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Emergence of power law for frequency-magnitude statistics of shallow landslides based on Self-Organized Criticality hydro-mechanical model

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Inventories of shallow landslides triggered by prolonged rainfall events often exhibit a power-law relationship between landslide size and frequency indicating that local perturbations may trigger a landslide of any size. Power-law relationships are characteristics of Self-Organized Critically (SOC) systems consisting of many interacting mechanical elements with local load thresholds. We explore analogy between hydrologic triggering of landslides and SOC by discretizing hillslopes into mechanically interacting soil columns with well-defined hydro-mechanical properties. During heavy rainfall, soil weight increases while the mechanical strength of soil columns decreases reducing shear resistance to the point of failure. The model considered different loading scenarios and resulting failure patterns that culminate in a landslide initiated by fluidized soil columns in response to downslope compressive stresses in excess of internal soil strength. The resulting stress redistribution may initiate failure in neighboring soil columns and landslides larger than 1000 m3 could be triggered. The frequency/magnitude distribution of simulated landslides followed a power-law with absolute values of exponent between 1.0 and 2.5, depending on soil type and soil depth distribution. These values are in agreement with reported landslide inventories, but differ from pure SOC-systems. These findings are compared with other measurements and model approaches resulting in power-law relations where the mechanics between elements and associated energy dissipation affect the deviation from purely SOC behavior resulting in exponents larger than 1.0.