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NUMERICAL MODELLING OF GROUNDWATER SEEPAGE AND LANDSCAPE EVOLUTION ALONG THE CANTERBURY COAST, SOUTH ISLAND, NEW ZEALAND.

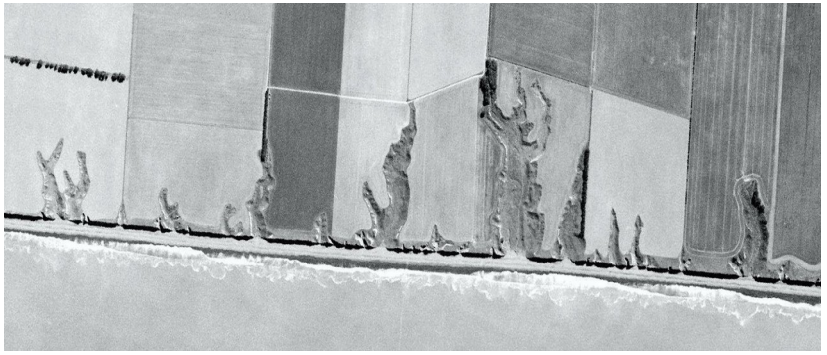
HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

GEOMAR

INTRODUCTION

- Groundwater is an important agent in landscape evolution, but the link between groundwater seepage and landscape evolution remains controversial and poorly quantified.

- Numerical modelling is a valuable tool that can allow us to better understand the evolution of landscapes by groundwater seepage.



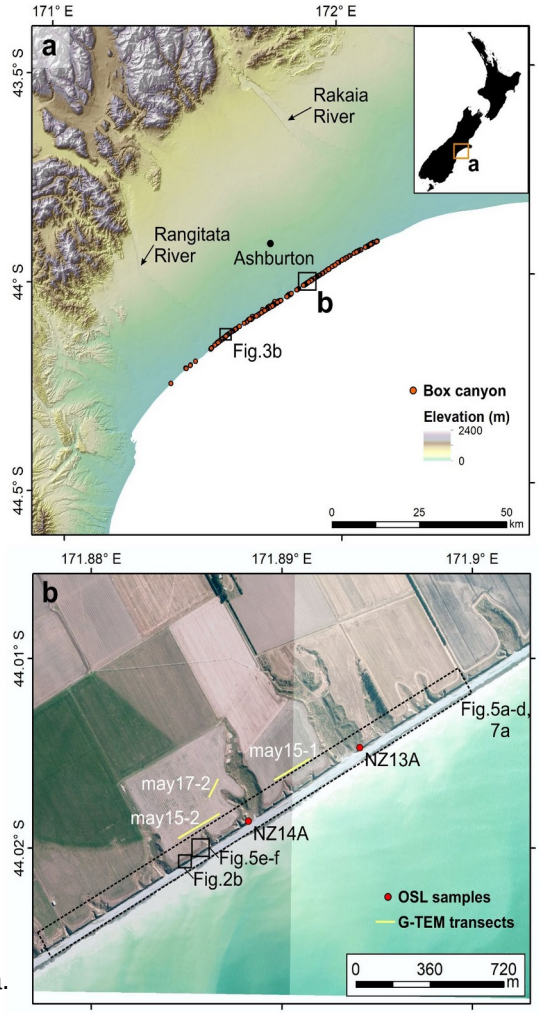
Set of gullies in the Canterbury Plains, New Zealand

Theatre-shaped valleys in the Apalachicola Bluffs and Ravines Preserve, Florida, USA

- Can we simulate the process that generate the box canyons obtaining realistic results integrating field data?
- Under what conditions do we model and obtain these geoforms?

METHOD

- We report preliminary results from a study focusing on the Canterbury coast of the South Island, New Zealand.
- The study area, located between the Ashburton and Rakaia Rivers, comprises a 20 m high coastal cliff of sandy gravels with isolated sand bodies that features a series of box canyons.
- Field visits carried out in 2017 and 2019 allowed us to characterise the geological framework of the area and monitor the formation and evolution of box canyons by groundwater seepage.



(a) Digital elevation model of the Canterbury plains, showing location of mapped box canyons. (b) Mosaic of aerial photographs of the study area.

LANDSCAPE EVOLUTION MODEL

We used Landlab (Hobley et al., 2017, Barnhart et al., 2020), an open source framework written in python, to build a LEM for the study area.

- The code includes a simplified groundwater model using the Dupuit approximation.

- The calculation of the drainage area, as well as erosion processes using diffusion and a power law functions.

$$\frac{\partial \eta}{\partial t} = -D\nabla^2\eta$$

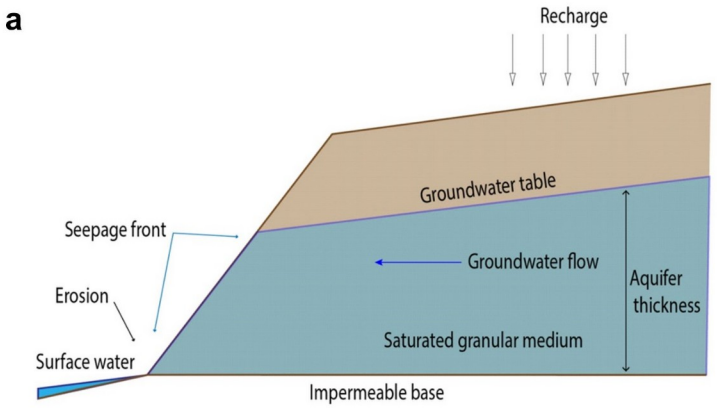
$$\frac{\partial \eta}{\partial t} = -KQ^m S^n$$

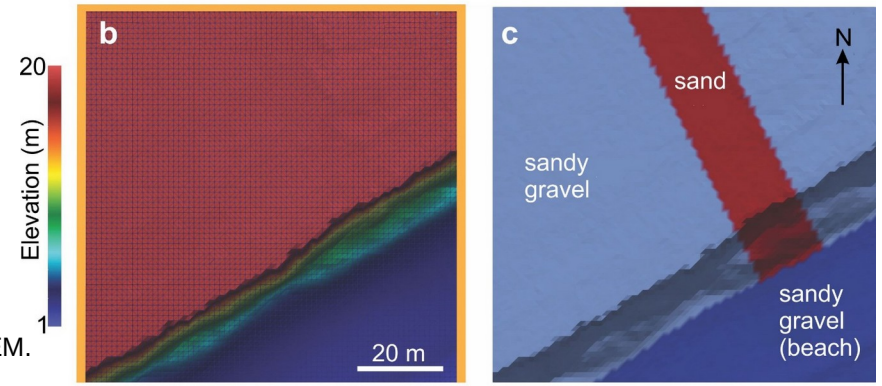
Hobley et al., 2017. Creative computing with Landlab: an open-source toolkit for building, coupling, and exploring two-dimensional numerical models of Earth-surface dynamics. Earth Surface Dynamics. Doi: 10.5194/esurf-5-21-2017.

Barnhart et al., 2020. Short communication: Landlab v2.0: A software package for Earth surface dynamics. Earth Surface Dynamics Discussions. Doi: 10.5194/esurf-2020-12.

RESULTS

- The model computes the evolution of the coastal landscape during 1 day.
- The initial topography is obtained from a 1x1m DEM and the initial conditions are derived from the fieldwork.
- Several examples have been run using different aquifer recharge rates and hydraulic conductivity.





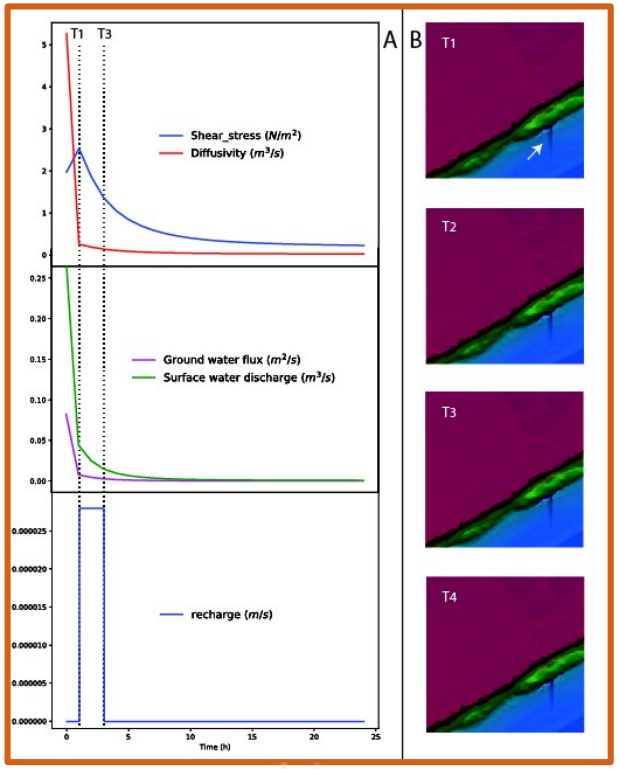
(a) Conceptual model of the LEM.

(b) Initial topography used in the LEM.

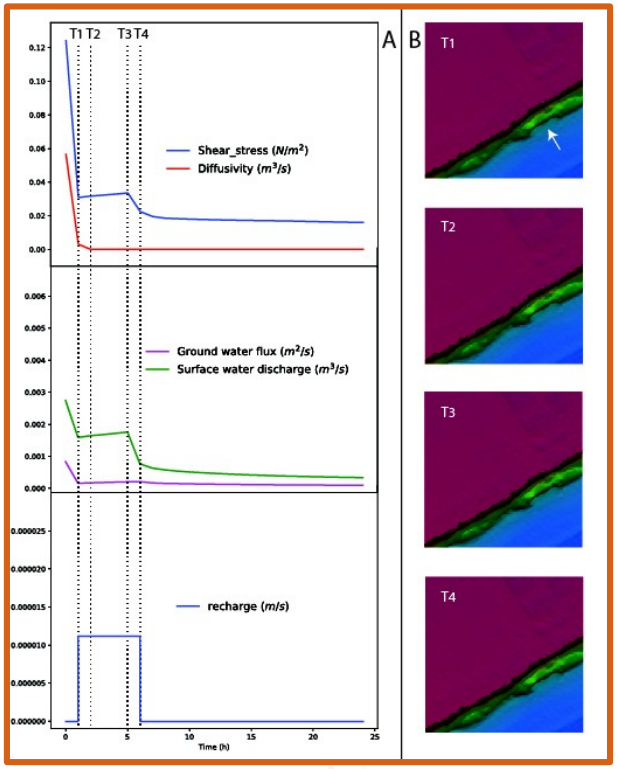
(c) Spatial distribution of sediment type in the LEM.

RESULTS

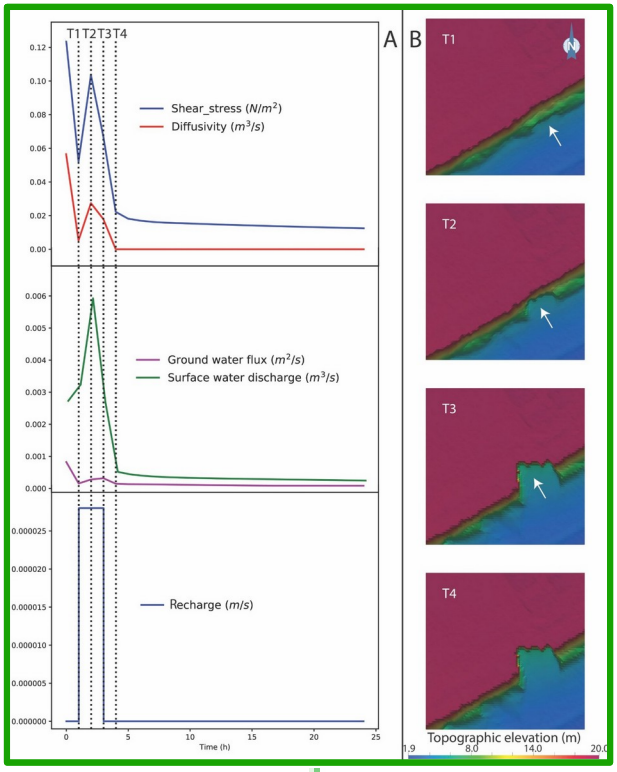
Stream power law with high intensity rainfall scenario.



Linear diffusion with low intensity rainfall scenario.



Linear diffusion with high intensity rainfall scenario.



Sections A show the evolution curves of the maximum value of the main parameters.
Sections B show the topographic evolution during the first 4 hours. White arrow denotes the direction of erosion.

CONCLUSIONS

- Can we simulate the process that generate the box canyons obtaining realistic results integrating field data?
  Yes, we can, and we have to observe:

  The stream power law is not a good approximation,
  instead a diffusion model fits better to the real morphology.

- Under what conditions do we model and obtain these geoforms?
- The main conditions are:

  The higher permeability of the sand unit, in comparison to the surrounding sandy gravel, facilitates the erosion in this area.

  The erosion process needs a rapid increase of water table. High intensity storms allow this increase and then the sandy sediments are eroded.

THANK YOU FOR YOUR ATTENTION

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