Investigation Of Earthquake Damage in Terms of Different Land Covers: 2023 Kahramanmaraş Earthquakes

Adem SAKARYA
Affiliation: Yildiz Technical University
Email: asakarya@yildiz.edu.tr

Abstract
On February 6, 2023, the Kahramanmaras earthquakes in Türkiye caused great loss of life and property. Studies on earthquake damage in the literature mostly focus on the built-up area, but studies on the land cover are limited. This study examines how earthquake damage differs in different land cover types. Land cover data and earthquake damage data are the main datasets. The areas with the highest damage rates are identified as bare ground, rangeland, and built-up area, respectively. Damage in agricultural and forest areas is lower. The findings show that damage is different for different land cover types. While assessments of earthquake damage are largely based on the built environment, this study reveals that earthquake damage is also important for different land cover types.

Keywords: Earthquake, Damage Proxy map, Land cover, Kahramanmaraş, Türkiye.

Introduction and Literature Review

On February 6, 2023, Türkiye was shaken by two major earthquakes 8 hours apart, with Kahramanmaraş as the epicenter. These earthquakes, with magnitudes of 7.7 and 7.6 respectively, directly affected 11 provinces, Kahramanmaraş in particular, resulting in the loss of more than 50,000 lives and the destruction of approximately 40,000 buildings. Described as the "disaster of the century, " this disaster caused loss of life and property and deeply affected all social, environmental, and spatial systems with its direct and indirect effects. A disaster of this scale reveals the necessity of a multidimensional examination of earthquake impacts and reassessment of existing disaster management approaches.

Earthquakes are important natural phenomena that affect both the physical and natural environment. In the literature, these impacts are mostly addressed on the built environment axis; analyzed through collapsed buildings, infrastructure losses, and human mobility. However, earthquakes can cause damage not only to the built-up area but also to different types of land cover. In this context, determining the damage to different land cover types such as forest, agriculture, rangeland, and bare ground, in addition to built-up areas, is of great importance for a more holistic understanding of the spatial effects of the disaster. This study aims to evaluate the impact area of the disaster from a broader perspective by analyzing the damage following the Kahramanmaraş earthquakes in terms of different land cover types. Relatedly, the question of the study is defined as "*does earthquake damage differ in different land cover types?*".

Studies on the built-up area in the analysis of earthquake damage are intensively included in the literature. These studies range from the building scale to the whole settlement. Studies focusing on the built environment associate earthquake damage with indicators of building height (Armaş et al., 2017), building floor area and building height (Doğan & Kalaylı, 2019), proximity of the building to the epicenter (Sangadji et al., 2023), and building material (Ruiz- Pinilla et al., 2016). In addition, some studies examine earthquake damage by associating natural structure with built environment factors (Sakarya et al., 2024).

Studies on the damage of natural disasters such as earthquakes on land cover other than the built-up area, consider this damage as earthquake environmental effects (Choudhury et al., 2016). Earthquake environmental effects are divided into primary and secondary. Primary effects are such surface ruptures or faulting; secondary effects are such landslides, liquefaction, tsunamis (Boulton et al., 2025; Bilir & İnci, 2024). This two-stage effect causes significant changes in land cover. Studies on the effects of earthquakes on land cover can be evaluated in two groups. While the studies in the first group examine the damage to different land covers after earthquakes over specific sample areas, the studies in the second group examine the land cover change caused by the damage with long-term data.

Among the first group of studies, Bpulton et al. (2025) examine the damage caused by the Kahramanmaraş earthquakes and find that landslide occurs in forest areas and liquefaction occurs in agricultural areas. Koyanagi et al. (2020) analyze the 2016 Kumamoto earthquake damage to compare forest and grassland cover. According to the results of the study, the damage was high in the grassland. It is also a basic finding that slope is a determining factor in damage.

Among the second group of studies, Xiang et al. (2022) examine the impact of the 2008 China-Wenchuan earthquake at the scale of Sichuan Province. The study, which examines the land cover change between 2011- 2014- 2017- 2020 after the earthquake, finds that earthquake damage is higher where vegetation is high. Ishihara and Tadono (2017) examine the impact of the 2011 Japan earthquake at the Tohoku district scale. The study, which analyzes land cover data for the years 2006- 2011- 2013- 2015, states that earthquake damage differs according to different land covers. While the rice paddy ratio decreases due to the tsunami effect, it is found that the damage to bare land is high in the short term, but in the long term, bare land increases with losses in forest and agricultural land. Wang et al. (2022) examines the 2013 China-Lushan earthquake damage at the scale of Lushan country. In the study comparing land cover data from 2012 to 2020, it is determined that cropland, forest, built-up area, and bare area have changed significantly, and natural ecological restoration is stated as an important recommendation. Karadeniz and Sümbül (2023) compare the land cover in 1990 and 2000 in their study of the 1999 Düze earthquake in Turkey. According to the results of the study, forest and agricultural areas decreased, and built-up areas increased. Balamurugan and Aravind (2015) examine the impact of the 2001 India, Bhuj earthquake in Mundra, Kutch District of Gujarat region. Similar to the results of Karadeniz and Sümbül (2023), it is found that agricultural areas decreased and built-up areas increased in the process. DiCarlo et al. (2015), on the other hand, conduct such a study in the context of the 2015 Nepal earthquakes. Focusing on Dolakha district, the study finds that the agricultural crop pattern has changed.

This study, which examines the damage of the Kahramanmaraş earthquake on different land covers, is similar to the first group of studies mentioned above by examining the short-term post-earthquake data but differs from the studies in this group by analyzing the entire area where the earthquake damage occurred. This points to a gap in literature.

Data and Methods

Two data sets were used in the study. The first data set is land cover. Land cover data for the year 2022 was obtained through the Esri Living Atlas application. This data, created by the remote sensing method, consists of water, forest, flooded vegetation, crops, built area, bare ground, snow/ice, and rangeland land covers. In this study, as most damaged covers, forest area, agricultural area, built-up area, bare ground, and range land, are used. Water, snow / ice and clouds covers are not included

The second data set is the regional damage proxy map. It was produced by the National Aeronautics and Space Administration (NASA). This map detects the change in the surface by comparing the satellite images before and after the earthquake and shows these areas as damaged. The damage proxy map is used in many studies for rapid damage assessment after disasters. By damage proxy map, Agapiou (2020) analyzes the Beirut explosion, Romaniello et al. (2017) evaluate the Haiti earthquake damage, and Nur and Lee (2021) analyze the effects of the 2016, 2017 earthquakes in Korea.

These two datasets were superposed in geographic information system (GIS), and the earthquake damage rate was calculated for different land cover types.

The Kahramanmaraş earthquakes affected 11 provinces; Adana, Adıyaman, Diyarbakır, Elazığ, Gaziantep, Hatay, Kahramanmaraş, Kilis, Malatya, Osmaniye, and Şanlıurfa. The area is officially defined as a disaster region. The scope of the study was determined within the boundaries of the damage proxy map in this disaster region. This area is approximately 58 km² (Figure 1).

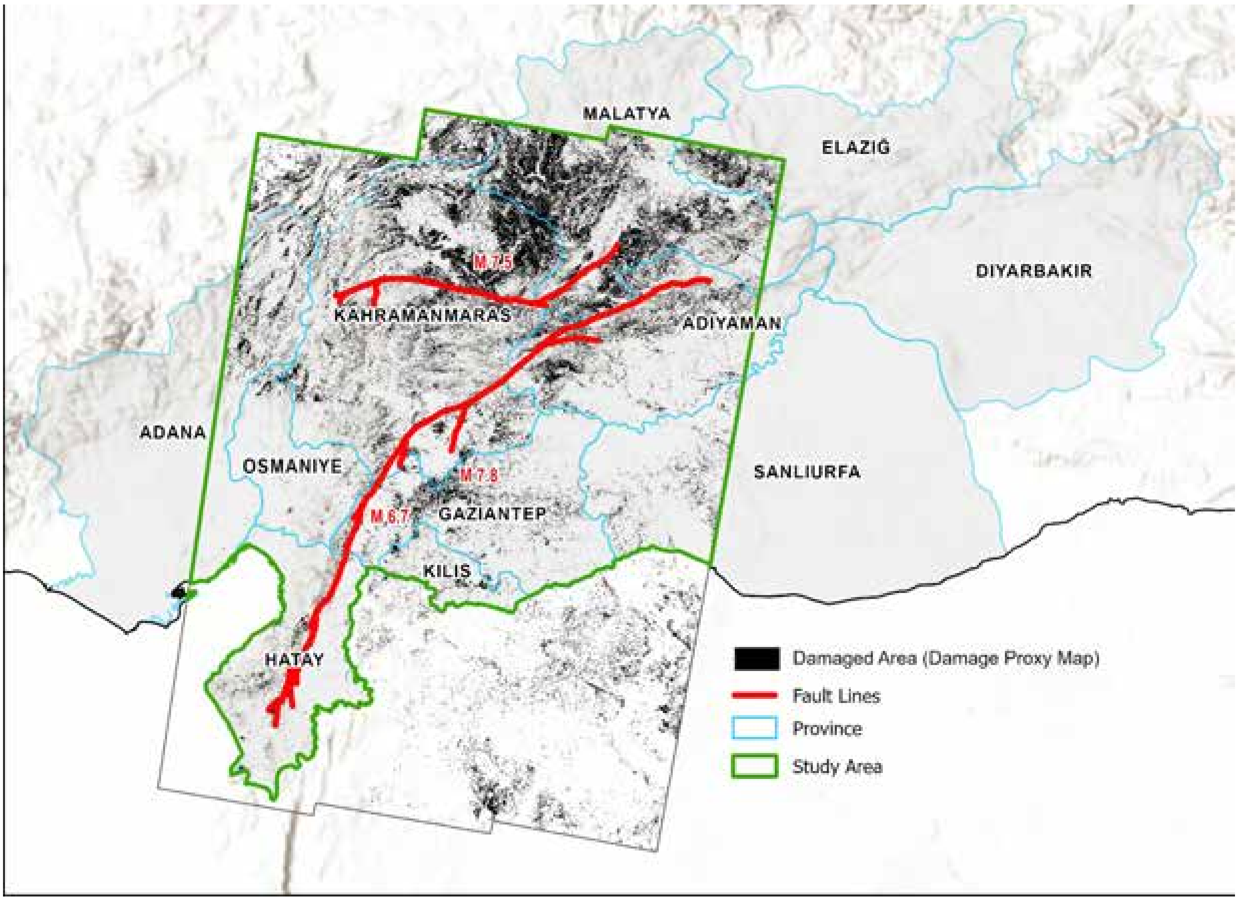

Figure 1: Study area

Findings

According to land cover in 2022, more than half of the area is rangeland. Rangelands are mostly concentrated in the east and north of the study area. The other land cover that has a significant size in the area is agriculture. Agricultural areas are especially dense in the south of the area. Forest areas are in the west of the area in the mountainous region between Hatay- Antakya, and Kahramanmaraş. The provincial centers of Hatay- Antakya, Kahramanmaraş, Gaziantep, and Malatya stand out with their built-up areas (Figure 2; Table 1).

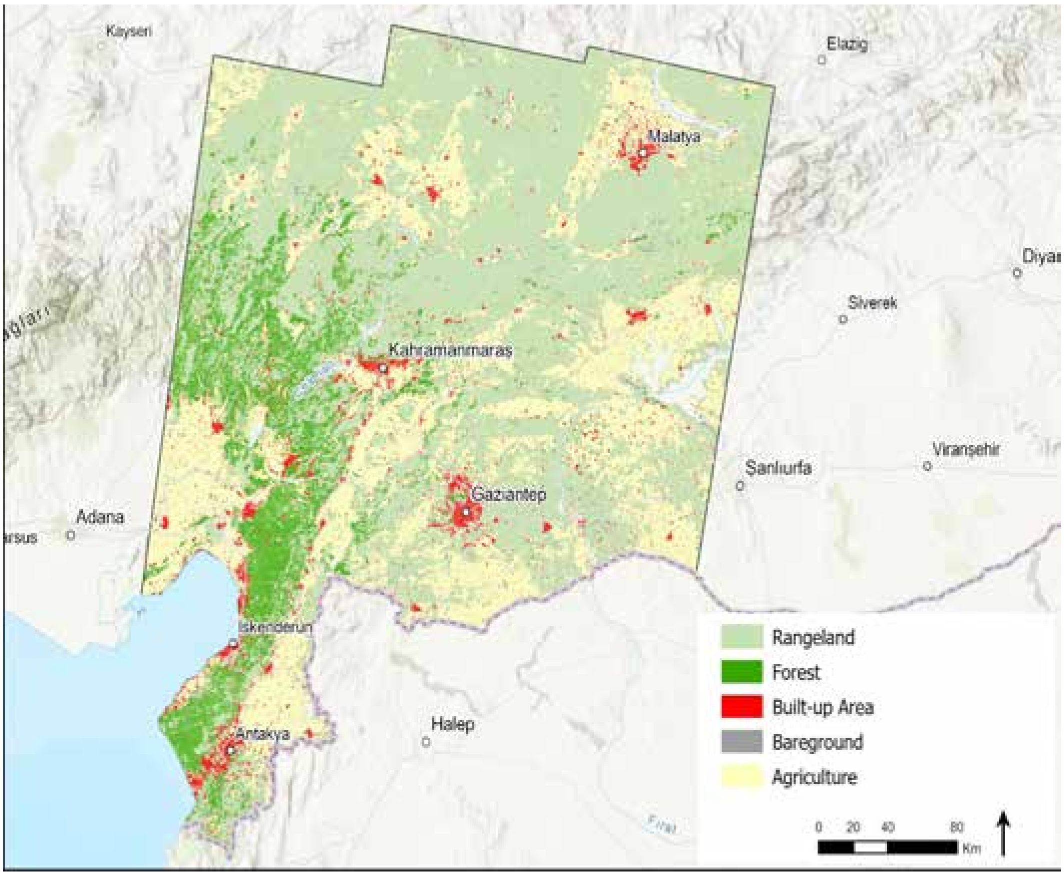

Figure 2: Land covers in the study area

Table 1: Land cover statistics

Land Cover	Area (ha)	Ratio
Rangeland	3.079.870	53%
Forest	595.460	10%
Built-up Area	290.792	5%
Bare Ground	41.453	1%
Agriculture	1.688.550	29%
Water- Snow/ Ice- Clouds	114.952	2%
Total	5.811.077	100%

The damage rate in the study averaged 18 % for the whole area. The land cover classes with the highest damage rates are bare ground, rangeland and built-up area, respectively. Especially in the north of the area where the slope is low, damaged rangeland areas are noteworthy in the region located in the west of Malatya. There are also damaged agricultural areas within these areas.

Damage in the built-up area is concentrated on the route between Hatay, Antakya and Kahramanmaraş, where the fault line also passes.

Damaged forest areas are also located in a limited area along the fault line. In this respect, the fact that the damage is higher in the northern part where the slope is flatter indicates that slope is an important factor, as stated in Koyanagi et al. (2020) (Figure 3; Table 2).

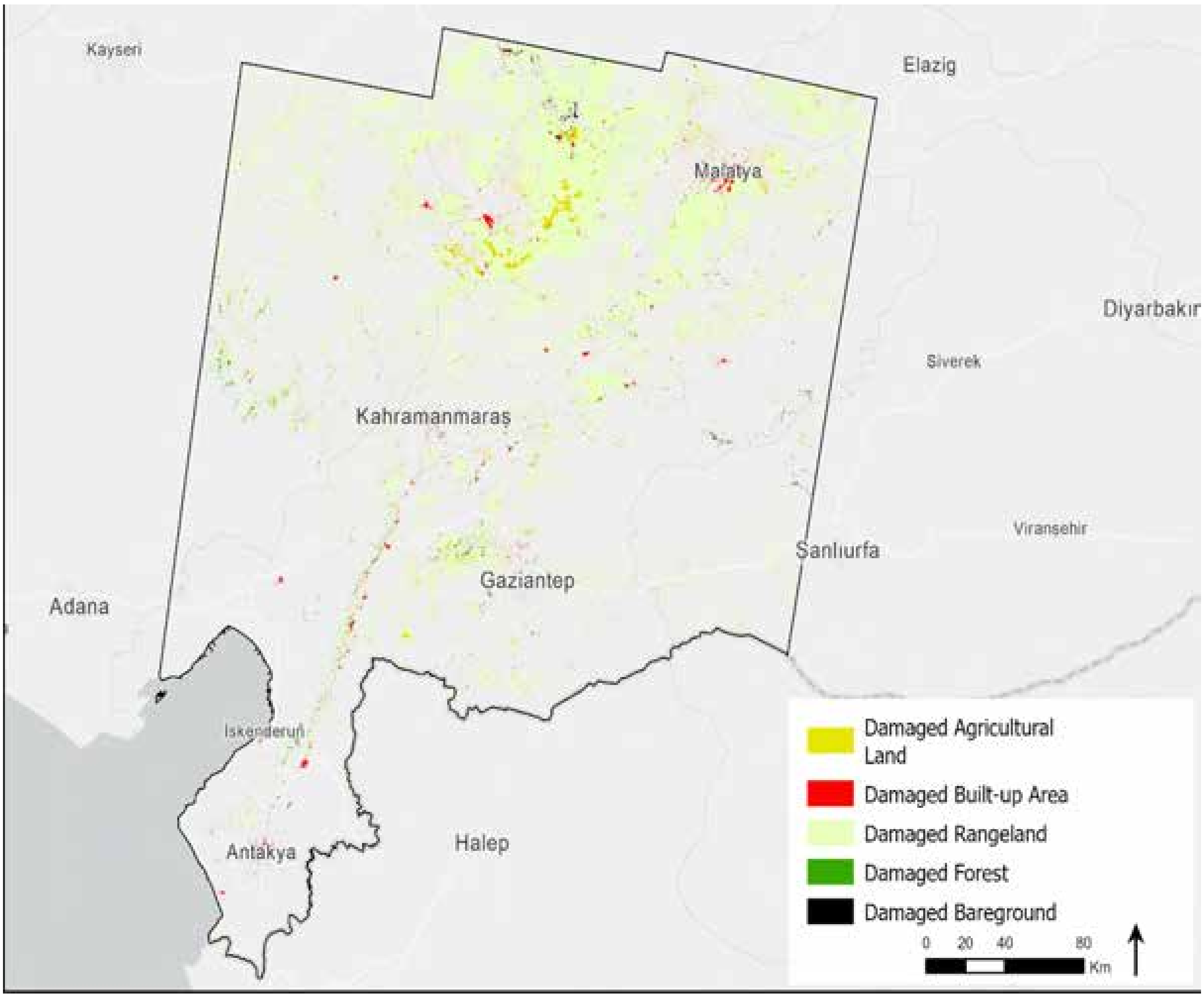

Figure 3: Damaged areas and land covers

Table 2: Damaged area land covers' statistics

Land Cover	Area (ha)	Damaged Area (ha)	Damaged Area Ratio
Forest	595.460	17.983	3%
Agriculture	1.688.550	77.101	5%
Built-up Area	290.792	40.075	14%
Bare Ground	41.453	14.256	34%
Rangeland	3.079.870	896.136	29%
Water- Snow/ Ice- Clouds	114.952		
Total	**5.811.077**	**1.045.551**	**18%**

Conclusion

This study aims to provide a holistic assessment of the spatial distribution of earthquake damages by analyzing the impact of the Kahramanmaraş-centered earthquakes that occurred on February 6, 2023 on different land cover types. The finding that earthquakes directly affect not only the built-up areas but also the natural environment reveals the necessity of considering natural land cover in post-disaster response and recovery strategies.

In the study, the analyses made by overlaying the land cover classes created using Esri Living Atlas data and the damage proxy map produced by NASA in the GIS, show that the highest damage occurs in bare ground, rangeland and built-up area, respectively.

This result indicates that damage varies across different land covers in relation to the research question identified by the study.

The findings reveal that significant damage occurred in rangeland and agricultural areas, especially in the northern parts where the slope is low, and emphasize the role of the morphological characteristics of the natural environment on the earthquake effect. Between Hatay-Antakya and Kahramanmaras, extensive damage was detected in built-up areas located along the fault line.

In the light of the data obtained, it is clear that land use decisions should be revised both in terms of the built-up area and the natural environment. With a disaster risk management perspective, integrating earthquake risk mitigation elements into land use plans can minimize not only loss of life and property but also loss of natural resources.

Damage to rangelands and agricultural areas is also critical for post-disaster food security and rural livelihoods. Therefore, developing policies to protect fragile natural areas will contribute to prevent post-disaster agricultural production losses. Likewise, the limited but strategically important damage to forest areas should be taken into account in terms of the continuity of ecosystem services. To increase the resilience of the natural environment in the face of disasters, more emphasis should be placed on ecological restoration and conservation-based approaches, as mentioned in Wang et al. (2022).

This study has some limitations as it is a short-term analysis with limited data. However, the assessment of damage to different land cover types at the scale of the whole study area differs from the examples in the literature in this respect and fills an important gap. For future studies, monitoring land cover changes using long-term satellite imagery will provide important findings in terms of the extent and significance of damage. For example, determining whether the increase in bare ground areas after the earthquake is related to construction or agricultural transformation in the following years will be of great importance in terms of guiding post-disaster spatial planning.

Furthermore, comparative studies with different types of disasters can reveal how the impacts of disasters on land cover differ from one another. Multidimensional analyses on how disasters such as floods, landslides and fires, as well as earthquakes, cause spatial changes in different cover types will contribute to the reshaping of both risk analyses and post-disaster response plans in a nature-sensitive manner. Such studies will serve as an important guide not only in the academic context but also for policy makers, local governments and disaster management institutions.

References

Agapiou, A. (2020). Damage proxy map of the Beirut explosion on 4th of August 2020 as observed from the Copernicus sensors. Sensors, 20(21), 6382.

Armaş, I., Toma-Danila, D., Ionescu, R., & Gavriş, A. (2017). Vulnerability to earthquake hazard: Bucharest case study, Romania. International Journal of Disaster Risk Science, 8, 182-195.

Bilir, B., & İnci, H. Ş. (2024). Depremlerin tarım, orman ve mera alanlari üzerine etkileri. In Proceedings of 7th International Çukurova Agriculture and Veterinary Congress, March 9-10, 2024.

Boulton, S. J., Jones, J. N., Malcioglu, F. S., O'Kane, A., Cleave, M. D., Adamidis, O., ... Aktaş, Y. D. (2025). Earthquake environmental effects and ESI 2007 of the 6th February 2023 Kahramanmaraş earthquakes along the east anatolian fault zone (Türkiye). Quaternary International, 732, 109804.

Choudhury, M., Verma, S., & Saha, P. (2016). Effects of earthquake on the surrounding environment: an overview. In Proceedings of international conference on recent advances in mechanics and materials.

DiCarlo, J., Epstein, K., Marsh, R., & Måren, I. (2018). Post-disaster agricultural transitions in Nepal. Ambio, 47(7), 794-805. doi:10.1007/s13280-018-1021-3

Doğan, O., & Kalaylı, M.A. (2019); Binalarda yükseklik / genişlik oranı ve zemin yatak katsayısına bağlı devrilme analizi, Gazi Mühendislik Bilimleri Dergisi, 5 (3), 300-314.

Ishihara, M., & Tadono, T. (2017). Land cover changes induced by the great east Japan earthquake in 2011. Scientific Reports, 7(1), 45769.

Karadeniz, E., & Sunbul, F. (2023). Land use and land cover change in Duzce region following the major earthquake: Implications for ANN and Markov chain analysis. Environmental Earth Sciences, 82(10).

Koyanagi, K., Gomi, T., & Sidle, R. C. (2020). Characteristics of landslides in forests and grasslands triggered by the 2016 Kumamoto earthquake. Earth Surface Processes and Landforms, 45(4), 893-904.

Nur, A. S., & Lee, C. W. (2021). Damage proxy map (DPM) of the 2016 Gyeongju and 2017 Pohang earthquakes using Sentinel-1 imagery. Korean Journal of Remote Sensing, 37(1), 13-22.

Romaniello, V., Piscini, A., Bignami, C., Anniballe, R., & Stramondo, S. (2017). Earthquake damage mapping by using remotely sensed data: the Haiti case study. Journal of Applied Remote Sensing, 11(1), 016042-016042.

Ruiz-Pinilla, J. G., Adam, J. M., Pérez-Cárcel, R., Yuste, J., & Moragues, J. J. (2016). Learning from RC building structures damaged by the earthquake in Lorca, Spain, in 2011. Engineering Failure Analysis, 68, 76-86.

Sakarya, A., Akın, O., & Kılıç, A. (2024). Investigating the damage from the February 6, 2023 earthquakes in terms of building characteristics in the Antakya and Defne districts of Hatay province. International Journal of Disaster Risk Reduction, 112, 104783.

Sangadji, A. R., Osok, R. M., & Talakua, S. M. (2023). Study of damage to residential buildings, soil geophysics and the relationship between the epicentrum distance and the level of damage caused by earthquake. International Journal of Multidisciplinary: Applied Business and Education Research, 4(2), 446-453.

Wang, J., Wang, Z., Cheng, H., Kang, J., & Liu, X. (2022). Land cover changing pattern in pre- and post-earthquake affected area from remote sensing data: A case of Lushan County, Sichuan province. Land, 11(8), 1205.

Xiang, M., Deng, Q., Duan, L., Yang, J., Wang, C., Liu, J., & Liu, M. (2022). Dynamic monitoring and analysis of the earthquake worst-hit area based on remote sensing. Alexandria Engineering Journal, 61(11), 8691-8702.