Ecohydrology and lithological controls on ephemeral catchments landscape evolution

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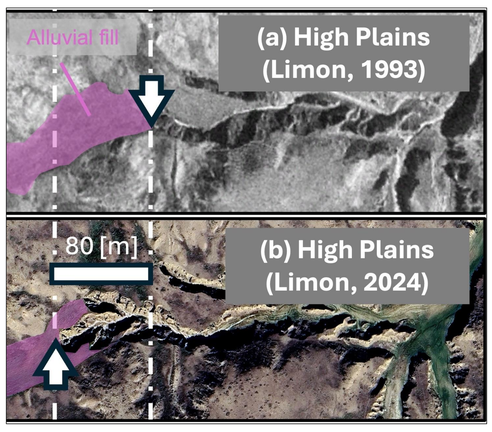
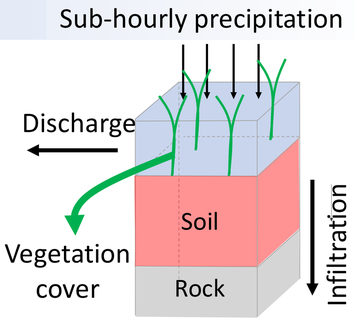
Motivation and modeling approach

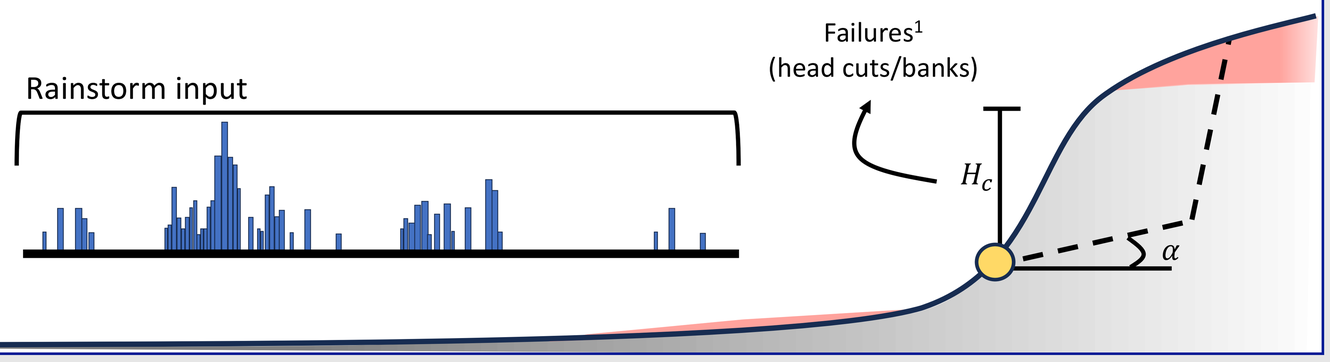
Changes in the sediment budget of low-order ephemeral catchments are among the fastest observed on Earth, with critical impacts on ecosystems and societies sustainability. Understanding drivers for changes in the sediment budget is, however, a long-lasting challenge: ephemeral catchments are greatly impacted by fine-scale and episodic erosion-triggered climatic events that are hard to observe and computationally complex over >decades.



Using new Landlab-based tools, here, we present a set of catchment-scale landscape evolution numerical experiments designed according to field observations and projected climate records for the end of the 21st century over the High Plains (CO).

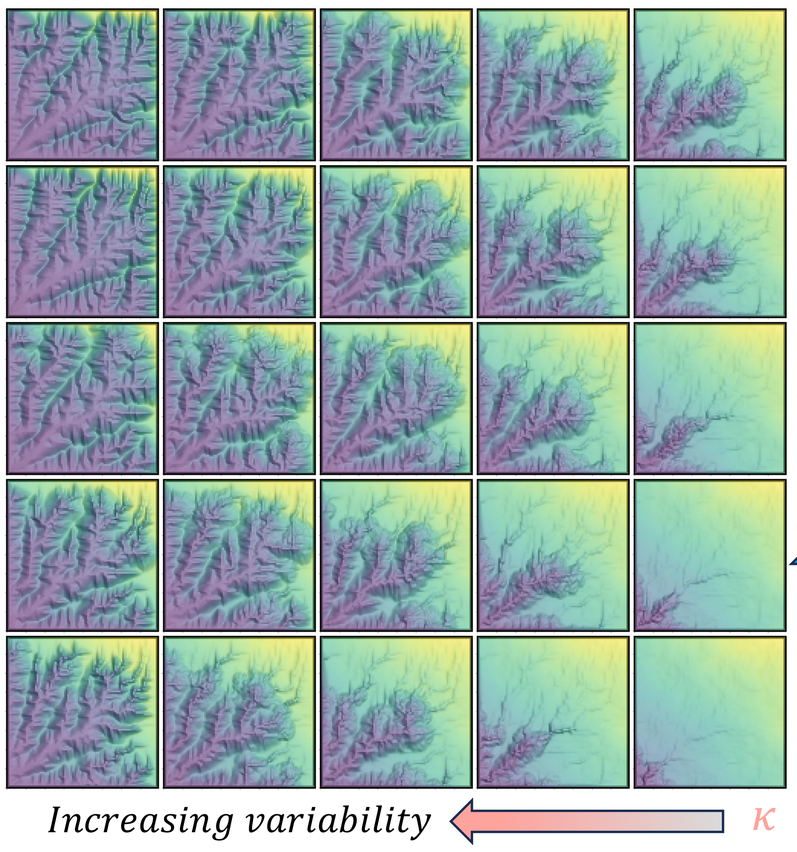
We develop a catchment-scale landscape evolution model with an explicit representation of storm-scale hydrology. The model distinguishes between a top layer (soil) that overlies a lower layer with a constant grain size distribution (representing cohesive soil or ”bedrock”). The topography is updated according to: (1) sediment transport by diffusion processes, (2) sediment transport (grain size-dependent) and incision by overland flow, and (3) headcuts/bank failures.





Earthcasting: projecting erosion and topography for the end-of-21-century (and beyond)

Erosion and landscape evolution experiments driven by 500-year-long stochastic rainfall records indicate that changes in the Weibull shape parameter (κ) could shift erosion rate and topography in the opposite direction to total rainfall.

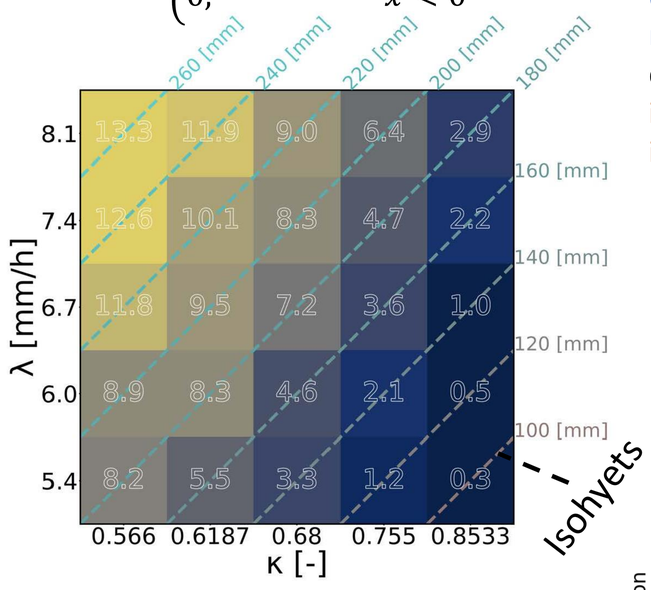


Long-term rainfall records were simulated using Weibull distribution:

$\kappa = shape$

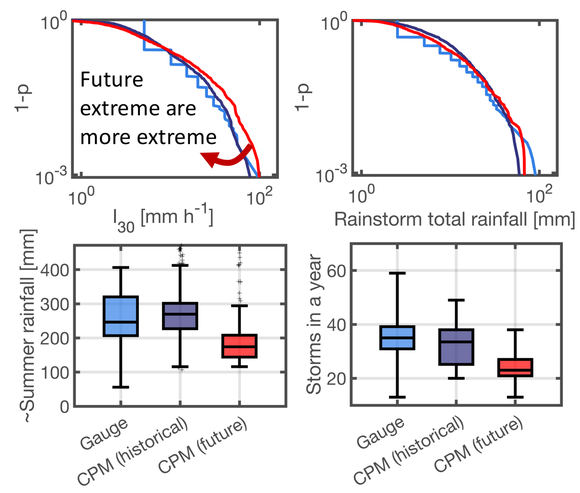
$\lambda = scale$

$$F(X) = \begin{cases} \left(1 - e^{\left(-\frac{x}{\lambda}\right)^{\kappa}}\right), & x \geq 0 \\ 0, & x < 0 \end{cases}$$

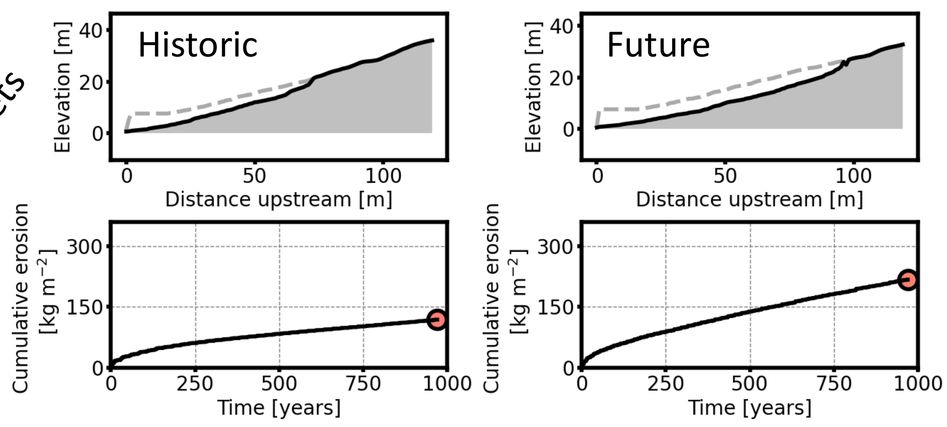


Check out our recent paper focusing on the role of changes in sub-daily rainfall distribution

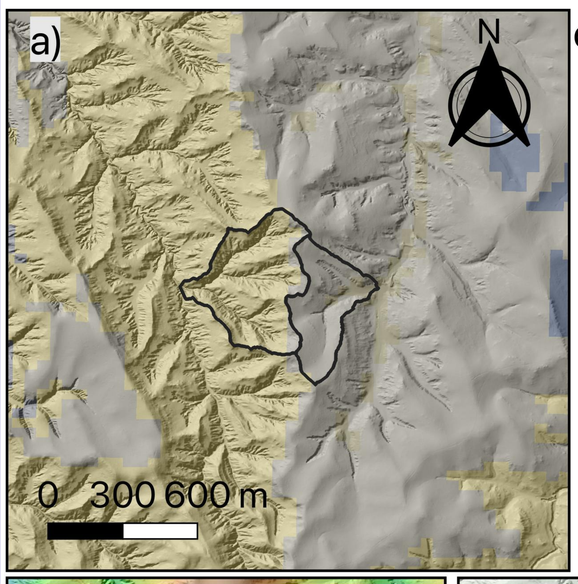
High-resolution climate projections[2] over the high plains predict contradictory precipitation trends: decreasing annual rainfall while short-duration maximal intensities are increasing.

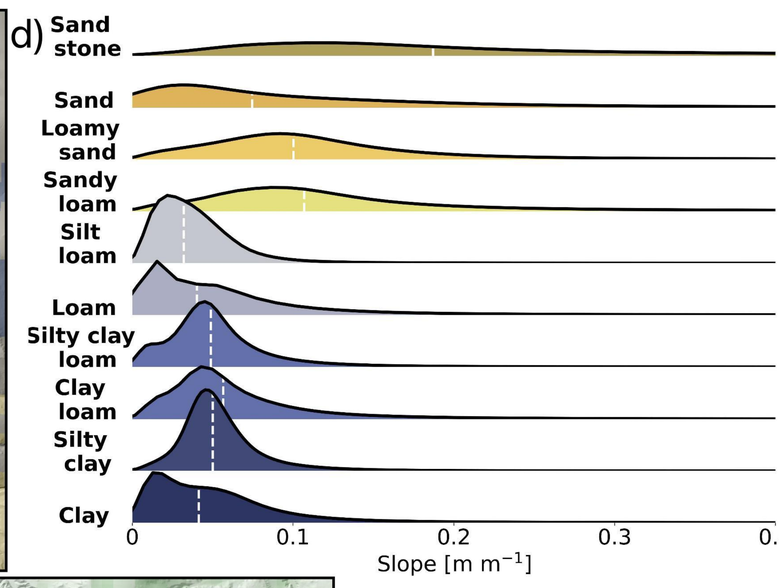


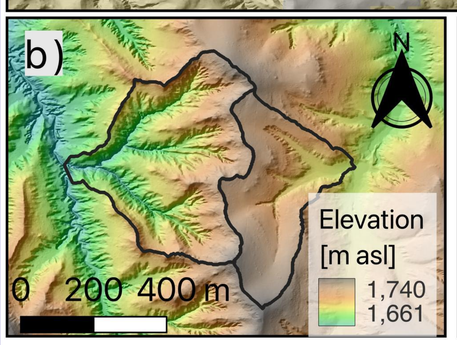
Under the future scenario, erosion increases, and gully headcut retreat rate is faster relative to the historic scenario

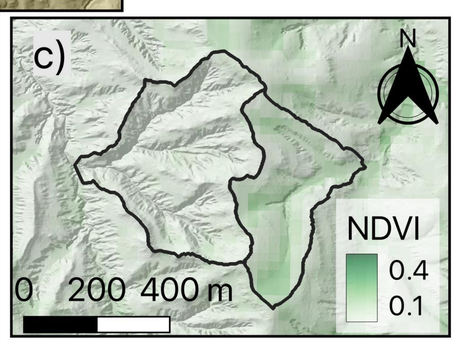


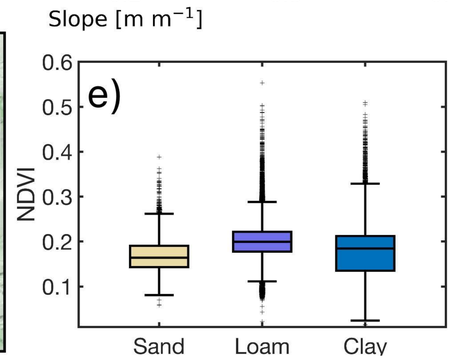
Ecohydrology and lithological controls: Hints from the High Plains (CO, USA)











Topographic and vegetation data from a study site in the High Plains (CO) may indicate soil texture-vegetation-topography links. Systematically, sand-rich catchments are associated with steeper slopes while also being associated with more pronounced head cuts and failures (resulting in sub-vertical ‘cliffs’) relative to loam and clay-rich catchments (panels a, b, and c). Loam and clay-rich catchments are also characterized by higher seasonal vegetation cover as revealed by NDVI maps (panels c and e).

We conduct 1000-year-long landscape evolution experiments with and without a (grid) node-based vegetation representation. The existence of vegetation results in a caprock-like effect that promotes the formation of un-dissected plateaus with distinct headcuts. Without the explicit representation of vegetation, channel density and erosion rate are higher.

Main conclusions

- Changes in the sub-daily rainfall distribution tail can shift landscape evolution in the opposite direction of changes in total rainfall
- A contradictory rainfall trend is predicted over the High Plains (CO) and is expected to increase the erosion rate
- The existence of vegetation induces a caprock-like effect, which preserves undissected plateaus above distinct channel headcuts

Future work and acknowledgments

We currently working on upscaling our numerical experiments to Holocene-scale time scales. We thank Victor Gensini for the help with the climate model data sets and Eric Hutton for the help with model development.

1. Densmore, A. L., Ellis, M. A., & Anderson, R. S. (1998). Landsliding and the evolution of normal-fault-bounded mountains. *Journal of geophysical research: solid earth*, *103*(B7), 15203-15219.
2. Gensini, V. A., Haberlie, A. M., & Ashley, W. S. (2023). Convection-permitting simulations of historical and possible future climate over the contiguous United States. *Climate Dynamics*, *60*(1), 109-126.

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