7th Intercontinental Geoinformation Days

igd.mersin.edu.tr

Spatial analysis of the vulnerability of rural housing to earthquakes (case study: rural settlements in the Tehran metropolitan area)

Bahman Tahmasi *[1], **Hassan Ali Faraji Sabokbar** [1], **Seyed Ali Badri** [1]

[1]University of Tehran, Faculty of Geography, Department of Human Geography and planning, Tehran, Iran

Keywords
Spatial analysis
Vulnerability
Rural housing
Earthquake
TMA

Abstract

Natural disasters are one of the main factors in the destruction of human settlements and cause much damage to human societies. An earthquake is one of the most destructive natural disasters that can destroy settlements in just a few seconds. Iran is located in an earthquake-prone region where many earthquakes occur every year. Also, the Tehran metropolitan area is one of the most prone to earthquakes in Iran. This area has a high risk of earthquake due to the high population density, high residential density and the existence of many faults. Rural settlements located in the Tehran metropolitan area have a high potential for vulnerability to earthquakes due to their high population density, low-quality housing, and unique socio-economic conditions. This is the reason this paper analyzes the vulnerability of housing of rural settlements in the Tehran metropolitan area. The statistical population in this research was the rural settlements located in the TMA region. For data analysis, several spatial analysis methods, including IDW interpolation, hotspot analysis, and KMeans spatial clustering, have been used. The results of this study show that the rural settlements located in the central area of TMA have more resistant housing and less vulnerability, and the peripheral areas have more non-resistant housing and more vulnerability.

1. Introduction

Natural disasters have a negative impact on human society. natural disasters can lead to substantial damages to human capital, including nutrition, education, and health. The impacts are often long-lasting and disproportionately affect the poorest socioeconomic groups (Baez et al, 2010; Felbermayr, & Groschl, 2014; Cavallo et al,2013; Khan et al, 2020; Murat & Sozen, 2021). Each year, natural disasters cause a large number of deaths as well as significant economic losses. The number of deaths and the amount of damages from natural disasters can be highly variable from year-to-year; some years pass with very few deaths and damages before a large disaster event claims many lives. If we look at the average over the past decade, approximately 45,000 people globally died from natural disasters each year. This represents around 0.1% of global deaths (Global Change Data Lab, 2023).

Among the natural hazards, earthquakes are one of the most destructive hazards and have many negative effects. Earthquakes can have devastating impacts in a matter of seconds. Their unpredictable nature and the potential scale of their impact make them one of the most lethal of all disasters, claiming an average of 27,000 lives a year worldwide since the 1990s (Guha-Sapir, 2010).

Earthquake has different effects in social, economic and physical dimensions (Alizadeh et al, 2021; Minos-Minopoulos, 2017). Therefore, seismic vulnerability can be classified into physical, social and economic components. But in practice, physical vulnerability, especially of buildings, is the most important and has attracted the most attention in evaluations, because so far the most deaths and casualties in earthquakes have been caused by building collapse (Gao & Ji, 2014). And this issue is more evident in developing countries (Kenny, 2009). For this reason, in this article, physical vulnerability to earthquakes in rural settlements has been considered the most important component of vulnerability to earthquakes.

Iran is located in one of the world's most seismically active areas. The Tehran metropolitan area (TMA) is one of the areas with a high risk of earthquakes in Iran due to the history of earthquakes and the presence of numerous and active faults. Rural settlements located in this area are vulnerable to earthquakes due to high population density and low quality of housing. The important issue is that the quality of rural houses and their vulnerability

* **Corresponding Author**

*(bahman.tahmasi@ut.ac.ir) ORCID ID 0000-0002-7742-814X
(hfaraji@ut.ac.ir) ORCID ID 0000-0002-5470-4287
(sabadri@ut.ac.ir) ORCID ID 0000-0001-7422-7281

Cite this study

Tahmasi, B., Faraji Sabokbar, H. A., & Badri, S. A. (2023). Spatial analysis of the vulnerability of rural housing to earthquakes (case study: rural settlements in the Tehran metropolitan area). Intercontinental Geoinformation Days (IGD), 7, 262-265, Peshawar, Pakistan

to earthquakes are not the same in the entire the Tehran metropolitan area (TMA), but some rural settlements have low-quality houses and higher vulnerability, and some other rural settlements have high-quality houses. and are less vulnerable to earthquakes. Therefore, the aim of this article is to spatially analyze the vulnerability of rural dwellings and clustering rural settlements located in the Tehran metropolitan area (TMA) based on the degree of vulnerability.

2. Method

This study is a type of applied research that was carried out using a quantitative methodology framework. The study's statistical population consists of 1519 rural settlements situated inside the Tehran metropolitan area (Statistical Centre of Iran, 2016). Among these, a statistical sample of 928 rural settlements with data on the types of building materials available was examined. The data used in this research was collected from the general census of population and housing, Statistical Centre of Iran. Data analysis was done using spatial analysis methods, spatial statistical techniques, and spatial clustering, including the IDW interpolation technique, HotSpot analysis, and the KMeans clustering technique. ArcMap and GeoDa software have been used for data analysis. The three variables used in this research include; The number of buildings built with metal materials, the number of buildings built with concrete materials, and the number of buildings built with low-quality materials such as wood, stone, brick, clay, etc.

2.1. Study area

The study area of this research includes the Tehran metropolitan area. The capital city of Iran is located in this region and almost 20% of the total population of Iran lives in this region. The two provinces of Alborz and Tehran are included in the Tehran metropolitan area. Tehran Province has an area of about 13842 square kilometers. Tehran province is divided into 16 counties, 46 cities, and 1048 villages. Also, Tehran province has a population of 13267637 people. Alborz province has an area of about 5182 square kilometers. Alborz province comprises 6 counties, 17 cities, and 471 villages. Also, Alborz province has a population of 27124000 people (Statistical Centre of Iran, 2021).

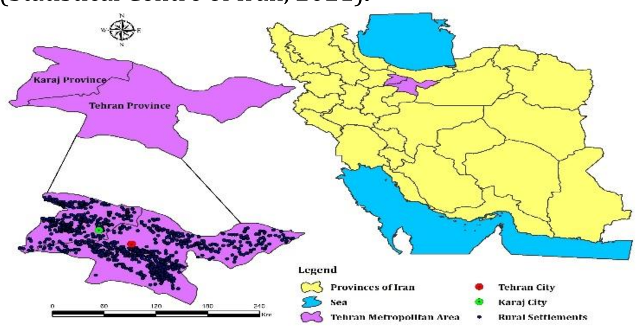

Figure 1. The location of the Tehran metropolitan area

The provinces of Mazandaran in the north, Qazvin in the west, Markazi in the southwest, Qom in the south, and Semnan in the southeast encircle the Tehran metropolitan area (Fig 1).

3. Results

The overall number of buildings in the 928 villages under study comes to 286,889, based on the information that was gathered. Among them, 145,664 (50.77%) were constructed using metal materials, 35,253 (12.29%) using concrete materials, and 105,083 (36.63%) using low-quality materials including clay, stone, brick, wood, etc. Furthermore, the type of materials in 889 (0.31%) rural buildings is also unknown "Table 1".

Table 1. The number of rural buildings by type of materials

Variable	All buildings	Metal materials	Concrete materials	Low quality materials	Unknown
Number	286889	145664	35253	105083	889
Percent	100	50.77	12.29	36.63	0.31

The utilization of metal materials is higher in TMA's center regions and less common in its other peripheral locations, according to the spatial distribution of the different types of materials utilized in rural buildings. Concrete materials are similarly distributed spatially in the same pattern. However, throughout the whole TMA range, the geographical distribution of low-quality materials is visible. Therefore, the number of housing built with metal and concrete materials is more in the central areas of TMA (Fig 2).

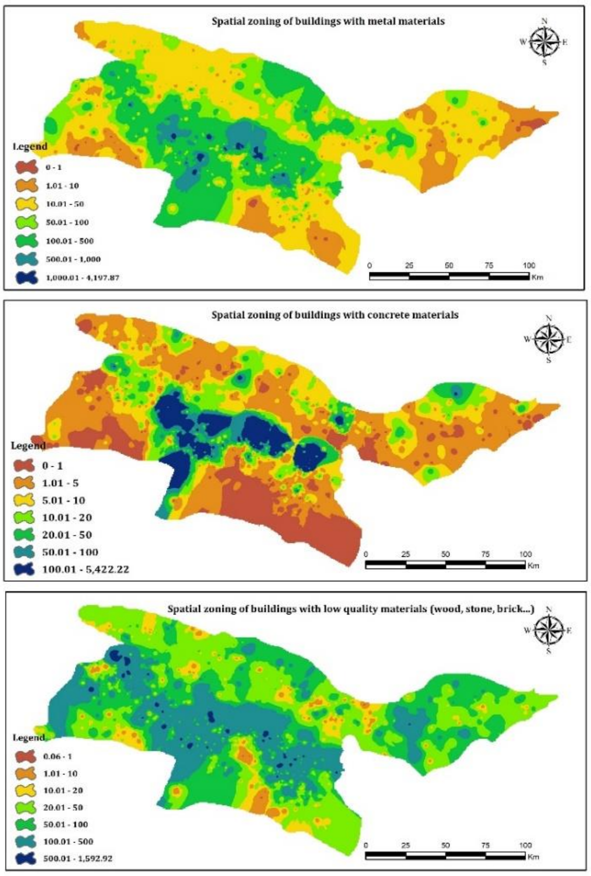

Figure 2. Spatial distribution of types of materials in rural buildings

At this stage, the ratio of buildings with resistant materials and the ratio of buildings with non-resistant materials has been calculated. For this action, the number of metal and concrete buildings have been added together and defined as resistant buildings. Also, buildings with low-quality materials (such as wood, stone, brick, clay, etc.) are defined as non-resistant buildings. Next, by dividing the number of resistant and non-resistant buildings by the total number of buildings, the ratio of each of them is obtained "Table 2".

Table 2. The ratio of resistant and non-resistant buildings

Variable	Ratio of resistant buildings	Ratio of non-resistant buildings	Ratio of unknown buildings	Total
Number	180917	105083	889	286889
Ratio (%)	63.06	36.63	0.31	100

The spatial distribution of the ratio of resistant and non-resistant buildings in the Tehran metropolitan area shows that the ratio of resistant buildings is higher in the center, south, north, and northeast of the TMA. Also, the proportion of non-resistant buildings is higher in the west, southwest, east, and southeast of TMA (Fig 3).

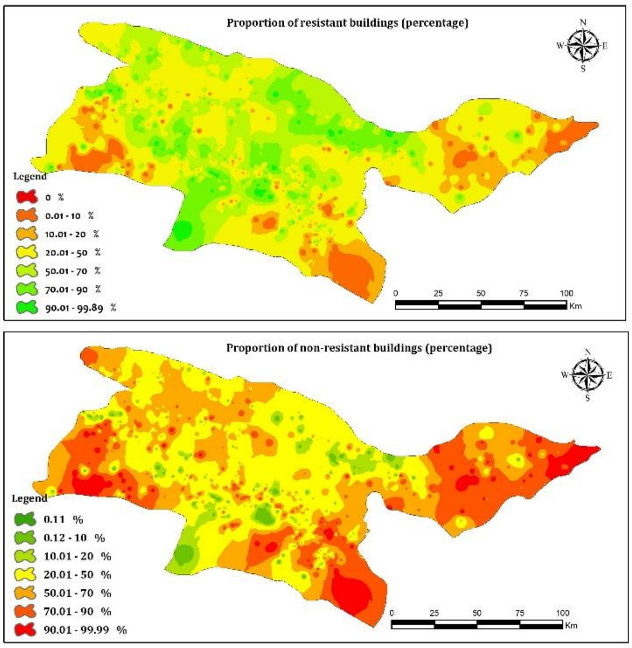

Figure 3. Spatial distribution of the ratio of resistant and non-resistant buildings

In the following, hotspots analysis has been used to identify the location of the concentration of hot and cold spots related to the ratio of resistant and non-resistant buildings. The hotspots analysis of the ratio of resistant buildings shows that a hot spot has been identified in the center of TMA. This spot shows the concentration of high values related to the proportion of resistant buildings. This spot is also statistically significant. In addition, three cold spots related to the proportion of resistant buildings have been identified in the southwest, south, and east of the TMA area. This spot shows the low value of the proportion of resistant buildings. These spots are statistically significant.

The hotspots analysis of the ratio of non-resistant buildings shows that a cold spot has been identified in the center of TMA. This spot shows the concentration of low values related to the proportion of non-resistant buildings. As well as, three hot spots related to the proportion of non-resistant buildings have been identified in the southwest, south, and east of the TMA area. This spot shows the high value of the proportion of non-resistant buildings (Fig 4).

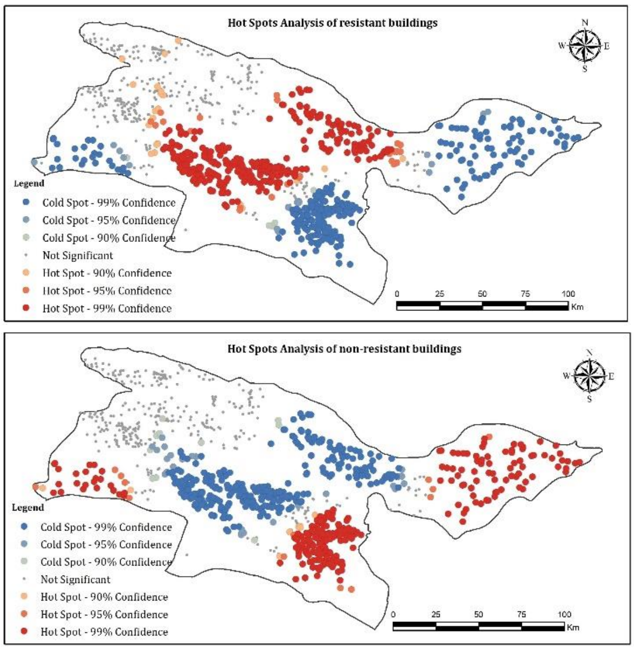

Figure 4. Hotspots analysis of the ratio of resistant and non-resistant buildings

Finally, based on the level of vulnerability of housing to earthquakes, rural settlements are clustered in TMA. Based on the level of housing vulnerability, rural settlements located in TMA are divided into 5 clusters. Cluster 1 in the north and northeast of TMA has more resistant housing and less vulnerability to earthquakes. Cluster 5 in the east of TMA has more non-resistant houses and more vulnerability to earthquakes. Three other clusters are located between these two clusters (Figure 5).

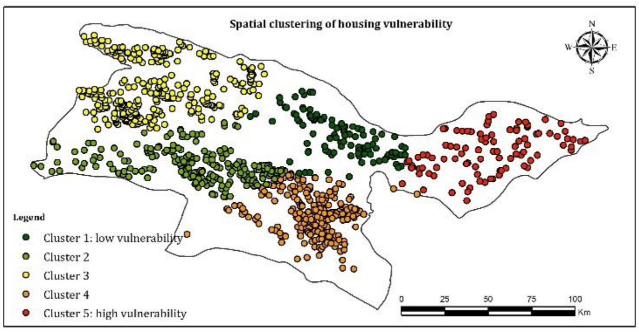

Figure 5. Spatial clustering of rural settlements based on KMeans

4. Discussion

Vulnerability to earthquakes has a direct relationship with the type of materials used in buildings and the level of resistance of housing. In this study, different dimensions of housing quality and their vulnerability to earthquakes in TMA were analyzed. And finally, rural settlements were divided into five categories according to physical vulnerability “Table 3”.

Table 3. Clustering of rural settlements

cluster	Resistant materials	Non-resistant materials	Number of rural
1	48.35	50.25	111
2	54.80	44.20	224
3	39.36	57.43	278
4	64.75	32.17	220
5	27.30	72.32	95

5. Conclusion

In this article, the spatial analysis of the vulnerability of rural housing in TMA to earthquake is discussed. The results of this study show that about one-third of the rural houses located in the Tehran metropolitan area are built using non-resistant materials such as wood, stone, brick, clay, etc. These results show that a significant number of rural housing units located in the Tehran metropolitan area are of low quality, which causes their destruction and severe vulnerability against a possible earthquake.

The spatial pattern related to the type of building materials shows that more resistant materials are used in the central areas of TMA, and low-quality and non-resistant materials are used more in the peripheral areas of TMA. Based on the hotspots analysis, it was also found that the focus of hot spots related to resistant houses is located in the central area of the TMA, and the focus of hot spots related to non-resistant houses is located in the peripheral area of the TMA.

The results of the spatial clustering of Kamenez divided the villages into five categories based on the vulnerability of the houses. Based on this method, the villages located in the central area of the TMA are less vulnerable, and the villages located in the peripheral area of the TMA are more vulnerable.

In this study, three IDW interpolation methods, hotspot analysis and cluster analysis—were used for the spatial analysis of the vulnerability of rural housing. The results of this study show that the output of different methods used for zoning and spatial clustering of the physical vulnerability of rural settlements to earthquakes is consistent.

References

Alizadeh, M., Zabihi, H., Rezaie, F., Asadzadeh, A., Wolf, I. D., Langat, P. K., ... & Pradhan, B. (2021). Earthquake vulnerability assessment for urban areas using an ANN and hybrid SWOT-QSPM model. Remote Sensing, 13(22), 4519.

Baez, J., De la Fuente, A., & Santos, I. V. (2010). Do natural disasters affect human capital? An assessment based on existing empirical evidence.

Cavallo, E., Galiani, S., Noy, I., & Pantano, J. (2013). Catastrophic natural disasters and economic growth. Review of Economics and Statistics, 95(5), 1549-1561.

Felbermayr, G., & Groschl, J. (2014). Naturally negative: The growth effects of natural disasters. Journal of development economics, 111, 92-106.

Gao, X., & Ji, J. (2014). Analysis of the seismic vulnerability and the structural characteristics of houses in Chinese rural areas. Natural hazards, 70, 1099-1114.

Global Change Data Lab. (2023). Natural Disasters Data. https://ourworldindata.org/natural-disasters

Guha-Sapir, D., & Vos, F. (2010). Earthquakes, an epidemiological perspective on patterns and trends. In Human casualties in earthquakes: progress in modelling and mitigation (pp. 13-24). Dordrecht: Springer Netherlands.

Kenny, C. (2009). Why do people die in earthquakes? The costs, benefits and institutions of disaster risk reduction in developing countries. The Costs, Benefits and Institutions of Disaster Risk Reduction in Developing Countries (January 1, 2009). World Bank Policy Research Working Paper, (4823).

Khan, A., Chenggang, Y., Khan, G., & Muhammad, F. (2020). The dilemma of natural disasters: Impact on economy, fiscal position, and foreign direct investment alongside Belt and Road Initiative countries. Science of the Total Environment, 743, 140578.

Minos-Minopoulos, D., Dominey-Howes, D., & Pavlopoulos, K. (2017). Vulnerability assessment of archaeological sites to earthquake hazard: an indicator based method integrating spatial and temporal aspects. Annals of Geophysics, 60(4), S0445-S0445.

Murat, G. E. N. Ç., & Sozen, E. (2021). The sustainable scale of earthquake awareness, development, validity and reliability study. International Electronic Journal of Environmental Education, 11(1), 24-41.