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The influence of subsurface topography on the triggering of rainfall-induced shallow landslide: a laboratory study

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The hydrological controls on the triggering of rainfall-induced shallow landslides are poorly understood. This is because measurement of stormwater infiltration and consequent reduction of soil-shear strength are difficult to make in open, environmental systems. Recent field-based and computer-modeling hydrological studies have suggested the failure surface often corresponds to the point of contact between the soil and the substrate, where a rapid transient pore pressure increase often occurs, in contact with the less permeable underlying bedrock. While subsurface topography of the soil-interface has been shown to control transient water table development, the connectivity of saturated patches at the soil-bedrock interface during rainfall is a pre-condition for lateral flow over larger patches of hillslope. This occurs when the bedrock depressions are filled and the water level in these depressions rise high enough for water to start spilling over the bedrock micro-topography (i.e. the fill and spill mechanism).

We test the hypothesis that these depressions in the bedrock could exhibit high values of localized pressure head during the “fill phase” to affect the overall slope stability.

We use the 11:1 scale model of the Panola Hillslope (a 46 m long and 20 m wide research hillslope located in Georgia USA, where considerable insights into the fill and spill mechanism have been derived) to examine the 3-dimensional dynamics of pore pressure which lead to hillslope instability under a controlled environment, where mechanical and hydrological soil-properties, spatial distribution of soil-thickness, shape of the bedrock, boundary and initial conditions, and spatial/temporal distribution of rainfall are known and controlled.

We report the preliminary results of experiments where a medium/fine sand soil, characterized by 10-cm of capillary fringe and steep shape of the retention curve for matric suctions larger than the air-entry value, is tested for different hillslope angles. Our head-based sprinkler system allows us to generate uniformly distributed high rainfall intensities (until 70 mm/h) across the ∼7 m2 hillslope surface. Measurement systems allow to record lateral flow at the slope base and pore pressure development in selected bedrock depressions, know from our field work to influence connectivity at the slope base.

Preliminary findings suggest that the irregular subsurface topography affects the landslide-relevant pore pressure dynamics at lower hillslope angles (below 25 degrees). Above 25 degrees, the opposite is true where fill and spill behaviour changes from one where positive pore pressures control lateral flow to one where “spill behaviour” dominates and pore pressure development rarely exceeds 15-cm pressure head.

These results highlight the importance of the spatial variability of soil-depth in controlling the switching between stable to unstable hillslope conditions.