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Vadose zone process that control landslide initiation and debris flow propagation

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Advances in the areas of geotechnical engineering, hydrology, mineralogy, geomorphology, geology, and biology have individually advanced our understanding of factors affecting slope stability; however, the interactions among these processes and attributes as they affect the initiation and propagation of landslides and debris flows are not well understood. Here the importance of interactive vadose zone processes is emphasized related to the mechanisms, initiation, mode, and timing of rainfall-initiated landslides that are triggered by positive pore water accretion, loss of soil suction and increase in overburden weight, and long-term cumulative rain water infiltration.

Both large- and small-scale preferential flow pathways can both contribute to and mitigate instability, by respectively concentrating and dispersing subsurface flow. These mechanisms are influenced by soil structure, lithology, landforms, and biota. Conditions conducive to landslide initiation by infiltration versus exfiltration are discussed relative to bedrock structure and joints. The effects of rhizosphere processes on slope stability are examined, including root reinforcement of soil mantles, evapotranspiration, and how root structures affect preferential flow paths. At a larger scale, the nexus between hillslope landslides and in-channel debris flows is examined with emphasis on understanding the timing of debris flows relative to chronic and episodic infilling processes, as well as the episodic nature of large rainfall and related stormflow generation in headwater streams. The hydrogeomorphic processes and conditions that determine whether or not landslides immediately mobilize into debris flows is important for predicting the timing and extent of devastating debris flow runout in steep terrain. Given the spatial footprint of individual landslides, it is necessary to assess vadose zone processes at appropriate scales to ascertain impacts on mass wasting phenomena. Articulating the appropriate level of detail of small-scale vadose zone processes into landslide models is a particular challenge. As such, understanding flow pathways in regoliths susceptible to mass movement is critical, including distinguishing between conditions conducive to vertical recharge of water through relatively homogeneous soil mantles and conditions where preferential flow dominates – either by rapid infiltration and lateral flow through interconnected preferential flow networks or via exfiltration through bedrock fractures. These different hydrologic scenarios have major implications for the occurrence, timing, and mode of slope failures.