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Physically-based approach for rainfall-induced landslide projections in a changing climate

DIANA SALCIARINI[1], LUCA BROCCA[2], STEFANIA CAMICI[2], EVELINA VOLPE[1], and LUCA CIABATTA[2]

[1]Department of Civil and Environmental Engineering, University of Perugia, via G. Duranti 93 – 06125 Perugia, Italy.
E-mail: diana.salciarini@unipg.it, evelina.volpe@gmail.com
[2]Research National Council, Research Institute for Geo-Hydrogeological Protection, via della Madonna Alta 126 – 06128 Perugia, Italy.
E-mail: luca.brocca@irpi.cnr.it, stefania.camici@irpi.cnr.it, luca.ciabatta@irpi.cnr.it

Prediction of rainfall-induced landslide occurrence has constituted a great challenge in the last decades. Different approaches have been adopted to include in the forecasts both the geometric, mechanical and climatic factors that affect the triggering phase of the process. A quite promising one is based on the probabilistic physically–based model implemented in the code PG_TRIGRS [1], which takes into account the uncertainty in soil spatial variability and characterization. It is an extension of the original TRIGRS code [2] that combines a 1–D hydrologic model with a simple slope stability computation to assess the probability of slope failure over a large area.
In a changing climate, assessing the effects that the variation of the expected rainfalls can cause to the natural environment and slope stability is of primary importance. Following the 5th Report of the IPCC [3], in Europe precipitations are expected to increase, and, in particular, there will be more events characterized by extreme rainfalls, which legitimates the possibility of an increase in landslide events. Comprehensive reviews of the attempts done to correlate future landslides to changed climate have been proposed by [4, 5 and 6]. However physically-based approaches to face the issue in a rational way are almost still missing, likely due to the high uncertainty that may affect the prediction.

In this work we show an application of PG_TRIGRS to four different study areas in Central Italy (Umbria Region), forced with different scenarios of expected rainfalls. For that first, the rainfall time series provided by 12 Regional Circulation Models (RCMs) were downscaled and weather generators [7] were used for obtaining hourly rainfall time series. For each RCM, three different time horizons (1990–2013 (*baseline*), 2040–2069 and 2070–2099) were considered, for a total of 36 rainfall time series.

Secondly, we applied the Kriging geostatistical technique to assess the spatially distributed soil properties for the study areas, starting from measurements at known locations. Kriging has also been used to define the synthetic indicators of the Probability Distribution Functions (PDFs) for the selected random variables (in this case: cohesion c', friction angle ϕ', permeability k_s).

Finally, the Point Estimate Method (PEM) has been adopted to evaluate the Probability of Failure (PoF) within the study area, where PoF is defined as the probability that the Factor of Safety (F_s) is less or equal than 1.

The results of the prediction provided by the models are compared in terms of variation of percentage of unstable territory. We subdivided the study areas into 5 categories of stability level (given by the PoF) and we computed the distribution of the number of cells in the different categories of stability, for the three time horizons considered. From this quantitative information, we observe that the projection of the expected rainfall produces a general increase of the number of potentially unstable cells. Although many uncertainties in the analyses of the climatic trends and in their related effects at the ground still exist, the presented approach shows that the current available physically based method can be used to support quantitative projections of the expected impacts.

Keywords: Physically based methods, Climatic scenarios, Downscaling, keyword4, keyword5, keyword6.

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