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Effects of heterogeneities on the infiltration through shallow layered pyroclastic slopes and possible implications on landslide triggering

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Layered pyroclastic deposits covering steep slopes, characteristic of large mountainous areas of Campania (southern Italy), are often affected by shallow landslides triggered by heavy rainfall events. The stability of such deposits is usually guaranteed by the contribution to soil shear strength offered by soil suction, which decreases during wetting. As the return period of the triggering events has been in many cases not extreme, other factors concur to establish triggering conditions. In this respect, heterogeneities, strongly affecting transient infiltration, may in some cases play a crucial role.

The pyroclastic covers of Campania, being the result of the deposition of materials originated by several eruptions of the nearby volcanic complexes, usually consist of alternating layers of ashes (silty sands) and pumices (gravel with sand), characterized by markedly different hydraulic properties. The presence of coarse-textured pumices between finer ashes strongly affects the infiltration process. In fact, the pumices, which are characterized by saturated hydraulic conductivity larger than ashes, are capable of retaining less water than ashes in unsaturated conditions, so that their unsaturated hydraulic conductivity is usually very small. Hence, depending on the water potential distribution throughout the cover at the onset of rainfall, pumices may act as a barrier to the propagation of the wetting front, or, approaching saturation, let the water pass through them very quickly.

In a steep slope characterized by regular layers with homogeneous hydraulic properties, a layer of dry pumices induces lateral redistribution of water through the overlying ashes, thus favoring the establishment of downslope directed subsurface runoff, which drains part of the infiltrating water towards the toe of the slope. Differently, when the soil profile is wet, a downslope subsurface drainage may establish through the coarse pumices. In both cases, layers have a beneficial effect on slope stability, as part of the water is drained out of the slope.

In real slopes, characterized by irregular layers and heterogeneity of soil properties, the water diversion may instead even contribute to the establishment of triggering conditions, as it can result in flow concentration leading to local failure. In this study, the complex behavior of shallow pyroclastic covers with irregular layers of soils with spatially variable saturated hydraulic conductivity has been simulated by means of a 2D mathematical model based on the integration of Richards' equation with the finite differences method. The obtained results confirm that heterogeneities, either geometrical or hydraulic, significantly affect the infiltration process, and thus may deeply modify the triggering mechanism of landslides.