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Identification of hydrological controls of slope response to precipitations using machine learning techniques

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The assessment of the response of slopes to precipitations is important for several applications: from drought associated problems to the evaluation of the occurrence of threatening events such as floods and landslides (Bogaard & Greco, 2016). This study aims at identifying the most important variables, that can be monitored in the field, suitable to describe the initial conditions that control the capability of a slope to store infiltrating water at the end of precipitation events. The case study of the slopes near the town of Cervinara, southern Italy, is presented, where field observations and laboratory experiments allowed the understanding of the water processes at different scales (Marino et al., 2020). A synthetic dataset, simulating the major hydraulic processes observed in the field, was generated to enrich the available data. It was built by simulating the response of the slope to a 1000-year long synthetic rainfall series, generated with the NSRP model, with a physically based model coupling the unsaturated flow in the coarse granular soil cover with the shallow aquifer hosted by the uppermost part of the underlying fractured limestone bedrock (Marino et al., 2021). The hydraulic behavior of the soil cover is modelled with the 1D Richards' equation, while the aquifer, connected to the soil cover through its lower boundary condition, is modelled as a simple linear reservoir.

Two variables expressing underground antecedent conditions, one hour before any rainfall event, were analyzed: mean water content in the uppermost meter of the soil cover and aquifer water level. The slope response was quantified as the fraction of rainwater remaining stored in the soil cover at the end of any rainfall event. The non-linear relationships linking the three variables were studied with clustering and random forest techniques, allowing the identification of three major hydrological conditions. The first one is linked to dry seasons, when the lowest aquifer water level coincides with soil water content below field capacity: in this condition, rainwater tends to remain completely stored in the soil at the end of rain events. Once the soil cover overcomes the field capacity, two different conditions are found. When the aquifer water level is high, active drainage through the soil-bedrock interface limits the increase of water stored in the soil cover. Conversely, when the aquifer water level is low, it corresponds to impeded drainage, i.e., there is little leakage from the soil cover to the bedrock. In this condition, most rainwater tends to remain stored in the soil cover even when it is already wet at the beginning of the rain event.

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