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Influence of oscillating vegetation cover, precipitation, and sediment transport on topography: Insights from a landscape evolution model

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Erosion and sediment transport in river catchments depend significantly on tectonics, climate and associated vegetation-cover. In this study, we used a numerical modelling approach to quantify the effects of temporal variations in precipitation rates and vegetation-cover over different uplift rates (0.05 mm a^{-1}, 0.1 mm a^{-1}, 0.2 mm a^{-1}) and periodicities (23 kyr, 41 kyr and 100 kyr) of climate and associated vegetation-cover oscillations on erosion, sediment transport and deposition at catchment scale. Landlab, a landscape evolution modelling toolkit was modified to incorporate surface vegetation-cover dependent hillslope and coupled detachment-transport limited fluvial processes, weathering and soil production. The model was applied to (two) sites in the Coastal Chilean Cordillera namely Pan de Acuzar (~26), and La Campana (~33). These sites show a steep gradient in climate and vegetation density from arid climate and sparse vegetation density in northern latitudes to wetter temperate climate and abundant vegetation in the south, with granitic bedrock. The model simulations were run for 15 Myr to create steady-state topographies for both model domains. The sensitivity of these landscapes to changing climate and surface vegetation-cover was analyzed for 3 Myr for five transient model scenarios: (1) oscillating precipitation and constant vegetation cover, (2) constant precipitation and oscillating vegetation cover, (3) coupled oscillations in precipitation and vegetation cover, (4) coupled oscillations in precipitation and vegetation cover with variable periodicities, (5) coupled oscillations in precipitation and vegetation cover with variable rock uplift rates. The results suggest that erosion and sediment transport in densely vegetated landscapes are dominated by changes in precipitation, rather than vegetation-cover change in the southern study area (La Campana), as a result of higher amplitude of precipitation change i.e., 460 mm. Arid (northern) and sparsely vegetated landscapes are dominated by changes in vegetation density rather than precipitation, explained by higher erosion rates in periods with no surface vegetation-cover. Coupled oscillations in climate and vegetation cover suggested dampened influence of transient forcing on climate or vegetation-cover. The influence of periodicity of climate oscillations is significantly pronounced for shorter period (23 kyr oscillations) in terms of erosion rates. Results from different uplift rates suggested a positive linear relationship of topographic elevation and slope, erosion and sediment transport. However, sediment thickness decreases with increasing uplift rates, attributed to higher sediment flux on hillslopes due to linear dependence of slope on rock uplift rates. These results broadly demonstrate the implications of long term climate change with associated vegetation density on

geomorphic processes shaping the topography.