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Water balance based on field monitoring for the assessment of landslide predisposing conditions in a slope covered with pyroclastic deposits over fractured limestone bedrock

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Many mountainous areas of Campania, southern Italy, are characterized by steep slopes covered with shallow deposits of loose pyroclastic materials, usually in unsaturated conditions, mainly constituted by layers of volcanic ash and pumice lapilli. The total cover thickness is quite variable, between 1.5 m and 2.5 m in the steepest part of the slopes while it reaches several meters at the foot, and it lays upon fractured limestone bedrock. Such pyroclastic materials usually exhibit extremely high porosity (even up to 75%) and saturated hydraulic conductivity (in the order of 10^{-4} m/s). The equilibrium of the soil cover is ensured, up to inclination angles of 50°, by the contribution of soil suction to shear strength. Wetting of the soil cover during rainfall infiltration can cause a reduction of suction and, therefore, of the effective shear strength. This action sometimes leads to the triggering of shallow landslides, which often develop in the form of fast and destructive flows.

To capture the main effects of precipitations on the equilibrium of these slopes, hydrological monitoring activities have been carried out at the slope of Cervinara, located around 40 km northeast of Naples, where a destructive flowslide occurred in December 1999. An automatic hydro-meteorological station was installed at the elevation of 585m a.s.l., immediately near the scarp of the major landslide occurred in 1999. The meteorological equipment includes a rain gauge, a thermo-hygrometer, a thermocouple for soil temperature, an anemometer, a pyranometer, and a barometric sensor. The hydrological equipment consists of six tensiometers (located at depths between -0.2 m and -3.0 m below the ground surface) and six metallic time domain reflectometry probes (buried at depths between -0.3 m and -2.0 m) for the measurements of soil suction and water content, respectively. Furthermore, the water level in two streams located at the foot of the slope has been first manually monitored every month, and then, since March 2019, one of the two stream sections was instrumented with a probe, measuring water pressure, temperature, and electrical conductivity with hourly resolution.

The measurements allowed quantifying the major hydrological processes draining the soil cover after rainwater infiltration (i.e. evapotranspiration, overland and sub-surface runoff, leakage through the soil-bedrock interface), eventually assessing the water balance of the slope for three hydrological years (2017-2018, 2018-2019, 2019-2020). The field monitoring data allowed the identification of the complex hydrological processes involving the unsaturated pyroclastic soil and the shallow groundwater system developing in the limestone bedrock, which control the conditions that potentially predispose the slope to landslide triggering. Specifically, late autumn has been identified as the potentially most critical period, when drainage through the soil-bedrock interface is not yet effective, owing to the still dry conditions at the base of the soil cover, but the slope already receives large amounts of precipitation.