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Numerical modelling of groundwater seepage and landscape evolution along the Canterbury coast, South Island, New Zealand

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Groundwater has been implicated as an important geomorphic agent in landscape evolution. The link between groundwater seepage and landscape evolution remains controversial and poorly quantified, however. Groundwater weathering and erosion processes have not been quantified in terms of mechanisms, rates or resulting morphologies. Experimental and numerical analyses of these processes have been based on simplistic assumptions about flow processes and hydraulic characteristics. There is also a paucity of process-based observations and detailed instrumental studies of seepage erosion and weathering due to the long timescales involved and the complexity of the process. Numerical modelling, in particular Landscape Evolution Modelling (LEM), is a valuable tool that can allow us to better understand the spatial and temporal evolution of landscapes by groundwater seepage, particularly when integrated with field data.

Here 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. We used Landlab, 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.

The model computes the evolution of the coastal landscape during 1 year. 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. The results suggest that the factor that controls the inception erosion is the spatial variability in permeability and initial topography, whereas the evolution of the canyon is controlled by the seepage flow, which depends on the hydraulic conductivity and the erosivity of the sediments.