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Modeling the roles of damage accumulation and mechanical healing on rainfall-induced landslides

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The abrupt release of rainfall-induced shallow landslides is preceded by local failures that may abruptly coalesce and form a continuous failure plane within a hillslope. The mechanical status of hillslopes reflects a competition between the extent of severity of accumulated local damage during prior rainfall events and the rates of mechanically healing (i.e. regaining of strength) by closure of micro-cracks, regrowth of roots, etc. The interplay of these processes affects the initial conditions for landslide modeling and shapes potential failure patterns during future rainfall events. We incorporated these competing mechanical processes in a hydro-mechanical landslide triggering model subjected to a sequence of rainfall scenarios. The model employs the Fiber Bundle Model (FBM) with bonds (fiber bundle) with prescribed threshold linking adjacent soil columns and soil to bedrock. Prior damage was represented by a fraction of broken fibers during previous rainfall events, and the healing of broken fibers was described by strength regaining models for soil and roots at different characteristic time scales. Results show that prior damage and healing introduce highly nonlinear response to landslide triggering. For small prior damage, mechanical bonds at soil-bedrock interface may fail early in next rainfall event but lead to small perturbations onto lateral bonds without triggering a landslide. For more severe damage weakening lateral bonds, excess load due to failure at soil-bedrock interface accumulates at downslope soil columns resulting in early soil failure with patterns strongly correlated with prior damage distribution. Increasing prior damage over the hillslope decreases the volume of first landslide and prolongs the time needed to trigger the second landslide due to mechanical relaxation of the system. The mechanical healing of fibers diminishes effects of prior damage on the time of failure, and shortens waiting time between the first and second landslides. These findings highlight the need to improve definition of initial conditions and the shortcomings of assuming pristine hillslopes.