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Analysis of the influence of rainfall in the triggering of landslides through machine learning: an innovative approach in the perspective of spatiotemporal landslide forecasting

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Machine learning algorithms are commonly used for landslide susceptibility mapping; however, their application for spatiotemporal landslides prediction remains widely unexplored. Only static predisposing factors are needed for susceptibility assessment, which indicates where landslides are more likely to occur in the future. Therefore, dynamic parameters, such as critical or antecedent rainfall, which are mainly related to the temporal occurrence of landslides, remain unused.

This work provides a contribution to fix this gap by proposing an innovative methodology for the application of the Random Forest (RF) algorithm for spatio-temporal landslides prediction, landing to a more complete hazard assessment. This dynamic approach is based on the method of identification of non-landslide events in comparison with the reporting day and location of the landslide events; conceived to include both static and dynamic parameters as model input variables. Among other advantages, RF allows the calculation of the Out-of-Bag Error (OOBE) and depicts Partial Dependence Plots (PDPs), two useful indices of the influence of each input variable in determining the triggering of landslides. In this work, these indicators were used to verify the applicability of RF with the proposed methodology, investigating if the model outcomes are consistent with the triggering mechanism observed in the inventoried landslides.

The study area is the Metropolitan City of Florence (MCF), Central Italy, for which a detailed and dated landslide inventory is available, mainly composed of shallow landslides and debris flows. As first dynamic variable it was chosen to use the cumulative rainfall at various time steps, which allows to consider both short and long-term rainfall. The month of observation of the events is used as second dynamic input parameter, as a categorical type, to represent the seasonal variability. In addition, a static index related to the predisposition of the area to landslides (i.e., a classical susceptibility map) was inserted, to directly compare the influence of static and dynamic parameters on spatiotemporal prediction of landslides.

The goals of this research are: i) to understand how to populate training and test datasets with observations sampled over space and time, ii) to assess which rainfall variables are statistically more influential on landslides triggering, and iii) to verify the applicability of the proposed dynamic approach for landslides probability assessment.

The RF model employed through the proposed methodology showed encouraging results, consistent with the actual knowledge of the physical mechanism of the triggering of shallow landslides and debris flows (mainly influenced by short and intense rainfall). Some benchmark configurations have been identified which represent a promising starting point for future applications of machine learning models for landslide probability mapping.