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Modeling Multi-Hazard Assessment in the Western Corinthian Gulf, central Greece, Using Machine Learning and GIS

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INTRODUCTION

Natural hazards are physical processes with potential risk to human society and the environment. A multi-hazard map synthesizes different hazard data for a given area, enabling planners to analyze multiple hazards simultaneously (Bathrellos et al., 2017).
The HOMEROS project advances the field of multi-hazard assessment by integrating seismological, geomorphological, and engineering geological analyses. Leveraging Open Science practices, the project systematically utilizes high-resolution datasets from regions of elevated hazard in Greece, providing a robust framework for the evaluation and mitigation of natural disaster risks.
This study presents a multi-hazard framework that integrates landslide, flood, and seismic hazards using open scientific data and selected methodological approaches combined with GIS. The individual hazard maps were merged into a final multi-hazard zonation map.

STUDY AREA

The study area lies in the western Gulf of Corinth, in the northern part of the Peloponnese Peninsula in Greece. It spans about 430 km^2, with elevations from sea level up to around 1,800 meters (**Fig. 1**).
The area under study is prone to frequent landslides and numerous flood events which have caused considerable damage (Skilodimou *et al.,* 2025).
The broader study area has recorded several strong earthquakes with substantial social and infrastructure impact (**Fig. 2**).

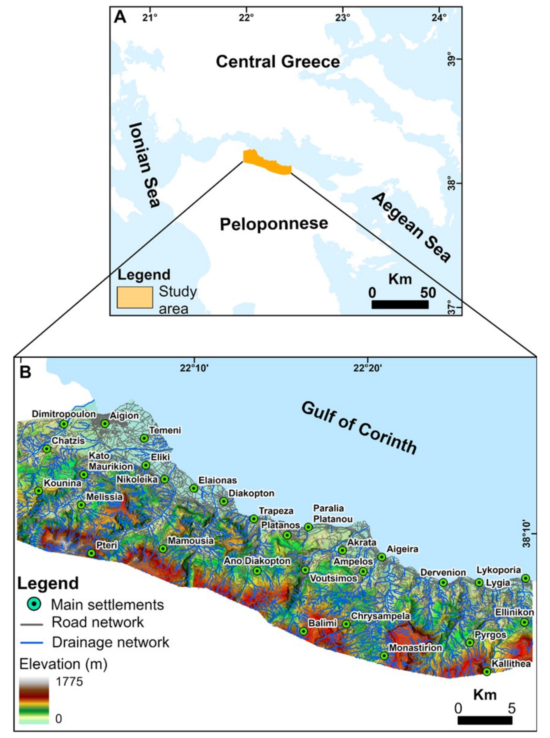

FIGURE 1: *A.* The area under study in the Peloponnese Peninsula. *B.* Elevations, streams, roads, and main settlements in the study area.

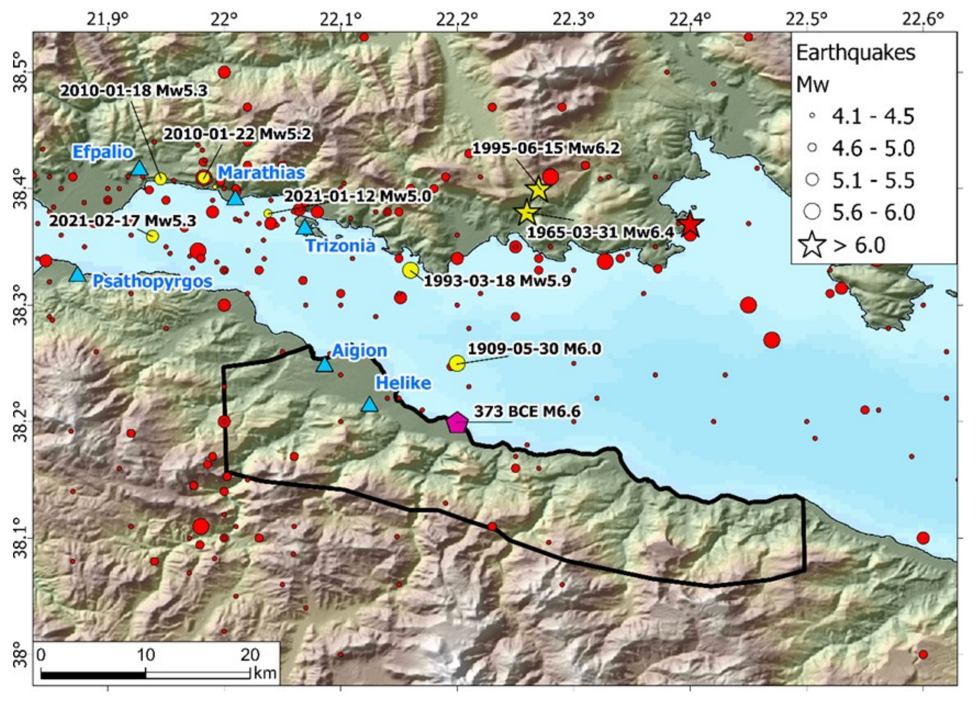

FIGURE 2: Seismicity map of the broader study area using the instrumental catalogue of Makropoulos *et al* (2012), updated up to 2023 (Zymvragakis *et al.*, 2026a).

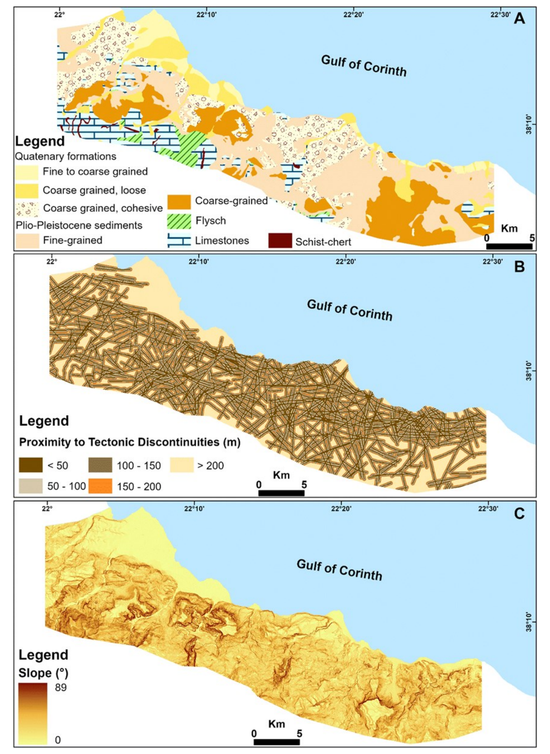

FIGURE 3: Maps used for landslide hazard assessment: *A.* Lithology, *B.* Proximity to Tectonic Discontinuities, *C.* Slope

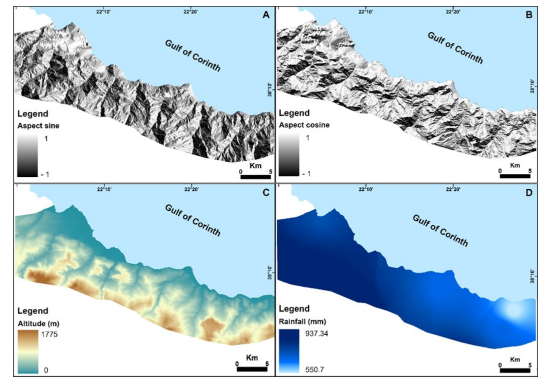

FIGURE 4: Maps used for landslide hazard assessment: *A.* Aspect sine, *B.* Aspect cosine, *C.* Altitude, *D.* Rainfall

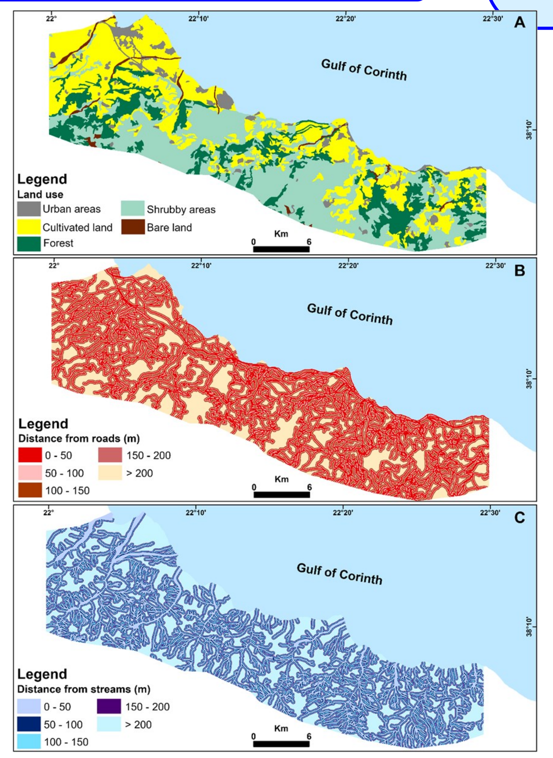

FIGURE 5: Maps used for flood hazard assessment: *A.* Land Use, *B.* Distance from roads, *C.* Distance from streams

METHODS

Landslide hazard map
The landslide hazard map was derived from an inventory of recorded landslide events. Multiple factors, to potentially control landslide susceptibility, were incorporated into the analysis. These factors included lithology, proximity to tectonic discontinuities, slope, aspect, altitude, rainfall, land use, and distances from roads and streams. Landslide susceptibility was evaluated using the Forest-based and Boosted Classification and Regression (FBCR) tool in ArcGIS Pro.

Flood hazard map
The flood hazard data was derived from open scientific data. The documented flood events, and the potential flood hazard map were retrieved from the Zenodo repository (Andriopoulou-Mounteanou *et al.*, 2026).

Seismic hazard map
Seismic hazard results (PGA for return period of 475 years) were obtained through a logic tree approach that combines source area and fault sources with Greek Ground Motion Models.

Multi-hazard assessment map
The relative importance of the three geohazard maps was assessed using Analytical Hierarchy Process (AHP) supporting GIS. The hazard zones depicted on the generated multi-hazard map underwent an evaluation process involving uncertainty analysis. The verification of the map was carried out through Receiver Operating Characteristic (ROC) analysis and the Area Under the Curve (AUC).

RESULTS

Hazard maps
The landslide hazard assessment map is presented in **Figure 6**. Analysis of the spatial distribution of landslide hazard classes indicates that areas characterized by very high and high landslide hazard are predominantly concentrated in the western, central, and southeastern sectors of the study area. The accuracy of the applied model reaches up to 71%.
The spatial distribution of potential flood hazard reveals (**Fig. 7**) that areas of highest flood susceptibility are primarily located in the northern, northwestern, and northeastern parts, as well as along the main channels of the drainage networks in the western part of the study area.
The interpolated PGA values, for an RP of 475 years across the southern margin of the Western Corinthian Gulf display a clear increase towards the north, with the peak being to the northeastern edge of the study area (**Fig. 8**).

Multi-hazard map
Three maps were produced: one showing the direct results of the AHP method, and two representing the minimum and maximum hazard values per pixel, incorporating uncertainties in the weighting coefficients. The continuous hazards values in all maps were classified into five hazard categories (**Fig. 9**).
The multi-hazard map highlights areas with very high and high hazard in the northwestern, central, and eastern sectors, where landslide, flood, and seismic hazards coincide. Neotectonic uplift, combined with the presence of Quaternary and Pliocene sediments in the area, creates conditions that favor the occurrence of natural hazards.
Minor variations between the base map and uncertainty-informed scenarios indicate the robustness of the applied method. The ROC analysis further supports this, with an AUC of 76%, demonstrating strong predictive performance.
As part of the HOMEROS project, this study compiles datasets and derived products related to landslide, flood, and seismic hazard mapping, which are stored in Zenodo and assigned DOIs to ensure persistent identification, version control, transparency, and reproducibility.

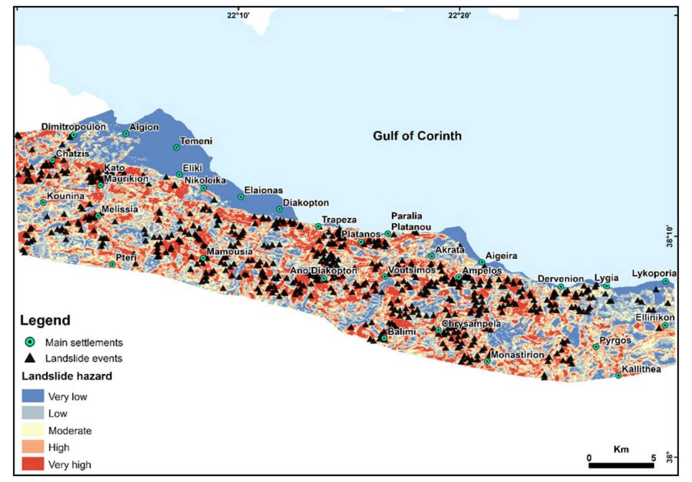

FIGURE 6: Landslide hazard map with different hazard levels, illustrating spatial variation in landslide susceptibility across the study area

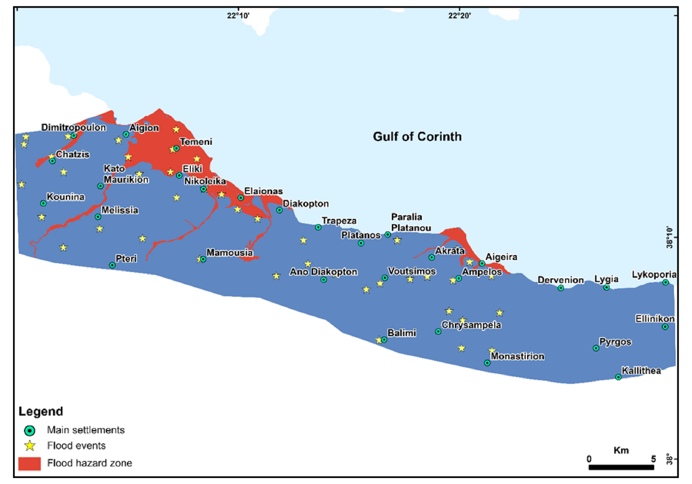

FIGURE 7: Flood hazard map, showing the spatial distribution of flood-prone areas in the study area

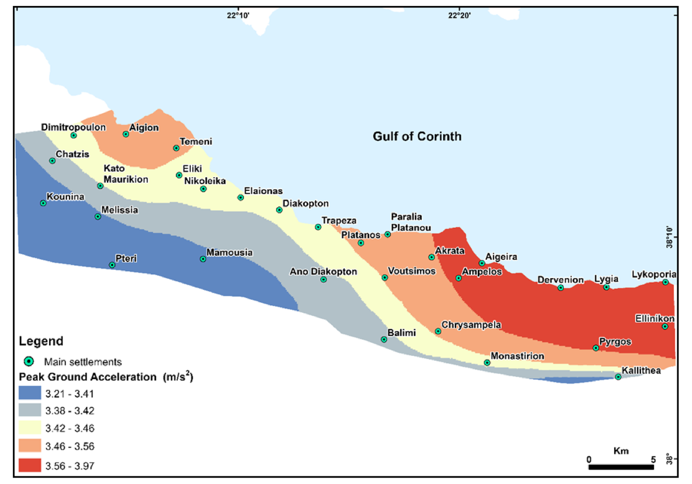

FIGURE 8: PGA values of Return Period (RP) of 475 years across the area of the southern margin of the Western Corinth Gulf

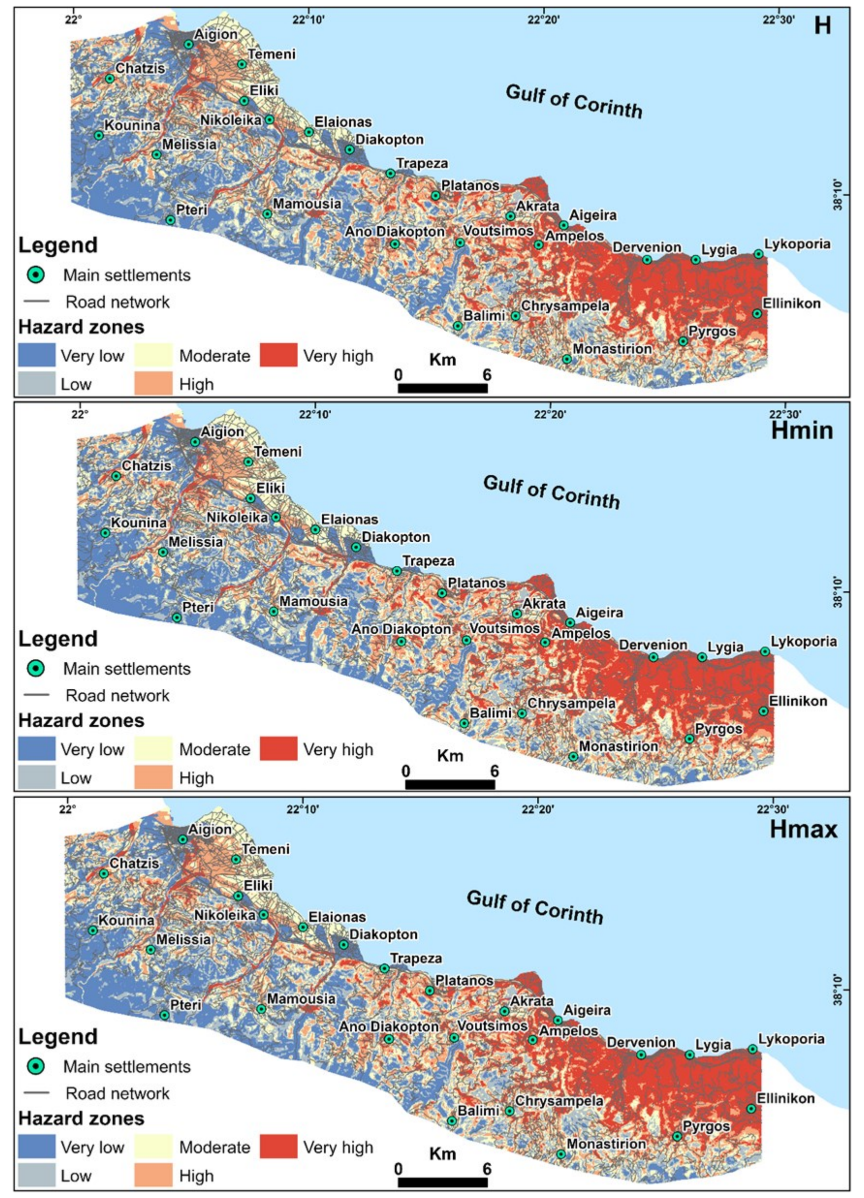

FIGURE 9: Multi-hazard (H) map with upper (Hmax) and lower (Hmin) hazard values, accounting for uncertainties in the weighting coefficients.

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