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Using the TRIGRS model to predict rainfall-induced shallow landslides over large areas

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Rainfall-induced landslides are a widespread and recurrent natural hazard in Italy, and their management requires forecasts. Physics-based (deterministic) methods proposed in the literature model the hydrologic response of soils to rainfall and determine the propensity for landslide initiation. These methods require understanding of many spatially and temporally variable factors. For this reason such models are commonly applied over small areas (few tens of km2). This paper describes a preliminary approach for calibrating a deterministic model to predict shallow landslides over a 550 km2 area of the Esino River basin, in the Marche Region of central Italy. This area is hilly and characterized by post-orogenic quaternary sediments prone to rainfall-induced shallow landslides. We used the U.S. Geological Survey Transient Rainfall Infiltration and Grid-based Regional Slope-stability (TRIGRS) model to compute infiltration-driven changes in factor of safety based on an infinite-slope stability analysis and a one-dimensional analytical solution for vertical infiltration. We assumed saturated initial conditions and impermeable boundary at the interface between soil and bedrock. We used rainfall information from a gage network, a 20m DEM and a hydrogeological map of the study area, and a grouping of three mapped hydrogeological units (clay, sandy-clay and loam) as a basis for division of mechanical and hydrological soil properties from published studies into zones. We quantified the variability of the data obtained from the literature and defined a range of property values for each zone in the calibration of the model. We ran TRIGRS for representative landslide-prone grid cells in each zone for different rainfall scenarios, and we compared the modeled responses (pressure head and factor of safety) with observed landslides in clayey, sandy-clayey and loamy soils. We used the best performing combination of input values, fitted a soil depth model and spline-interpolated the rainfall data to test TRIGRS for the entire study area. A ROC (receiver operator characteristics) analysis of the factor of safety distribution after several storm events that triggered landslides in the past two decades (1990-2012), compared with the observed landslides, reached an effective prediction level (the true positive rate > 0.5 and the false positive rate < 0.5). The agreement between known and expected landslides was maximized by considering the range of factors of safety from < 1.0 to 1.3 to be potentially unstable. Results showed that by evaluating the model's output in a probabilistic framework, TRIGRS can be used to map landslide susceptibility and may be suitable for the prediction of rainfall-induced landslides over large regions even where geotechnical and hydraulic property information must be inferred from small-scale mapping of soils or geology.