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Effects of Spatial Variability of Soil Properties on the Triggering of Rainfall-Induced Shallow Landslides

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Naturally-occurring spatial variations in soil properties (e.g., soil depth, moisture, and texture) affect key hydrological processes and potentially the mechanical response of soil to hydromechanical loading (relative to the commonly-assumed uniform soil mantle). We quantified the effects of soil spatial variability on the triggering of rainfall-induced shallow landslides at the hillslope- and catchment-scales, using a physically-based landslide triggering model that considers interacting soil columns with mechanical strength thresholds (represented by the Fiber Bundle Model). The spatial variations in soil properties are represented as Gaussian random distributions and the level of variation is characterized by the coefficient of variation and correlation lengths of soil properties (i.e. soil depth, soil texture and initial water content in this study). The impacts of these spatial variations on landslide triggering characteristics were measured by comparing the times to triggering and landslide volumes for heterogeneous soil properties and homogeneous cases. Results at hillslope scale indicate that for spatial variations of an individual property (without cross correlation), the increasing of coefficient of variation introduces weak spots where mechanical damage is accelerated and leads to earlier onset of landslide triggering and smaller volumes. Increasing spatial correlation length of soil texture and initial water content also induces early landslide triggering and small released volumes due to the transition of failure mode from brittle to ductile failure. In contrast, increasing spatial correlation length of soil depth "reduces" local steepness and postpones landslide triggering. Cross-correlated soil properties generally promote landslide initiation, but depending on the internal structure of spatial distribution of each soil property, landslide triggering may be reduced. The effects of cross-correlation between initial water content and soil texture were investigated in detail at the catchment scale by incorporating correlations of both variables with topography. Results indicate that the internal structure of the spatial distribution of each soil property together with their interplays determine the overall performance of the coupled spatial variability. This study emphasizes the importance of both the randomness and spatial structure of soil properties on landslide triggering and characteristics.