International Cartographic Association
Association Cartographique Internationale

Measuring Social Vulnerability to Earthquakes in Ishikawa, Japan utilizing Spatial Analysis

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Keywords: Seismic Hazard, Vulnerability, Suitability

Abstract:

In January of 2024, Japan experienced a powerful earthquake on its Western Coast. Officially named the 2024 Noto Peninsula Earthquake, this event was one of the strongest earthquakes to hit mainland Japan since the infamous 2011 Tohoku Earthquake. Recorded as being 7.5 on the moment magnitude scale (M_w), the tremors of the Noto Earthquake caused many aftereffects. These included a massive geological uplift in the region, landslides, fire hazards, and tsunami hazards. The geographical position which Japan finds itself in places it at a high risk to powerful earthquakes. However, with proper damage mitigation technologies and policies, the effects of the seismic events can be lowered, and Japan is a leader in this field of earthquake innovation.

A key effort in damage mitigation is to identify who and where are the most vulnerable and "at risk" populations so that resources can be utilized efficiently. Many studies that identify vulnerable populations in Japan are regional, focusing on highly urbanized areas that frequently experience earthquakes (Takahashi & Yasufuku, 2024). However, understanding the social vulnerability in rural locations that are experiencing population decline is just as important. The objective of this study is to measure the earthquake risk within rural regions of Japan that may not experience severe earthquakes as frequently but have socially vulnerable populations. The Ishikawa prefecture was selected as the case study due to it being the location of the 2024 Noto Peninsula Earthquake.

To meet this objective, this study uses suitability analysis to identify high-risk areas in rural Ishikawa prefecture (Fig. 1). The selection of these criteria was guided by FEMA's National Risk Index for National Hazards that considers criteria capturing social vulnerability and physical hazards (Table 1). The variables were transformed using fuzzy membership, where locations meeting criteria that indicated the most risk were assigned a value closer to 1 and the least risk were assigned a value closer to 0. Each criterion was given weight to reflect its overall importance to the risk score, focusing on social vulnerability. The weights were determined using expert opinion and pair-wise comparison through the Analytical Hierarchy Process (AHP) (Abdelkarim et al., 2020).

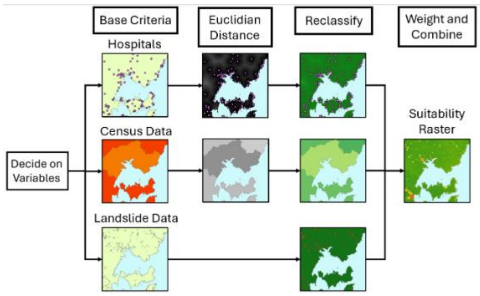

Fig 1. Basic flow of data in the project

Table 1. Criteria for Suitability Analysis

Criteria	Description	Weight
Tsunami Inundation Area (NL NI, 2017)	Expected area affected by a tsunami at different severity	0.18
Flooding Max. Expected Area (NL NI, 2023)	Maximum flood extent on coast and rivers	0.18
Landslide Warning Area (NL NI, 2021)	Areas at risk to a landslide	0.13
Population 60+ Density (HDX, 2019)	Density of elderly across entire prefecture	0.11
Evacuation Facilities (NL NI, 2012)	Point data of evacuation facilities	0.09
Emergency Transport Roads (NL NI, 2020)	Line data of essential emergency roads	0.07
Percent of Population in Solitary Housing (e-Stat, 2020)	Percent of housing units with one occupant	0.06
Hospital Locations (NL NI, 2020)	Point data on medical facilities	0.05
Percent of Population in Single Parent Households (e-Stat, 2020)	Percent of housing units with single parent	0.04
Population 15 to 24 Density (HDX, 2019)	Density of age cohort across entire prefecture	0.03
Percent Population without Highschool Education (e-Stat, 2020)	Percent of each municipality with a high-school education	0.03
Percent of Population Unemployed (e-Stat, 2020)	Percent of each municipality unemployed	0.02
Coastline of the Prefecture (NL NI, 2006)	Line data of prefecture coast	0.02

Abstracts of the International Cartographic Association, 10, 110, 2025
32nd International Cartographic Conference (ICC 2025), 17–22 August 2025, Vancouver, Canada.
https://doi.org/10.5194/ica-abs-10-110-2025

Finally, criteria were combined into a map (30x30 resolution) where each location is described by a single score capturing the overall social vulnerability and areas at risk of earthquakes (Figure 2). After creating the final suitability raster for social vulnerability, the completed map of the prefecture could be compared to a map depicting the chance of a severe earthquake occurring across the region (*What Are the National Seismic Hazard Maps for Japan? | J-SHIS*, 2010 https://www.j-shis.bosai.go.jp/en/shm). By looking at where there is an overlap between high vulnerability and high earthquake potential, officials of the prefecture would be able to focus disaster relief and training on those specific areas

The results showed that the more urban areas would have the highest population of vulnerable people. In fact, the highest concentration of high-risk points was at the location of the largest city in the prefecture, Kanazawa City (Fig. 3). That being said, very high-risk points were lacking in this location and were instead found in more isolated towns around the Noto Peninsula to the north (Fig. 2). Along with this, there are significant risky locations in more rural areas, primarily due to distance to resources and landslide danger. While other criteria could be considered to enhance analysis, datasets for rural Japan locations are limited. Such a risk analysis could support decision making and natural hazard response in Japan. Future work may include the development of a dynamic risk index that is updated in real time to incorporate social media data as well as other seismic sensors. The methodology uses open and available data that could be used to estimate risk and social vulnerability to different hazards across Japan.

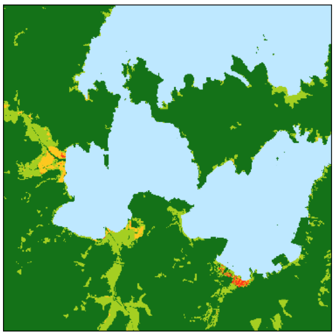

Fig 2. North Ishikawa Suitability

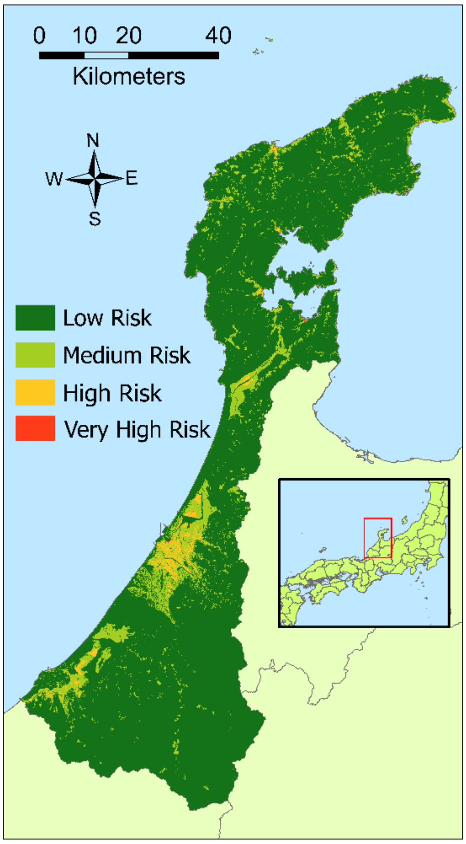

Fig 3. Final Suitability Map

Acknowledgments:

We would like to thank the George Mason University Office of Student Creative Activities and research for providing the funding and support which allowed for the completion of this project.

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