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Definition of physically-based regional soil moisture-rainfall thresholds for the assessment of landslide hazard

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Landslides are one of the most dangerous natural hazards, causing every year fatalities, considerable damage and relevant economic losses. Early warning systems (EWS) for rainfall-induced landslides represent an useful tool for mitigating the impact of such hazard. Traditionally, EWS are based on physically-based models or on empirical relationships between rainfall and landslide occurrence.

With the aim of taking into account the hydrological settings within the slope, the Umbria Regional Civil Protection Service started in considering also the soil moisture conditions as triggering factor during the daily analysis of shallow landslide hazard. The historical analysis of landslide events leaded to the definition of a set of soil moisture-based thresholds.

By analyzing the soil saturation conditions before and after the rainfall event (by using a hydrological model), it has been seen that most of the activations occurred when the soil reached saturation. This hypothesis has been validated by performing a historical analysis on more than 500 landslides occurred during the period 1990-2022. In this work, we took advantages of this finding and proposed an improvement of the current thresholds that considers the amount of rainfall needed by the soil to reach saturation, and hence, the slope instability. The amount of rainfall needed to reach saturation has been calculated through the definition of soil hydraulic parameters and the saturation degree at the start of the rainfall event. Then, if the fallen rainfall is higher than the critical value needed to reach saturation, an alarm is issued. The obtained threshold is based on soil characteristics and it is independent by the input data (no need for recalibration or threshold adjustment). The proposed methodology is able to identify correctly most of the proposed events (>70%) with a very limited amount of false alarms (4%) considering all the rainfall events occurred during the 1990-2022 period.

Further analyses are required for a better definition of the soil hydraulic parameters and the rainfall events but the obtained results confirmed the added value of using soil moisture conditions as triggering factor for shallow landslides activation.