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Effects of tree roots on shallow landslides distribution and frequency in the European Alps using a new physically-based discrete element model

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Shallow landslides are hillslope processes that play a key role in shaping landscapes in forested catchments. Shallow landslides are, in some regions, the dominant regulating mechanisms by which soil is delivered from the hillslopes to steep channels and fluvial systems. Several studies have highlighted the importance of roots to better understand mechanisms of root reinforcement and their contributions to the stabilization of hillslopes. In this context, the spatio-temporal distribution of root reinforcement has a major repercussion on the dynamic of sediment transport at the catchment scale and on the availability of productive soils. Here we present a new model for shallow slope stability calculations, SOSlope, that specifically considers the effects of root reinforcement on shallow landslide initiation. The model is a strain-step discrete element model that reproduces the self-organized redistribution of forces on a slope during rainfall-triggered shallow landslides. Tree roots govern tensile and compressive force redistribution and determine the stability of the slope, the timing, location, and dimension of the failure mass. We use SOSlope to quantify the role of protection forest in several localities in the European Alps, making use of detailed field measurements of root densities and root-size distribution, and root tensile and compressive strength for three species common in the Alps (spruce, fir, and beech) to compute landslide distributions and frequency during landslide-triggering rainfall events. We show the mechanisms by which tree roots impart reinforcement to slopes and offer protection against shallow landslides.