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Precursor events and self-organization leading to landslide triggering

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Hillslopes often consist of many interacting soil and land-cover elements differing in hydraulic properties and mechanical strength. Intense rainfall events may result in heterogeneous distribution of hydrologic loading and internal weakening leading to local failure and stress redistribution to neighboring intact units. For certain spatial distributions of hydro-mechanical properties and timing of local failure events, ‘local’ failure may propagate across the entire system culminating in landslide release (a ‘global’ failure). Such ‘global’ event is often preceded by numerous small precursor events (local failures) that theoretically may contain statistical information regarding imminent ‘global’ failure and thus could provide certain early warning.

We model the system and precursor events by combining concepts of Self-Organized Criticality (SOC) and Fiber Bundle Models (FBM) in a physically-based hydro-mechanical framework. The model consists of hexagonal soil columns connected by fiber bundles at their base and between adjacent elements. Fiber bundles represent mechanical bonds made of numerous connections (fibers) representing friction, roots, cementing agents, water bridges and alike that impart soil strength. Hydrological pathways and load distribution are simulated enabling updating of stresses on fiber bundles. When a bundle fails at element base, stress is redistributed to adjacent connected elements which may initiate a cascade of failures similar to other SOC models (e.g. sand pile model). Increasing hydro-mechanical loads during a rainfall event results in gradual small local fiber failures whose statistics follow a power-law with exponent depending on proximity to global failure. Such state-dependent precursor event statistics could provide a physical basis for field monitoring networks for early warning and hazard prediction. Additionally, the SOC concepts provide a simple framework for landslide susceptibility mapping in space and time and may provide input for subsequent debris flow routing models.