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Effect of initial conditions and of intra-event rainfall intensity variability on shallow landslide triggering return period

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Assessment of shallow landslide hazard is important for appropriate planning of mitigation measures. Generally, return period of slope instability is assumed as a quantitative metric to map landslide triggering hazard on a catchment.

The most commonly applied approach to estimate such return period consists in coupling a physically-based landslide triggering model (hydrological and slope stability) with rainfall intensity-duration-frequency (IDF) curves. Among the drawbacks of such an approach, the following assumptions may be mentioned: (1) prefixed initial conditions, with no regard to their probability of occurrence, and (2) constant intensity-hyetographs.

In our work we propose the use of a Monte Carlo simulation approach in order to investigate the effects of the two above mentioned assumptions. The approach is based on coupling a physically based hydrological and slope stability model with a stochastic rainfall time series generator. By this methodology a long series of synthetic rainfall data can be generated and given as input to a landslide triggering physically based model, in order to compute the return period of landslide triggering as the mean inter-arrival time of a factor of safety less than one. In particular, we couple the Neyman-Scott rectangular pulses model for hourly rainfall generation and the TRIGRS v.2 unsaturated model for the computation of transient response to individual rainfall events. Initial conditions are computed by a water table recession model that links initial conditions at a given event to the final response at the preceding event, thus taking into account variable inter-arrival time between storms. One-thousand years of synthetic hourly rainfall are generated to estimate return periods up to 100 years. Applications are first carried out to map landslide triggering hazard in the Loco catchment, located in highly landslide-prone area of the Peloritani Mountains, Sicily, Italy. Then a set of additional simulations are performed in order to compare the results obtained by the traditional IDF-based method with the Monte Carlo ones.

Results indicate that both variability of initial conditions and of intra-event rainfall intensity significantly affect return period estimation. In particular, the common assumption of an initial water table depth at the base of the pervious strata may lead in practice to an overestimation of return period up to one order of magnitude, while the assumption of constant-intensity hyetographs may yield an overestimation by a factor of two or three. Hence, it may be concluded that the analysed simplifications involved in the traditional IDF-based approach generally imply a non-conservative assessment of landslide triggering hazard.