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The effects of vegetation and climate change on catchment erosion over millennial time scales: Insights from coupled dynamic vegetation and landscape evolution models

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Recent studies hypothesize that vegetation and the morphology of landscapes are strongly coupled. On a small scale, plants influence the erosivity of soil and sediments and therefore systematically impact catchment erosion and topography. Previous landscape evolution modeling studies primarily focus on changes in fluvial and hillslope erosion due to variations in climate and tectonics, without explicit consideration of vegetation effects. In this study, we complement previous work by investigating the effects of vegetation and vegetation change on hillslope and fluvial processes by combining LPJ-GUESS, a dynamic global vegetation model, with a modified version of the Landlab surface process model. The LandLab model was extended to account for vegetation-dependent sediment fluxes for both hillslope and detachment-limited fluvial erosion. The models are coupled by using predicted changes in surface vegetation from LPJ-GUESS for different climate scenarios as input for vegetation dependent erosional coefficients in Landlab.

Simulations were conducted with the general climate and vegetation conditions representative between 25° and 40°S along the Coastal Cordillera of Chile. This region is the focus of the EarthShape research program (www.earthshape.net). These areas present a natural climatic and associated vegetation gradient that ranges from hyper-arid (Atacama desert) to humid-temperate conditions without a dry season and pristine temperate Araucaria forest. All study areas considered have a similar and uniform granite substrate, which minimizes lithologic variations and their effect on catchment erosion.

Simulations are in progress that were designed to independently determine the climatic or vegetation controls on topography and erosion histories over the last ~21 kyr.

Our preliminary findings suggest that an increase in the surface vegetation results in a modulation of the mean hillslope angle and the average drainage density. In addition, we find that a decrease in surface vegetation density within a landscape can act as a trigger for sudden pulses of erosion, leading towards a new equilibrium topography. Our study suggests that vegetation changes (e.g. from the Last Glacial Maximum to present) act as a main agent of perturbing topographic equilibria. Reducing surface vegetation increases erosional efficiency and therefore sediment transport until a new stable state is reached.