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Insensitivity of the threshold hillslope angle for shallow landsliding to climate

Jeffrey Prancevic (1,2), Michael Lamb (2), and James Kirchner (1)

(1) Department of Environmental Systems Science, ETH Zurich, Zurich, CH, (2) Division of Geological and Planetary Sciences, Caltech, Pasadena, CA, USA

Shallow landslides are typically thought to affect hillslope topographic form by setting a maximum hillslope gradient through the onset of landsliding. This mechanism has been used to explain observations of consistent modal hillslopes that cluster around values of 30° to 35° in steep landscapes globally, despite wide variability of climate, erosion rate, and soil characteristics. However, landslide initiation is not limited to this narrow range of hillslope gradients and can occur over a range that spans at least the saturated angle of repose (∼25°) to the dry angle of repose (∼45°). Within this range, 1-D slope stability models predict that the minimum slope required for landslide initiation depends on soil properties and typical subsurface flow rates. To explore the connection between the critical gradient for landslide initiation and subsurface flow rates, we use a series of laboratory experiments to measure the flow required to initiate landslides over a wide range of topographic gradients and sediment sizes. Contrary to 1-D slope stability models, we find that topographic gradient has little effect on the critical flow rate required to initiate experimental landslides at gradients between the saturated and dry angles of repose. These data suggest that shallow landslides triggered by subsurface flow may not favor any particular gradient and could give rise to a distribution of hillslope gradients that does not reflect landslide frequency, climate, or erosion rate. In contrast, in landscapes where subsurface flow rates are not sufficient to initiate landslides below the dry angle of repose, hillslopes may tend strongly toward that limiting gradient. On such stable hillslopes, the distribution of hillslope gradients will be strongly influenced by the dry bulk friction angle and may also be relatively insensitive to climate or erosion rate.