Enhancing Flood Resilience: A GIS-Based Analysis of Evacuation Centre Site Suitability

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Abstract *Flooding is one of the most frequent and destructive natural hazards affecting Southeast Asia, particularly in low-lying urban areas such as Kuantan, Malaysia. The increasing intensity of flood events due to climate change and urban expansion underscores the urgent need for resilient infrastructure planning. This study aims to support disaster preparedness and enhance flood resilience by identifying optimal locations for evacuation centres using a GIS-based Multi-Criteria Evaluation (MCE) framework. The methodology integrates remote sensing data, spatial analysis, and the Analytical Hierarchy Process (AHP) to assess land suitability. Key criteria include elevation, slope, proximity to disaster-prone areas, landslides, floods, river, and land use. Each layer was standardized, weighted based on literature review, and combined using a weighted overlay analysis in ArcGIS. The final suitability map classifies land into five categories: Extremely Suitable, Very Suitable, More Suitable, Moderately Suitable, and Less Suitable. Results indicate that among the 127 evacuation centres evaluated, 31.50% were categorized as Less Suitable, 7.09% as Moderately Suitable, 19.69% as More Suitable, 26.77% as Very Suitable, and 14.96% as Extremely Suitable, and. These findings reveal a limited distribution of highly suitable areas, highlighting the importance of integrating geospatial hazard data with topographic constraints in planning decisions. This research demonstrates the practical application of remote sensing and GIS in improving urban flood resilience and emergency response planning. It contributes to Sustainable Development Goals by supporting inclusive, safe, and disaster-resilient infrastructure (SDG 11) and promoting climate adaptation strategies (SDG 13). The study offers a transferable and scalable approach that can benefit disaster-prone regions across Asia, aligning with the broader goals of advancing remote sensing science for sustainable development.*

Keywords: Flood resilience, evacuation, site suitability analysis, remote sensing, GIS, AHP

Introduction

Flood events in Malaysia have become increasingly frequent and intense, largely driven by climate change and urbanisation. According to the Department of Irrigation and Drainage Malaysia (DID), the country has experienced an average of 50 significant flood events annually over the past decade, with the most catastrophic floods occurring in December 2021, resulting in economic losses estimated at RM1.4 billion (Rahman, 2022). As flood intensity continues to increase, it necessitates a substantial transformation in how the country manages disaster risk, particularly through the evolution of evacuation centres. These centres are fundamental in safeguarding lives during floods, especially when homes are submerged or rendered unsafe. Their presence significantly reduces fatalities, injuries, and the overall impact of disasters on affected populations (Wu et al., 2019).

Despite their importance, many evacuation centres face critical challenges, including inadequate infrastructure and poor site selection. Frequently located in flood-prone areas, these centres often lack the safety specifications required to protect displaced populations effectively during emergencies. For instance, SK Sungai Ular in Kuantan, Pahang, a designated evacuation centre, has been inundated multiple times, forcing evacuees to relocate to the upper floor. In response, the Pahang Government allocated RM31 million for the development of Permanent Evacuation Centres. While this represents a commendable initiative, notable gaps remain in the evaluation of site suitability, as research on evacuation centre planning and placement in Malaysia remains alarmingly scarce.

Compounding these concerns, Kuantan has long been identified as a high-risk flood district, where approximately 355,140 residents are exposed to recurrent flooding and are frequently compelled to seek refuge in evacuation centres during each monsoon season (Mabahwi et al., 2021). Consequently, this study seeks to assess the geospatial criteria for evacuation centres in Kuantan through a GIS-based multi-criteria analysis. The urgency of this undertaking is underscored by Kuantan's vulnerability, given the large population at risk and the persistent shortcomings in evacuation centres revealed during past flood events. By employing advanced geospatial analysis, this research provides a structured evaluation of evacuation centre suitability, underscoring the importance of integrating scientific methodologies into the site selection process. Ultimately, the study contributes to strengthening disaster preparedness and enhancing community resilience in flood-prone areas.

Literature Review

Evacuation centres are critical during flooding events, as their strategic placement can significantly mitigate human casualties and property losses. Research indicates that well-distributed evacuation centres can effectively reduce casualties by providing timely access to safe havens (Rahman et al., 2021; Samany et al., 2021). The use of optimal site selection models, such as location-allocation models, helps ensure that these centres remain accessible and safe from inundation, which is vital for efficient emergency response (Rahman et al., 2021). Thus, the presence of strategically located evacuation centres can enhance community resilience by ensuring that populations have immediate access to safety during flood events.

Evacuation is a crucial non-structural measure aimed at relocating individuals from flood-affected areas to safer locations. The timing of evacuation is paramount, as research shows that flood depths of 5 to 30 cm can extend travel time by 40 to 670 minutes (Suwanno et al., 2023). This highlights the necessity for timely evacuation planning, as delays can significantly hinder the ability to escape rising waters. Factors such as community characteristics and infrastructure also influence evacuation efficiency; areas with high population density may experience longer evacuation times, while sufficient shelter capacity can enhance the overall effectiveness of the evacuation process (Oh et al., 2021; Wang et al., 2020).

Elevation plays a vital role in flood management, affecting flood risk analysis, shelter site selection, and evacuation planning. Accurate digital elevation models (DEMs) are essential for predicting flood extents and depths. However, global DEMs often contain inaccuracies that can lead to overestimated flood impacts compared to more precise LIDAR-based models (Hawker et al., 2022; McClean et al., 2020; Mohanty et al., 2020). In Kuantan, Malaysia, GIS-based analyses have been employed to determine the suitability of flood shelter sites, reinforcing the need for continuous reassessment to ensure safety and effectiveness (Mabahwi & Nakamura, 2024). Furthermore, the Base Flood Elevation (BFE) is commonly used as a standard for elevating structures to mitigate flood risks, with historical data providing valuable insights into past flood levels and recurrence intervals, aiding in the appropriate elevation of ECs (Mobley et al., 2020). High-standard levee projects are essential, with the design and elevation of levees being crucial for their effectiveness and cost-efficiency (Dwijendra & Majdi, 2022).

The slope of an area is a critical factor in selecting suitable sites for flood ECs, as it significantly influences water flow and flood risk. Low to moderate slopes are generally recommended for flood shelter site selection because they help control water flow and reduce the potential for rapid inundation. Research indicates that the recommended slope gradient for flood emergency ECs should not exceed 7%, with a preference for slopes between 2% and 3% (Bolanio et al., 2023). Such gradients minimize the risk of flooding and ensure accessibility for individuals, including those with disabilities. By prioritizing sites with suitable slope gradients, communities can enhance urban resilience and ensure the safety of flood ECs during emergencies.

The strategic placement of evacuation centres in relation to residential areas is crucial for effective emergency management. Proximity to residential areas significantly increases the odds of survival during evacuations, particularly in urban settings where response times are shorter (Moriyama et al., 2022). Additionally, locating evacuation centres away from industrial zones is important to minimize exposure to potential hazards during emergencies, such as chemical spills or explosions (Yuan et al., 2019). A robust road network is also essential for effective evacuation, as the quality and connectivity of roads directly influence the speed and safety of evacuations.

Population density is a pivotal factor in the strategic selection of emergency centres, particularly for flood management. Optimal location models, such as Location-Allocation Models (LAMs), are crucial for optimizing the spatial distribution of ECs. These models aim to ensure that centres are strategically placed to cover the maximum population effectively (Rahman et al., 2021). Emergency services typically aim to cover a range within a radius of 500 meters to 5,000 meters, with an average coverage of about 2 kilometres(Liu et al., 2025). This systematic approach allows for effective evaluations of potential sites to ensure that emergency services can reach the maximum number of people within designated coverage areas.

In the selection of flood emergency centres, neglecting the potential for secondary disasters can severely undermine resource allocation and facility location strategies. Secondary disasters, such as landslides triggered by intense rainstorms, can obstruct access to emergency ECs and complicate evacuation efforts. Research suggests that a multi-objective optimization model that considers a range of disaster scenarios can aid in developing robust strategies for evacuation and relief distribution (Ji & Fu, 2023). By incorporating these scenarios into planning, emergency planners can enhance shelter accessibility and optimize resource distribution during emergencies, ultimately reducing human casualties and property losses.

Road accessibility and network vulnerability are pivotal in managing flood events, as they directly influence the delivery of timely responses and the allocation of resources. Research indicates that accessibility measures are crucial in assessing road network vulnerability during floods (Papilloud & Keiler, 2021). Floods can significantly restrict access to emergency medical services (EMS), with varying changes in accessibility observed across different regions. Identifying critical points in road networks where accessibility loss accelerates is essential for early warning and infrastructure protection. An integrated analysis of physical and social vulnerabilities can inform equitable resilience enhancement plans, considering community tolerance for access disruptions (Dong et al., 2020).

The proximity of evacuation centres to rivers is a crucial factor in disaster risk management, particularly in flood-prone regions. Research has shown that households in the Seti River Basin of Nepal face disproportionately high exposure to flooding, especially among impoverished and immigrant groups who often inhabit low-lying, river-adjacent areas (Thapa et al., 2022). Furthermore, human settlements tend to relocate further away from rivers following significant flood events, reflecting both collective memory and heightened risk awareness (Alonso et al., 2020). This adaptive behaviour suggests that communities recognize the dangers of river proximity, and similar considerations should guide the selection of evacuation sites. By incorporating historical flood patterns and recurrence intervals into planning, authorities can better anticipate long-term risks associated with river proximity.

Methodology

The research methodology employed in this study is a comprehensive GIS-based approach combined with the AHP to assess the suitability of flood shelter sites. This methodology effectively addresses the complexities of flood risk management by integrating multiple criteria and utilizing both spatial and non-spatial data to produce informed decision-making outputs. The GIS-based site suitability assessment employs a multi-criteria analysis method that allows for the integration and transformation of diverse input data into a cohesive framework for decision-making. AHP plays a critical role in this analysis by providing a structured hierarchy for decision-making, utilizing a predefined reference scale that considers various influencing factors and their relative importance. This systematic approach ensures that variations in value among different criteria are converted into percentage representations, facilitating a clearer understanding of how each factor impacts the overall suitability of potential flood shelter sites.

The initial phase of the analysis involved comprehensive mapping of all flood ECs within the study area, utilizing topographic mapping derived from a DEM to study elevation changes and slopes. The elevation data was obtained from Google Earth Engine (GEE) using the Shuttle Radar Topography Mission (SRTM) DEM at a spatial resolution of 30 meters. The dataset was clipped to the defined study area boundary to ensure spatial relevance and accuracy. The processed DEM was then exported from GEE as a GeoTIFF format through the Export function and subsequently downloaded from Google Drive. In

ArcMap, the GeoTIFF file was imported directly as a raster dataset for further spatial analysis. To facilitate data management and integration with other spatial layers, the raster was optionally converted into a geodatabase raster format using ArcToolbox's conversion tools. Following the creation of the DEM, it was converted into a slope map using the Spatial Analyst extension, the Slope function was applied to the DEM to calculate the rate of elevation change, producing a slope raster expressed in degrees. Additionally, layers indicating flood-prone and landslide areas were sourced from government datasets; however, the original shapefile was not in raster format, necessitating the use of the Spatial Analyst Tools, specifically the Distance, Euclidean Distance function, to determine the proximity of flood ECs to hazard-prone areas. The Proximity tool further assessed distances between flood ECs and landslide-prone areas, ensuring that ECs were located at a safe distance from potential secondary disasters. The river buffer analysis was carried out using the Buffer tool in ArcMap. The river polyline dataset was first projected into an appropriate coordinate system to ensure accurate distance measurements. Buffer zones were then generated at specified distances from the river channel, with the dissolve option applied to produce continuous buffer areas.

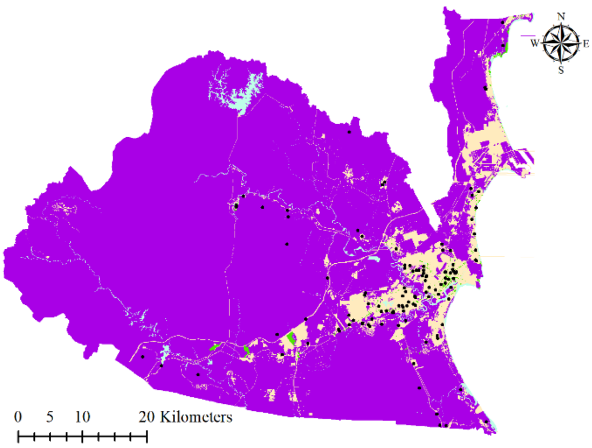
The assessment of potential flood shelter sites was conducted using a multi-criteria evaluation (MCE) approach, integrating the AHP with Weighted Overlay Analysis (WOA) in a GIS environment. Six criteria were considered based on their significance to shelter suitability: elevation (17%), slope (16%), land use (16%), flood-prone areas (16%), secondary disasters (16%), and proximity to rivers (16%). Each criterion was classified into suitability ratings, with higher scores assigned to conditions more favourable for shelter placement, such as elevated terrain above 20 meters, slopes between 2% and 4%, residential land use, and locations more than 400 meters away from rivers. Restricted areas, including industrial zones, forest reserves, agriculture, water bodies, and landslide-prone sites, were excluded from consideration. To assess the final site suitability, all criteria identified through the GIS analysis were first converted into raster format, reclassified, and subsequently integrated using the Spatial Analyst Weighted Overlay tool (see Figure 1 to 5). The weighting of each criterion was determined using the AHP scale, which was then applied in the overlay process to generate the overall suitability results. Within the GIS environment, the Weighted Overlay Analysis ranks areas based on suitability, where a value of 0 represents 'not suitable' or 'restricted', thereby excluding such areas from consideration. In this study, landslide-prone zones, forest reserves, and agricultural land, were classified as 'restricted' and deemed highly unsuitable for flood shelter placement.

Similarly, industrial areas were also categorized as restricted to ensure that ECs are not located near potential hazards. The influence of each criterion was expressed as a percentage weight derived from AHP, and in this analysis, all criteria were assigned equal importance in the final suitability assessment. A summary of the criteria employed in the Weighted Overlay Analysis integrated with AHP is provided in Table 1.

Table 1: Weighted Overlay

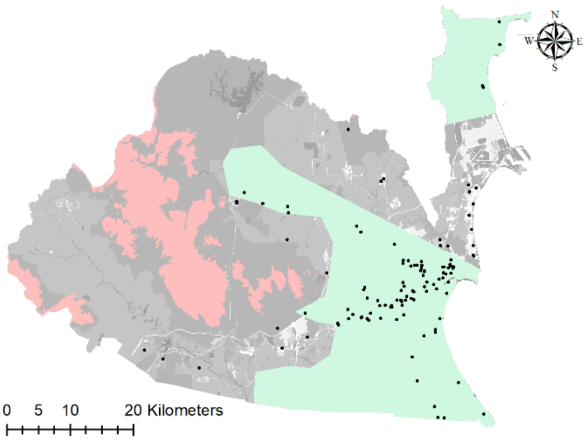
Criteria (raster layer)	***Influence (%)***	***Field***	***Scale value (AHP)***	***Description Scale***
Elevation	17%	<5 m	1	Less suitable
		5.1 m – 10 m	3	Moderately suitable
		10.1 m – 15 m	5	More suitable
		15.1m – 20 m	7	Very suitable
		>20m	9	Extremely suitable
Slope	16%	1% - 1.9%	5	More suitable
		2% - 4%	9	Extremely suitable
		4.1% - 5%	7	Very suitable
		>5%	1	Less suitable
Land Use	16%	Residential	9	Extremely suitable
		Industrial	Restricted	Restricted
		Forest reserve	Restricted	Restricted
		Agriculture	Restricted	Restricted
		Water body	Restricted	Restricted
Flood prone area	16%	Flood area	1	Less suitable
Secondary disasters	16%	Landslide	Restricted	Restricted
Proximity to the river	16%	<100 m	1	Less suitable
		100 m – 200 m	3	Moderately suitable
		200 m – 300 m	5	More suitable
		300 m – 400 m	7	Very suitable
		>400 m	9	Extremely suitable

Source: Author, 2025



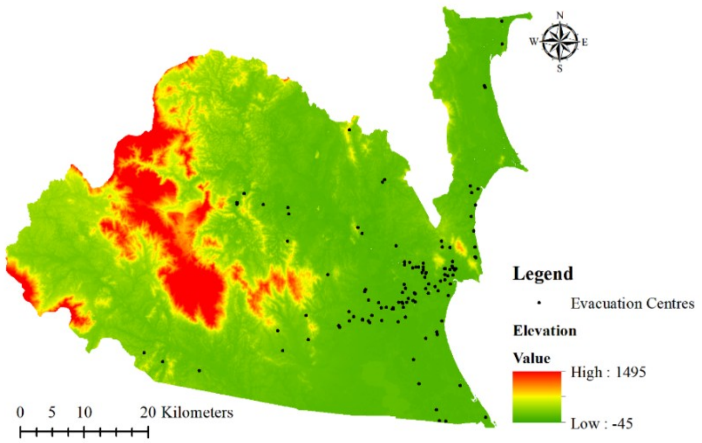
Source: Author, 2025

Figure 1: Reclassified Land Use



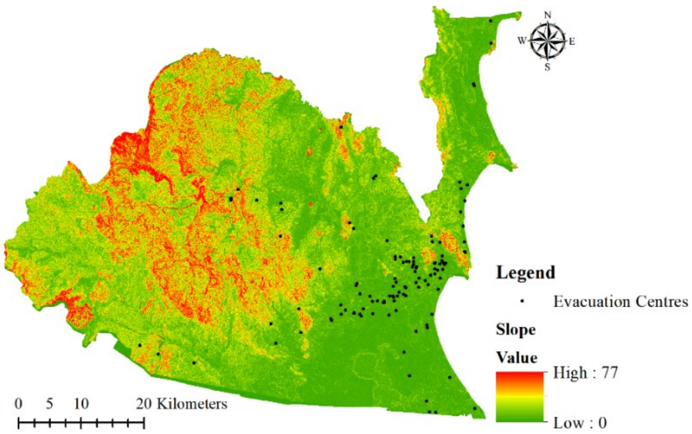
Source: Author, 2025

Figure 2: Flood Prone Area and Landslides



Source: Author, 2025

Figure 3: Elevation



Source: Author, 2025

Figure 4: Slope

Results and Discussion

This study applied a GIS-based multi-criteria WOA to evaluate the suitability of flood ECs in Kuantan by integrating land use with other environmental and spatial criteria. The approach proved valuable in revealing the interrelationships among multiple factors such as elevation, proximity to rivers, land use, slope, and landslide risk, thereby offering a more holistic understanding of shelter suitability in flood-prone areas. Such integration is critical, as disaster preparedness planning cannot rely on single-variable assessments, particularly in regions facing recurrent and increasingly severe floods.

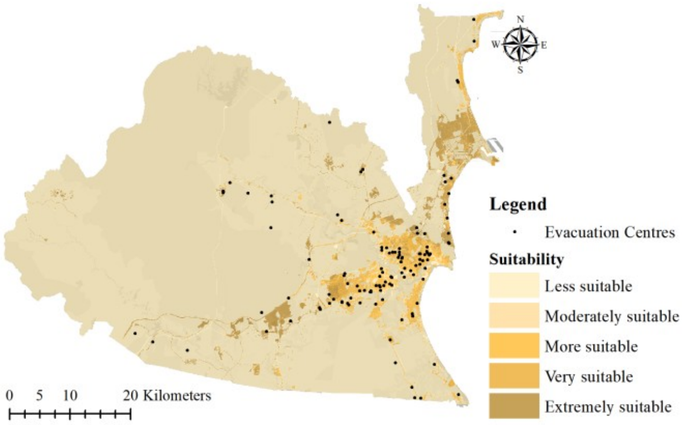
The findings reveal significant variation in suitability levels across the assessed ECs. Based on elevation, 9.38% of ECs were classified as less suitable, 35.16% as moderately suitable, 18.75% as more suitable, 8.59% as very suitable, and 27.34% as extremely suitable. The predominance of the moderately suitable category reflects an overreliance on the Base Flood Elevation (BFE) standard, which is commonly applied as a benchmark for elevating structures above predicted flood levels. While compliance with the BFE is commendable, this reliance is problematic. BFE thresholds are often based on historical flood records, which, although useful, may underestimate future risks under conditions of climate change, urbanisation, and catchment modification. International evidence increasingly shows that static elevation benchmarks are insufficient to cope with flood variability; adaptive design standards, incorporating updated hydrological models and projected rainfall intensities, are required (Mobley et al., 2020).

River proximity provides further insight into shelter vulnerability. The analysis shows that 62.99% of ECs are located more than 400 metres from rivers, which on the surface suggests safer siting. However, 74.02% of ECs are still situated in flood-prone areas, demonstrating that river distance alone does not guarantee safety. This paradox underscores the complex nature of flood risk, where factors such as catchment hydrology, upstream water retention, and drainage capacity influence flood behaviour. This finding raises questions about the adequacy of current site selection practices, which often emphasise distance from rivers without considering broader floodplain dynamics. The reliance on simple locational criteria, in the absence of hydrological modelling, risks giving a false sense of security. Structural flood protection measures, such as levees, may provide partial solutions. Lessons from international contexts, for instance, the Manafwa region in Uganda, where 8-metre levees significantly reduced flood damage highlight that engineered interventions can be effective, but they must be integrated with spatial planning to avoid maladaptation (Dwijendra & Majdi, 2023).

Other factors, including land use, slope, and landslide susceptibility, also exert a decisive influence on shelter suitability. This study supports earlier findings by Mabahwi (2024) that a single-criterion approach is insufficient and often misleading. In Kuantan, ECs located near incompatible land uses (e.g., industrial areas or dense commercial zones) and steep terrain face compounded risks, which could compromise both accessibility and safety during emergencies. These findings highlight a critical gap in current planning: the absence of comprehensive land-use integration when designating or upgrading evacuation centres.

When considering all 127 evacuation centres (Figure 5), the overall distribution of suitability illustrates systemic weaknesses in disaster preparedness within the study area. Specifically, 31.50% of ECs were classified as less suitable, 7.09% as moderately suitable, 19.69% as more suitable, 26.77% as very suitable, and only 14.96% as extremely suitable. That nearly one-third of centres fall into the "less suitable" category is a serious concern, as it suggests that a significant proportion of evacuees may not be adequately protected during major flood events. This points to a misalignment between current planning practices and the resilience needed to confront intensifying flood risks. The relatively low percentage of extremely suitable ECs underscores the limited effectiveness of existing policies, which tend to prioritise short-term compliance over long-term resilience.

Critically, the results demonstrate that Malaysia's current reliance on elevation benchmarks and ad hoc site selection does not fully account for the complex, multi-scalar nature of flood hazards. The evidence from Kuantan underscores the urgent need for a paradigm shift in evacuation centre planning from reactive, single-factor compliance models to proactive, multi-criteria, GIS-based frameworks that integrate hydrological modelling, climate projections, and land-use planning. Such an approach not only aligns with international best practices but also ensures that evacuation centres function as genuine safe havens rather than vulnerable spaces during disasters.



Source: Author, 2025

Figure 5: Overall Suitability Map

Conclusion and Recommendation

This study emphasises the importance of assessing the suitability of flood ECs in flood-prone areas such as Kuantan, Malaysia, through a GIS-based multi-criteria evaluation combined with Weighted Overlay Analysis and the Analytic Hierarchy Process. The results reveal significant variations in suitability among the 127 evacuation centres assessed: 31.50% were categorized as less suitable, 7.09% as moderately suitable, 19.69% as more suitable, 26.77% as very suitable, and only 14.96% as extremely suitable. The distribution indicates that a considerable proportion of ECs are located in areas with lower suitability, often influenced by factors such as proximity to flood-prone zones, topographic constraints, and surrounding land use.

This research underscores the critical role of geospatial criteria, including elevation, slope, hazard proximity, and land use, in determining appropriate sites for flood ECs. These factors directly affect the safety, accessibility, and overall effectiveness of evacuation centres during emergencies. The integration of GIS-based WOA and AHP provides a robust framework for site suitability analysis, offering valuable insights for urban planning and disaster risk reduction.

In conclusion, although some ECs are situated in highly suitable areas, a significant number remain in less optimal locations, underscoring the need for continuous reassessment and strategic planning. Future initiatives should consider dynamic environmental and urban changes to enhance the safety and functionality of ECs. By integrating geospatial hazard data with topographic and land-use considerations, this study contributes to sustainable disaster management practices. It highlights the value of data-driven, spatially informed decision-making in strengthening urban resilience, aligning with global climate adaptation efforts and the Sustainable Development Goals.

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References

Ahmad, S., Waseem, M., Hussain, S., Shah, M. M., Malik, F. P., Masood, S., & Leta, M. K. (2024). GIS-Based Identification and Analysis of Optimal Evacuation Areas and Routes in Flood-Prone Zones of Swabi District, Pakistan. *Journal of Engineering (United Kingdom)*, *2024*. https://doi.org/10.1155/2024/9550808

Alonso Vicario, S., Mazzoleni, M., Bhamidipati, S., Gharesifard, M., Ridolfi, E., Pandolfo, C., & Alfonso, L. (2020). Unravelling the influence of human behaviour on reducing casualties during flood evacuation. *Hydrological Sciences Journal*, *65*(14), 2359–2375. https://doi.org/10.1080/02626667.2020.1810254

Bolanio, K. P., Gagula, A. C., Bermoy, M. M., Jagna, J. M. B., & Coquilla, S. M. (2023). Mapping and assessment of flood evacuation sites in a geospatial environment: A case in Las Nieves, Agusan Del Norte, Philippines. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, *48*(4), 473–482. https://doi.org/10.5194/isprs-archives-XLVIII-4-W6-2022-473-2023

Dong, S., Esmalian, A., Farahmand, H., & Mostafavi, A. (2020). An integrated physical-social analysis of disrupted access to critical facilities and community service-loss tolerance in urban flooding. *Computers, Environment and Urban Systems*, *80*. https://doi.org/10.1016/j.compenvurbsys.2019.101443

Dwijendra, N. K. A., & Majdi, A. (2022). Compare and evaluate the performance of structural flood risk management options. *Journal of Water and Land Development*, *54*, 172–176. https://doi.org/10.24425/jwld.2022.141569

Hawker, L., Uhe, P., Paulo, L., Sosa, J., Savage, J., Sampson, C., & Neal, J. (2022). A 30 m global map of elevation with forests and buildings removed. *Environmental Research Letters*, *17*(2). https://doi.org/10.1088/1748-9326/ac4d4f

Ji, X., & Fu, S. (2023). Modeling Multi-Objective Optimization with Updating Information on Humanitarian Response to Flood Disasters. *Water (Switzerland)*, *15*(11). https://doi.org/10.3390/w15112122

Liu, B., Li, Y., Zhang, Y., Wu, Z., Pan, Y., & Li, M. (2025). Multi-criteria decision-making method for emergency shelter site selection considering flood risk: A case study of Zhuhai, China. *Cleaner Engineering and Technology*, *24*. https://doi.org/10.1016/j.clet.2025.100892

Mabahwi, N. A. B., Bhattacharya, Y., & Nakamura, H. (2021). GIS-based multi-criteria analysis to identify site suitability of flood ECs in Kuantan, Malaysia. *IOP Conference Series: Earth and Environmental Science*, *799*(1). https://doi.org/10.1088/1755-1315/799/1/012027

Mabahwi, N. A., & Nakamura, H. (2024). ENHANCED GIS-BASED MULTI-CRITERIA DECISION ANALYSIS FOR OPTIMAL FLOOD SHELTER SITE SELECTION: A CASE STUDY OF KUANTAN, MALAYSIA. In *Journal of the Malaysian Institute of Planners VOLUME* (Vol. 22).

McClean, F., Dawson, R., & Kilsby, C. (2020). Implications of Using Global Digital Elevation Models for Flood Risk Analysis in Cities. *Water Resources Research*, *56*(10). https://doi.org/10.1029/2020WR028241

Mobley, W., Atoba, K. O., & Highfield, W. E. (2020). Uncertainty in flood mitigation practices: Assessing the economic benefits of property acquisition and elevation in flood-prone communities. *Sustainability (Switzerland)*, *12*(5). https://doi.org/10.3390/su12052098

Moriyama, N., Morita, T., Nishikawa, Y., Kobashi, Y., Murakami, M., Ozaki, A., Nonaka, S., Sawano, T., Oikawa, T., & Tsubokura, M. (2022). Association of Living in Evacuation Areas with Long-Term Care Need After the Fukushima Accident. *Journal of the American Medical Directors Association*, *23*(1), 111-116.e1. https://doi.org/10.1016/j.jamda.2021.05.030

Oh, W. S., Yu, D. J., & Muneepeerakul, R. (2021). Efficiency-fairness trade-offs in evacuation management of urban floods: The effects of the shelter capacity and zone prioritization. *PLoS ONE*, *16*(6 June). https://doi.org/10.1371/journal.pone.0253395

Papilloud, T., & Keiler, M. (2021). Vulnerability patterns of road network to extreme floods based on accessibility measures. *Transportation Research Part D: Transport and Environment*, *100*. https://doi.org/10.1016/j.trd.2021.103045

Prakash Mohanty, M., Nithya, S., Nair, A. S., Indu, J., Ghosh, S., Mohan Bhatt, C., Srinivasa Rao, G., & Karmakar, S. (2020). Sensitivity of various topographic data in flood management: Implications on inundation mapping over large data-scarce regions. *Journal of Hydrology*, *590*. https://doi.org/10.1016/j.jhydrol.2020.125523

Rahman, M., Chen, N., Islam, M. M., Dewan, A., Pourghasemi, H. R., Washakh, R. M. A., Nepal, N., Tian, S., Faiz, H., Alam, M., & Ahmed, N. (2021). Location-allocation modeling for emergency evacuation planning with GIS and remote sensing: A case study of Northeast Bangladesh. *Geoscience Frontiers*, *12*(3). https://doi.org/10.1016/j.gsf.2020.09.022

Rahman, S. (n.d.). *Malaysia's Floods of December 2021: Can Future Disasters be Avoided?*

Samany, N. N., Sheybani, M., & Zlatanova, S. (2021). Detection of safe areas in flood as emergency evacuation stations using modified particle swarm optimization with local search. *Applied Soft Computing*, *111*. https://doi.org/10.1016/j.asoc.2021.107681

Suwanno, P., Yaibok, C., Tsumita, N., Fukuda, A., Theerathitichaipa, K., Seefong, M., Jomnonkwao, S., & Kasemsri, R. (2023). Estimation of the Evacuation Time According to Different Flood Depths. *Sustainability (Switzerland)*, *15*(7). https://doi.org/10.3390/su15076305

Thapa, B., Watanabe, T., & Regmi, D. (2022). Flood Assessment and Identification of Emergency Evacuation Routes in Seti River Basin, Nepal. *Land*, *11*(1). https://doi.org/10.3390/land11010082

Wang, Z., Huang, J., Wang, H., Kang, J., & Cao, W. (2020). Analysis of flood evacuation process in vulnerable community with mutual aid mechanism: An agent-based simulation framework. *International Journal of Environmental Research and Public Health*, *17*(2). https://doi.org/10.3390/ijerph17020560

Wu, J., Huang, C., Pang, M., Wang, Z., Yang, L., Fitzgerald, G., & Zhong, S. (2019). Planned sheltering as an adaptation strategy to climate change: Lessons learned from the severe flooding in

Anhui Province of China in 2016. The Science of the total environment, 694, 133586. https://doi.org/10.1016/j.scitotenv.2019.133586.

Yuan, H., Wang, R., Zhang, X., Hu, Y., Zhang, F., Zhu, T., & Liu, H. (2019). Evacuation Strategy Optimization Study Based on System Theory. *IEEE Access*, *7*, 111232–111244. https://doi.org/10.1109/ACCESS.2019.2934473