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Coupling scale-dependent slope stability and fractal analysis of topography for the investigation of landslide size distributions

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We investigate the physics laying behind landslide size distributions, by coupling slope stability analysis and scale-sensitive fractal analysis of topography within a probabilistic approach. Slope stability analyses have been performed under ideal conditions, in order to highlight the control of slope angle, friction angle, and cohesion on the size distribution of landslides. We demonstrate that, for a given slope angle, cohesion exerts a primary control on both the depth and the length of landslides: the larger the cohesion, the deeper and longer the landslide. As a consequence, the landslide size distribution in cohesive materials is limited toward the smaller size. Scale-sensitive fractal analysis of topography have been performed by using the patchwork method, by applying triangular patches to virtually tile the topographic surface. The fractal behaviour of the topography is modelled by decreasing triangle sizes (i.e., scale of measurement), thus replicating the surface more and more precisely. We apply the patchwork method to study the fractal behaviour of two topographic datasets from Avisio river Catchment, Trento Province (Italy): an interpolated 10x10 m DTM and a Lidar 2x2 m DTM. The interpolated DTM shows a fractal behaviour in a range of area scale between 10-4 and 10-6 sqm. For smaller scale, we observe a rollover that is caused by artificial smoothing of topographic data due to interpolation algorithms. The Lidar DTM shows a fractal behaviour between 10-2 and 10-6. For smaller scales, the rollover seems to be related to a transition from a landscape composed of ridges and valleys to one composed of relatively smooth hillslopes. Results of slope stability analyses over idealized cases and topographic analysis have been used to derive a synthetic landslide size distributions, by applying few simplifying assumptions and a probabilistic approach. As a result, we show that: (1) the landslide size distribution of non cohesive materials does not show a rollover for smaller landslides; (2) the landslide size distributions of cohesive materials are limited for smaller scales, showing a slight rollover; (3) by combining cohesive materials with different properties (i.e., friction angle and cohesion) it is possible to replicate the rollover that have been observed in the actual landslide inventory. Nonetheless, the slope (i.e., power exponent) of synthetic inventories differs from the slope of actual inventory, thus suggesting that part of the physics is not fully explained by our simple model considering only a few association of material and slope characteristics.