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Toward Pragmatic Landslide Susceptibility Mapping for Railway Planning: A Comparative Analysis of Statistical and Machine Learning Methods - The Case Study of the Marche Region, Italy

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The integration of Machine Learning (ML) into susceptibility mapping and hazard modelling has unveiled complex relationships between landslide predisposing factors and occurrence. However, understanding the practical implications of landslide susceptibility results still crucial. One concern is the conventional treatment of landslide inventory data, where various landslide types are uniformly addressed during model training, proving unrealistic given diverse geological and geomorphological conditions for distinct landslide types. Moreover, each landslide type requires a unique mitigation strategy, and valuable information is lost when treating all landslides uniformly. Another challenge is how susceptibility models typically present probabilities, while practical applications demand clear categories to avoid underestimation or overestimation of risks.

This study explores the practical application of landslide susceptibility to linear infrastructure, specifically railway design. The investigation centres on two established models, comparing each other: firstly, the classical statistical-based method, Weight of Evidence (WoE); and secondly, a ML method, the Generalized Additive Model (GAM). WoE was chosen for its clarity, while GAM accommodates continuous variables, offering a nuanced understanding of non-linear relationships. The study area encompasses a new 22.11 km railway stretch in the central Marche Region, Italy. We assessed the susceptibility to five landslide types, as classified in the Italian Landslide Inventory (IFFI). The models (WoE and GAM) are applied using different landslide types as distinct training datasets, resulting in unique susceptibility maps for each type. Additionally, the study evaluates the models using the Area Under the Receiver Operating Characteristic (AUROC) curve, providing insights into their performance. The rockfall susceptibility map demonstrates high reliability (AUROC of 0.942 with WoE and 0.978 with GAM), while slide-type landslides show more modest but fairly good results (AUROC of 0.696 with WoE and 0.784 with GAM).

To provide a comprehensive understanding of the study area, overall landslide susceptibility was calculated, corresponding to the probability of failure for any type of landslide. The overall probability was obtained by implementing a complementary probability approach for landslide probability analysis. A method is then proposed to classify the sensitivity of landslide types by considering the difference in their influences, facilitating a clearer understanding of their

contributions to the overall susceptibility assessment.

The second practical concern involves the accurate definition of hazard classes, pivotal due to its direct impact on risk management, decision-making, and overall infrastructure resilience. The study introduces a novel approach, using mode calculation to consolidate results from various reclassification methods. This strategic use of mode calculation ensures a reliable representation of hazard classes, addressing the limitations of individual methodologies.

The results underscore the importance of considering multiple models and methodologies to obtain a comprehensive perspective in decision-making processes. Importantly, the study highlights the use of both classical statistical methods, exemplified by WoE, and ML methods like GAM, showcasing the benefits of a diverse analytical approach in landslide risk assessment for linear infrastructure.