Causal Inference-Based Seismic Multi-Hazard Estimation for the 2025 Myanmar Earthquake

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Abstract

Following the extensive cascading hazards from the March 28, 2025, M7.7 Myanmar earthquake, we applied a causal Bayesian network (CBN) for multi-hazard estimation. Our framework integrates satellite remote sensing, specifically Damage Proxy Map (DPM) scores from InSAR, with prior geospatial models to infer the probability of landslides, liquefaction, and building damage. A key feature is its unsupervised training through a variational Bayesian inference algorithm, which eliminates the need for labeled ground truth and allows the model to generalize across diverse regions. Results from the Myanmar scenario show that estimated liquefaction and landslide zones corresponded with observed sedimentary conditions and damage reports, while building damage probabilities clustered in areas of reported collapse. This work confirms the transferability of our causality-based seismic hazard model for rapid, satellite-driven assessment in global post-earthquake response.

Introduction

Triggering Event: The M7.7 Myanmar earthquake (28 March 2025), which caused catastrophic and interconnected hazards.

Cascading Impacts: Widespread landslides, liquefaction, and severe building damage, revealing a complex multi-hazard disaster.

Assessment Gap: Traditional post-disaster methods are too slow and focus on single hazards, limiting effective emergency response.

Motivation: The urgent need for a rapid, integrated, and multi-hazard assessment framework to better support disaster relief efforts.

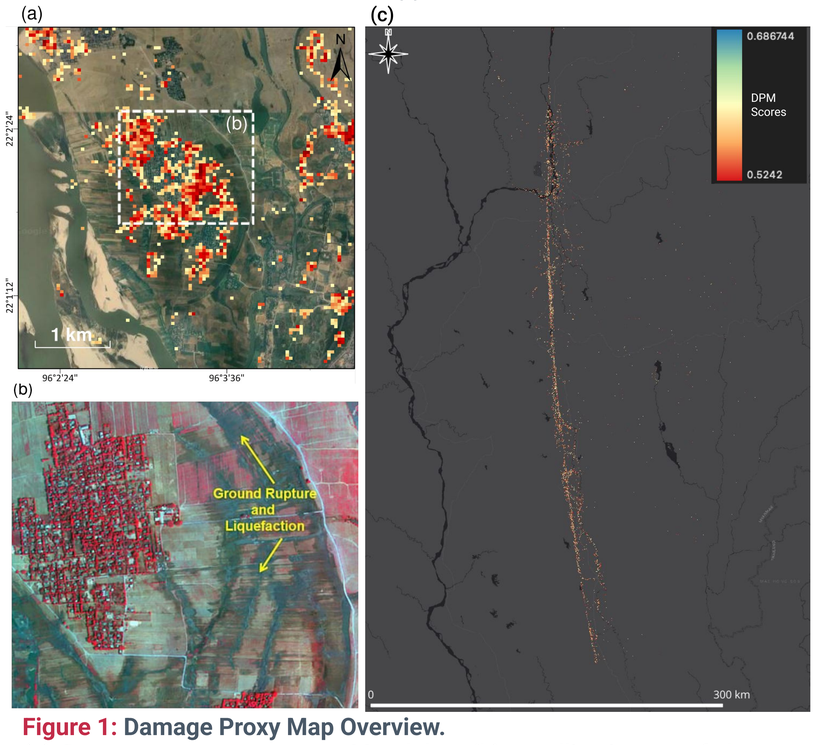

Figure 1: Damage Proxy Map Overview.
(a) Damage proxy map near Mandalay. (b) satellite image of the area highlighted by the white dashed box in (a), which reveals extensive ground rupture and liquefaction. (Yang) (c) Full DPM in Myanmar, with clustered values tracing the Sagaing Fault.

Methodology

- Integrated Sentinel-1 DPMs with priors: ground shaking, slope, soil, buildings
- Built causal Bayesian network linking hazards, damage, and DPMs
- Trained unsupervised with stochastic variational inference
- Estimated posterior probabilities of landslides, liquefaction, and damage without labels.

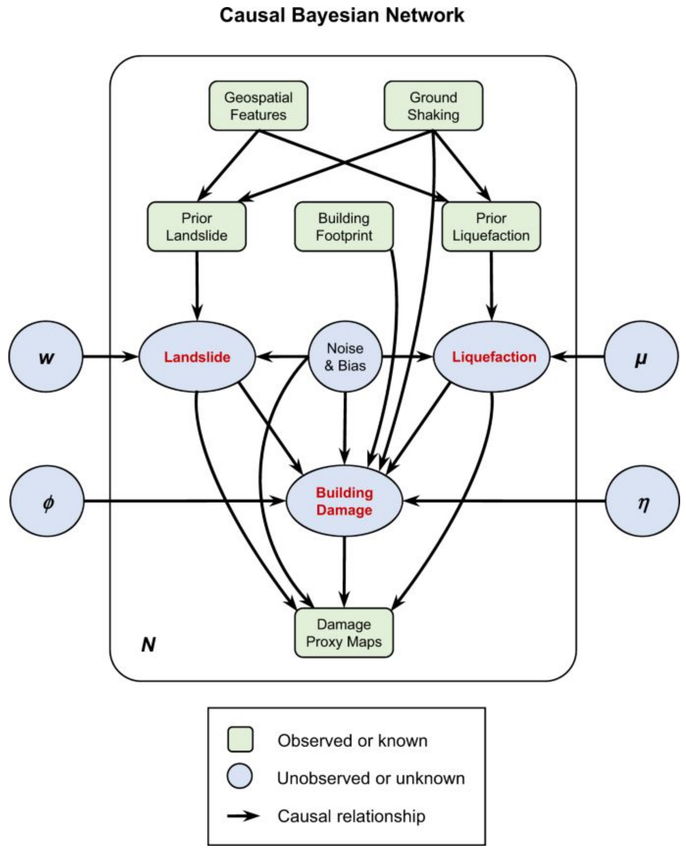

Figure 2: Causal Bayesian Network for multi-hazard earthquake assessment. Green nodes = observed variables (geospatial features, shaking, DPMs); blue nodes = latent variables (landslide, liquefaction, damage). Arrows show causal dependencies used to jointly estimate hazard and damage probabilities. (Xu, 2022)

Results

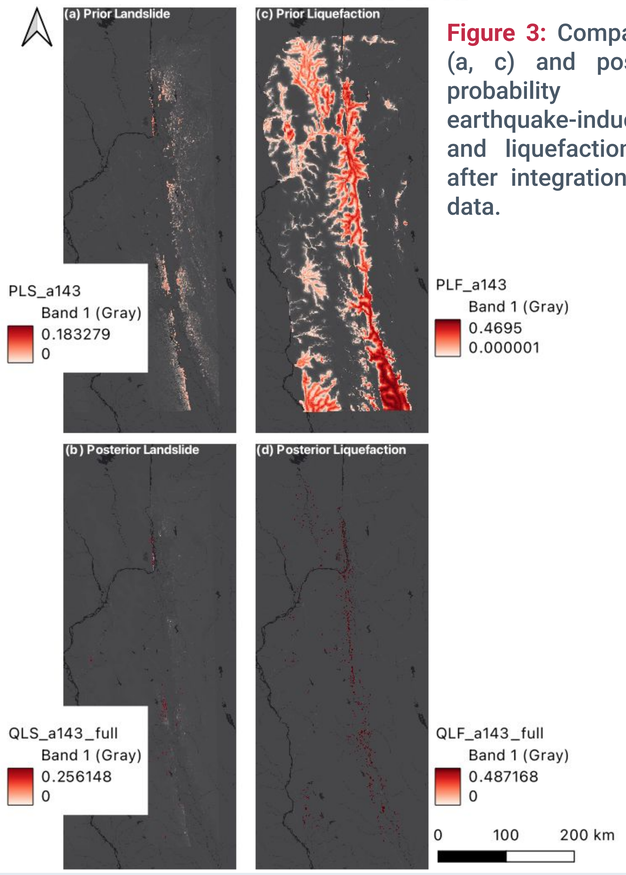

Figure 3: Comparison of prior (a, c) and posterior (b, d) probability maps for earthquake-induced landslides and liquefaction, before and after integration with satellite data.

Building Damage

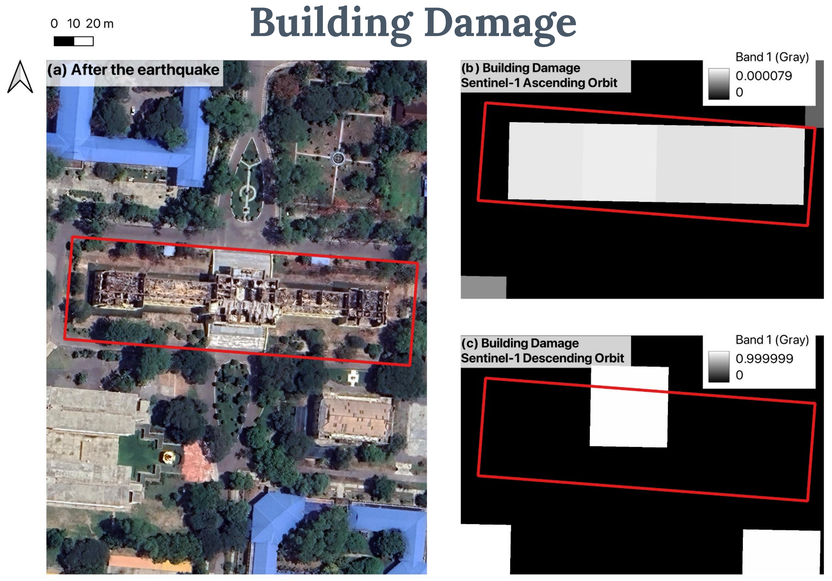

Figure 5: The site is in University of Mandalay, Mandalay (city) (Lon. 96.0942° E, Lat. 21.9567° N). (a) Google Earth image of the site after the Myanmar Earthquake. (b) Predicted Building Damage (BD) map from Sentinel-1 (Ascending orbit a143). (c) Predicted Building Damage (BD) map from Sentinel-1 (Descending orbit d033).

Future Work

Multi-class damage detection (MCDD) model fusing DPM, Normalized Difference Built-Up Index (NDBI), and Peak Ground Acceleration (PGA) to classify building damage levels

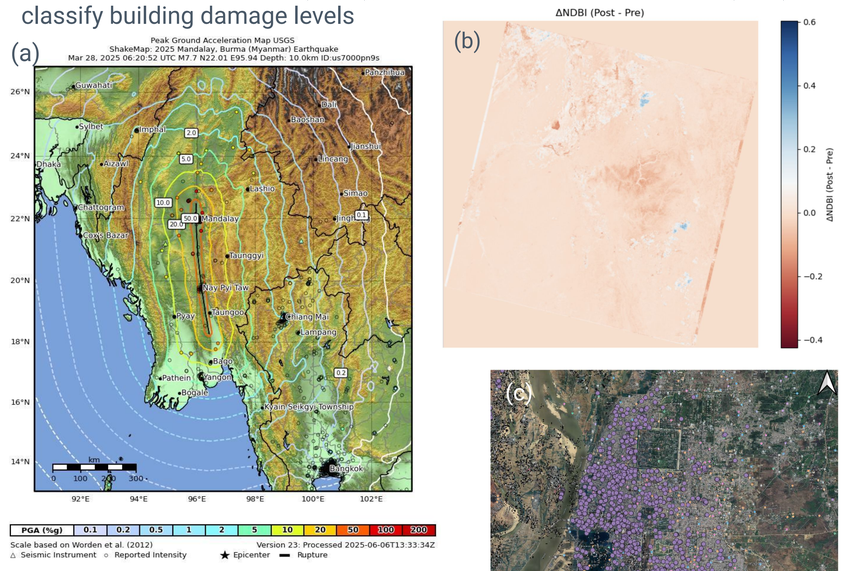

Figure 5: Features for training. (a) PGA map for Myanmar Earthquake (USGS, 2025) (b) NDBI differencing before & after the earthquake in Mandalay (c) Damaged buildings in Mandalay (Purple dots)

References

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Acknowledgements

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