INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN BUSINESS & SOCIAL SCIENCES
Vol 15, Issue 2, (2025) E-ISSN: 2222-6990

Integrating GIS-Based Spatial Analysis to Assess the Relationship between Population Density and Landslide Risk in the Langat Basin, Malaysia

Nurakmar Hakim Jasni[1] & Nuriah Abd Majid[1]
Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia, 43600, Bangi, Selangor, Malaysia[1]
Corresponding Author Email: nuriah@ukm.edu.my

To Link this Article: http://dx.doi.org/10.6007/IJARBSS/v15-i2/24457 DOI:10.6007/IJARBSS/v15-i2/24457

Published Date: 25 February 2025

Abstract
Landslides pose significant threats to communities, particularly in densely populated areas with heightened vulnerability. This study explores the relationship between population density and landslide risks in the Langat Basin, Malaysia, a region characterized by steep slopes, frequent rainfall, and diverse human settlements. Using GIS-based spatial analysis, population density data and historical landslide records were integrated to identify high-risk zones. The findings reveal a substantial overlap between densely populated areas and landslide-prone regions, especially in the upstream areas of Hulu Langat. These results highlight the compounded risks communities face due to economic pressures, inadequate land-use planning, and limited infrastructure. This study underscores the importance of incorporating demographic factors into disaster mitigation strategies. Mapping population density against landslide susceptibility, it offers valuable insights for policymakers to prioritize high-risk areas, improve urban planning, and design targeted community resilience programs.
Keywords: Population Density, Landslides risk, Vulnerability, Spatial Analysis, Disaster Risk Management

Introduction

Landslides are among the most destructive natural hazards, particularly in regions characterized by steep slopes, fragile geological formations, and dense human settlements. These disasters pose significant threats to lives, infrastructure, and economic stability, with population density playing a critical role in amplifying vulnerability and exposure to such hazards (Chuang & Shiu, 2018; Herrera et al., 2018). Moreover, slope failures are particularly common in mountainous regions and areas with heavy rainfall, where the combination of steep slopes, unstable geological conditions, and bad weather increases the chances of slope failures (Greco et al., 2021; Liu et al., 2021; Ma et al., 2023). Similarly, GIS-based studies in Indonesia have highlighted how population density and slope gradients directly influence landslide vulnerability patterns (Puji Hastuty et al., 2020). The consequences of these events go beyond physical damage because they also cause long-term socio-economic instability for the communities affected (Turner, 2018). Landslides are a critical hazard in regions with complex terrain and dense human settlements, such as the Langat Basin in Malaysia. Recent studies emphasize the value of integrating GIS-based spatial analysis to assess the relationship between population density and landslide risks, providing actionable insights for risk mitigation. Techniques like artificial neural networks (ANN) have been applied to model landslide susceptibility in the basin, demonstrating the effectiveness of predictive modeling in identifying high-risk zones (Selamat et al., 2022, 2023). Furthermore, the interplay between human activities and environmental factors underscores the importance of incorporating population density and land-use patterns into spatial assessments to understand vulnerability (Selamat et al., 2023). Research from other Malaysian regions, such as Pulau Pinang and Kuala Lumpur, also highlighted how local physical and demographic characteristics influence landslide risks, further validating the role of GIS in capturing these dynamics (Zulkafli et al., 2023a, 2023b).

The study area, Langat Basin, Malaysia is a critical area that is highly prone to these hazards due to its geological features, frequent intense rainfall, and increased human activities. The number of slope failures in the Langat Basin has also been growing, resulting in serious impacts like loss of life, property damage, and environmental harm, such as vegetative cover loss. However, the most critical impact of landslides from a social perspective is the increased vulnerability of communities in these risky areas. It is important to analyze the issue of social vulnerability to slope failures and the resilience of the community toward the disaster which requires looking into various contributing factors (Antronico et al., 2020; Derakhshan et al., 2022). In rapidly urbanizing regions of Langat Basin, the expansion of human settlements into landslide-prone areas is a growing concern. The combination of poor land-use planning, economic pressures, and a lack of disaster awareness often results in vulnerable populations residing in high-risk zones. Understanding the relationship between population density and landslide risk is essential for developing strategies to reduce vulnerabilities and enhance community resilience. This study focuses on exploring the connection between population density and landslide risk through a spatial analysis approach. By identifying areas where dense populations overlap with high landslide susceptibility, this research aims to provide insights into the dynamics of risk and inform future efforts in disaster mitigation and urban planning. The findings from this assessment will contribute to a broader understanding of how human and environmental factors interact to shape disaster vulnerabilities.

Methodology

Study Area

The Langat Basin is located in the central region of Peninsular Malaysia, with coordinates ranging approximately from 2.500N to 3.200N in latitude and 101.300E to 102.000E in longitude. The basin covers an area of about 2,350 km² with a diverse geographical characteristic including the hilly terrains in the upstream region, which makes it highly susceptible to slope failures, while the downstream area is characterized by more flatlands. The Langat Basin experiences a tropical climate with high temperatures and significant rainfall throughout the year. The mean annual rainfall is about 2,470 mm concentrated mainly in March and November, while the average temperature is about 27°C and remains relatively uniform throughout the year. This heavy rainfall, combined with the geological features of the basin, contributes to the instability of slopes and increases the risk of landslides.

The Langat Basin encompasses a combination of rural and urban areas, with significant development concentrated in its central region, particularly around Putrajaya, Sepang, and the lower section of Hulu Langat. According to the Department of Statistics Malaysia (DOSM 2024), the basin is home to approximately 3 million residents. This diverse population reflects a broad spectrum of socio-economic backgrounds, including civil servants, entrepreneurs managing businesses of varying scales, and individuals engaged in multiple jobs to meet their livelihood needs. Figure 1 shows the location of Langat Basin and the area that it covers in Malaysia.

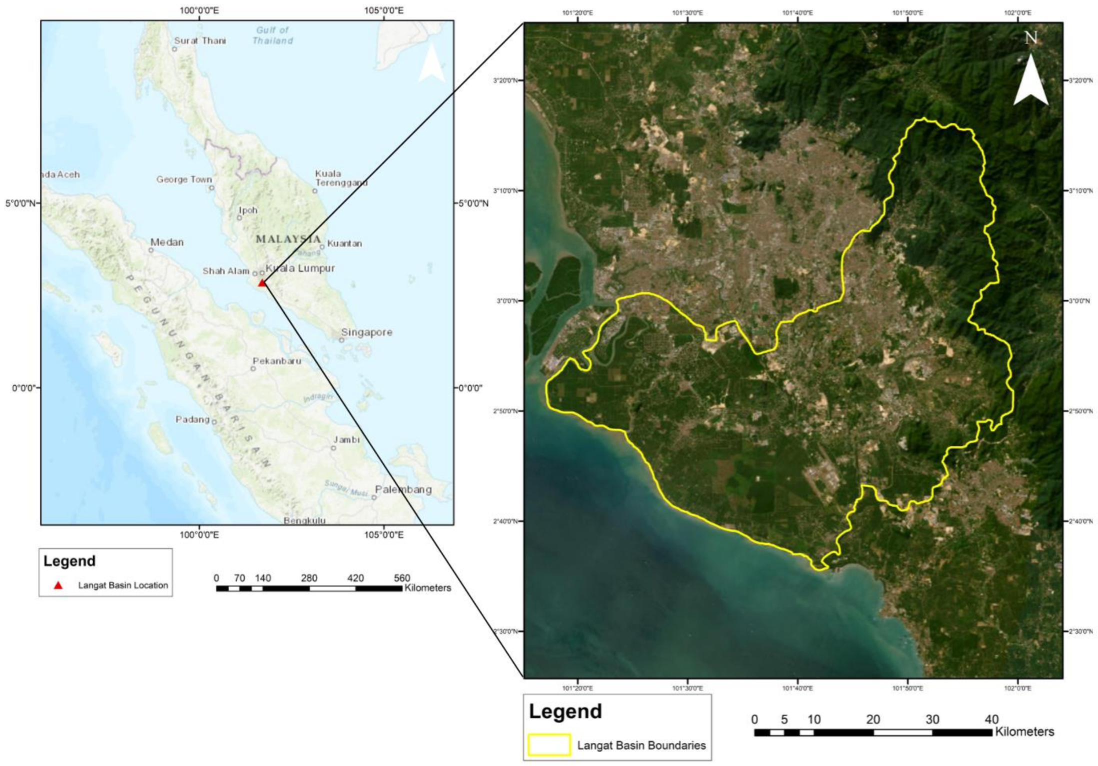

Figure 1 : The Location of Langat Basin

Data Collection

The analysis utilizes two primary datasets. Population density data is derived from spatial datasets to visualize the geographic distribution of populations across the study area. Additionally, population counts are sourced from the latest census reports to provide accurate demographic details. Historical landslide data, on the other hand, consists of spatial information on past landslide occurrences, which includes geolocations of landslide incidents and their associated environmental contexts. These datasets form the basis of the study's analytical framework. Moreover, the data also include the spatial analysis of high risk zones for landslide which is further analyzed and visualized in Figure 1.

The first step involves data preparation, where datasets are preprocessed to ensure consistent spatial resolution and coordinate projections. Population count data is harmonized with spatial population density maps in Figure 1 to provide a unified dataset for analysis. Following this, a GIS-based spatial analysis is conducted to better represent the population density data. Overlay analysis combines spatial population density data with historical landslide maps to identify zones where high population concentrations intersect with past landslide events. Additionally, proximity analysis or the buffer zone analysis in Figure 1 evaluates the distance of population centers to landslide occurrences to determine spatial relationships and potential exposure levels. Mapping and visualization are integral to this process, with maps generated to highlight high-density areas with significant historical landslide activity. These visual tools help identify critical areas requiring detailed assessment or intervention.

Data Validation

To ensure the reliability of the findings, the validation process involves a thorough cross-referencing of the identified high-risk zones with documented evidence of landslide impacts from past reports and incident. This includes comparing the spatial overlap of high population density and historical landslide-prone areas with real-world records such as damage reports and expert assessments in Langat Basin (Selamat et al., 2024). These external sources provide contextual insights into the accuracy of the spatial analysis, confirming whether the high-risk zones align with areas known to have experienced significant landslide activity. Additionally, historical records serve as a critical benchmark, offering a temporal perspective that helps validate the consistency and robustness of the identified patterns and relationships.

This study acknowledges potential limitations. There may be variability in the accuracy of historical landslide data, the static nature of population data may not reflect recent changes in settlement patterns, and potential biases could arise in the spatial interpolation of population density data. Despite these limitations, the methodology provides a robust approach for understanding the spatial connections between population density and landslide risks. This early assessment aims to inform future, more detailed investigations and disaster risk management efforts.

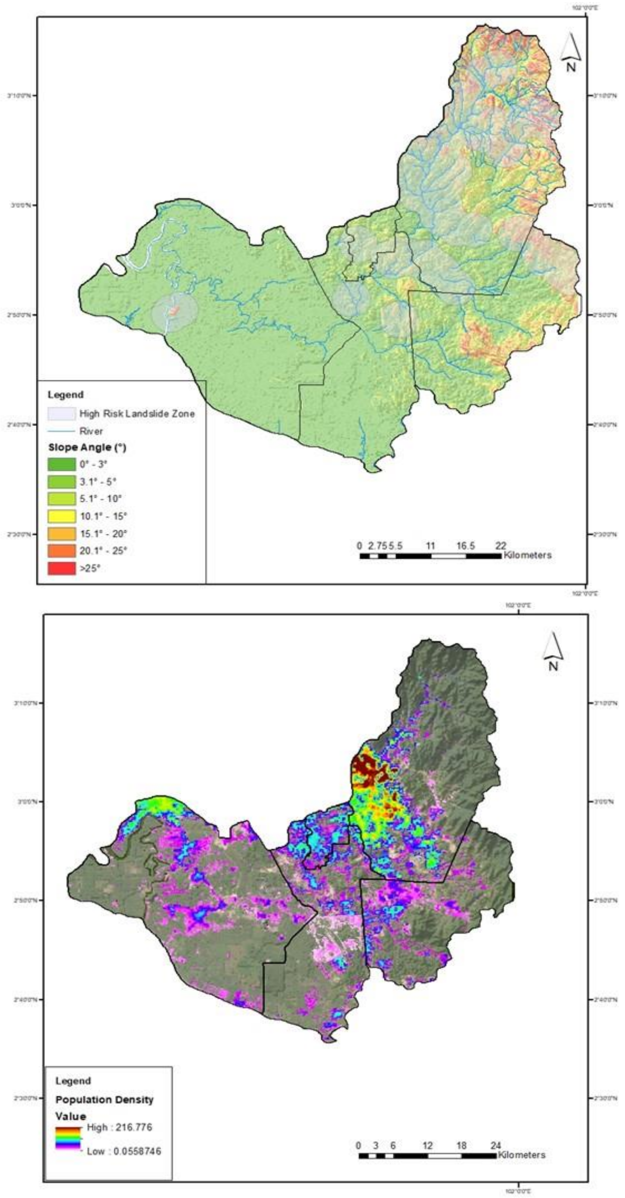

Figure 1: High Risk Zone of Landslide and Population Density in Langat Basin

The slope analysis in Figure 1 was conducted using Digital Elevation Model (DEM) data to identify areas with steep gradients that are more susceptible to slope failures. The Langat Basin's slopes were grouped into three categories based on their risk levels: Low Risk (0-10 degrees), Medium Risk (10.1-20 degrees), and High Risk (>20 degrees). Areas with gentle and low slopes ranging from 0 to 10 degrees are generally considered to have a low likelihood of slope failure due to their relatively stable nature. This area is mostly located in the middle and downstream region of the Langat Basin with relatively flat lands. In contrast, areas with slopes between 10.1 and 20 degrees are categorized as medium risk. These regions are more susceptible to landslides when other contributing factors, such as high water saturation or weak soil types are present in the area. The area with this slope based on Figure 1, can be seen mostly in the upstream part of Langat Basin and some of it in the middle regions. Finally, areas with slopes greater than 20 degrees are classified as high risk particularly when combined with poor soil cohesion and proximity to rivers. These steep areas are highly prone to landslides, and the risk increases significantly during periods of intense rainfall or seismic activity. Based on Figure 1, the slope with highest angle can be seen mostly in the upstream part of the Langat Basin with a small area in Bukit Jugra, downstream part of the basin. The landslide inventory, which includes historical landslide locations, was also integrated into the analysis to understand the spatial relationship between past landslide events and current risk factors. A buffer zone of 5km was applied around these locations to determine areas of continuing vulnerability such as highlighted in Figure 1 as high risk landslide zones.

Moreover, the population density map was developed based on (UN, 2020) data to identify the accessibility of the infrastructures in the Langat Basin by determining where the residing population is living in the prone to landslide areas at Langat Basin. This analysis highlights the regions where the population intersect with physical risks analyzed earlier in this study, providing a better understanding of the population itself. The Langat Basin was divided into three regions for a more localized assessment: the upstream region, middle region, and downstream region. The upstream region includes the Hulu Langat District and part of Seremban, Negeri Sembilan. The middle region covers Putrajaya, a part of Seremban, Negeri Sembilan and Sepang. The downstream region comprises Kuala Langat and also a part of Sepang. The population data from the Department of Statistic Malaysia DOSM, (2024) data shows that Hulu Langat has the highest population with approximately 1,508,100 people, followed by Seremban with 712,700, Sepang with 346,900, Kuala Langat with 326,300, and Putrajaya with 120,300 people. The density of the population and the population spread can also be seen in Figure 2 which shows that the density of the people is the highest in Hulu Langat, based on the reddish shade of the map in Figure 1. However, it is important to note that the population figures for each district in Langat Basin may not fully represent the actual population within since the basin boundaries do not align and connect perfectly with administrative boundaries of Malaysia. Some areas of the districts are excluded from the basin, resulting in certain populations not being properly recorded and included in this analysis.

Results and Discussion

The Langat Basin's river networks that have been derived from OpenStreetMap (OSM) data, and the corresponding slope characteristics analyze from the DEM data play a very significant role in influencing slope stability. The Langat Basin is divided into three distinct regions based on topography and development patterns: the upstream region includes Hulu Langat and part of Seremban, the middle region covers Putrajaya and Sepang, and the downstream region comprises Kuala Langat. The population density is the highest in the Hulu Langat District (upstream region), based on WorldPop United Nations (2020) data and the national census agency. The analysis of the Langat Basin has shown that high-risk zones are mostly located in the upstream region, where the gradient is steepest and river flow is most intense. However, a certain high-risk zone for a landslide to happen has also been identified in Bukit Jugra, Kuala Langat despite being in the downstream region. This anomaly is attributed to the unique geological conditions of the hill and human activities in that area. Additionally, areas around the river are particularly prone to landslides due to proximity and soil erosion, which weakens slope stability. This can be seen from the map highlighted based on Figure 1.

Even though Hulu Langat is located in the upstream part, some areas in Hulu Langat are more developed and have easy access to good infrastructure, reducing their vulnerability. However, rural areas within Hulu Langat still face significant challenges, with limited road access and fewer essential services, which increases their vulnerability and requires targeted attention (Banuzaki & Ayu, 2021; Gangwal et al., 2023; Salini & Rahul, 2024). The upstream region which in Hulu Langat district, exhibits the highest population density located in the urban area, leading to increased vulnerability in the event of a landslide (Puji Hastuty et al., 2020). Moreover, especially in the rural areas with limited infrastructure and services of Hulu Langat located in the hilly region based on Figure 1, the disaster risk of the community is highly visualized due to the community also being located within a prone to landslide area based on the physical analysis (Aksha et al., 2020; Guillard-Gonçalves & Zêzere, 2018; Pollock & Wartman, 2020). It also highlighted the location of where the population is more dense which can account for more socially vulnerable people in Langat Basin. According to Pollock & Wartman (2020), the behavior of the people in times of disaster would contribute to social vulnerabilities, which can be mitigated by simple procedures of management such as providing and preparing the refuge places for emergencies, moving higher in the building, community engagement, and awareness programs.

The study's findings highlight substantial spatial overlaps between areas of high population density and historical landslide zones. Through GIS-based analysis, it became evident that urban fringes and specific rural areas located on steep slopes serve as critical hotspots of landslide risk within the Langat Basin (Au, 1998; Dhungana & Maharjan, 2023; Pozo et al., 2019). These regions, marked by dense human settlements and a history of landslides, are particularly at risk due to inadequate urban planning and the expansion of settlements into unstable terrains.(Nazrien Ng et al., 2022; Puji Hastuty et al., 2020; Zhang et al., 2021) Proximity analysis revealed that densely populated areas near historical landslide sites face increased exposure, emphasizing the influence of socioe conomic factors. Populations in these zones often reside in risk-prone areas due to economic constraints or the limited availability of safe land. The analysis consistently demonstrated a trend of human encroachment into landslide-prone regions, showcasing the interplay between demographic pressures and environmental hazards. In the Langat Basin, population density is unevenly distributed, with certain regions experiencing higher development and concentrated settlements. Notably, high-density areas near historically recorded landslide sites are at significantly greater risk (Puji Hastuty et al., 2020). Spatial analysis identified a recurrent overlap between these high-density zones and past landslide locations, emphasizing the compounded risks faced by these communities. This heightened risk arises not only from direct exposure to potential hazards but also from challenges related to evacuation, emergency response, and recovery efforts in densely populated areas (Augustine & Schoettmer, 2005; Lee et al., 2016; Serulle & Cirillo, 2014). The study underscores the critical role of incorporating population density metrics and the spatial relationships of historical landslide events into disaster risk assessment and urban planning. Such integration is essential for identifying key vulnerabilities, optimizing resource allocation, and formulating community-specific mitigation strategies that are both equitable and effective.

Visualization through GIS mapping in Figure 1, provided a clear depiction of these risk dynamics. Composite maps were generated to overlay population density data with historical landslide occurrences, pinpointing regions where these two factors converge. The maps identified high-risk zones, which are essential for prioritizing disaster risk reduction and urban planning interventions. Overall, the findings emphasize the necessity of integrating population density considerations into landslide risk assessments. By identifying the areas of greatest overlap and proximity, this study lays the groundwork for targeted strategies aimed at reducing vulnerability and enhancing resilience in at-risk communities (Mioc et al., 2015; Wadhawan, 2019).

This study addresses a critical gap in disaster risk management by integrating population density data with landslide susceptibility analysis in the Langat Basin, Malaysia. Unlike the approaches that primarily focus on geophysical factors, this research emphasizes the socio-spatial dynamics that amplify community vulnerabilities. By highlighting the compounded risks faced by densely populated and socio-economically disadvantaged regions, the study contributes to the broader understanding of disaster resilience. Additionally, the findings underscore the need for equitable urban planning and targeted interventions, offering policymakers actionable insights to prioritize high-risk zones. This integrative approach not only bridges the gap between demographic and environmental risk factors but also sets a foundation for future studies to incorporate dynamic data and predictive modeling for real-time risk assessment.

Conclusion

This study has demonstrated the critical role of population density in shaping landslide vulnerability, using the Langat Basin as a case study to illustrate the spatial and demographic dynamics at play. By integrating GIS-based spatial analysis with historical landslide data, the research highlights the significant overlap between densely populated areas and landslide-prone zones. These findings underscore the compounded risks faced by communities living in high-density regions with historical landslide activity, where economic and spatial constraints often force populations into hazardous areas. The socio-economic dimension of vulnerability emerges as a key factor in understanding these risks. Economic pressures and the lack of affordable, well-planned housing options compel vulnerable populations to settle in marginal lands, further exacerbating their exposure to landslide hazards. This intersection of social inequality and environmental risk highlights the importance of equitable urban planning and targeted disaster mitigation strategies. GIS-based visualizations have proven invaluable in identifying high-risk zones and guiding decision-making processes. These tools not only provide clear, actionable insights for policymakers and urban planners but also serve as a foundation for resource allocation and community-focused risk reduction efforts. The ability to visually represent the interplay between population density and historical landslide data enables a more strategic approach to disaster resilience planning.

In conclusion, this study emphasizes the intertwined nature of demographic, spatial, and socio-economic factors in landslide vulnerability. By identifying critical high-risk areas and highlighting the need for integrated strategies, the research provides a pathway for improving disaster risk management and enhancing resilience in vulnerable communities. Future studies should build upon these findings, incorporating temporal and land-use dynamics to refine risk assessments and inform sustainable urban development.

Acknowledgment

We extend our heartfelt gratitude to the Fundamental Research Grant Scheme (FRGS/1/2024/SS07/UKM/02/1) for their invaluable support. This funding has been instrumental in advancing our research, enabling us to explore new frontiers and achieve significant outcomes. We also wish to express our sincere appreciation to all researchers and collaborators whose contributions, insights, and dedication have been pivotal in the success of this project.

References

Aksha, S. K., Resler, L. M., Juran, L., & Carstensen Jr., L. W. (2020). A geospatial analysis of multi-hazard risk in Dharan, Nepal. *Geomatics Natural Hazards & Risk*, 11(1), 88–111. https://doi.org/10.1080/19475705.2019.1710580

Antronico, L., De Pascale, F., Coscarelli, R., & Gullà, G. (2020). Landslide risk perception, social vulnerability and community resilience: The case study of Maierato (Calabria, southern Italy). *International Journal of Disaster Risk Reduction*. https://doi.org/10.1016/j.ijdrr.2020.101529

Au, S. W. C. (1998). Rain-induced slope instability in Hong Kong. *Engineering Geology*, 51(1), 1–36. https://doi.org/10.1016/S0013-7952(98)00038-6

Augustine, J., & Schoettmer, J. T. (2005). Evacuation of a Rural Community Hospital: Lessons learned from an unplanned event. *Disaster Management and Response*. https://doi.org/10.1016/j.dmr.2005.05.005

Banuzaki, A. S., & Ayu, A. K. (2021). Landslide vulnerability assessment using gis and remote sensing techniques: A case study from Garut - Tasikmalaya road. *IOP Conference Series: Earth and Environmental Science*, 622(1). https://doi.org/10.1088/1755-1315/622/1/012005

Chuang, Y. C., & Shiu, Y. S. (2018). Relationship between landslides and mountain development—Integrating geospatial statistics and a new long-term database. *Science of the Total Environment*, 622–623, 1265–1276. https://doi.org/10.1016/j.scitotenv.2017.12.039

Department of Statistic Malaysia (2024). OpenDOSM. Https://open.dosm.gov.my/.

Derakhshan, S., Emrich, C. T., & Cutter, S. L. (2022). Degree and direction of overlap between social vulnerability and community resilience measurements. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0275975

Dhungana, S., & Maharjan, M. (2023). Assessment of slope-cut landslides along Pokhara-Baglung Highway, Nepal. *Archives of Agriculture and Environmental Science*, 8(3), 302–309. https://doi.org/10.26832/24566632.2023.080305

Gangwal, U., Siders, A. R., Horney, J., Michael, H. A., & Dong, S. (2023). Critical facility accessibility and road criticality assessment considering flood-induced partial failure. *Sustainable and Resilient Infrastructure.* https://doi.org/10.1080/23789689.2022.2149184

Greco, R., Comegna, L., Damiano, E., Marino, P., Olivares, L., & Santonastaso, G. F. (2021). Recurrent rainfall-induced landslides on the slopes with pyroclastic cover of Partenio Mountains (Campania, Italy): Comparison of 1999 and 2019 events. *Engineering Geology.* https://doi.org/10.1016/j.enggeo.2021.106160

Guillard-Gonçalves, C., & Zêzere, J. L. (2018). Combining social vulnerability and physical vulnerability to analyse landslide risk at the municipal scale. *Geosciences (Switzerland)*, 8(8). https://doi.org/10.3390/geosciences8080294

Herrera, G., Mateos, R. M., García-Davalillo, J. C., Grandjean, G., Poyiadji, E., Maftei, R., Filipciuc, T. C., Jemec Auflič, M., Jež, J., Podolszki, L., Trigila, A., Iadanza, C., Raetzo, H., Kociu, A., Przyłucka, M., Kułak, M., Sheehy, M., Pellicer, X. M., McKeown, C., … Jensen, O. A. (2018). Landslide databases in the Geological Surveys of Europe. *Landslides*, 15, 359–379. https://doi.org/10.1007/s10346-017-0902-z

Lee, Y.-H., Lee, J.-S., & Hong, W.-H. (2016). A Study on the possible evacuation distance for the elderly considering the slope in order to prepare for Flood Disaster. 103–108. https://doi.org/10.14257/astl.2016.124.21

Liu, Y., Deng, Z., & Wang, X. (2021). The effects of rainfall, soil type and slope on the processes and mechanisms of rainfall-induced shallow landslides. *Applied Sciences (Switzerland*). https://doi.org/10.3390/app112411652

Ma, S., Shao, X., & Xu, C. (2023). Landslides Triggered by the 2016 Heavy Rainfall Event in Sanming, Fujian Province: Distribution Pattern Analysis and Spatio-Temporal Susceptibility Assessment. *Remote Sensing*. https://doi.org/10.3390/rs15112738

Mioc, D., Nkhwanana, J. N., Moreiri, K. K., Nickerson, B., Santos, M., McGillivray, E., Morton, A., Anton, F., Ahmad, A., Mezouaghi, M., Mofford, L., & Tang, P. (2015). Natural and man-made flood risk mapping and warning for socially vulnerable populations. *International Journal of Safety and Security Engineering,* 5(3), 183–202. https://doi.org/10.2495/SAFE-V5-N3-183-202

Nazrien Ng, J., Mohd Taib, A., Razali, I. H., Abd Rahman, N., Wan Mohtar, W. H. M., A. Karim, O., Mat Desa, S., Awang, S., & Mohd, M. S. F. (2022). The Effect of Extreme Rainfall Events on Riverbank Slope Behaviour. *Frontiers in Environmental Science*. https://doi.org/10.3389/fenvs.2022.859427

Pollock, W., & Wartman, J. (2020). Human Vulnerability to Landslides. *GeoHealth*. https://doi.org/10.1029/2020GH000287

Pozo, A. F. R., Jaramillo, H. Y., & Amaya, R. J. G. (2019). Landslide risk assessment in slopes and hillsides. *Methodology and application in a real case*. *DYNA*. https://api.semanticscholar.org/CorpusID:132477381

Puji Hastuty, I., Ahmad, F., Roesyanto, Ridwan Anas, M., & Hidayati, Y. R. (2020). Vulnerability analysis of landslide at Sibolangit using Geographic Information System (GIS) based on population density and slope gradient. IOP Conference Series: *Materials Science and Engineering*, 801. https://doi.org/10.1088/1757-899X/801/1/012008

Salini, P. N., & Rahul, P. (2024). Risk And Vulnerability Analysis Of Road Network In Landslide Prone Areas In Munnar Region, India. *Transportation Engineering*, 100275. https://doi.org/https://doi.org/10.1016/j.treng.2024.100275

Selamat, S. N., Majid, N. A., & Taha, M. R. (2024). Multicollinearity and spatial correlation analysis of landslide conditioning factors in Langat River Basin, Selangor. Natural Hazards. https://doi.org/10.1007/s11069-024-06903-8

Selamat, S. N., Abd Majid, N., & Mohd Taib, A. (2023a). A comparative assessment of sampling ratios using artificial neural network (ANN) for landslide predictive model in Langat River Basin, Selangor, Malaysia. *Sustainability*, 1–21.

Selamat, S. N., Abd Majid, N., Mohd Taib, A., Taha, M. R., & Osman, A. (2023b). The spatial relationship between landslide and land use activities in Langat River Basin: A case study. Physics and Chemistry of the Earth, 1–5.

Selamat, S. N., Abd Majid, N., Taha, M. R., & Osman, A. (2022). Landslide susceptibility model using artificial neural network (ANN) approach in Langat River Basin, Selangor, Malaysia. Land, 1–21.

Serulle, N. U., & Cirillo, C. (2014). Accessibility of low-income populations to safe zones during localized evacuations. In Transportation Research Record (Vol. 2459, pp. 72–80). *National Research Council*. https://doi.org/10.3141/2459-09

Turner, A. K. (2018). Social and environmental impacts of landslides. *In Innovative Infrastructure Solutions.* https://doi.org/10.1007/s41062-018-0175-y

UN, W. P. (2020). Population Density of Malaysia. https://doi.org/10.5258/SOTON/WP00675

Wadhawan, S. K. (2019). Landslide susceptibility mapping, vulnerability and risk assessment for development of early warning systems in India. *In Advances in Natural and Technological Hazards Research* (Vol. 50, pp. 145–172). *Springer Netherlands*. https://doi.org/10.1007/978-3-319-77377-3_8

Zhang, J., Luo, Y., Zhou, Z., Victor, C., & Duan, M. (2021). Research on the rainfall-induced regional slope failures along the Yangtze River of Anhui, China. Landslides, 18(5), 1801–1821. https://doi.org/10.1007/s10346-021-01623-7

Zulkafli, S. A., Abd Majid, N., Syed Zakaria, S. Z., Razman, M. R., & Ahmed, M. F. (2023a). Influencing physical characteristics of landslides in Kuala Lumpur, Malaysia. *Pertanika Journal of Science & Technology,* 995–1010.

Zulkafli, S. A., Abd Majid, N., & Rainis, R. (2023b). Local variations of landslide factors in Pulau Pinang, Malaysia. Proceedings of the *International Conference on Science & Technology Applications in Climate Change* (STACLIM), 1–8.