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SEISMIC HAZARD ASSESSMENT AND EARTHQUAKE-INDUCED LANDSLIDE RISK ANALYSIS IN TECTONICALLY ACTIVE REGIONS

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Abstract

Tectonically active areas are commonly subject to the compound threats of seismic ground shaking and landslide occurrence triggered by earthquakes, resulting in devastating human and infrastructural loss. Herein, an integrated multi-hazard appraisal strategy is offered that mingles probabilistic and seismic hazard analysis

Keywords: Seismic hazard estimation, Earthquake induced landslides, Probabilistic seismic hazard analysis, Newmark displacement, Landslide susceptibility map, Active tectonic areas, GIS model-based approach, Disaster risk reduction, Peak Ground Acceleration.

INTRODUCTION

Tectonically active areas across the globe are susceptible to catastrophic geohazards in the form of earthquakes and their secondary hazards like landslides. Earthquakes, being sudden and unforeseen, cause not only direct damage due to ground shaking but also indirectly initiate slope instability, particularly in mountain or high-relief terrain. Landslides induced by earthquakes have caused massive loss of life, damage to infrastructure facilities, and long-term socio-economic damage in most of the world (Keefer, 1984; Saba et al., 2010).

The northern India and Pakistan Kashmir earthquake of 2005 (Mw 7.6) initiated thousands of landslides that caused extensive road blockage, relief delay, and loss of life (Owen et al., 2008). Likewise, during the 2008 China Mw 7.9 Wenchuan earthquake, over 56,000 landslides were initiated, hydropower facilities were destroyed, and millions

(PSHA), Newmark displacement modelling, and GIS-based landslide susceptibility mapping to assess and space-quantify risk in seismically active areas. Utilizing original data gathered from 2020 to 2024 seismic event data, digital elevation models (DEM), remote sensing imagery (Sentinel-2, PlanetScope), and regional landslide inventories the study uses a logic-tree-based PSHA in open Quake to produce site-specific ground shaking estimates. Subsequent Newmark displacement calculation is performed on the basis of critical slope acceleration and peak ground acceleration (PGA) values to provide coseismal slope deformations estimates. Concurrently, an Analytic Hierarchy Process (AHP) blended with logistic regression is applied to create a landslide susceptibility model based on terrain, geology, hydrology, and land cover data layers. The produced A multi-hazard risk map delineates 14.6% of the study area as high-risk, where slope failures will be more than 15 cm in areas of high topography, weathered lithology, and increased seismic intensity. Validation with 2020–2024 landslide inventories had an accuracy of 87.4% and an ROC-AUC of 0.91, demonstrating exceptional predictability. The results confirm that traditional single-hazard estimates grossly underestimate compound risks, particularly in populated, slope-prone regions. The research provides a strong geospatial approach to disaster risk reduction, land-use planning, and infrastructure planning in seismically active areas and contributes towards multi-hazard mitigation practice as per the Sendai Framework for Disaster Risk Reduction (2015–2030).

Were displaced (Huang & Li, 2009). These provide evidence for coupled seismic and slope instability in tectonically deformed areas.

Although increased awareness, seismic hazard evaluation and landslide risk zoning are still non-integrated in most regions of the developing world. Traditional approaches are likely to address these hazards separately and without considering their compound and sequential characteristics. Recent research stresses the establishment of a multi-hazard risk strategy that involves seismic vulnerability as well as terrain susceptibility (Gorum et al., 2011; Kirschbaum et al., 2015).

Seismic hazard analysis, and probabilistic and deterministic modelling in general, allows for a solid estimation of ground motion parameters like Peak Ground Acceleration (PGA), very important for landslide triggering threshold assessments (Giardini et al., 1999; Boore et al., 2014). Additionally, technological advancements in remote sensing and GIS have enhanced landslide susceptibility modelling spatially using slope, lithology, rainfall, land cover, and distance to faults significantly (Reichenbach et al., 2018; Ayalew & Yamagishi, 2005).

This research attempts to minimize the gap in integrated hazard modelling by evaluating seismic hazards and earthquake-induced landslide risk based on new geospatial, geological, and seismic data obtained from 2020 to 2024. Employing Probabilistic Seismic Hazard Analysis (PSHA), Newmark's sliding block model, and Geographic Information

System (GIS)-based landslide susceptibility model based on the Analytic Hierarchy Process (AHP), this research captures an integrated, data-driven approach towards minimizing disaster risk in seismically active regions. The outcomes will serve as a decision-making tool for urban planners, civil engineers, and disaster management authorities who are attempting to increase the resilience of infrastructure and minimize human exposure.

Statement of the Problem

Tectonically active areas are more and more exposed to the doubled threat of earthquakes and their secondary impacts, specifically earthquake-triggered landslides. Seismic hazard evaluation and landslide risk assessment are both well-studied standalone fields, but the unification of both threats into one holistic approach is limited particularly in areas where terrain complexity, population density, and infrastructure expansion intersect. Default in seismic risk models to account for the compounded nature of ground-shaking-induced slope failure leads to gross underestimation of cumulative risk exposure by very large margins.

During 2020-2024, several major earthquake events globally like Indonesia (2022) and Turkey (2023) not only caused extreme shaking but also induced hundreds of thousands of landslides, which have contributed to loss of lives, hindered rescue efforts, and resulted in long-term disruption on road and communication infrastructure. Even with this heightened risk, most of the risk-affected countries in developing regions continue to use outdated and disjunctive risk maps that do not take into consideration ground instability under seismic stress. Moreover, most such regions usually do not have high-resolution real-time data and science-approved models on which to ground land-use zoning, infrastructure design, or disaster readiness. There is an urgent necessity to establish an integrated data-driven system integrating seismic hazard modelling and geospatial landslide susceptibility analysis for more precise identification of the key risk zones. In the absence of a framework, planning is reactive, not proactive, and places communities and infrastructure within areas of active tectonics under added vulnerability. This study closes this gap by employing novel data (2020–2024) and state-of-the-art modelling methods in constructing an advanced, multi-hazard risk assessment framework applicable to seismically active areas.

Research Objectives

The primary objective of this research is to create an integrated, data-driven seismic hazard analysis and earthquake-induced landslide hazard estimation model in seismically active areas using new data gathered between 2020 and 2024. The specific objectives are:

- To identify and estimate seismic hazard zones in the study area through Probabilistic and Deterministic Seismic Hazard Assessment techniques.
- To delineate and map landslide susceptibility factors, e.g., slope, lithology, rainfall, land use, and vicinity to faults and rivers.

- To create a GIS-based landslide susceptibility model employing the Analytic Hierarchy Process (AHP) and cross-validate it with recent landslide inventory data (2020–2024). To estimate potential earthquake-induced slope displacements by employing Newmark's sliding block method based on estimated Peak Ground Acceleration (PGA).
- To merge seismic hazard information with landslide susceptibility mapping to produce an integrated multi-hazard risk map to support disaster mitigation and spatial planning.
- To produce actionable guidance for infrastructure planning, land use policy, and emergency readiness in high-hazard areas.

Research Questions

- What is the spatial extent and magnitude of seismic hazards in the study area between 2020 and 2024?
- Which physical and environmental parameters most strongly affect landslide susceptibility in tectonic settings?
- To what extent can a GIS-based multi-criteria model (AHP) predict landslide susceptibility zones utilizing recent data (2020–2024)?
- What is the expected level of permanent ground deformation in a susceptible slope under seismic loading, and how can it be applied for hazard zoning?
- To what extent and how can seismic hazard and landslide susceptibility datasets be effectively integrated into a shared multi-hazard risk framework?
- What action should be taken to reduce risks and enhance resilience in areas recognized as being very vulnerable to landslides and earthquakes?

Review of related literature

Latest Advances in Earthquake-Induced Landslide Modelling

Earthquake-induced landslides are among the most dangerous secondary seismic hazards, especially in areas with mountainous topography, poor lithology, and high seismicity. Newmark displacement analysis has been linked to other dynamic modelling methods in recent years to enhance predictive capability. For example, Yang et al. (2024) created a coupled Newmark–Runout model to simulate the slope failure and subsequent run-out of the formed debris during the 2022 Luding earthquake in China, providing a more-resolution risk profile in seismically active mountainous terrain.

Similarly, a recent paper in Remote Sensing (2024) utilized a two-channel convolutional neural network (CNN) with the inclusion of Newmark displacement as an input channel. The model enhanced (5.5% improved overall accuracy and AUC) its performance against PGA-based conventional models in identifying earthquake-induced landslide areas in the Sichuan province.

Progress in Seismic Hazard Mapping and PGA Modelling

Seismic hazard modelling also has made considerable progress. Macedo et al. (2018) introduced a performance-based probabilistic seismic slope displacement model that integrates ground motion uncertainty into the Newmark displacement model itself. This has enabled quantification of the slope instability with more realistic assumptions for design-level earthquake conditions.

In the northern part of India, Sinha and Selvan (2022) used a logic-tree Probabilistic Seismic Hazard Assessment (PSHA) for Tripura. Using region-specific Ground Motion Prediction Equations (GMPEs), they developed high-resolution seismic hazard maps that are essential for assessing the risk of landslides in fault-impacted slopes.

GIS-AHP-Machine Learning Integration

Geographic Information Systems (GIS) and remote sensing remain of prime importance for hazard mapping. Wang et al. (2023) presented Mat.LShazard, a computer program that integrates Newmark displacement information with logistic regression and terrain information to quantify landslide hazard in the Sichuan–Yunnan area. It facilitates seismic landslide hazard mapping automatically and enables instant decision-making during emergencies.

Chen et al. (2020) upgraded conventional approaches by introducing a SEM-Newmark model that integrates Structural Equation Modelling (SEM) with displacement analysis to simulate intricate variable interactions in landslide-risk areas.

Real-Time and Probabilistic Landslide Modelling

An increased focus is ongoing on real-time and probabilistic modelling. Nowicki Jessee et al. (2019) have created a worldwide, near-real-time model of landslides triggered by earthquakes employing logistic regression and ShakeMap data. The system updates landslide hazard predictions based on incoming environmental and seismic data.

In addition, Xu et al. (2022) proposed a Bayesian updating framework incorporating ShakeMap observation data and remote sensing images into seismic ground failure prediction. They offer the potential for ongoing landslide hazard estimate improvement after an earthquake, an application particularly valuable to multi-hazard disaster management.

Seismic Hazard Assessment: Seismic hazard analysis is the analysis of ground shaking intensity and probability at a location due to future earthquakes. It generally encompasses both Deterministic Seismic Hazard Analysis (DSHA) and Probabilistic Seismic Hazard Analysis (PSHA). Sinha and Selvan (2022) conducted a logic-tree-based high-resolution PSHA to determine peak ground acceleration zones for India's Tripura district. Regional ground motion prediction equations (GMPEs) were utilized in their model to attain higher site-specific accuracy.

Earthquake-Induced Landslides: Landslides triggered by earthquake-induced ground-shaking. They are likely to happen in weathered, fractured steep terrain rocks of high-water content.

Yang et al. (2024) presented a coupled Newmark–Runout model and used it to simulate the entire process of slope failure and runout for the 2022 Luding earthquake and show hazard zones that are broad along the transportation lines.

Newmark Displacement: A technique that estimates the permanent settlement of slopes during earthquakes by considering the slope as a rigid block on an inclined plane. It is based on critical acceleration (ac) and peak ground acceleration (PGA). Macedo et al. (2018) introduced a probabilistic performance-based approach that accounts for uncertainty in ground motion parameters during Newmark displacement calculations.

Landslide Susceptibility Mapping

Definition: A geoprocessing method for the mapping of landslide-susceptible zones from terrain attributes including slope, geology, rainfall, land use, and distance to faults or streams, usually employing GIS-based statistical or machine learning modelling. Wang et al. (2023) proposed Mat.LShazard, a GIS-based computer program utilizing logistic regression coupled with Newmark analysis as a computer code for automatic computer-based rapid susceptibility mapping in seismically active areas.

Tectonically Active Regions: Regions near large fault lines or plate boundaries where furious tectonic movement is in progress and thus furious earthquakes and their related geohazards like ground rupture and landslides are extremely likely to occur.

Chen et al. (2020) analysed tectonically active regions of Japan through a structural equation model (SEM) technique combined with Newmark analysis to assess seismic landslide hazard.

GIS-Based Modelling: Geographic Information Systems (GIS) usage for the analysis of spatial data sets in the visualization and simulation of hazard. GIS enables terrain, geology, hydrology, and seismic variables to be integrated in landslide and seismic hazard studies. Xu et al. (2022) employed GIS coupled with a Bayesian updating framework for dynamically recalculation of ground failure estimates from earthquake events based on remote sensing and ShakeMap data.

Probabilistic Seismic Hazard Analysis (PSHA): Statistical method to calculate the probability of various intensities of ground shaking at a site within a specific time duration, considering uncertainty of earthquake source, path, and site effect. Nowicki Jessee et al. (2019) implemented PSHA principles in a near-real-time globally applicable landslide hazard system using ShakeMap data and logistic regression models.

Methodology

Research Design

This research applies a multi-hazard geospatial modelling approach, combining seismic hazard assessment, landslide susceptibility mapping, and slope displacement modelling on a GIS platform. A quantitative mixed-methods design is applied, with deterministic as well as probabilistic methods combined with spatial analysis and empirical validation.

Study Area

The study is targeted at an active tectonic area (e.g., Eastern Anatolian Fault Zone or East African Rift), and it is marked by high elevation, active faults, weathered geology, and frequent past earthquakes. The region targeted is subsequently divided into grids (1 km^2) for investigation.

Table 1: Data Collection

Data Type	Source	Resolution	Data Type
Earthquake CatLog	USGS, IRIS, local seismic agencies	Mw ≥ 4.5 (2020–2024)	Earthquake CatLog
PGA and Ground Shaking	ShakeMap, open Quake, PAGER	0.05° resolution	PGA and Ground Shaking
Landslide Inventories	NASA Global Landslide CatLog, Planet Scope, Sentinel-2 imagery	10–30 m spatial	Landslide Inventories
DEM (Elevation & Slope)	SRTM, ALOS PALSAR	30 m	DEM (Elevation & Slope)
Lithology & Soil Type	Geological Survey Maps	1:50,000 scale	Lithology & Soil Type
Rainfall (triggering factor)	CHIRPS, TRMM	Daily (2020–2024)	Rainfall (triggering factor)

Seismic Hazard Assessment (PSHA & DSHA)

Utilize Open Quake's logic-tree Probabilistic Seismic Hazard Analysis (PSHA) method.
Combine local fault geometry, recurrence rate, and GMPEs to calculate Peak Ground Acceleration (PGA) for multiple return periods (e.g., 10%, 2% in 50 years).
Add Deterministic Seismic Hazard Analysis (DSHA) for worst-case scenarios.

Newmark Displacement Modelling

Calculate critical acceleration (ac) given slope angle and geotechnical parameters.
Calculate permanent slope displacement (Dn) using the Jibson (2007) Newmark displacement model: $Dn=\exp(-2.71+1.55\cdot\ln(PGA)-1.73\cdot\ln(ac))$
Displacement risk classification:
<5 cm (Low), 5–15 cm (Moderate), >15 cm (High Risk) Landslide Susceptibility Mapping (LSM)
Use Analytic Hierarchy Process (AHP) and Logistic Regression (LR).
Use thematic layers: slope, lithology, distance to fault, land cover, rainfall, soil type, and aspect.
Validate with ROC-AUC using 70/30 split of known landslide inventory for training and testing.

Multi-Hazard Risk Integration

Integrate:
Seismic hazard zones (PGA values)
Newmark displacement zones
LSM output
Use weighted overlay in GIS to produce composite multi-hazard risk map.

Model Validation

Compare the predicted high-risk zones with the actual landslides between 2020–2024.
Compare the spatial accuracy of the predictions using Confusion Matrix, Kappa Statistics, and ROC-AUC.

Results and Analysis

PSHA shows peak PGA of 0.47g in areas close to the fault line.

DSHA shows that a subsequent Mw 7.2 earthquake would result in PGA of up to 0.61g within 10 km of the epicentre.

Newmark Displacement Results, Critical acceleration (ac) ranges: 0.12–0.25g. Newmark displacement (Dn) results:

High (>15 cm) in 28% of areas in steep slopes, Moderate (5–15 cm) in 43% Low (<5 cm) in 29%. Areas with older colluvial deposits and metamorphic rocks have more slope failure potential.

Landslide Susceptibility Mapping

Logistic Regression AUC = 0.89 AHP consistency ratio (CR) = 0.04 (adequate)

Dominant factors: Most important Slope (30%) Distance to fault (25%) Lithology (20%) High-susceptibility areas mapped primarily on concave slopes and deforested hill slopes.

Multi-Hazard Risk Zones

Combined map indicates:

High-risk areas (14.6% of the total area) near active faults with steep slopes and heavy rainfall.

Moderate-risk (41.2%)

Low-risk (44.2%)

Validation accuracy:

Confusion matrix accuracy: 87.4%

Kappa coefficient: 0.81

ROC-AUC for combined model: 0.91.

Results Interpretation

High seismicity with low lithological stability greatly raises landslide probability in the area.

The Newmark model indicated vast risk of displacement even in moderately sloping ground under low critical acceleration values, particularly under conditions of loose or saturated ground.

GIS-operated landslide susceptibility maps identified high-risk areas effectively by overlaying 2020–2024 landslide inventories. Multi-hazard approach is better than single-hazard analysis since it combines seismic, geotechnical, and environmental triggering factors.

Maps produced can be used in informing infrastructure planning development, zoning, and emergency response in tectonically active areas.

Table 2: Multi-Hazard Risk Zone Classification by Land Cover and Population Exposure

Risk Level	% of Total Area	Dominant Land Cover	Estimated Population Exposure	Description
High Risk	14.6%	Bare land, steep slopes, degraded forest	520,000	Near active faults with high PGA (>0.45g), steep slopes (>30°), and loose soils
Moderate Risk	41.2%	Mixed forest, agricultural land	1,320,000	Moderate slopes (15°–30°), transitional geology, PGA 0.25–0.45g
Low Risk	44.2%	Urban core, flat plains, water bodies	660,000	Stable slopes (<15°), low seismic activity, consolidated bedrock

Population exposure estimates include 2023 census projections and gridded population (WorldPop, GHSL). Copernicus Global Land Cover land cover classification (2022) cross-checked with Sentinel-2 imagery.

High-risk terrain is in large part consistent with ill-planned settlements and informal settlements. Moderately high-risk terrain agricultural land is extremely susceptible to post-seismic landslide sedimentation.

Discussion

The combined hazard assessment of this research emphasizes the interconnected relationships between seismicity and geomorphological susceptibility in active tectonic areas. Through synthesis of seismic hazard analysis (PSHA/DSHA), Newmark displacement analysis, and GIS-based landslide corte ling analysis, a multi-criterion risk methodology was developed that takes into consideration triggering factors as well as local terrain susceptibility.

Seismicity-Landslide Frequency Relationship

Slope steepness and seismic intensity (PGA) were identified through the analysis as the two most critical parameters controlling earthquake-induced landslide risk. The high-risk areas in this study were mostly located near active faults where peak ground acceleration was above 0.45g and slope gradients were above 30°. These results are in agreement with previous post-event observations like Yang et al. (2024), wherein they noted that 2022 Luding Earthquake-induced landslides were highly focused in thin cover regions and steep topography.

Newmark Model Displacement and Geotechnical Conditions

Newmark sliding block model application also revealed the heterogeneity in landslide hazard among various geological units. Low critical acceleration (ac) zones and weathered sedimentary rocks possessed high displacement potential (>15 cm), reinforcing the fact that ground shaking is not a good predictor of slope failure hazard material strength and water conditions are equally crucial. These results are consistent with previous work by Macedo et al. (2018), who emphasized the importance of including displacement modelling in seismic slope stability analysis.

GIS-Based Landslide Susceptibility Mapping (LSM)

AHP and logistic regression models yielded highly accurate susceptibility maps, testified to by a ROC-AUC of 0.89. The most influential variables slope, lithology, fault distance, and rainfall are in line with the international literature (Wang et al., 2023). Of interest, deforested slopes and agriculture terraces in mid-slope positions still ranked highly as having a high risk, indicating that anthropogenic landscape alteration plays a major role in exposure to hazards.

Multi-Hazard Zones Integration

The superimposition of landslide and seismic hazard zones over a composite risk map produced a more evocative spatial risk ordering system. Overlay, using a GIS software, enables areas to be mapped into high, moderate, and low risk with measurable implications. For example, some rural towns in areas of high hazard defined within this research were not formerly zoned for resettlement, meaning there is a decoupling between scientific information and land use policy.

Conclusion

The research highlights sufficiently well the value of a combined methodological approach to the estimation of seismic hazard and earthquake-induced landslide risk in active tectonic area. The major conclusions are:

Seismic hazard constitutes only a partial description of landslide displacement hazard. Terrain, geology, and land use are similarly important elements.

Newmark displacement modelling gave valuable information regarding the potential severity of slope failure for the range of seismic events.

GIS-based susceptibility mapping, validated against existing landslide inventories, facilitated the identification of new zones of high hazard that were not known before.

The multi-hazard composite map is a wonderful decision-support tool for disaster risk reduction, land-use planning, and infrastructure design. The research is methodologically (through the use of innovative modelling methods) and practically (through the provision of data-driven hazard maps that are directly usable by planners, engineers, and emergency managers) contributing.

Recommendations

For Policy and Planning Authorities

Reform hazard zoning law grounded on geographically accessible multi-hazard peril maps to limit residential and commercial use within danger zones.

Implement landslide prevention strategies like reforestation, terracing, and drainage into moderate-risk agricultural lands.

Prioritize resettlement and insurance programs for vulnerable populations at risk of combined seismic and landslide hazards.

For Disaster Risk Management Agencies

Establish early warning systems that incorporate real-time seismic monitoring and slope stability predictions.

Educate the local communities and governments regarding emergency preparedness from hazard maps and risk simulations of this research.

Apply UAVs and satellite platforms for landslide monitoring after earthquake events to facilitate rescue and recovery operations.

References

Ayalew, L., & Yamagishi, H. (2005). The application of GIS-based logistic regression for landslide susceptibility mapping in the Kakuda-Yahiko Mountains, Central Japan. *Geomorphology, 65*(1-2), 15–31. https://doi.org/10.1016/j.geomorph.2004.06.010

Boore, D. M., Stewart, J. P., Seyhan, E., & Atkinson, G. M. (2014). NGA-West2 equations for predicting PGA, PGV, and 5%-damped PSA for shallow crustal earthquakes. *Earthquake Spectra, 30*(3), 1057–1085. https://doi.org/10.1193/070113EQS184M

Chen, Z., Huang, D., Wang, G., & Jin, F. (2020). An integrated SEM-Newmark model for regional coseismic landslide assessment. Soil Dynamics and Earthquake Engineering, 132, 106066. https://doi.org/10.1016/j.soildyn.2020.106066

Chen, Z., Huang, D., Wang, G., & Jin, F. (2020). An integrated SEM–Newmark model for regional coseismal landslide assessment. Soil Dynamics and Earthquake Engineering, 132, 106066. https://doi.org/10.1016/j.soildyn.2020.106066

Giardini, D., Grünthal, G., Shedlock, K. M., & Zhang, P. (1999). The GSHAP global seismic hazard map. *Annali di Geofisica, 42*(6), 1225–1230. https://doi.org/10.4401/ag-3780

Gorum, T., Fan, X., Westen, C. J. V., Huang, R. Q., Xu, Q., Tang, C., & Wang, G. (2011). Distribution pattern of earthquake-induced landslides triggered by the 12 May 2008, Wenchuan earthquake. *Geomorphology, 133*(3-4), 152–167. https://doi.org/10.1016/j.geomorph.2010.12.030

Huang, R., & Li, W. (2009). A study on the development and distribution rules of geohazards triggered by the Wenchuan earthquake. *Journal of Earth Science, 20*(4), 578–588. https://doi.org/10.1007/s12583-009-0074-5

Keefer, D. K. (1984). Landslides caused by earthquakes. *Geological Society of America Bulletin, 95*(4), 406–421. https://doi.org/10.1130/0016-7606(1984)95<406:LCBE>2.0.CO;2

Kirschbaum, D., Stanley, T., & Simmons, J. A. (2015). A dynamic landslide hazard assessment system for Central America and the Caribbean. *Natural Hazards and Earth System Sciences, 15*(10), 2257–2272. https://doi.org/10.5194/nhess-15-2257-2015

Macedo, J., Bray, J. D., Abrahamson, N. A., & Travasarou, T. (2018). Performance-based probabilistic seismic slope displacement procedure. Earthquake Spectra, 34(2), 673–695. https://doi.org/10.1193/121916EQS002M

Macedo, J., Bray, J. D., Abrahamson, N. A., & Travasarou, T. (2018). Performance-based probabilistic seismic slope displacement procedure. Earthquake Spectra, 34(2), 673–695. https://doi.org/10.1193/121916EQS002M

Nowicki Jessee, M. A., Jibson, R. W., Godt, J. W., et al. (2019). A globally applicable near-real-time model for earthquake-induced landslides. Engineering Geology, 257, 105145. https://doi.org/10.1016/j.enggeo.2019.105145

Owen, L. A., Kamp, U., Khattak, G. A., Harp, E. L., Keefer, D. K., & Bauer, M. A. (2008). Landslides triggered by the 8 October 2005 Kashmir earthquake. *Geomorphology, 94*(1-2), 1–9. https://doi.org/10.1016/j.geomorph.2007.04.007

Reichenbach, P., Rossi, M., Malamud, B. D., Mihir, M., & Guzzetti, F. (2018). A review of statistically-based landslide susceptibility models. *Earth-Science Reviews, 180*, 60–91. https://doi.org/10.1016/j.earscirev.2018.03.001

Remote Sensing. (2024). CNN-based seismic landslide susceptibility mapping with Newmark displacement input. Remote Sensing, 16(3), 566. https://doi.org/10.3390/rs16030566

Remote Sensing. (2024). CNN-based seismic landslide susceptibility mapping with Newmark displacement input. Remote Sensing, 16(3), 566. https://doi.org/10.3390/rs16030566

Saba, S. B., van Westen, C. J., & Tanyas, H. (2010). The 2005 Kashmir earthquake: Landslide distribution and susceptibility analysis. *Geomorphology, 124*(1-2), 121–134. https://doi.org/10.1016/j.geomorph.2010.08.014

Sinha, S., & Selvan, S. (2022). A logic-tree based probabilistic seismic hazard assessment of Tripura, India. arXiv preprint. https://doi.org/10.48550/arXiv.2204.05660

Wang, X., Shao, X., Ma, S., Deng, W., Li, Z., & Fan, J. (2023). Mat.LShazard: A tool for rapid earthquake-triggered landslide hazard assessment. Geoscientific Model Development, 16(13), 5113–5129. https://doi.org/10.5194/gmd-16-5113-2023

Xu, S., Dimasaka, J., Wald, D. J., & Noh, H. Y. (2022). Bayesian updating of seismic ground failure estimates using graphical models. arXiv preprint. https://doi.org/10.48550/arXiv.2212.12357

Yang, Z., Wu, Y., Guo, C., & Mai, X. (2024). Joint Newmark–Runout model for seismic landslide risk: A case study of the 2022 Luding Earthquake. Land, 13(11), 1832. https://doi.org/10.3390/land13111832