                                                                    | Clearly defines who the stakeholders are in the mariculture process, ensuring that all relevant parties are included in the dialogue and planning.                                                                                                                                                                                            |
| Exchange of information according to CBD                                                                                 | The Contracting Parties are required to facilitate information exchange on biological diversity conservation and sustainable use, considering developing countries' needs. This includes technical, scientific, and socio-economic research results, training programs, specialized knowledge, and indigenous technologies.                   |
| Inclusive Stakeholder engagement in mariculture and blue economy policy formulation                                      | This code reveals how Blue Economy Development Policy emphasizes collaboration among government entities, NGOs, and other stakeholders. It categorizes institutions by their role in policy formulation and impact, highlighting varying levels of influence on the Blue Economy sector's development. The                                    |



|                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                       | policy underscores the importance of stakeholder involvement at all levels to achieve effective implementation.                                                                                                                                                                                                                                                                                                                                                                                  |
| Lack of hazard awareness can affect community resilience and lead to greater social disruption during hazard events.                                                                  | Highlights the importance of preparing communities for environmental hazards to maintain social stability and resilience.                                                                                                                                                                                                                                                                                                                                                                        |
| Organizational structures within Belize's fishing communities, including fishing associations and cooperatives                                                                        | It reflects the role of local organizations in supporting community participation and managing resources effectively.                                                                                                                                                                                                                                                                                                                                                                            |
| Prioritization of community stewardship, moral norms, social norms, and public accountability                                                                                         | Encourages a sense of responsibility within communities to manage resources sustainably and hold one another accountable.                                                                                                                                                                                                                                                                                                                                                                        |
| 2. Education and Public Awareness                                                                                                                                                     | This code focuses on the need for educating the public and stakeholders about mariculture, its benefits, and potential impacts. It underscores the role of public awareness campaigns in fostering a supportive environment for sustainable mariculture practices. This includes campaigns to inform consumers and businesses about trademarks and legal protections, fostering environmental stewardship, addressing public health determinants through initiatives like the Food and Drug Act. |
| Conduct public awareness campaigns to educate consumers and businesses about the significance of trademarks and the legal protections available, especially in seaweed-based products | This sub-code emphasizes the need for educational initiatives aimed at informing consumers and businesses about the importance of trademarks and the legal frameworks that protect intellectual property.                                                                                                                                                                                                                                                                                        |
| Fostering a culture of environmental stewardship Belize Tourism Board (BTB)                                                                                                           | This sub-code highlights efforts to promote environmental awareness and responsibility, particularly by institutions like the Belize Tourism Board, to encourage sustainable practices within communities and businesses.                                                                                                                                                                                                                                                                        |
| Public health initiatives must address these social determinants of health                                                                                                            | This sub-code focuses on public health campaigns that aim to tackle the underlying social factors affecting health outcomes, such as socioeconomic status, education, and access to healthcare.                                                                                                                                                                                                                                                                                                  |
| Food and Drug Act                                                                                                                                                                     | This sub-code references the need to align public health initiatives with existing legislation, such as the Food and Drug Act, to ensure that health determinants are adequately addressed through regulatory measures.                                                                                                                                                                                                                                                                          |
| There is a need for relevant advocacy to allow for a better understanding of the use of statistics and indicators                                                                     | This sub-code underscores the importance of advocacy for statistical literacy and the proper use of data indicators in public discourse, policy-making, and decision-making processes.                                                                                                                                                                                                                                                                                                           |
| 3. Social Equity and Gender Balance                                                                                                                                                   | This code addresses the need for ensuring that mariculture practices are inclusive and equitable, providing equal                                                                                                                                                                                                                                                                                                                                                                                |

|                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                   |
|-------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                           | opportunities for all social groups, including gender balance. It aims to promote fairness in access to resources, decision-making, and benefits.                                                                                                                                                                                 |
| Gender equity as a social benefit of sustainable mariculture                                                                              | This sub-code highlights the importance of achieving gender equity as a key social outcome of sustainable mariculture practices, emphasizing how such equity can enhance the overall benefits of mariculture to society.                                                                                                          |
| Gender-Balanced Approach in Mariculture                                                                                                   | This sub-code focuses on promoting a gender-balanced approach within the mariculture industry, ensuring that both men and women have equal opportunities and representation in all aspects of mariculture activities and decision-making.                                                                                         |
| Human right approach to marine conservation participation                                                                                 | This sub-code advocates for incorporating human rights principles into marine conservation efforts, ensuring that all individuals, regardless of gender, have the right to participate equitably in conservation activities and decision-making processes.                                                                        |
| Intergenerational Equity for Positive Community Impact                                                                                    | This sub-code emphasizes the need for intergenerational equity, which involves considering the impacts of mariculture and conservation practices on future generations, ensuring that today's actions do not compromise the ability of future generations to meet their own needs and contribute positively to their communities. |
| 4. Food Security and Safety                                                                                                               | This code pertains to the role of mariculture in contributing to food security by providing a reliable source of nutrition. It also emphasizes the importance of ensuring that mariculture products meet safety standards for consumption.                                                                                        |
| Food Safety Regulations and Standards                                                                                                     | This sub-code focuses on the establishment and enforcement of regulations and standards that ensure the safety and quality of food products, preventing foodborne illnesses and protecting public health.                                                                                                                         |
| Food security through aquaculture and sustainable mariculture                                                                             | This sub-code highlights the role of aquaculture and sustainable mariculture in contributing to food security by providing a reliable source of food, particularly in regions where traditional agricultural methods may not be sufficient.                                                                                       |
| National Agriculture and Food Policy of Belize 2015 to 2030                                                                               | This sub-code references Belize's comprehensive policy framework aimed at enhancing food security and agricultural development through sustainable practices, including mariculture.                                                                                                                                              |
| HACCP guidelines are designed to prevent foodborne illnesses and ensure the safety of food products                                       | This sub-code emphasizes the importance of Hazard Analysis Critical Control Point (HACCP) guidelines in preventing foodborne illnesses by ensuring that food production processes meet rigorous safety standards.                                                                                                                 |
| Mariculture as a source of community livelihood [traditional preference] for diversified income sources and food and nutritional security | This sub-code underlines the significance of mariculture in providing a sustainable livelihood for communities, offering diversified income opportunities while enhancing food and nutritional security.                                                                                                                          |
| Preventing foodborne illnesses and ensuring that water used in agricultural and food processing practices meets safety requirement        | This sub-code addresses the need for stringent safety measures in food processing, particularly ensuring that water used in agricultural and food production meets necessary safety standards to prevent contamination and foodborne diseases.                                                                                    |
| 5. Cultural and Historical Aspects                                                                                                        | This code considers the cultural and historical context within which mariculture operates. It acknowledges the significance                                                                                                                                                                                                       |

|                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                     |
|------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                          | of preserving cultural heritage and integrating traditional knowledge into modern mariculture practices.                                                                                                                                                                                                                            |
| Cultural and community aspects of non-commercial fishing practices and community use                                                     | This sub-code explores the traditional and cultural practices related to non-commercial fishing within communities. It emphasizes the importance of these practices for cultural identity, community cohesion, and local food security, highlighting their role beyond economic activities.                                         |
| Historical understanding of mariculture for inclusive policy formulation process                                                         | This sub-code focuses on the significance of understanding the historical context of mariculture practices in a given region. By acknowledging history, policymakers can develop more inclusive and contextually relevant policies that respect and integrate traditional knowledge and practices in mariculture development.       |
| 6. Institutional Support and Capacity Building                                                                                           | This code emphasizes the importance of building the capacity of institutions to support sustainable mariculture. It includes the development of skills, knowledge, and infrastructure necessary for effective mariculture management.                                                                                               |
| Enhancing resource allocation, policy development, transparency, and public trust through social planning in National Statistical System | This sub-code emphasizes the importance of improving the allocation of resources and the development of policies within national institutions. It highlights the role of transparency and social planning in building public trust, particularly through the effective use of the National Statistical System.                      |
| Need for improved technical capacity in local insurers for contract design, monitoring, and access to reinsurance markets                | This sub-code addresses the need to strengthen the technical expertise of local insurers. It focuses on enhancing their ability to design and monitor insurance contracts, as well as improving their access to international reinsurance markets, which is crucial for the financial sustainability of the sector.                 |
| Role of Academic Institutions and Private Sector                                                                                         | This sub-code explores the contributions of academic institutions and the private sector in building institutional capacity. It highlights their involvement in research, development, and the provision of technical expertise that can support policy implementation and capacity-building efforts.                               |
| Role of ENGOs and Community-Based Organizations                                                                                          | It highlights the role of local non-governmental and community-based organizations in supporting fishing communities, which is crucial for the development and sustainability of seaweed farming within the Blue Economy framework.                                                                                                 |
| Rural well-being and training initiatives by international partners                                                                      | This sub-code focuses on the impact of international partners in promoting rural well-being through targeted training initiatives. It highlights the importance of international cooperation in providing the necessary skills and knowledge to rural communities, contributing to their overall development and capacity building. |
| 7. Safety, Security, and Social Responsibility                                                                                           | This code covers the need for ensuring the safety and security of mariculture operations, including the welfare of workers and communities. It also touches on the broader social responsibility of mariculture enterprises, ensuring they contribute positively to society.                                                        |
| Empowers citizens and police to act against criminal activities, promoting a safer community environment                                 | This sub-code focuses on initiatives that empower both citizens and law enforcement to collaborate in combating criminal activities, thereby enhancing the overall safety and security of the community.                                                                                                                            |
| Provision of safety and security of marine                                                                                               | This sub-code emphasizes the importance of safeguarding marine resources through joint efforts between various                                                                                                                                                                                                                      |

|                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                 |
|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| resources through collaborative efforts with coast guard                                        | stakeholders, including governmental and non-governmental organizations, to ensure sustainable use and protection of these resources.                                                                                                                                                                                                                                                           |
| Safety for workers and the community by allowing prompt action to prevent dangers in sea        | This sub-code addresses the need for immediate and effective responses to potential hazards in workplaces and communities, particularly those related to marine and aquaculture activities, to prevent accidents and ensure the safety of all involved.                                                                                                                                         |
| Port Authority Act                                                                              | The Belize Port Authority Act outlines the powers and responsibilities of the Ports Commissioner and port managers, including removing obstructions, managing accidents, regulating port activities, ensuring safety, and enforcing regulations. The Act also includes provisions for licensing, fees, and penalties, emphasizing safety, control, and efficient management of port operations. |
| Social responsibility and community protection including livelihoods protection                 | This sub-code highlights the role of social responsibility in protecting communities and their livelihoods. It underscores the importance of initiatives that ensure communities are safeguarded from social and economic vulnerabilities, particularly those connected to environmental and marine activities.                                                                                 |
| Worker Safety and Efficiency in Aquaculture Facilities but does not specify seaweed mariculture | This sub-code focuses on the safety and efficiency of workers in aquaculture facilities. While it does not specify seaweed farming, it generally covers the need for protocols and practices that ensure the well-being of workers in the aquaculture industry.                                                                                                                                 |
| 8. Economic and Social Policy Integration                                                       | This code highlights the need to align mariculture policies with broader economic and social policies. It aims to ensure that mariculture development is integrated into the wider socio-economic framework of the region.                                                                                                                                                                      |
| Alignment with national and international principles                                            | This code focuses on the social dimension of the guiding principles, reflecting the policy's commitment to aligning with national and international principles. It underscores the importance of ensuring that the policy is inclusive, socially responsible, and reflective of the values declared in relevant national and international frameworks.                                          |
| Centrality of Ocean Resources                                                                   | Emphasizes the importance of ocean resources as the core element of economic and social policies, ensuring that ocean-based activities are central to national development strategies.                                                                                                                                                                                                          |
| Integrating global best practices into the National Mariculture Policy                          | Focuses on adopting internationally recognized best practices within the National Mariculture Policy to enhance sustainability, efficiency, and global competitiveness.                                                                                                                                                                                                                         |
| Multi-stakeholder co-designs such as FIP+FDMM and managed access                                | Highlights the involvement of multiple stakeholders in co-designing frameworks such as Fishery Improvement Projects (FIP) and Fishery Development Models (FDM) for better resource management.                                                                                                                                                                                                  |
| Property rights and theft issue                                                                 | Addresses the challenges related to securing property rights and preventing theft, which are crucial for the stability and security of mariculture operations.                                                                                                                                                                                                                                  |
| Socio-economic dimensions and blue economy considerations                                       | Integrates socio-economic factors with blue economy principles, ensuring that mariculture policies contribute to broader economic and social objectives.                                                                                                                                                                                                                                        |
| 9. Consumer Protection and Quality Assurance                                                    | This code focuses on the importance of protecting consumers by ensuring that mariculture products meet quality standards. It emphasizes the need for robust quality assurance mechanisms to maintain consumer trust and market stability.                                                                                                                                                       |

|                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|----------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Consumer Protection Safety and Quality Assurance                                                                                       | The Bureau of Standards is tasked with protecting consumers by ensuring that products and services meet established safety and quality standards. Provides information and guidelines to consumers about standards and compliance, promoting informed choices.                                                                                                                                                                                                                                                                   |
| Technological                                                                                                                          | The technological factors captured in this thematic code encompass a wide range of issues related to the development, implementation, and management of technology within the context of the mariculture sector and broader economic activities. These factors collectively represent the technological foundation necessary for the sustainable development and management of mariculture and other related industries.                                                                                                         |
| 1. Access and Transfer of Technology                                                                                                   | Focuses on the mechanisms and policies that facilitate the sharing and adoption of new technologies, particularly for sustainable practices in mariculture.                                                                                                                                                                                                                                                                                                                                                                      |
| Access to and transfer of technology according to CBD                                                                                  | This sub-code refers to the principles and guidelines established by the Convention on Biological Diversity regarding the equitable access to and transfer of technologies that are crucial for the conservation and sustainable use of biological resources. In the context of mariculture, it highlights the importance of ensuring that developing countries and local communities have the opportunity to access and implement advanced technologies that support sustainable practices.                                     |
| Innovation and technology transfer considerations as best practices in mariculture                                                     | This sub-code focuses on the strategies and practices involved in the successful transfer and implementation of innovative technologies in mariculture. It encompasses the assessment of best practices, the adaptation of new technologies to local conditions, and the consideration of various factors that influence the effectiveness of technology transfer, such as training, capacity building, and infrastructure development. This ensures that technological advancements are not only accessible but also effective. |
| 10. Virtual and Digital Platforms for Engagement and Statistics                                                                        | Highlights the role of digital platforms in facilitating communication, data collection, and analysis, which are essential for informed decision-making and stakeholder engagement.                                                                                                                                                                                                                                                                                                                                              |
| Use of technology in these processes ensures high-quality and timely statistical outputs but is not mainstreamed in mariculture sector | The National Statistical System (NSS) of Belize is a coordinated partnership that improves statistical quality, coherence, and governance by harmonizing efforts across agencies. It emphasizes efficient data collection, analysis, dissemination, and the need for strong political commitment, resource allocation, and strategic planning to support development policies.                                                                                                                                                   |
| 2. Advanced Early Warning and Monitoring Systems                                                                                       | Involves the development and deployment of sophisticated systems to predict and monitor environmental changes, which are critical for disaster preparedness and response.                                                                                                                                                                                                                                                                                                                                                        |
| Advanced early warning technologies to the public                                                                                      | This sub-code refers to the mechanisms established under the Convention on Biological Diversity (CBD) that facilitates the access to and transfer of relevant technologies among nations. The focus is on ensuring that developing countries have access to advanced technologies to help them manage their biological resources sustainably.                                                                                                                                                                                    |
| Lack of knowledge about the importance of hazard and underutilization of technologies for hazard monitoring and                        | This sub-code identifies a gap in knowledge and utilization of technologies related to hazard monitoring and response, particularly within the context of seaweed farming. It suggests that the underuse of such technologies can lead to increased vulnerability to natural hazards, affecting both the industry and the communities reliant on it.                                                                                                                                                                             |

|                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                            |
|------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| response especially in seaweed farming                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 3. Climate-smart Technologies and Regional Climate Studies                                     | Highlights the use of innovative technologies and research efforts aimed at understanding and mitigating the impacts of climate change on marine ecosystems and mariculture.                                                                                                                                                                                                                                               |
| Advocacy for the adoption of climate-smart technologies                                        | This sub-code emphasizes the importance of promoting and encouraging the adoption of technologies that are designed to be resilient to the impacts of climate change. It involves efforts to raise awareness and persuade stakeholders—such as governments, businesses, and communities—to implement these technologies to enhance their capacity to adapt to and mitigate climate-related risks.                          |
| Regional Climate Modelling and Impact Studies                                                  | This sub-code pertains to the use of climate models that are specific to regions to study and predict the potential impacts of climate change. These studies provide crucial data and insights that can inform policymaking, adaptation strategies, and the development of climate-smart technologies. It highlights the need for localized climate data to address region-specific challenges effectively.                |
| 4. Promotion of Biotechnology and Bioprospecting                                               | Encourages the exploration and application of biotechnological advancements for improving mariculture practices, including the sustainable harvesting of marine resources.                                                                                                                                                                                                                                                 |
| Bioprospecting in advancing scientific knowledge and its application in the mariculture sector | This sub-code highlights the exploration and study of biological resources, especially in marine environments, to discover and develop new products that can be applied to mariculture. Bioprospecting is crucial for advancing scientific knowledge and technological innovations that support sustainable practices in the mariculture sector.                                                                           |
| Biotechnology definition according to CBD                                                      | This sub-code focuses on the definition and scope of biotechnology as outlined by the Convention on Biological Diversity (CBD). It addresses the legal and scientific frameworks that govern the use and development of biotechnology, particularly in relation to biodiversity conservation and sustainable use.                                                                                                          |
| Virtual Platforms for Stakeholder Engagement                                                   | This sub-code emphasizes the use of digital and virtual platforms to facilitate the engagement and collaboration of stakeholders involved in biotechnology and bioprospecting. These platforms enable broader participation, knowledge sharing, and collective decision-making processes, ensuring that various perspectives are considered in the development and application of biotechnology in the mariculture sector. |
| 5. Innovation, Research and Development (RD&I)                                                 | Emphasizes the importance of continuous research and innovation to drive technological advancements in mariculture and related sectors.                                                                                                                                                                                                                                                                                    |
| Innovation and Development through Testing and Analysis                                        | This sub-code refers to the process of fostering innovation and development in mariculture and fisheries management through rigorous testing and analysis. It emphasizes the importance of empirical data and scientific testing in driving advancements and improvements in the sector.                                                                                                                                   |
| Research and scientific research in fisheries management (including mariculture)               | This sub-code highlights the crucial role of scientific research in the effective management of fisheries and mariculture. It includes studies focused on understanding ecosystems, species behavior, and the impacts of different management practices to ensure sustainable and productive fisheries.                                                                                                                    |
| The need for research, development and innovation (RD & I) in mariculture development          | This code focuses on the technological dimension of the policy, emphasizing the importance of research, innovation, and the adoption of new technologies in advancing mariculture practices. This sub-code underscores the importance of continuous research, development, and innovation in the                                                                                                                           |

|                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                    | growth and sustainability of mariculture. It points out the necessity of investing in RD&I to address challenges, improve practices, and enhance the overall productivity and sustainability of mariculture operations.                                                                                                                                                                                                                                                                                                                                                |
| 6. Specialized Equipment and Technological Tools                                                                                   | Referring to the development and use of specialized tools and equipment that enhance efficiency and sustainability in mariculture operations.                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Constraints to Climate Change Pest Models and general environment                                                                  | This sub-code refers to the limitations and challenges in developing and applying models that predict the impacts of climate change on pests and the general environment, particularly within the context of mariculture and fisheries.                                                                                                                                                                                                                                                                                                                                |
| Encourages the use of specialized vehicles designed for specific tasks within aquaculture                                          | This sub-code highlights the promotion of using specialized vehicles that are specifically designed for tasks in aquaculture, such as transportation, harvesting, or monitoring, to improve efficiency and effectiveness in aquaculture operations.                                                                                                                                                                                                                                                                                                                    |
| Monitoring and Documentation Tools & Enhancement of Technical Capabilities                                                         | This sub-code emphasizes the importance of utilizing advanced tools for monitoring and documentation in mariculture and fisheries management. It also underscores the need for enhancing technical capabilities to ensure accurate data collection and informed decision-making.                                                                                                                                                                                                                                                                                       |
| Test-Fishing Operations for Feasibility Assessment                                                                                 | This sub-code involves the use of test-fishing operations as a means of assessing the feasibility of fishing activities. It includes evaluating the potential yield, sustainability, and environmental impact before full-scale operations are implemented.                                                                                                                                                                                                                                                                                                            |
| Use of Mobile Transceiver Units (MTUs) in Fisheries Management                                                                     | This sub-code describes the application of Mobile Transceiver Units (MTUs) in managing fisheries. These units help in tracking and monitoring fishing activities, ensuring compliance with regulations, and enhancing overall management and enforcement efforts.                                                                                                                                                                                                                                                                                                      |
| 7. Intellectual Property and Technological Infrastructure                                                                          | Addresses the legal and institutional frameworks necessary to protect technological innovations and support their deployment, including infrastructure development.                                                                                                                                                                                                                                                                                                                                                                                                    |
| Establishment and Functions of the Intellectual Property Office                                                                    | This code refers to the creation of a governmental or regulatory body responsible for managing and regulating intellectual property (IP) rights within a country or region. The primary functions of the Intellectual Property Office include overseeing the registration of trademarks, patents, and copyrights; protecting intellectual property rights; and ensuring compliance with relevant laws. This office may also play a role in educating the public and businesses about IP rights and facilitating dispute resolution.                                    |
| Invention definition                                                                                                               | This code defines what constitutes an invention within the legal framework, typically specifying the criteria an idea or creation must meet to be eligible for patent protection. In most jurisdictions, an invention must be novel, non-obvious, and useful to qualify for patent registration. This definition is important for determining whether an innovation can be legally protected as intellectual property.                                                                                                                                                 |
| Need to invest in technological infrastructure to support the trade-mark registration process and enhance enforcement capabilities | This code highlights the necessity for governments or institutions to invest in upgrading their technological systems to streamline the trademark registration process. By enhancing technological infrastructure, countries can improve efficiency, accessibility, and transparency of IP registration. Additionally, such investments help strengthen enforcement capabilities, ensuring better protection against infringement and faster resolution of trademark disputes. This is essential for creating a more robust and reliable intellectual property system. |

|                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 8. Technological Solutions for Compliance and Anti-Corruption                                                                                                                                          | Focuses on the use of technology to improve regulatory compliance and combat corruption, ensuring transparency and accountability in the sector.                                                                                                                                                                                               |
| Need to invest in technology to support the enforcement of anti-corruption laws, such as implementing digital platforms for reporting and tracking corruption cases especially in Fisheries Department | This sub-code emphasizes the importance of investing in technology to enhance the enforcement of anti-corruption laws. It includes implementing systems such as digital tracking, transparency tools, and automated processes that can help reduce corruption by ensuring accountability and traceability in various sectors.                  |
| Promotion of technological solutions for environmental compliance                                                                                                                                      | This sub-code focuses on the promotion and adoption of technological tools and systems designed to ensure environmental compliance. These solutions may include monitoring systems, data analytics, and automated reporting tools that help organizations and authorities track environmental impacts and adhere to regulations.               |
| 9. Capacity Building and Human Development                                                                                                                                                             | Involves training and education initiatives to enhance the technical skills and knowledge of individuals working in mariculture, ensuring they can effectively use and manage new technologies.                                                                                                                                                |
| Technological Empowerment for Gender Equality in Mariculture                                                                                                                                           | This code focuses on the role of technology in supporting gender equality in mariculture. It emphasizes the use of innovative technologies and training programs to empower women, enhance their skills, and ensure they have equal access to resources and opportunities.                                                                     |
| There is a need for qualified human resources and capacity building involving training and retaining skilled statisticians and data analysis and needs to capture mariculture activities               | This sub-code highlights the necessity for qualified human resources in mariculture, particularly in the areas of statistics and data analysis. It stresses the importance of training and retaining skilled personnel who can effectively manage and analyze data crucial for the development and sustainability of the mariculture industry. |

Table 9.90. PESTEL policy analysis codebook identifying how legal and policy frameworks are addressing climate and non-climatic hazards in the seaweed mariculture sector in the SIDS of Belize.

#### 9.7.2.1 Word Frequency Analysis

The word cloud analysis was conducted using a query criterion that focused on words with a minimum length of seven letters. This approach was designed to capture and highlight the more substantial and meaningful terms that frequently appeared across the dataset. The analysis revealed several key themes central to the discussions within the documents reviewed.





*Figure 9.18. Key words captured in the word cloud analysis of the policy discourse on seaweed farming: Governance, Climate, and Resource Management (Author's own elaboration).*

Key summary of word cloud: The most prominent terms, such as "management," "national," "development," "climate," "authority," "fisheries," "resources," "government," and "implementation," indicated that the discussions largely centered on governance, policy implementation, natural resource management, and climate-related issues. The frequent occurrence of terms like "national" and "government" underscored a strong focus on state-level initiatives and the significant role of governmental bodies in policymaking and execution.

Specific areas of focus emerged from terms such as "climate" and "adaptation," highlighting the emphasis on environmental concerns, particularly related to climate change and the strategies aimed at mitigating its impacts. The prominence of "fisheries" and "aquaculture" suggested a considerable focus on marine resource management, aligning with the broader context of seaweed farming and marine economic activities.

Supporting concepts were also evident in the frequent appearance of words like "vulnerable," "sustainable," "strategy," "capacity," "resources," and "coastal." These terms pointed to the ongoing discussions around vulnerability, sustainability, and the strategic management of coastal and natural resources. Additionally, the presence of terms such as "education," "monitoring," "support," and "economic" indicated that the documents also covered aspects of capacity building, monitoring mechanisms, and the economic implications of policy measures.

The broader governance and policy context was reflected in the occurrence of terms like "framework," "ministry," "section," and "necessary," which pointed to the structural and regulatory frameworks either in place or required to support various policy initiatives. The appearance of terms such as "implementation," "necessary," and "required" suggested ongoing debates about the challenges and necessities associated with effective policy execution.

Less frequent but still relevant terms like "international," "protected," "tourism," "increase," and "vulnerable" indicated that while these issues were not as prominently discussed, they

remained significant within the overall discourse. The word cloud, therefore, provided a visual summary of the most salient topics and concepts within the data, reflecting the importance of governance, environmental management, and policy implementation in the context of Belize's policy measures, particularly in relation to climate and marine resource management. This analysis offered a comprehensive understanding of the key focus areas and recurring themes in the documents reviewed.

### *Reflections note*

Reflecting on the ways the word 'seaweed' was mentioned in various policy documents and its context was important to highlight as it didn't appear in the word cloud. The Belize National Development Strategy 2022-2026 mentions seaweed in coastal area development, fish processing, and other activities, but lacks specific policies or strategic measures related to seaweed farming. The Environmental Protection Act 2020 mentions seaweed in relation to broader environmental context, including fish stocks, fisheries, and the culture of seaweed. The Mariculture Policy covers seaweed extensively, discussing its low environmental impact, economic growth, and ecological benefits. The plan also discusses seaweed cultivation trials, economic contribution, and mariculture industry, but lacks extensive strategic directions. The Ocean Economy and Trade Strategy on Belize Marine Fisheries and Seafood Processing acknowledges seaweed farming groups' activities and highlights economic opportunities in cosmetics and food consumption.

The most comprehensive mentions of seaweed are found in the Mariculture Policy, which discusses its environmental, economic, and practical aspects of farming. However, the environmental context is not detailed, and the Economic and Developmental context lacks detailed policy measures to promote seaweed farming. The Mariculture Policy stands out as the document with the most detailed focus on seaweed, including guidelines and strategies for its development.

The overall coverage percentage for seaweed across these documents is extremely low, with mentions ranging from 0.01% to 0.11%. This indicates that while seaweed is acknowledged in multiple policy areas, it is not a primary focus in most of these documents. The most significant discussions of seaweed are found within the Mariculture Policy, suggesting that specialized sector policies provide the most comprehensive treatment of seaweed-related issues.

The analysis reveals that seaweed is mentioned in several key policy documents, but its coverage is minimal. This highlights the need for greater integration and emphasis in national development strategies, environmental protection acts, and maritime economic plans. The Mariculture Policy provides the most extensive coverage, but overall, there is a significant gap in policy focus on seaweed, which could impact its development as a viable economic activity and its role in climate adaptation strategies.

The Belize National Development Strategy 2022-2026 mentions seaweed in the context of coastal area development, alongside other activities like fish processing. However, the mention is very brief and does not delve into specific policies or strategic measures related to seaweed farming. The Environmental Protection Act 2020 mentions seaweed in relation to the broader environmental context, including fish stocks, fisheries, and the culture of seaweed. The Mariculture Policy extensively mentions seaweed, covering various aspects such as its low environmental impact, its role in economic growth, and its ecological benefits. The plan discusses trials of seaweed cultivation, its economic contribution, and its role in the mariculture industry. However, the mention is relatively brief and does not provide extensive strategic directions.

The Ocean Economy and Trade Strategy on Belize Marine Fisheries and Seafood Processing acknowledges the activities of seaweed farming groups and highlights the economic opportunities that seaweed farming presents, particularly in cosmetics and food consumption. The most comprehensive mentions of seaweed are found in the Mariculture Policy, where it is discussed in relation to its environmental, economic, and practical aspects of farming.

The overall coverage percentage for seaweed across these documents is extremely low, with mentions ranging from 0.01% to 0.11%. This indicates that while seaweed is acknowledged in multiple policy areas, it is not a primary focus in most of these documents. The most significant discussions of seaweed are found within the Mariculture Policy, suggesting that specialized sector policies provide the most comprehensive treatment of seaweed-related issues.

### 9.7.2.2 Tree Map Analysis

The tree map visualization provided a graphical representation of the frequency and relative importance of various terms within the dataset. Each rectangle in the tree map corresponded to a different term, with the size of the rectangle reflecting the frequency of that term's occurrence in the analyzed documents. The figure below describes the tree map

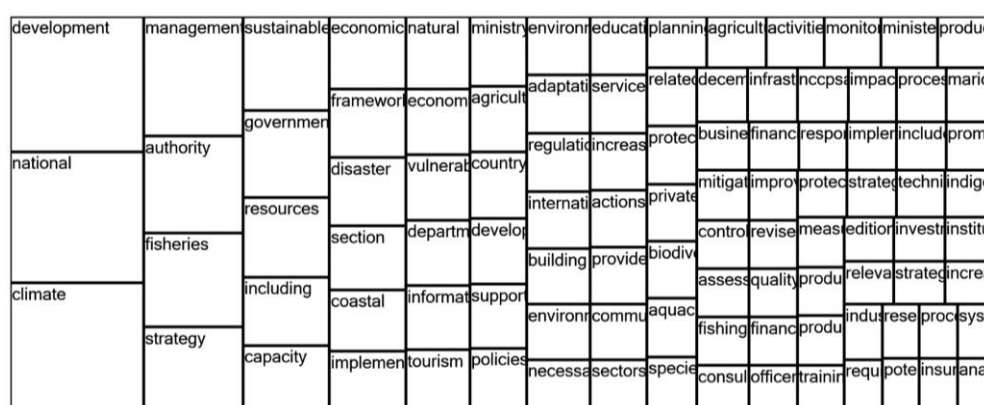


Figure 9.19. Key Themes in PESTEL policy analysis of the seaweed mariculture sector in Belize (Author's own elaboration).

Key significance of tree map: The documents frequently mentioned terms like "development," "management," "national," "climate," and "fisheries," highlighting key themes such as development strategies, governance, national policies, climate considerations, and fisheries management, highlighting the dominant themes.

The discussions included secondary themes such as sustainable, economic, natural, and government, which were discussed within the context of the dominant themes, suggesting that these themes were important but less frequent than the dominant ones.

The discussion focused on specific areas such as resources, authority, strategy, capacity, and framework, likely related to resource management, strategic planning, capacity building, and governance framework establishment within larger themes.

The terms "implementation," "section," "department," and "ministry" emphasize the crucial roles of various governmental and organizational bodies in policy implementation and resource management.

Discussions on environmental vulnerabilities, sustainability practices, and economic impacts, particularly in climate change and natural resource management, are deeply influenced by words like "disaster," "vulnerable," "adaptation," "sustainable," and "economic."

The tree map emphasized the interconnectedness of development, governance, climate, and resource management in the dataset. It highlighted central themes of national policy and strategy, especially in managing environmental challenges and fostering sustainable development. This visualization provided a quick understanding of the core areas of focus within the broader discourse.

#### *Reflection notes*

Reflecting on the tree map findings, the placement and size of the rectangle representing "seaweed" is analyzed separately as rectangle representing "seaweed" is significantly smaller compared to the dominant terms like "development," "management," "national," and "climate." This indicates that "seaweed" was mentioned far less frequently in the dataset, suggesting that while it is a part of the discourse, it is not a central theme.

Moreover, considering the terms in the tree map, they were ranked by their frequency of occurrence, "seaweed" which is in the lower quartile. This positioning implies that discussions around seaweed, though present, are less prominent compared to broader themes like governance, resource management, and climate. Furthermore, the smaller size of the "seaweed" rectangle could also reflect its role as a specific focus area within larger discussions on marine resource management or sustainable practices, rather than a standalone topic of major concern.

Given the dominance of terms like "fisheries," "resources," and "sustainable," it can be inferred that seaweed is discussed in relation to these broader themes but does not dominate the conversation. The frequency of "seaweed" mentions is likely minimal compared to other resource management topics. While seaweed is a part of the broader policy and resource management discourse, it is not a primary focus, and its discussion is likely embedded within larger themes rather than standing out on its own.

## 9.8 Appendix H (Conferences, Workshops, Professional Development Activities and Peer-Reviewed Publications (2021–2025))

This doctoral research was undertaken between October 2021 and November 2025 within the Islands and Small States Institute (ISSI), University of Malta. There was no extension to this research study under title “Sustainability of Seaweed Farming Livelihoods and Climate Change Adaptation in Small Island Developing States (SIDS): A Case Study of Belize”. The research integrated the Sustainable Livelihoods Framework (SLF) and mixed methods to assess the impacts of six livelihood capitals; human, social, natural, physical, financial, and cultural, on the productivity of red seaweed farming (*Eucheuma isiforme*, *Gracilaria crassissima* and *Kappaphycus alvarezii*) in Belize.

The following sections summarize academic, professional, and policy-oriented engagements (2021–2025), and list peer-reviewed publications produced during the programme. These activities substantively strengthened the methodological rigor, policy relevance, and dissemination of the thesis.

*Doctoral College Workshops (University of Malta, 2021–2025):*

Throughout the doctoral journey, a series of workshops were completed under the Doctoral College Training Programme, contributing to the enhancement of methodological, analytical, and academic writing skills.

| Academic Year | Semester | Course Code | Title                                                    |
|---------------|----------|-------------|----------------------------------------------------------|
| 2021/22       | Sem 2    | DOC6003     | Recognizing Stress and Developing Coping Strategies      |
| 2021/22       | Sem 2    | DOC6016     | Upgrading from M.Phil. to Ph.D. – The Transfer Phase     |
| 2021/2        | Sem 2    | DOC6017     | Managing your Doctoral Journey Successfully              |
| 2021/22       | Sem 2    | DOC6023     | Approaching Doctoral Research through Mixed Methods      |
| 2022/3        | Sem 1    | DOC6010     | An Introduction to Critical and Creative Thinking        |
| 2022/23       | Sem 1    | DOC6024     | Data Analysis with Python                                |
| 2022/3        | Sem 2    | DOC6018     | Introducing the Library Services to Doctoral Researchers |

|         |       |         |                                                                        |
|---------|-------|---------|------------------------------------------------------------------------|
| 2022/3  | Sem 2 | DOC6027 | Getting Published: The Journal Article (Humanities, Education and Law) |
| 2022/3  | Sem 2 | DOC6040 | Understanding Research Philosophy and Approaches to Theory Development |
| 2023/4  | Sem 1 | DOC6022 | Qualitative Research Methods: An Introduction                          |
| 2023/24 | Sem 1 | DOC6051 | Introduction to NVivo for Qualitative Data Analysis                    |
| 2024/25 | Sem 1 | DOC6068 | Project Management                                                     |
| 2023/4  | Sem 2 | DOC6005 | Articulating the Research Gap in the Doctoral Thesis                   |
| 2022/3  | Sem 2 | DOC6039 | The Literature Review                                                  |
| 2024/5  | Sem 2 | DOC6043 | Research Integrity and Research Ethics                                 |
| 2024/5  | Sem 2 | DOC6013 | Writing Effective CVs and Job Application Letters                      |
| 2024/5  | Sem 2 | DOC6048 | Validity and Reliability in Quantitative and Qualitative Research      |

*Table 9.91. Doctoral College Workshops Attended (2021-2025).*

*Professional Development Training and Workshops:*

The following professional training and capacity-building events supported the development of technical, policy, and management skills relevant to the doctoral research on sustainable livelihoods and climate adaptation in SIDS.

| <b>Event / Training/ Workshop</b>                                                          | <b>Location</b>     | <b>Dates</b>     | <b>Details / Focus</b>                                                                                                                | <b>Lessons Learnt / Achievements</b>                                                                                      |
|--------------------------------------------------------------------------------------------|---------------------|------------------|---------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|
| Commonwealth Blue Charter Policy Considerations When Developing a Sustainable Blue Economy | Hybrid              | 4-5 October 2021 | Training on policy frameworks supporting sustainable blue economy development across the Commonwealth.                                | Improved understanding of Blue Charter Action Groups and governance processes.                                            |
| Early Career Ocean Professionals (ECOP) Caribbean MSP Training                             | Hybrid              | 8-10 March 2022  | Hands-on training using SeaSketch, Miro, and Blue Planning in Practice (BPiP) manuals for marine spatial planning.                    | Gained practical skills in participatory spatial planning and MSP digital platforms.                                      |
| 1st Postgraduate Conference in Islands and Small States Studies                            | Valletta, Malta     | 20 June 2022     | Presented paper titled 'Systematic Literature Review on Seaweed Farming in Open Marine Environments in SIDS'.                         | Engaged in discussions regarding authorship and governance gaps in Belize's seaweed sector.                               |
| Commonwealth Youth of the Year Awards                                                      | London, UK          | 12 June 2022     | Attended official ceremony recognizing youth leaders across the Commonwealth; event hosted at St James's Palace by HRH Prince Edward. | Strengthened links with Commonwealth Secretariat officials and climate youth networks.                                    |
| Youth for Innovation and Resilience (YouthFIRE) Forum & CDB Future Leaders Network Launch  | Castries, St. Lucia | 13–15 June 2023  | Participated in regional youth leadership forum convened by the Caribbean Development Bank (CDB).                                     | Gained insight into youth-led solutions for climate and development challenges; enhanced visibility of doctoral research. |
| CDB Blue Economy Pitch Presentation: Advancing Seaweed Farming in the Caribbean            | Castries, St. Lucia | 15 June 2023     | Delivered pitch presentation highlighting the contribution of seaweed farming to the Caribbean Blue Economy.                          | Promoted awareness of Belize's seaweed mariculture and discussed regional threats to sustainable farming in SIDS.         |

|                                                                                                   |        |               |                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                            |
|---------------------------------------------------------------------------------------------------|--------|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Powering Change: Fueling a Gender-Responsive Energy Transition in Fisheries training and workshop | Hybrid | 24 March 2025 | The workshop/training focused on integrating gender equality principles into Belize's clean and just energy transition within the fisheries and aquaculture sectors, strengthening national capacity for gender-responsive policy and action planning | It successfully enhanced stakeholder understanding, collaboration, and commitment to embedding gender-responsive approaches and renewable energy solutions within the implementation of Belize's Fisheries Gender Action Plan (2022–2027). |
|---------------------------------------------------------------------------------------------------|--------|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Table 9.92. *Conferences, Seminars, and Events Attended (2021–2024).*

*Peer-Reviewed Publications:*

Throughout the doctoral programme, the researcher produced and contributed to peer-reviewed academic publications that align closely with the thematic scope of this thesis. These works extend the research's empirical and theoretical contributions by examining the intersections of seaweed aquaculture, cultural heritage, governance, and sustainable blue economy development within the context of Small Island Developing States (SIDS). The following two peer-reviewed publications were published throughout the last three years:

1. Gutierrez-Corley, Ruth., et al. (2025). Sustainable blue economy practices in seaweed farming, Belize: Cultural heritage and climate resilience in a Small Island Developing State. *Small States & Territories*, 8(1), 189–204.
2. Gutierrez-Corley, R., et al. (2023). Network governance and the role of environmental non-governmental organizations in Belize. In Briguglio, L., Bunwaree, S., Briguglio, M., & Slatter, C. (Eds), *Handbook of Civil Society and Social Movements in Small States* (pp. 46–61). Routledge eBooks.