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Doctoral Dissertation

Doctoral Program in Civil and Environmental Engineering (38<sup>th</sup> Cycle)

# **Climate change impacts on landslide susceptibility in the Alpine region using a machine learning approach**

By

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## **Abstract**

Assessing the effects of climate change on the natural environment poses significant challenges for the scientific community and decision-makers, particularly in understanding how it influences geo-hydrological hazards such as landslides. This Thesis investigates the potential impacts of climate change on landslide susceptibility in the Aosta Valley, Italy, and evaluates the associated implications for critical infrastructure. The primary objective is to develop spatially and temporally landslide susceptibility maps that account for monthly climatic variability and to apply these results to support infrastructure resilience assessment. Monthly landslide susceptibility maps were produced for a present-day baseline period and for a near-future scenario. Climatic inputs for the current scenario were derived from a twenty-year dataset of daily precipitation and temperature with high spatial and temporal resolution. Since the timing of landslide events was available from regional inventories, precipitation and temperature values were accurately extracted at each landslide location to characterize both antecedent and event-related conditions. The predictor variables included three dynamic factors, namely mean monthly precipitation, mean monthly temperature, and mean seven-day precipitation, one semi-static factor represented by land cover, and nine static factors including slope, soil type, lithology, aspect, profile curvature, plan curvature, Normalized Difference Vegetation Index, Stream Power Index, and Sediment Transport Index. These variables were assigned to each recorded landslide event to construct twelve-month specific datasets. A supervised machine learning algorithm was trained and tested separately for each month to generate twelve monthly landslide susceptibility maps. The results indicate that during the last twenty years, in the analysed study area, the highest proportions of areas classified as high and very high susceptibility occur in spring, particularly in April, May, and June, which is consistent with the observed seasonal distribution of landslide occurrences. To represent the worst-case conditions, the monthly susceptibility maps were combined by selecting, for each grid cell, the maximum susceptibility value across all months, producing an envelope susceptibility map. This envelope map was validated using an independent landslide dataset to evaluate

## *Abstract*

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its predictive performance and spatial reliability. Future projections were developed by first comparing multiple climate scenarios for the next twenty years. Among the available scenarios, SSP5-8.5 exhibited the most critical temperature and precipitation patterns. The trained monthly models were then used to assess projected monthly precipitation and temperature data for the period 2021 to 2040 under the high emission SSP5-8.5 scenario to generate future monthly susceptibility maps and a corresponding future envelope map. The results suggest that under this scenario the proportion of areas classified as high and very high susceptibility is expected to increase, especially in autumn. Finally, power transmission towers within the study area were digitized from aerial imagery and overlaid on both current and future envelope susceptibility maps to quantify infrastructure exposure and identify network segments at elevated landslide risk. For a selected area, the cascading impacts of power outages were also evaluated and combined with landslide risk at the tower level, providing an integrated assessment of direct and indirect impacts.

**Keywords:** Landslide susceptibility, Climate change impacts, Spatio-temporal modelling, Critical infrastructure, Risk assessment.