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Identification of regional landslide triggering thresholds in the Lombardy region using multivariate statistical analysis

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Landslides represent a critical natural hazard in many mountain and hilly regions worldwide, provoking causalities and property damages. Landslide triggering thresholds are at the basis of early warning systems to protect livelihoods. Traditionally, landslide triggering thresholds are expressed in terms of not more than two or three precipitation variables, mostly rainfall event depth, and duration. Indeed, the availability of soil moisture information and its proxies (such as antecedent precipitation), can improve the performance of landslide triggering thresholds, thus calling for a multivariate approach.

Given the above context, this study aims to develop regional landslide triggering thresholds by using multivariate statistical analysis to investigate the performance of multiple combinations of rainfall variables and event soil moisture data, in the identification of regional rainfall thresholds for landslide initiation. Lombardy region (northern Italy) was selected as a study area since it is one of the most susceptible Italian regions to landslide risk. The data on landslides were retrieved from the FraneItalia project that is a comprehensive spatio-temporal database of recent landslides affecting the Italian territory from 2010 onwards. For the Lombardy region, from 2010 to 2019, 592 landslides events triggered by rainfall were detected, all distributed within the mountain and hilly areas of the region.

Precipitation and soil moisture time series, instead, were derived from the ERA5-Land reanalysis dataset and the rainfall events were reconstructed using the CTRL-T code developed by IRPI-CNR, which characterizes each rainfall event by duration, mean intensity, total depth, and peak intensity. The most probable rainfall conditions associated with each landslide are, then, computed based on the distance between the rain gauge and the landslide location. Different combinations of precipitation and soil moisture variables are tested using dimensionality reduction multivariate statistical techniques. An optimization procedure is set up with the aim to maximize the True Skill Statistic (TSS) ROC index associated with parametric thresholds. Several multivariate combinations show better performances than the traditional depth-duration power-law thresholds.