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The convexity of carbonate hillslopes: the influence of climate, chemical weathering and dust flux

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Convex soil-covered hillslopes are ubiquitous in various tectonic and climatic settings and are often modeled based on a mass balance relating hillslope convexity to regolith transport and soil production. In order to account for chemical weathering of carbonate rocks and dust input to the regolith, two fluxes that are commonly neglected in settings with silicate-dominated bedrock, we modify this mass balance.

We studied 7 study sites in carbonate rocks across an Eastern Mediterranean gradient in the mean annual rainfall (250 to 900 mm yr^{-1}) and dust flux (150 to 40 g m^{-2} yr^{-1}). Combining cosmogenic ^{36}Cl-derived hilltops denudation rates with an estimate of the regolith chemical depletion and dust fraction based on immobile elements, we predict the hillslope curvature and compare our predictions with observations based on high-resolution airborne LiDAR.

Our results demonstrate that soft carbonates (chalk) experience faster denudation rates relative to resistant dolo-limestone. However, the harder carbonates are more prone to chemical weathering, which systematically constitutes around half of their total denudation. Soil production rates exhibit a humped dependency on soil thickness, with an apparent maximum at a depth of 8-16 cm.

The observed hillslope curvature vary as function of rainfall and dust flux with a minimum at sub-humid sites with intermediate rainfall of 500-600 mm/yr. The predicted curvature based on our new mass balance is not far from the observed curvature, illustrating the prominent effects of dust flux and chemical weathering on hillslope morphology. Our model also implies that drier sites in the south probably experienced a more complex history of regolith production due dust flux fluctuations.

By incorporating dust flux and chemical weathering to the classic hillslope evolution model we identify a complex relation between hillslope curvature, soil production, and climate. These two fluxes are not unique to carbonate bedrock and should be incorporated in hillslope evolution models.