Advanced GIS

http://publish.mersin.edu.tr/index.php/agis/index

e-ISSN:2822-7026

A post earthquake damage assessment using GIS in district Mirpur, Pakistan

Warda Habib[1], Shakeel Mahmood[*1], Noor ul Huda[1], Siddra Noor[1], Arslan Saleem[1], Muhammad Siraj[1] Haseeb Ahmad[1]

[1]*Government College University, Department of Geography, Lahore, Pakistan*

Keywords
Earthquake,
Damages,
GIS,
Fault Line,
Seismic Zone

check for updates

Research Article
Received: 17/03/2023
Revised: 27/04/2023
Accepted: 13/07/2023
Published: 12/09/2023

ABSTRACT

A moderate earthquake of magnitude Mw 5.6 struck the Kashmir region of Pakistan on September 24th, 2019, causing severe damage to buildings and infrastructure. The study aims to assess the extent of damage in Mirpur district, Azad Kashmir. In this research, the map of the affected area and damages is developed using Geographic Information System (GIS). Results indicated that damage to roads and houses is severe in the proximity of Mangla Dam. It was found from the analysis that shallow earthquakes with high magnitude can have disastrous consequences. It also poses the risk of Dam Lake Outburst Flooding (DLOF) which can cause disaster in the downstream regions. So, there is the utmost need to work on the mapping and hotspot analysis of the places susceptible to earthquakes. The result and findings of such a study can assist disaster management authorities and donor agencies reduce the risk of potential damage and suffering by preparing earthquake risk reduction plans and investments in disaster preparedness and prevention.

1. Introduction

Disasters are increasing tremendously over the earth resulting in high risks and vulnerabilities (Çelik & Yakar, 2023). Hydro-meteorological and geological hazards are common in South Asia (Rafi et al., 2022). Earthquakes are one of the most destructive and unpredictable geological hazards. Pakistan is also prone to earthquakes, floods, and landslides with different levels of vulnerabilities in both the rural and urban areas disrupting the physical, social, and economic environment (Ainuddin et al., 2014). Pakistan is a seismically active area that has experienced numerous earthquakes throughout history. (Stevenson et al., 2017).

Earthquakes leave a serious impact on the community (Wu et al., 2022). The cities located in the earthquake zone are exposed to earthquakes (Khan, 2021). The resilience of the community, infrastructure, and economy is playing a crucial role because it is indirectly related to vulnerability. The vulnerability of the community transforms hazard into disaster (Hidayat et al., 2020). Densely populated areas with a high density of infrastructure which are poorly prepared for such crises are more vulnerable and result in significant mortality rates during unexpected catastrophes (Idris et al., 2022). These outcomes include physical destruction, adverse effects on the economy, and casualties (Sidi, 2017). Even though a tremor usually can last for a short time, the aftershocks could last for days, and the destruction is for a longer period (Kencanawati et al., 2020). Housing area security and seismic hazard analysis research are critical in designing sustainable reconstruction and decision-making, enhancing resilience, and limiting damages in densely populated regions (Mangkoesoebroto et al., 2019).

Pakistan is exposed to a variety of geo-environmental hazards (Sengara et al., 2016). Earthquakes are one of the geological hazards, leading to human life loss, and damage to property and infrastructure (Ahmed et al., 2022). Geologically, Pakistan lies in the region where the Indian, Eurasian, and Arabian tectonic plates interact and lead to earthquakes (Mikhail et al., 2019). Seismically, it is the active region having active faults (Gardezi et al., 2021). In the last eight decades, the country has been struck by many disastrous quakes including; the 1935-Quetta earthquake with a magnitude of 7.6 destroyed the historic city of Quetta, the 1947 Hunza Earthquake in

***Corresponding Author**

(wardahabib419@gmail.com) ORCID 0000-0002-1803-1572
*(shakeelmahmoodkhan@gmail.com) ORCID 0000-0001-6909-0735
(noor.ul.houda@gmail.com) ORCID 0009-0001-2524-1631
(lilyqamar@gmail.com) ORCID 0009-0006-4712-626X
(waseer10@gmail.com) ORCID 0000-0001-5176-0403
(Siraj23105@gmail.com) ORCID 0009-0006-1079-4539
(haseekhanb@gmail.com) ORCID 0009-0001-4150-3785

Cite this article

Habib, W., Mahmood, S., Huda, N. U., Noor, S., Saleem, A., Siraj, M., & Ahmad, H. (2023). A post earthquake damage assessment using GIS in district Mirpur, Pakistan. *Advanced GIS*, 3(2), 53-58.

which 5300 people lost their lives and 17000 were injured, the 2005 Kashmir Earthquake in which more than 80 thousand people died and 3.5million loss their shelter (Lallemant et al., 2017). In the year 2013, district Awaran in Balochistan was struck by a sequence of two earthquakes that rocked the Awaran district within a span of 4 days (Shakya et al., 2021).

On September 24, 2019, a moderate yet severe earthquake of Mw 5.6 at a hypocentral depth of 10 km struck in the Kashmir Himalayas at the axis of Hazara Kashmir Syntaxis, because of reverse faulting convergent between the Indian and Eurasian plates (Gardezi et al., 2021). The tremors were felt in a radius of ~100km with damage taking place in the area of 700 km2 including human life losses. The epicenter was close to Mirpur in Kashmir, with a peak ground acceleration (PGA) of around 0.35 g (Khan et al., 2021).

The Mirpur Earthquake is the result of an onward collision between Indian and Eurasian plates on a main thrust fault namely the Samwal Fault in the epicentral region. Moreover, this earthquake caused several deaths and huge damage to the infrastructure in the epicentral zone (Sreejith et al., 2021). This study aims to assess the post-earthquake damages in Mirpur City, Azad Jammu Kashmir, Pakistan. The results of the study can be helpful for decision-making and further research on seismic risk assessment and reduction.

2. Study area

Mirpur is one of the districts in Azad Kashmir. Administratively, Mirpur is comprised of two sub-divisions namely Mirpur and Dadyal (Figure 1). Relatively, the study area is bounded by Kotli district in the north and east, by Potohar region (Punjab) in the west and Bhimber district in the south. According to Census 2017 the total population of Mirpur district was approximately 456,200. Geologically, the study area is seismically active. Mirpur experiences a humid subtropical climate. The annual average temperature is about 25°C and 1,380mm of rain.

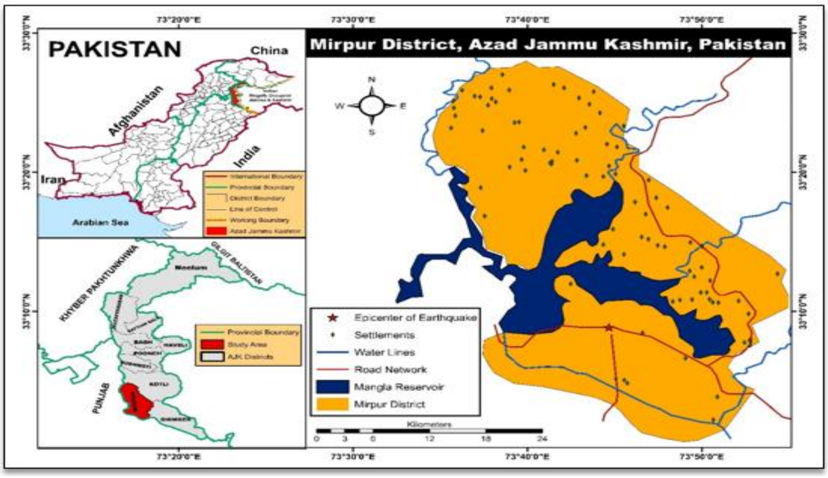

Figure 1. Location of study area

3. Research methods

For this research, data were acquired from secondary sources like National Disaster Management Authority (NDMA), Provincial Disaster Management Authority (PDMA), and satellite images. Damage data were geo-coded and then geo-visualized. The results were represented in the form of tables, graphs, and maps. Landsat Satellite data was downloaded from the open-source United State Geological Survey (USGS) open-source database (Table 1).

Table 1. Characteristics of Landsat Data (USGS, 2023)

<table>
<tr><th>Sr. No</th><th>Images</th><th>Year</th><th>Month</th></tr>
<tr><td>1</td><td>LANDSAT-8</td><td>2019</td><td>September</td></tr>
<tr><th colspan="4">Attributes of used Bands:</th></tr>
<tr><th>Bands</th><th>Wavelength (micrometers)</th><th colspan="2">Resolution (m)</th></tr>
<tr><td>Band 1 - Coastal aerosol</td><td>0.43-0.45</td><td colspan="2">30</td></tr>
<tr><td>Band 2 - Blue</td><td>0.45-0.51</td><td colspan="2">30</td></tr>
<tr><td>Band 3 - Green</td><td>0.53-0.59</td><td colspan="2">30</td></tr>
<tr><td>Band 4 - Red</td><td>0.64-0.67</td><td colspan="2">30</td></tr>
<tr><td>Band 5 - Near Infrared (NIR)</td><td>0.85-0.88</td><td colspan="2">30</td></tr>
<tr><td>Band 6 - Shortwave Infrared (SWIR) 1</td><td>1.57-1.65</td><td colspan="2">30</td></tr>
<tr><td>Band 7 - Shortwave Infrared (SWIR) 2</td><td>2.11-2.29</td><td colspan="2">30</td></tr>
<tr><td>Band 8 - Panchromatic</td><td>0.50-0.68</td><td colspan="2">15</td></tr>
<tr><td>Band 9 - Cirrus</td><td>1.36-1.38</td><td colspan="2">30</td></tr>
<tr><td>Band 10 - Thermal Infrared (TIRS) 1</td><td>10.6-11.19</td><td colspan="2">100</td></tr>
<tr><td>Band 11 - Thermal Infrared (TIRS) 2</td><td>11.50-12.51</td><td colspan="2">100</td></tr>
</table>

3.1. Data processing and analysis

Satellite images were processed to map land use land cover of district Mirpur using supervised classification Satellite as suggested by (Habib et al., 2020; Shafiq & Mahmood, 2022; Gull & Mahmood, 2022; Siraj et al., 2023; Saleem & Mahmood, 2023). For this purpose, ERDAS IMAGINE was used to organize, enhance, and display the images in Geographic Information System (GIS) environment (Bayo et al., 2022). The following steps were taken in the processing of the image:

The image downloaded from the geo-database of USGS was present in multiple bands. These bands had to be combined to get a single-layered image. It was done through the process of layer stacking in ERDAS IMAGINE. In this process, all the bands of the image were added and by running the layer stacking function single layered image was gathered. The next step was to clip the study area from the image. In the ERDAS IMAGINE, vector data was added in the form of a shape file of district Mirpur. Then, the function of the Subset was applied to the image as well as the .shp file to clip the study area.

After extracting the study area, the next step was to do supervised classification. It was done in ERDAS IMAGINE. Supervised classification was used to analyze the digital image. The pixels in the image were specified with different values to make a class of the image to analyze according to the required need of the study. It was done by clicking the RASTER tab in ERDAS IMAGINE. And clicked the SUPERVISED classification option. There appeared, a signature editor. By clicking it, the signature editor's file popped up on the screen. This signature file was used to add multiple pixels with different shades by employing drawing tools. Four classes were added under the names of Built-up, vegetation cover, barren land, and water body. Colors were assigned to the field names accordingly. Then after saving the signature file, the function of supervised classification was rubbed by clicking the supervised classification option in the raster tab. The output image was saved for processing in other software. ArcGIS 10.5 was used to work with maps and geospatial data.

Google Earth is used for the accuracy assessment of classified images. The supervised classified image was opened in ArcGIS. To calculate the area of all fields, the raster was converted into a shape file using the conversion tool in Data Management Toolbox. Then every field was selected through the selection by attributes function. In the whole process after the conversion from raster to polygon and the area of each class is calculated using an attribute table in the GIS environment.

3.2. Economic loss estimation

The estimates were based on the book value of the assets. The economic loss in various affected sectors like housing, infrastructure, and agriculture was calculated using data from concerned Department's and Authorities' websites like Livestock Census of Pakistan, Agricultural Statistics of Pakistan etc.

4. Results and discussion

A moderate earthquake of magnitude Mw 5.6 struck the Mirpur and Bhimber districts in Azad Jammu and Kashmir (AJK) Pakistan on September 24th, 2019, at 16:02 local time, causing severe damage to human life, buildings, and infrastructure. The USGS declared it a shallow earthquake.

4.1. Loss of human life

Children and women have suffered significant consequences. Table 2 shows that there were 725 total injuries, 160 of which required immediate medical attention, and 38 individuals died, of whom 34 were from the Mirpur District and 4 were from Bhimber.

Table 2. Human life loss in the study area (NDMA, 2019)

Districts	Deaths	Injuries
Bhimber	4	14
Mirpur	34	711
Total	38	725

4.2. Damages to Infrastructure

The second most terrible and unpleasant direct effect that counts a lot is the breakdown of the infrastructure. Buildings, roads, bridges, and transmission lines were all directly impacted by this earthquake. The major area in a 14km radius was impacted severely (Figure 2).

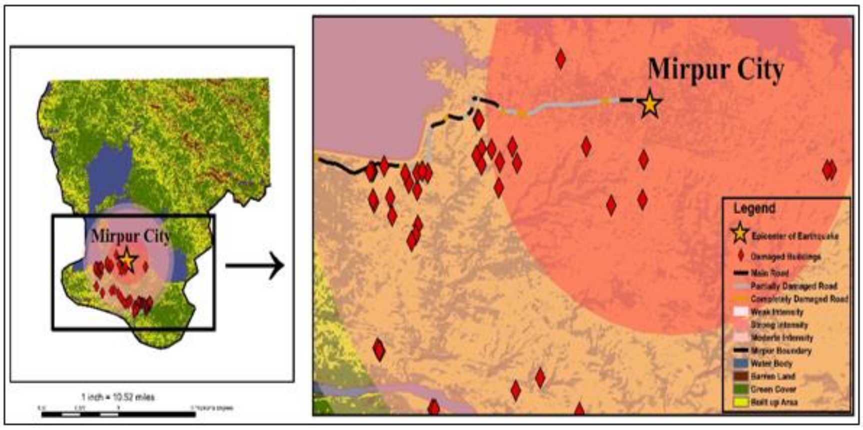

Figure 2. Spatial distribution of damages to infrastructure

Houses, workplaces, and other physical infrastructure were adversely impacted. The completely damaged (1756) and partially damaged houses (5709) in the Mirpur District. Shankikri; a village on the outskirts of Mirpur, all houses (400) were destroyed. Table 3 shows the damage to dwellings, which are divided into entirely and partially damaged entities, including residential, public, and private buildings.

Table 3. District-wise damages to buildings

	Houses		Private / Govt. Buildings	
Districts	*CD	**PD	CD	PD
Bhimber	-	4	-	-
Mirpur	1,756	5,709	9	132
Total	7,469		141	

**Completely Damaged (CD), **Partially Damaged (PD)*

Land communications, another essential component of infrastructure, were also damaged. Parts of several roads were also reportedly damaged, including two bridges. The main route between Mangla and Jatlan sustained substantial damage. Two kilometers (Km) of the road leading to Jatlan town were damaged, while 14 km of the road leading from Kharri Shareef to Jaltan was wrecked. In most places in Mirpurr and Jaltan, power cables were also disrupted. The Mangla Dam powerhouse was closed, which cost Pakistan's national power grid 900 Mega Watts (MW). At 7:20 pm, Mangla's power generation started up again, adding 700MW to the national grid. The Upper Jhelum Canal had started to develop fissures and cracks. In Jatlan town's Chak Nigah settlement, floodwaters had made it in. Later, as a precaution, the canal was closed.

The estimated economic damage generated by Completely Damaged (CD), Partially Damaged (PD) public and private buildings is highest followed by residential buildings and then roads and bridges (Table 4). The total economic loss caused by the damage is 1130 million PKR in district Mirpur.

Table 4. Total estimated economic loss in Mirpur (million PKR) (NDMA, 2019)

Sectors	Houses		*Buildings*		Cattles	Bridges	Total Estimated Economic Loss
	C.D.	P.D.	C.D.	P.D.			
Number	512	4044	9	312	580	8	
Estimated Economic loss	138	230	85	412	140	125	**1130**

4.3. Earthquake risk reduction

Pakistan has experienced different disasters in the past two decades. The social, economic, and physical infrastructure is badly affected by disasters. The risk of hydro-meteorological and geological disasters is still high because of the climatic conditions and geological settings. Therefore, it is essential to devise and practice methods to reduce disaster risks. There is a need for an earthquake risk reduction plan. Seismic risk zonation is highly required. Then zone-specific earthquake risk reduction plan needs to be prepared. The construction of earthquake resilient buildings should be encouraged. It is crucial to focus on research for seismic risk analysis at regional and national levels to increase the coping capacity of this vulnerable region. The relief activities should be planned as a risk-reduction strategy. Table 5 represents the relief provided by different authorities, departments, organizations, and agencies but still, there were deficiencies. Relief activities should be planned based on hazard spatial extent, exposure, and risk.

Table 5. Relief provided by various government and non-governmental agencies

Items	Departments								Total	Deficient
	NDMA	SDMA	DDMA Mirpur	PDMA KP	PDMA PB	Army	PRCS	NGOs		
Tents	4500	480	100	200	1000	2644	-	300	**9932444**	**3500**
Blankets	590	200	200	400	-	4500	-	-	**11200**	**7000**
Ration Packs (Kg)	1300	-	-	-	3500	-	500	175	**5676**	**6000**
First Aid Kits	200	-	-	-	-	-	-	-	**200**	**500**
Water Bottles (Liters)	50000	-	-	-	-	4300	-	6000	**60,300**	**40,000**
Kitchen Sets	275	-	-	200	-	-	-	-	**475**	**500**
Generators	-	5	1	-	-	-	-	-	**6**	**4**
Plastic Mats	-	200	60	-	-	-	-	-	**260**	**500**

5. Conclusion

A disaster such as an earthquake has the potential to significantly harm the environment, buildings, and structures yet resulting in a significant number of fatalities. As a result, disaster relief and rescue authorities must evaluate the damage for the purpose of planning. This paper assesses the post-earthquake damage that occurred in Mirpur on 2019-September. The study concludes that Mirpur is in a seismically active region where earthquakes are frequent leading to human life loss and damage to property and infrastructure. An earthquake of magnitude Mw 5.6 struck the Mirpur and Bhimber districts in Azad Jammu and Kashmir (AJK) Pakistan on September 24th, 2019, caused severe damage to human life, buildings, and infrastructure. Mirpur city, Jatlan town, and Manda and Afzalpur villages were the most affected areas. The findings revealed that road and housing damage is significant in proximity to the Mangla Dam. According to the analysis, shallow earthquakes with high magnitudes can have catastrophic impacts. Additionally, it increases the possibility of Dam Lake Outburst Flooding (DLOF), which may severely damage areas downriver. The estimated economic loss caused by damage to buildings was the highest followed by infrastructure, particularly roads and bridges. The total estimated economic loss was 1130 million PKR in district Mirpur.

An earthquake risk reduction plan is highly required to reduce human losses, economic losses, and physical damage. District Disaster Management Authority should capacitate for quick response in emergencies. Evacuation plans and community training are highly required. Land use planning and management, and implementation of building codes are also the need of time to reduce the risk of potential damage.

Author Contributions

Warda Habib: Literature review, field study. **Shakeel Mahmood:** Conceptualization, methodology, original-draft, supervision. **Noor ul Huda:** Literature review, investigation. **Siddra Noor:** Methodology, literature review. **Arslan Saleem:** Conceptualization, literature review. **Muhammad Siraj:** Literature review, investigation. **Haseeb Ahmad:** Investigation, field study.

Statement of Conflicts of Interest

There is no conflict of interest.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

References

Ahmed, J., Shah, M., Awais, M., Jin, S., Zafar, W. A., Ahmad, N., Amin, A., Shah, M. A., & Ali, I. (2022). Seismo-ionospheric anomalies before the 2019 Mirpur earthquake from ionosonde measurements. *Advances in Space Research*, 69(1), 26-34. https://doi.org/10.1016/j.asr.2021.07.030

Ainuddin, S., Mukhtar, M., & Ainuddin, S. (2014). Public perception about enforcement of building codes as a risk reduction strategy for seismic safety in Quetta, Baluchistan. *International Journal for Disaster Risk Reduction,* 9, 99-106. https://doi.org/10.1016/j.ijdrr.2014.04.007

Bayo, B., Habib, W., & Mahmood, S. (2022). Spatio-temporal assessment of mangrove cover in the Gambia using combined mangrove recognition index. *Advanced Remote Sensing*, 2(2), 74-84.

Çelik, M. Ö., & Yakar, M. (2023). Monitoring land use and land cover change using remote sensing and GIS: A case study in Mersin, Türkiye. *Turkish Journal of Geographic Information Systems,* 5(1), 43-51. https://doi.org/10.56130/tucbis.1300704

Gardezi, S. A. H., Hussain, G., Neupane, B., Imran, M., Hamid, Q. Y., Ikram, N., Usmani, N. A., & Asghar, H. (2021). Geological investigation of 5.6 MW Mirpur earthquake, northwestern Himalayas, Pakistan. *International Research Journal of Earth Sciences*, 9(1), 20-31.

Gull, A., & Mahmood, S. (2022). Spatio-temporal analysis and trend prediction of land cover changes using the markov chain model in Islamabad, Pakistan. *Advanced GIS,* 2(2), 52-62.

Habib, W., Aslam, R. W., Akram, M. A. N., Khalid, M. B., Abbas, W., Tahir, M. H., Ullah, H., Mehmood, H., & Mirza, A. I. (2020). Assessment of temporal changes in landuse patterns by incorporating topographical parameters. *International Journal of Sustainable Development*, 2, 99-113

Hidayat, R. F., Kiyota, T., Tada, N., Hayakawa, J., & Nawir, H. (2020). Reconnaissance on liquefaction-induced flow failure caused by the 2018 M W 7.5 Sulawesi earthquake, Palu, Indonesia. *Journal of Engineering and Technological Sciences*, 52(1), 51-65.

Idris, Y., Cummins, P., Rusydy, I., Muksin, U., Syamsidik, Habibie, M. Y., & Meilianda, E. (2022). Post-earthquake damage assessment after the 6.5 mw earthquake on December 7th, 2016, in Pidie Jaya, Indonesia. *Journal of Earthquake Engineering*, 26(1), 409-426. Post-earthquake damage assessment after the 6.5 mw earthquake on December 7th, 2016, in Pidie Jaya, Indonesia. https://doi.org/10.1080/13632469.2019.1689868

Kencanawati, N. N., Agustawijaya, D. S., & Taruna, R. M. (2020). An Investigation of building seismic design parameters in Mataram city using Lombok earthquake 2018 ground motion. *Journal of Engineering & Technological Sciences,* 52(5). https://doi.org/10.5614/j.eng.technol.sci.2020.52.5.4

Khan, M. M. J. (2021). Capacity need assessment for earthquake response in Dhaka city [Doctoral thesis, University of Dhaka]. Institute of Business Administration. http://repository.library.du.ac.bd:8080/handle/123456789/1727

Khan, M. Y., Turab, S. A., Riaz, M. S., Atekwana, E. A., Muhammad, S., Butt, N. A., Abbas, S. M., Zafar, W. A., & Ohenhen, L. O. (2021). Investigation of coseismic liquefaction-induced ground deformation associated with the 2019 Mw 5.8 Mirpur, Pakistan, earthquake using near-surface electrical resistivity tomography and geological data. *Near Surface Geophysics*, 19(2), 169-182. https://doi.org/10.1002/nsg.12148

Lallemant, D., Soden, R., Rubinyi, S., Loos, S., Barns, K., & Bhattacharjee, G. (2017). Post-disaster damage assessments as catalysts for recovery: A look at assessments conducted in the wake of the 2015 Gorkha, Nepal, earthquake. *Earthquake Spectra*, 33(1_suppl), 435-451. https://doi.org/10.1193/120316eqs222m

Mangkoesoebroto, S. P., Prayoga, M. H., & Parithusta, R. (2019). Collapse Risks of Fail-Safe RC Frames Due to Earthquakes: Fragility Assessments. *Journal of Engineering & Technological Sciences,* 51(4).

Mikhail, R., Irsyam, M., Nazir, R., Asrurifak, M., Hutapea, B.M., Rustiani, S., Munirwansyah, M., & Harninto, D.S. (2019). Development of Nationwide Surface Spectral Acceleration Maps for Earthquake Resistant Design of Bridges Based on National Hazard Maps of Indonesia 2017. *Journal of Engineering and Technological Sciences,* 51(4). https://doi.org/10.5614/j.eng.technol.sci.2019.51.4.4

NDMA. (2019) National Disaster Management Authority (NDMA) Situation Report No. 19 - Mirpur Earthquake 2019. Retrieved March 15, 2023, https://reliefweb.int/report/pakistan/ndma-situation-report-no-19-mirpur-earthquake-2019-dated-11-october-2019-1500-hours

Rafi, M. M., Ahmed, M., Lodi, S. H., Varum, H., & Arshad, M. T. (2022). Investigation of damage to Reinforced concrete buildings due to the 2019 Mirpur Earthquake, Azad Kashmir. *Journal of Performance of Constructed Facilities,* 36(5), 04022037. https://doi.org/10.1061/(ASCE)CF.1943-5509.000174

Saleem, A.., & Mahmood, S. (2023). Spatio-temporal assessment of urban growth using multi-stage satellite imageries in Faisalabad, Pakistan. *Advanced Remote Sensing,* 3(1), 10–18.

Sengara, I.W., Sidhi, I.D., Mulia, A., Asrurifak, M., & Hutabarat, D. (2016). Development of Risk Coefficient for Input to New Indonesian Seismic Building Codes. *Journal of Engineering & Technological Sciences*, 48(1). https://doi.org/10.5614/j.eng.technol.sci.2016.48.1.5

Shafiq, M., & Mahmood, S. (2022). Spatial Assessment of Forest Cover Change in Azad Kashmir, Pakistan. *Advanced GIS,* 2(2), 63-70.

Shakya, M., Kawan, C. K., Gaire, A. K., & Duwal, S. (2021). Post-earthquake damage assessment of traditional masonry buildings: A case study of Bhaktapur municipality following 2015 Gorkha (Nepal) earthquake. *Engineering Failure Analysis*, 123, 105277. https://doi.org/10.1016/j.engfailanal.2021.105277

Sidi, I.D. (2017). Probabilistic Modeling of Seismic Risk Based Design for a Dual System Structure. *Journal of Engineering & Technological Sciences,* 49(2). https://doi.org/10.5614/j.eng.technol.sci.2017.49.2.2

Siraj, M., Mahmood, S., & Habib, W. (2023). Geospatial assessment of land cover change in District Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan. *Advanced Remote Sensing*, 3(1), 1–9.

Sreejith, K. M., Jasir, M. C. M., Agrawal, R., & Rajawat, A. S. (2021). The 2019 September 24, Mw= 6, Mirpur earthquake, NW Himalaya: Geodetic evidence for shallow, near-horizontal décollement rupture of the Main Himalayan Thrust. *Tectonophysics*, 816, 229013. https://doi.org/10.1016/j.tecto.2021.229013

Stevenson, J. R., Becker, J., Cradock-Henry, N., Johal, S., Johnston, D., Orchiston, C., & Seville, E. (2017). Economic and social reconnaissance: Kaikōura earthquake 2016. *Bulletin of the New Zealand Society for Earthquake Engineering*, 50(2), 343-351. https://doi.org/10.5459/bnzsee.50.2.343-351

USGS. (2023). Belsis. (2023). United States Geological Survey, Science Technology. Retrieved June 15, 2023, from https://www.usgs.gov/faqs/what-are-band-designations-landsat-satellites

Wu, H., Ai, H., Zhou, R., Hong, Z., He, Y., & Li, J. (2022). Research on Rapid Assessment of Earthquake Disaster and Emergency Relief Material Distribution System--Case Study on Earthquake in Yangbi County, Yunnan Province, China. *Sensors & Materials*, 34.