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A COMPREHENSIVE APPROACH TO LANDSLIDE TRIGGERING

Abstract of the doctoral thesis

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The presented research tackles the triggering of shallow landslides from a process-based point of view. Physical processes responsible for shallow landslide triggering have a double nature: hydrological and geotechnical. Hydrological processes control water redistribution via lateral and vertical flows and, as a consequence, soil water content. Geotechnical processes and soil properties control soil behaviour and shear resistance. Previous works have dealt with the hydrological and the geotechnical aspects of slope stability separately, but none of them has captured their interdisciplinary nature and integrated their insights to achieve a common goal.

In shallow landslide hazard analyses, the assumption of worst-case (i.e. saturated) conditions is typically made with the belief that this approach is conservative and can be used for sound policy decisions. However, recent theoretical and experimental works point to the occurrence of shallow landslides in the absence of widespread areas of positive pore-water pressure. Therefore, analyses that consider saturated conditions only, may be appropriate for engineering designs of man-made slopes, but may inadequately capture time-dependent failure processes of natural slopes at regional scales. Using a physically-based approach, shallow soil failures are described as a consequence of stress changes in the hillslope, due to the progressive wetting during rainfall infiltration. Based on a new theory of effective stress in the unsaturated zone, the infinite slope-stability analysis is extended to account for interparticle stresses that develop with variation in water content. This analysis describes the evolution of slope stability during rainfall events and simulates the effect of transient infiltration processes on slope stability, by calculating the factor of safety at arbitrary time steps for numerically-computed pore-water conditions. The more physically realistic description of soil effective stress, combined with the distributed evolution of soil moisture conditions provides a time-variable assessment of slope stability. To account for the uncertainty related to the natural variability in the factors influencing the stability of natural slopes, the factor of safety is computed through a probabilistic approach, in order to determine the likelihood of slope failures, assigning to soil parameters distributions instead of single deterministic values.

This new approach has been implemented in a version of a quasi-3D, distributed, coupled hydrological-geotechnical model, GEOtop-FS. In addition, applications to areas prone to landsliding, located in steep alpine catchments are presented. Topographic input data for such areas were derived from a LIDAR topography, and point landslide locations with timing information are available to test results. Results show that the total area predicted to be unstable for a given rainstorm is less than that computed assuming saturated conditions. In addition, results highlight that the time-dependent redistribution of moisture and matric suction during infiltration controls transient changes in suction stress profile. The reduction of suction stress, as soil becomes wetter, can be identified as the physical mechanism triggering many shallow landslides when slopes are subjected to intensive precipitations.