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A modeling approach for the assessment of landslide probability and return period in a changing climate

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Quantification of landslide frequency modifications induced by climate change is of key importance for adaptation measures. Nevertheless, methodologies for this quantification are currently quite scarce, in spite of the availability of several advanced tools, such as regional climate and landslide models.

In this work, we provide a modeling approach for assessing the impacts of climate change on landslide probability and return period – well known metrics of how extreme landslide occurrence is.

The proposed approach capitalizes on the combined use of a stochastic rainfall model, RCM simulations, and a hydrological and slope stability model. The stochastic model generates rainfall event sequences based on copula functions, which allow to capture the statistical dependence between event depth and duration. For the baseline period (1971-2001) the model is calibrated on observed high resolution series, while for future periods rainfall sequences are generated by perturbing the calibrated stochastic model, based on factors of changes. These factors are estimated by comparing RCM future projections with their baseline climate reconstructions. The generated rainfall sequences are used as input to a physically based landslide model, which comprises two hydrological components and an infinite slope stability module. The first hydrological component models infiltration based on an analytical solution of a linearized version of the 1D Richards equation, and aims at computing the transient pressure head response to rainfall events. The second component is based on a linear reservoir drainage model, which allows to derive the soil moisture conditions at the beginning of each rainfall event, based on antecedent rainfall time history. The described modeling chain is applied sequentially on a future moving time window, to derive a yearly series of future landslide triggering probability. This series is then used to compute landslide return period by formulas suitable under nonstationary conditions.

The developed methodology is applied to the landslide prone region of Peloritani Mountains, Southern Italy. In the application, climate change projections of several RCMs of the CORDEX initiative are used. An assessment of the impacts of intermediate- and high-emission scenarios, RCP 4.5 and RCP 8.5, is carried out. Results show that a significant number of RCMs indicate, for both scenarios, an increase of landslide hazard in the future.