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Precipitation, temperature and snow related predictors for a potentially dynamic rockfall susceptibility model in Aosta Valley

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The overarching goal of the study was to test the influence of climate-related spatially distributed predictors on rockfall susceptibility in an Alpine environment. The study focused over the central part of Aosta Valley (Western Italian Alps), where a large historical rockfall inventory and an extensive, multi-variable meteorological dataset are available for the period 1990-2020.

The first part of the study regarded the definition of process-based climate predictors for the susceptibility model. Based on previous studies (Bajni et al., 2021), three climate indices were known to influence rockfall occurrence in the area: effective water inputs (EWI, including rainfall and snow melting), wet-dry episodes (WD), and freeze-thaw cycles (FT). For each index, the spatially-distributed predictor for the susceptibility analysis was calculated as the mean annual exceedance frequency of previously defined thresholds. Such predictors were produced both starting from a station-based hourly dataset, and consequent regionalization, and a grid-based hourly dataset.

The second part of the study comprised the set-up of a rockfall susceptibility model by means of Generalized Additive Models (GAM), including topographic, climatic and two additional snow-related predictors (derived from a Snow Water Equivalent weekly gridded dataset, Camera et al., 2021). The validation of the produced models was carried out through a k-fold cross-validation (CV), while the evaluation of its performance was expressed in terms of area under the receiver operating characteristic curve (AUROC). Variable importance was assessed through the decrease in explained deviance (mDD%).

To improve and optimize the model, stepwise modifications of its setup were carried out:

- a visibility mask related to roads and main infrastructures was introduced to reduce the rockfall inventory bias.
- Models including alternatively the station-based and grid-based climatic predictors were compared. The evaluation was based both on the physical plausibility of the smoothing functions describing predictors behaviour, and in terms of quantitative performance. For the grid-based model, performance and predictors transferability were evaluated comparing a random CV, a spatial CV and a holdout CV.
- Concurvity among predictors was reduced through the implementation of a Principal Component Analysis.

The key results were: (i) the use of climate predictors (both station-derived and gridded-derived) resulted in an improvement of the model performance (AUROC up to 3%) in comparison to a topographic-only model; (ii) the climate predictors with the strongest physical significance were EWI and WD, with a mDD%= 5-10% each, followed by the maximum cumulated snow melting over a 32-day period (mDD%= 3-5%); (iii) the effect of FT was masked by elevation; (iv) the station-based models were more strongly affected by concurvity issues; (v) the PCA derived predictors maintained explainable physical meanings while consistently decreasing concurvity.

The presented procedure is reproducible in other environmental and climatic conditions and allows to implement process-related non-stationary susceptibility models, making them adaptable for future climate change scenarios.

References

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