ANDMEJ
ASEAN Natural Disaster Mitigation and Education Journal
ANDMEJ 1(2): 55-65
ISSN 3025-0285

Landslide risk management using geospatial technique: Comparative insights of China and Indonesia

Yakin Ermanto [1]* and Raldi Hendro Koestoer [1]

[1] School of Environmental Science, University of Indonesia; Salemba, Raya Rd, Jakarta, Indonesia

* Correspondence: hseengineer85@gmail.com

Received Date: October 18, 2023 Revised Date: October 26, 2023 Accepted Date: January 31, 2024

Abstract

Landslides are defined as the movement of soil and rocks that form slopes. Landslides can cause environmental damage, property losses, and deaths for people in disaster-prone areas. This study aims to review and compare landslide risk management patterns in China and Indonesia from research conducted in 2019-2023. The method used in this study is a Systematic Literature Review (SLR). While searching for literature using Scopus, Mendeley has a publication period of 2019-2023. The research findings show that disaster risk management also focuses on more than community knowledge in disaster emergency response. However, other elements need attention, namely road sections most vulnerable to landslides, slope conditions, river density, land use, GIS, resources, community participation, and training. In Fengjie County, China, landslide vulnerability is a significant problem, with about 70% of areas in the vulnerability zone very high. In Pengasih Sentolo district, Indonesia, nine villages are included in the very high-risk site, showing significant landslide vulnerability. The integration and application of GIS technology have greatly assisted in assessing landslide susceptibility and identifying high-risk zones. Conclusion: The case study in Fengjie County, China and the study in Pengasih Sentolo District, Kulon Progo, Indonesia, emphasize the importance of using geospatial techniques, particularly GIS, for landslide risk assessment.

Keywords: community; disaster; GIS; knowledge; landslide; risk management

Cite This Article:
Ermanto, Y., & Koestoer, R. H. (2024). Landslide risk management using geospatial technique: comparative insights of China and Indonesia, *ASEAN Natural Disaster Mitigation and Education Journal, 1*(2). 55-65. https://doi.org/10.61511/andmej.v1i2.2024.289

1. Introduction

Regarding disaster risk reduction, theoretical Landslide risk assessment is essential to natural disaster risk reduction and management (Nseka et al., 2021). It involves evaluating and analyzing various factors and elements contributing to landslides (Hammad et al., 2020). These assessments help reduce risks to communities living in landslide-prone areas, assist local governments in future regional planning in a particular area, and identify potential locations vulnerable to landslides (Qi et al., 2021). From a disaster perspective, documenting landslide events in mountainous regions is a prerequisite for evaluating landslide vulnerability so that they do not reoccur (Li. et al., 2020).

In recent decades, landslide hazard analysis and risk assessment have emerged as essential subjects in landslide studies, leading to advancements in local landslide early warning systems (Faillettaz et al., 2019). These systems rely on various monitoring strategies and methods to detect precursors of landslides and provide timely warnings to the affected population (Tella and Balogun, 2022). One area where a landslide risk assessment has been conducted is Fengjie County in China. Fengjie County is located in the mountainous region of China, making it prone to landslides. Recently, fatal landslides have severely affected China, especially in its southwest mountainous areas (Li. et al., 2020).

Existing gaps in assessing roadway networks exposed to landslides involve analyzing slope stability, soil characteristics, geological formations, and hydrological conditions (Sui et al., 2021). Understanding these factors makes it possible to identify high-risk areas where

landslides are more likely to occur and impact transportation infrastructure (Richer et al., 2023). One approach to assessing roadway networks exposed to landslides is using Geographic Information Systems (Li et al., 2022). Previous research explained that Geographic Information Systems play a crucial role in landslide risk assessment by integrating diverse datasets and spatial analysis techniques (Mostafiz et al., 2020). These systems enable the creation of detailed susceptibility maps that indicate areas with a higher likelihood of landslides (Tran et al., 2021). By analyzing the terrain characteristics, historical landslide data, and other relevant factors, a risk assessment framework can be developed to prioritize high-risk road segments (Molina et al., 2021). The research significance study aims to review and compare landslide risk management patterns in China and Indonesia from research conducted in 2019-2023.

2. Methods

The method used in this study is a Systematic Literature Review (SLR). While searching for literature using Scopus, Mendeley has a publication period of 2019- 2023. The sample of this study reviews risk assessment techniques in mountainous regions. Materials used in the study Geographic information systems (GIS) have proven valuable tools in assessing landslide risks in mountainous areas (Khasanov et al., 2021). These systems allow for the integration and analysis of various spatial data, including topography, geological features, vegetation cover, and rainfall patterns (Priyono et al., 2020). By combining these data layers, researchers and decision-makers can create comprehensive landslide susceptibility maps that highlight areas of high risk. In the Fengjie County, China case study, landslide risk assessment was conducted using GIS techniques to analyze slope stability, soil characteristics, and rainfall patterns. This analysis helped identify the areas within the county most susceptible to landslides and could affect roadway networks (de Brito Robalo et al., 2022). However, the study found that about 70% of the area in Fengjie County is located within high and very high landslide susceptibility zones.

Table 1. Comparison of disasters and the number of victims in the world

Period 2022		
Country	Category Disaster	Fatalities
Afghanistan	Flood	182 Persons
India	Flood	192 Persons
Uganda	Drought	200 Persons
Afrika Selatan	Flood	461 Persons
Brazil	Flood and Landslides	233 Persons
Filipina	Tropical Storm	214 Persons
Indonesia	Earthquake	234 Persons
Afghanistan	Landslides	1036 Persons
Nigeria	Flood	812 Persons
Pakistan	Flood	1739 Persons

Source: Infographic on the list of world disasters in 2022

Based on Table 1, during the 2022 period, there was an increase in disaster casualties, namely, 1739 victims died in Pakistan, and 1036 victims died in Afghanistan. This means that studies on disaster-prone areas in each country require attention; the number of people experiencing climate change and increasing environmental damage in several countries will be affected. Indonesia is experiencing a disaster of ecological damage, loss of life, and property loss. Studies are needed on the sustainability of landslide risk management in vulnerable communities. Catastrophic changes in land movement caused by climate change and weather are cliff landslides. This natural phenomenon is controlled by rainfall and land

use conditions on cliff slopes that are not environmentally friendly in areas prone to soil movement for a long time (Richer et al., 2023).

3. Results and Discussion

3.1. Case Study: Fengjie County, China

In the Fengjie County, China case study, landslide risk assessment was conducted using GIS techniques. The objective was to assess the susceptibility of roadway networks in Fengjie County to landslides and identify areas at high risk. The study utilized various spatial data, including slope stability, soil characteristics, and rainfall patterns, which were integrated and analyzed using Geographic Information Systems (Wang et al., 2021).

Figure 1. shows the comparison of administrative divisions of the People's Republic of China, its dependencies, and Chinese Taipei (Taiwan) with the actual ethnolinguistic distribution. Colours show how administrative divisions would look if they were based on ethnolinguistic distribution; thicker black borders show natural administrative division.

Figure 1. Comparison of administrative divisions of the People's Republic of China, its dependencies, and Chinese Taipei (Taiwan) with the actual ethnolinguistic distribution
Source: Ethno-linguistic based administrative division map of China

Landslide susceptibility analysis and risk assessment are crucial for effective geological hazard management in Fengjie County, which has experienced significant landslide incidents over the past four decades, attributing to the combination of geological factors inherent to the Regio Landslide susceptibility analysis and risk assessment the combination of geological factors inherent to the region (Yoshida et al., 2023). These incidents have resulted in severe damage to infrastructure and lon. These incidents have resulted in severe damage to infrastructure and loss of lives. The research conducted by Xinjiang Hejing County Beizhan Mining Co., Ltd. shows that factors such as soil composition, slope steepness, rainfall patterns, and geological conditions play a significant role in slope landslides (Zhang et al., 2022). These findings further emphasize the importance of comprehensive risk assessment in formulating disaster prevention and mitigation measures, ultimately guiding landslide disaster mitigation planning and economic construction in disaster-prone areas. In the context of landslide studies in Fengjie County, China, it is essential to understand the susceptibility and risk of landslides to develop effective prevention and mitigation strategies. This includes studying historical landslide occurrences, analyzing contributing factors such as mining activities and reservoir water level fluctuations, and utilizing a Geographic Information System for landslide susceptibility analysis. By assessing and managing areas vulnerable to landslides, it is possible to mitigate the associated risks (Qin et al., 2021).

3.2. Understanding Landslides Through GIS Technology

Using GIS technology, researchers could understand the contributing factors to landslides in the area. These factors included slope steepness, soil type, and precipitation patterns. The integration and analysis of these factors allowed for the creating of a comprehensive landslide susceptibility map, highlighting areas at high risk (Khouz et al., 2022). This information was crucial for identifying the sections of roadway networks in Fengjie County that were most vulnerable to landslides. As a result of the analysis conducted in the case study, it was found that about 70% of the area in Fengjie County is located within high and very high landslide susceptibility zones.

This finding indicates that a significant portion of the county's roadway networks are at risk of being affected by landslides in the future. However, the study identified specific areas within the county that are particularly prone to landslides. A susceptibility map visually represented the spatial likelihood of landslide occurrence, which accurately corresponded to historical landslide locations. The success rate of the generated landslide susceptibility map was evaluated at 87%, indicating high accuracy and reliable prediction (Yoshida et al. et al., 2023).

The application of GIS in landslide risk assessment has revolutionized the field of geological hazard management (Luo et al., 2021). GIS allows for integrating and analyzing various spatial data, providing a comprehensive understanding of the factors contributing to landslides. This enables researchers and decision-makers to accurately assess the susceptibility of an area to landslides and identify high-risk zones (Khan et al., 2022). However, GIS technology allows for data visualization through maps, making communicating and sharing information with stakeholders easier. GIS-based techniques have greatly assisted in determining landslide susceptibility in the Pengasih Sentolo District case study, Kulon Progo, Indonesia.

Geoscientists, local administrations, and other relevant stakeholders must work together to develop practical landslide risk assessment and mitigation strategies. The use of geospatial techniques, particularly GIS, for landslide risk assessment in mountainous regions such as Fengjie County in China and Pengasih Sentolo District in Kulon Progo, Indonesia, has provided valuable insights into the vulnerability of roadway networks in these regions.

The use of geospatial techniques, particularly GIS, for landslide risk assessment in mountainous regions such as Fengjie County in China and Pengasih Sentolo District in Kulon Progo, Indonesia, has provided valuable insights into the vulnerability of roadway networks in these regions. Integrating other factors, such as land use changes and climate change, into the assessment process is essential for a comprehensive understanding of landslide dynamics and drivers. This multidisciplinary approach allows for a more accurate assessment of landslide hazards and the development of effective mitigation strategies. By incorporating high-resolution spatial data sets, GIS, remote sensing, and powerful computers with fast processing capacity, it is possible to automate parts of the landslide hazard and susceptibility mapping process, reducing the need for extensive fieldwork.

3.3. Case Study: Pengasih Sentolo District, Kulon Progo, Indonesia

In the Pengasih Sentolo District case study in Kulon Progo, Indonesia, GIS techniques were employed to assess landslide susceptibility. The study utilized various spatial data, including information on slope stability, soil characteristics, and rainfall patterns (Luo et al., 2021). By analyzing and integrating these data using GIS, the researchers created a comprehensive landslide susceptibility map for the district (Sridhar et al., 2020). The study's findings revealed that nine villages in the community are classified as falling within the very high-risk zone, indicating a significant vulnerability to landslides (Gumilang et al., 2021).

Figure 2 The potential for landslides is found in five sub-districts: Pengasih, Girimulyo, Kokap, Samigaluh, and Kalibawang Districts. The Kokap sub-district is known as an area that often experiences landslides. Kalirejo Village is one of the villages located in Kokap District and the Menoreh hills with many high cliffs. Any site with a high rainfall

intensity will have the potential for landslides. The role of the community and stakeholders in each region is needed to improve disaster prevention.

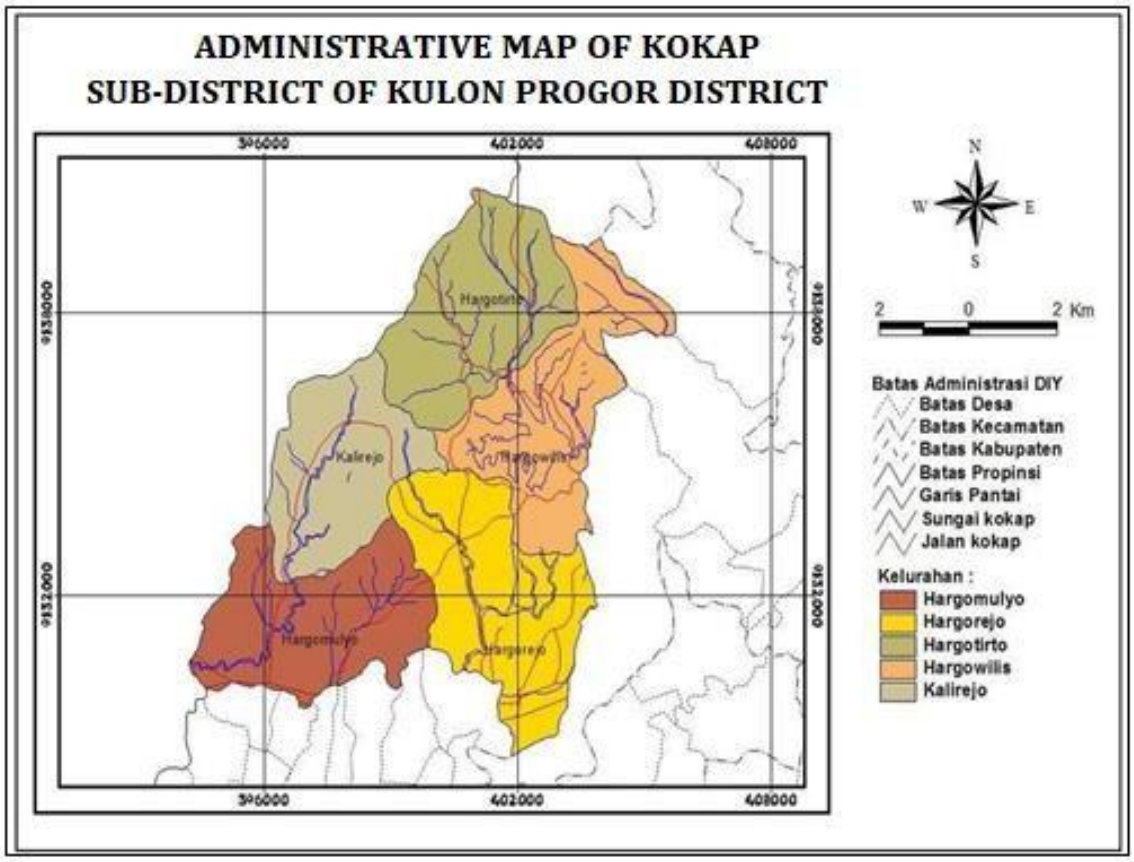

Figure 2. Map of Kabuapten Kulon Progo Administrative Division
Source: pengasih.kulonprogokab/detil/677/peta-pengasih

In Pengasih Sentolo District, Kulon, various prevention strategies are implemented to mitigate the risk of landslides. These include regular slope stability monitoring, rigorous assessments of soil composition and gradient, and developing emergency response plans and community education programs to raise awareness about landslide risks and how to respond in case of an incident (Xiao et al., 2020). These prevention strategies also involve implementing slope stabilization measures, such as constructing retaining walls and vegetative cover to protect vulnerable slopes (Zhang et al., 2021).

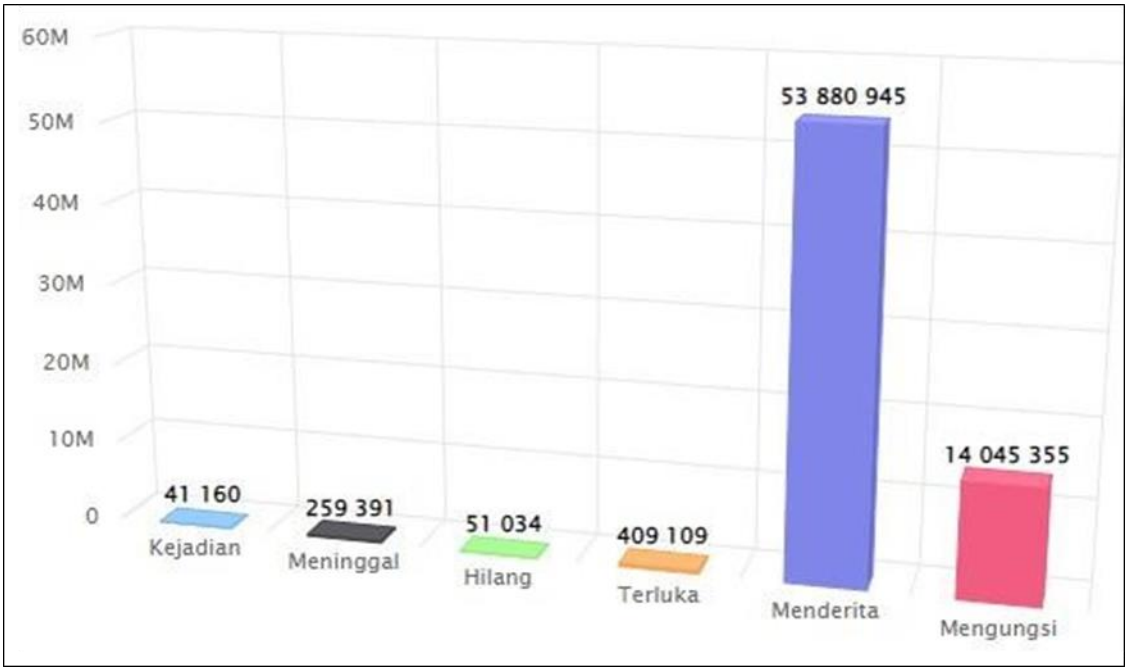

Figure 3 Comparison of disasters and fatalities in Indonesia
Source: BNPB, 2023

Figure 3 During the 2023 period, there was an increase in disaster casualties, namely 41,160, 259,391 died, 51,034 were missing, 409,109 were injured, 53,880,945 suffered, 14,045,355 were displaced. This means that the number of disaster events is greater than the disaster risk management strategy carried out. Conduct research to identify integrated risk management, and the results of the study only assess the level of difficulty of carrying out risk management in construction activities, and only risks that have a negative impact are identified (Dandridge et al., 2023; Yoshida et al., 2023). This is understandable because traditionally, the risk is viewed as one-sided as something negative and describes harm to society, the environment, and society (Guo et al., 2019).

3.4. Comparative Analysis of Landslide Risk in Different Regions

Comparing the findings from the case studies in Fengjie County, China, and Pengasih Sentolo District, Kulon Progo, Indonesia, provides insights into the commonalities and differences in landslide risk assessment in mountainous regions. Both studies highlight the importance of geospatial techniques, specifically GIS, to assess landslide susceptibility and identify high-risk zones (Sridhar et al., 2020).

The studies demonstrate that many roadway networks in both Fengjie County and Pengasih Sentolo District are at high risk of being affected by landslides. In Fengjie County, China, it was found that landslide susceptibility is a significant issue, with the county being heavily influenced by landslides in the past 40 years (Yoshida et al., 2023). The study in Fengjie County used GIS-based techniques to determine landslide susceptibility and found that about 70% of the area is located within high and very high susceptibility zones (Abdullah et al., 2019). Similarly, in Pengasih Sentolo District, Kulon Progo, Indonesia, the study identified nine villages in the district that fall within the very high-risk zone, indicating a significant vulnerability to landslides (Gnyawali et al., 2023).

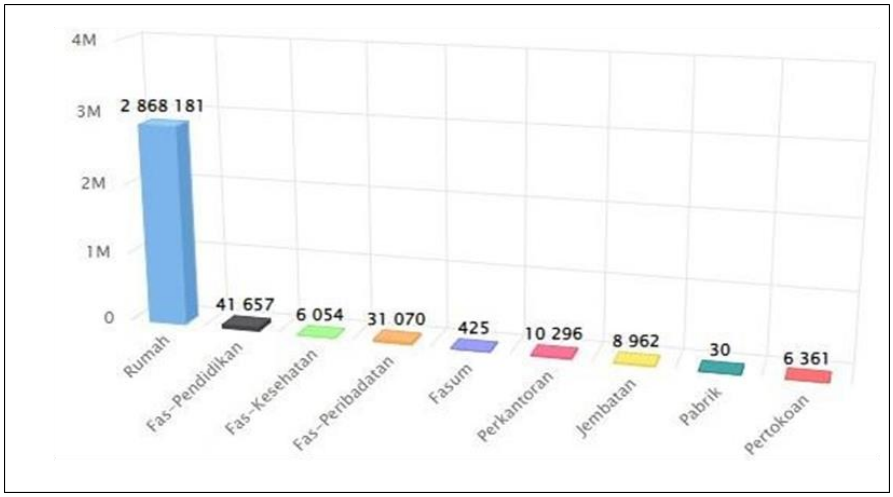

Figure 4. Comparison of infrastructure damage due to disasters in Indonesia
Source: BNPB, 2023

Based on Figure 4, during the 2023 period, there are infrastructure damages, namely 2,868,181 houses, 41,657 education, 6,054 health, 31,070 worship, injured, 425 public, 10,296 offices, 8,962 bridges, 30 factories, 6,361 urban areas. This means that spatial priorities are needed to finance damaged infrastructure in landslide- affected areas (Gnyawali et al., 2023; Saha et al., 2022). Landslides impact the closure of public roads, so people have to find alternative ways to mobilize. Handling infrastructure due to disasters needs to be addressed quickly and precisely. Stakeholders involved in landslide disaster mitigation are the government, communities, practitioners, and students (Karstens et al., 2023).

The study of landslides in different geographical areas, such as Fengjie County in China and Pengasih Sentolo District in Indonesia, is crucial as it allows us to understand the contributing factors better and develop more targeted and effective prevention mechanisms, thereby reducing the impact of these disasters on human lives and infrastructure. Through the integration of Geographic Information Systems and traditional geoscience research methods, valuable insights have beenvgained into the susceptibility and risk of landslides in both Fengjie County, China and Pengasih Sentolo District, Kulon (Alcántara-Ayala et al., 2023).

Contrasting the approaches of Fengjie and Pengasih Sentolo in utilizing tools like GIS for landslide management can provide valuable insights into effective disaster risk reduction strategies for other regions facing similar challenges. Fengjie County in China, as mentioned earlier, has a long history of landslide occurrences. This has led to the development and implementing of comprehensive landslide susceptibility analysis methods using GIS technology (Zhao and Chen, 2020). These methods integrate various data sources, including weather conditions, topography, and vegetation, to accurately assess areas with high landslide susceptibility. These methods integrate various data sources, including weather conditions, topography, and vegetation, to accurately assess areas with high landslide susceptibility. These efforts have been immensely beneficial in managing landslide risks owing to their high accuracy and interpretability, as illustrated in the research conducted by Zhang, He et al. On the other side, the Pengasih Sentolo area has also utilized a combined approach of entropy and logistic regression to effectively model landslide susceptibility, thereby easing their preventive measures and response mechanisms (Martínez-Álvarez and Bui, 2020). By leveraging the power of geographical information systems and statistical methods, Fengjie and Pengasih Sentolo have enhanced their ability to identify high-risk areas and implement targeted landslide prevention and mitigation measures. These proactive approaches have proved to be instrumental in minimizing the impact of landslides on local communities and infrastructure. In the same vein, advanced analysis methods, such as integrating random forest and extreme gradient

boosting algorithms, have been employed in Fengjie County to refine landslide susceptibility mapping further. These advancements in methodology highlight the ongoing efforts to improve landslide management and reduce the associated risks (Wang et al., 2021).

3.5. Future Perspectives for Landslide Risk Management

GIS technology in landslide risk assessment has proven effective in identifying high- risk areas and assisting in decision-making processes for mitigation and management (Nabukonde et al., 2023). Moving forward, it is crucial to enhance and refine GIS-based techniques for landslide risk assessment (Nseka et al., 2021). Additionally, there is a need for continuous monitoring and updating of spatial data to ensure the accuracy and reliability of landslide susceptibility maps (Pasang and Kubíček, 2020). However, it is essential to integrate other factors, such as land use changes, climate change, and human activities, into landslide risk assessment models. This will enable a more comprehensive understanding of the dynamics and drivers of landslides in mountainous regions, ultimately enhancing the effectiveness of risk management strategies (Shah et al., 2020). However, a multidisciplinary approach is required to effectively mitigate landslide risks in these regions (Nabukonde et al., 2023). This approach should involve geoscientists, engineers, urban planners, and policymakers collaborating. By bringing together expertise from various fields, a holistic understanding of landslide dynamics can be achieved, and appropriate measures can be implemented to reduce the vulnerability of roadway networks to landslide hazards (Yoshida et al., 2023).

One critical aspect of landslide risk assessment is the evaluation of roadway networks that are exposed to landslides (Cantarino et al., 2021). This is important because roadways are essential for transportation and communication, and their disruption can have significant socio-economic impacts. For example, in Fengjie County, China, the road network is crucial for connecting various communities and facilitating trade and access to essential services. It is imperative to assess and understand the susceptibility of roadway networks to landslides to mitigate risks and ensure the safety and functionality of these routes in the face of potential landslide events (Alarcon et al., 2022).

The analysis showed that approximately 50% of the district's area is classified as high or very high susceptibility zones. This indicates that a significant portion of the community is at an increased risk of experiencing landslides. These findings emphasize the need for proactive measures to mitigate landslide risks in Fengjie County, China, and the Pengasih Sentolo District, Indonesia.

4. Conclusions

Risk assessment of roadway networks exposed to landslides in mountainous regions is critical to geological hazard risk management. The integration and application of GIS technology have greatly assisted in assessing landslide susceptibility and identifying high-risk zones. Differences in landslide risk management using geospatial techniques in China and Indonesia are In Fengjie County, China, a risk assessment framework was established to assess the risk of landslides along roadways in mountainous regions. The support vector machine model was used to assess landslide susceptibility across the regional roadway network and can support adaptive strategies for landslide mitigation, preparedness, and emergency response services. In Pengasih and Sentolo, Indonesia is growing as an industrial area. GIS was used to assess the landslide, and the results showed that the area is prone to landslides. Landslides are geological disasters that often occur in Pengasih.

Based on these findings, the following recommendations are: First, Enhance and refine GIS-based techniques for landslide risk assessment. This includes improving the accuracy and resolution of spatial data, developing advanced algorithms for landslide susceptibility modelling, and integrating other factors such as land use changes and climate change into the assessment process. Second, implement continuous monitoring and updating of spatial data. This will ensure that landslide susceptibility maps are up-to-date and reflect the most recent changes in the landscape. Third, Promote interdisciplinary

collaboration. This involves experts from various disciplines, such as geology, engineering, geography, and environmental science, to comprehensively understand landslide dynamics and drivers. Promote community engagement and awareness.

Conflicts of Interest

The authors declare no conflict of interest.

References

Abdullah, A. F., Aimrun, W., Nasidi, N. M., Hazari, K., Sidek, L. M., & Selamat, Z. (2019). Modelling erosion and landslides induced by farming activities at Hilly Areas, Cameron Highlands, Malaysia. *Jurnal Teknologi, 81*(6), 195–204. https://doi.org/10.11113/jt.v81.13795

Alarcon, J., Garavito, A., Velasquez, P., & Santis, A. (2022). Design of the Occupational Health and Safety Management System Based on the ISO 45001:2018 Standard, Adjusted to the Needs of an Association of Waste Pickers in the City of Bogotá. *Chemical Engineering Transactions, 91*(January), 313–318. https://doi.org/10.3303/CET2291053

Alcántara-Ayala, I., Ribeiro Parteli, E. J., Pradhan, B., Cuomo, S., & Vieira, B. C. (2023). Editorial: Physics and modelling of landslides. *Frontiers in Physics, 11*(February). https://doi.org/10.3389/fphy.2023.1146166

Cantarino, I., Carrion, M. A., Palencia-Jimenez, J. S., & Martínez-Ibáñez, V. (2021). Landslide risk management analysis on expansive residential areas study of la Marina (Alicante, Spain). *Natural Hazards and Earth System Sciences, 21*(6), 1847–1866. https://doi.org/10.5194/nhess-21-1847-2021

Dandridge, C., Stanley, T. A., Kirschbaum, D. B., & Lakshmi, V. (2023). Spatial and Temporal Analysis of Global Landslide Reporting Using a Decade of the Global Landslide Catalog. *Sustainability (Switzerland), 15*(4), 15043323. https://doi.org/10.3390/su15043323

de Brito Robalo, B. M., de Luca, A., Chen, C., Dewenter, A., Duering, M., Hilal, S., Koek, H. L., Kopczak, A., Lam, B. Y. K., Leemans, A., Mok, V., Onkenhout, L. P., van den Brink, H., & Biessels, G. J. (2022). Improved sensitivity and precision in multicentre diffusion MRI network analysis using thresholding and harmonization. *NeuroImage: Clinical, 36(*October), 103217. https://doi.org/10.1016/j.nicl.2022.103217

Faillettaz, J., Funk, M., Beutel, J., & Vieli, A. (2019). Towards early warning of gravitational slope failure with co-detection of microseismic activity: The case of an active rock glacier. *Natural Hazards and Earth System Sciences, 19*(7), 1399–1413. https://doi.org/10.5194/nhess-19-1399-2019

Gnyawali, K., Dahal, K., Talchabhadel, R., & Nirandjan, S. (2023). Framework for rainfall-triggered landslide-prone critical infrastructure zonation. *Science of the Total Environment, 872*, 162242. https://doi.org/10.1016/j.scitotenv.2023.162242

Gumilang, S. I., Sutoyo, & Putra, H. (2021). Landslide analysis in the Cisarua District using geographic information system. *IOP Conference Series: Earth and Environmental Science, 871(*1). https://doi.org/10.1088/1755- 1315/871/1/012049

Guo, W., Xu, X., Wang, W., Liu, Y., Guo, M., & Cui, Z. (2019). Rainfall-triggered mass movements on steep loess slopes and their entrainment and distribution. *Catena*, p. 183, 2023. https://doi.org/10.1016/j.catena.2019.104238

Hammad, M., Leeuwen, B. V., & Mucsi, L. (2020). Integration of gis and advanced remote sensing techniques for landslide hazard assessment: a case study of northwest syria. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 6*(3/W1), 27–34. https://doi.org/10.5194/isprs-annals-VI 3-W1-2020-27-2020

Karstens, J., Haflidason, H., Berndt, C., & Crutchley, G. J. (2023). Revised Storegga Slide reconstruction reveals two major submarine landslides 12,000 years apart. *Communications Earth and Environment, 4*(1), 43247. https://doi.org/10.1038/s43247-023-00710-y

Khan, S., Kirschbaum, D. B., Stanley, T. A., Amatya, P. M., & Emberson, R. A. (2022). Global Landslide Forecasting System for Hazard Assessment and Situational Awareness. *Frontiers in Earth Science, 10*(July), 1–15. https://doi.org/10.3389/feart.2022.878996

Khasanov, S., Juliev, M., Uzbekov, U., Aslanov, I., Agzamova, I., Normatova, N., Islamov, S., Goziev, G., Khodjaeva, S., & Holov, N. (2021). Landslides in Central Asia: A review of papers published in 2000-2020 focusing on the importance of GIS and remote sensing techniques. *GeoScape, 15*(2), 134–145. https://doi.org/10.2478/geosc-2021-0011

Khouz, A., Trindade, J., Oliveira, S. C., El Bchari, F., Bougadir, B., Garcia, R. A. C., & Jadoud, M. (2022). Landslide susceptibility assessment in the rocky coast subsystem of Essaouira, Morocco. *Natural Hazards and Earth System Sciences, 22*(11), 3793–3814. https://doi.org/10.5194/nhess-22-3793-2022

Li, L., & Lan, H. (2020). Integration of spatial probability and size in slope-unit-based landslide susceptibility assessment: A case study. *International Journal of Environmental Research and Public Health, 17(*21), 1–17. https://doi.org/10.3390/ijerph17218055

Li, Y., Deng, X., Ji, P., Yang, Y., Jiang, W., & Zhao, Z. (2022). Evaluation of Landslide Susceptibility Based on CF-SVM in Nujiang Prefecture. *International Journal of Environmental Research and Public Health, 19*(21). https://doi.org/10.3390/ijerph192114248

Luo, Y., Li, M., Tang, J., Ren, J. L., Zheng, Y., Yu, X. L., Jiang, L. R., Fan, D. L., & Chen, Y. H. (2021). Design of a Virtual Reality Interactive Training System for Public Health Emergency Preparedness for Major Emerging Infectious Diseases: Theory and Framework. *JMIR Serious Games, 9*(4). https://doi.org/10.2196/29956

Martínez-Álvarez, F., & Bui, D. T. (2020). Advanced machine learning and big data analytics in Remote Sensing for Natural Hazards Management. *Remote Sensing, 12*(2), 10–12. https://doi.org/10.3390/rs12020301

Molina, F. E. E., Ramirez, B. D. V. A., Izquierdo, F. A., & Ortega, D. C. Z. (2021). Road safety perception questionnaire (RSPQ) in Latin America: A development and validation study. *International Journal of Environmental Research and Public Health, 18*(5), 1–21. https://doi.org/10.3390/ijerph18052433

Mostafiz, R. Bin, Friedland, C. J., Rohli, R. V., Gall, M., Bushra, N., & Gilliland, J. M. (2020). Census-Block-Level Property Risk Estimation Due to Extreme Cold Temperature, Hail, Lightning, and Tornadoes in Louisiana, United States. *Frontiers in Earth Science, 8*(November), 1–13. https://doi.org/10.3389/feart.2020.601624

Nabukonde, A., Barakagira, A., & Akwango, D. (2023). The Use of Geographical Information System (GIS) and Remote Sensing (RS) Technologies in Generation of Information Used to Mitigate Risks from Landslide Disasters: An Application Review. *Archives of Current Research International, 23*(2), 43–49. https://doi.org/10.9734/acri/2023/v23i2558

Nseka, D., Mugagga, F., Opedes, H., Ayesiga, P., Wasswa, H., Mugume, I., Nimusiima, A., & Nalwanga, F. (2021). The damage caused by landslides in socio-economic spheres within the Kigezi highlands of South Western Uganda. *Environmental and Socio-Economic Studies, 9*(1), 23–34. https://doi.org/10.2478/environ-2021-0003

Pasang, S., & Kubíček, P. (2020). Landslide susceptibility mapping using statistical methods along the Asian Highway, Bhutan. *Geosciences (Switzerland), 10*(11), 1–26. https://doi.org/10.3390/geosciences10110430

Priyono, K. D., Jumadi, Saputra, A., & Fikriyah, V. N. (2020). Risk analysis of landslide impacts on Karanganyar, Central Java, Indonesia settlements. *International Journal of GEOMATE, 19*(73), 100–107. https://doi.org/10.21660/2020.73.34128

Qi, T., Zhao, Y., Meng, X., Chen, G., & Dijkstra, T. (2021). Ai-based susceptibility analysis of shallow landslides from heavy rainfall in Tianshui, China. *Remote Sensing, 13*(9). https://doi.org/10.3390/rs13091819

Qin, Y., Yang, G., Lu, K., Sun, Q., Xie, J., & Wu, Y. (2021). Performance evaluation of five gis-based landslide susceptibility prediction and mapping models: A case study of Kaiyang county, China. *Sustainability (Switzerland), 13*(11). https://doi.org/10.3390/su13116441

Richer, B., Saeidi, A., Boivin, M., Rouleau, A., & Lévesque, Y. (2023). Development of a methodology for predicting landslide hazards at a regional scale. *Geoenvironmental Disasters, 10*(1), 40677. https://doi.org/10.1186/s40677-022-00231-4

Saha, S., Saha, A., Hembram, T. K., Mandal, K., Sarkar, R., & Bhardwaj, D. (2022). Prediction of spatial landslide susceptibility applying the novel ensembles of CNN, GLM and random forest in the Indian Himalayan region. *Stochastic Environmental Research and Risk Assessment, 36(*10), 3597–3616. https://doi.org/10.1007/s00477-022-02212-3

Shah, A. A., Gong, Z., Ali, M., Jamshed, A., Naqvi, S. A. A., & Naz, S. (2020). Measuring education sector resilience in the face of flood disasters in Pakistan: an index- based approach. *Environmental Science and Pollution Research, 27*(35), 44106– 44122. https://doi.org/10.1007/s11356-020-10308-y

Sridhar, B. B. M., Johnson, J., & Mosuro, A. (2020). Impact of Land Cover Changes on the Soil and Water Quality of Greens Bayou Watershed. *Water, Air, and Soil Pollution, 231*(10). https://doi.org/10.1007/s11270-020-04890-7

Sui, Z. F., Yuan, W., Yi, W., & Yang, W. (2021). Stability analysis of ecological slopes based on a 3D finite element model. *Advances in Materials Science and Engineering*, 2021: 1-11. https://doi.org/10.1155/2021/3785943

Tella, A., & Balogun, A. L. (2022). GIS-based air quality modelling: spatial prediction of PM10 for Selangor State, Malaysia using machine learning algorithms. *Environmental Science and Pollution Research, 29*(57), 86109–86125. https://doi.org/10.1007/s11356-021-16150-0

Tran, T. H., Dam, N. D., Jalal, F. E., Al-Ansari, N., Ho, L. S., Phong, T. Van, Iqbal, M., Le, H. Van, Nguyen, H. B. T., Prakash, I., & Pham, B. T. (2021). GIS-Based Soft Computing Models for Landslide Susceptibility Mapping: A Case Study of Pithoragarh District, Uttarakhand State, India. *Mathematical Problems in Engineering*, 2021. https://doi.org/10.1155/2021/9914650

Wang, Q., Liu, K., Wang, M., & Koks, E. E. (2021). A River Flood and Earthquake Risk Assessment of Railway Assets along the Belt and Road. *International Journal of Disaster Risk Science, 12*(4), 553–567. https://doi.org/10.1007/s13753-021-00358-2

Wang, Y., Wen, H., Sun, D., & Li, Y. (2021). Quantitative landslide risk assessment based on susceptibility mapping using random forest and geodetector. *Remote Sensing, 13*(13). https://doi.org/10.3390/rs13132625

Xiao, L., Wang, J., Zhu, Y., & Zhang, J. (2020). Quantitative Risk Analysis of a Rainfall- Induced Complex Landslide in Wanzhou County, Three Gorges Reservoir, China. *International Journal of Disaster Risk Science, 11*(3), 347–363. https://doi.org/10.1007/s13753-020-00257-y

Yoshida, M., Sawano, T., Kobashi, Y., Hori, A., Nishikawa, Y., Ozaki, A., Nonaka, S., Tsuboi, M., & Tsubokura, M. (2023). Importance of continuing health care before emergency hospital evacuation: a fatal case of a hospitalized patient in a hospital within 5 km radius of Fukushima Daiichi Nuclear Power Plant: a case report. *Journal of Medical Case Reports, 17(*1), 37. https://doi.org/10.1186/s13256-022-03744-6

Zhang, R., Wu, S., Xie, C., & Chen, Q. (2021). Study the geological condition analysis and grade division of high altitude and cold stope slope. *Sustainability (Switzerland), 13*(22). https://doi.org/10.3390/su132212464

Zhang, R., Wu, S., Xie, C., & Chen, Q. (2022). Risk Monitoring Level of Stope Slopes and Landslides in High-Altitude and Cold Mines. *Sustainability (Switzerland), 14*(13), 1–12. https://doi.org/10.3390/su14137581

Zhang, Y., Ayyub, B. M., Gong, W., & Tang, H. (2023). Risk assessment of roadway networks exposed to landslides in mountainous regions—a Fengjie County, China case study. *Landslides, 20*(7), 1419–1431. https://doi.org/10.1007/s10346-023-02045-3

Zhang, Y., Yang, Y., Zhang, J., & Wang, Y. (2023). Sensitivity study of multi-field information maps of typical landslides in mining areas based on transfer learning. *Frontiers in Earth Science, 11(*January), pp. 1–15. https://doi.org/10.3389/feart.2023.1105985

Zhao, X., & Chen, W. (2020). GIS-based evaluation of landslide susceptibility models using certainty factors and functional trees-based ensemble techniques. *Applied Sciences (Switzerland), 10*(1). https://doi.org/10.3390/app10010016