Assessing multi-hazard vulnerability and risk applying a random forest algorithm and statistical approaches, a case study of Hunza

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The Northern Pakistan is a disaster-prone area that has experienced frequent and devastating natural hazards, including landslides, debris flows, floods, and glacial lake outburst floods (GLOFs). The region's unique geology, rugged terrain, and changing climate make it highly susceptible to these hazards, which have resulted in significant loss of life, and infrastructure. Despite the high risk, there is a lack of comprehensive risk assessments that integrate multiple hazards, vulnerability, exposure, and capacity to inform disaster risk reduction and management efforts. This study addresses this gap by presenting a comprehensive risk assessment of District Hunza, which integrates multi-hazard susceptibility, multi-dimensional vulnerability, integrated exposure, and capacity index maps. A machine learning model was used to develop the multi-hazard susceptibility map by integrating landslide, debris flow, seismic, GLOF, and flash flood susceptibility maps. Meanwhile, the weights for the multi-dimensional vulnerability, integrated exposure, and capacity index maps were calculated using statistical approaches, which considered various socio-economic, infrastructural, and environmental indicators. The statistical approaches allowed for the objective-subjective assignment of weights to each indicator, ensuring that the resulting maps accurately reflected the complex interactions between these components. The final risk map categorizes the district into eight zones of varying risk levels, covering a total area of 22.19km², falling under the Extremely High-Risk zone. The findings of this study provide a critical framework for disaster risk reduction and management, enabling policymakers and stakeholders to prioritize resource allocation and mitigation efforts in the most vulnerable areas, and ultimately reducing the risk of disasters and promoting sustainable development in the region.

Keywords: Disaster Risk reduction; Climatic hazards; Multi-hazard susceptibility; Machine Learning; RF