JPPIPA 12(4) (2026)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Flood Disaster Mitigation Strategy in Kuala Lumpur

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Received: January 08, 2026
Revised: March 25, 2026
Accepted: April 25, 2026
Published: April 30, 2026

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DOI: 10.29303/jppipa.v12i3.14202

Abstract: In Malaysia, flash floods or major floods often occur in the capital city of Kuala Lumpur, flooding is a natural phenomenon that occurs when the volume of water flowing in rivers, lakes, or other bodies of water overflows onto land. The purpose of this study is to determine the level of flood vulnerability and determine flood mitigation strategies. This research is descriptive quantitative, which describes the phenomenon of flood disasters through mapping results. To produce a map of flood-prone areas, mapping was carried out using ArcGIS with a scoring method to see flood hazard vulnerability. The results of the flood vulnerability mapping study in Kuala Lumpur show critical conditions with almost 90% of the total area of 27.195.47 hectares categorized as vulnerable to very vulnerable to flooding. Analysis using the Analytic Hierarchy Process (AHP) method identified three priority mitigation strategies, namely Regulation (57.7%) as the highest priority which includes policy enforcement and implementation of MSMA, followed by Education (25.8%) to increase public awareness and preparedness, and Conservation (16.5%) through ecological rehabilitation and green infrastructure. The integration of these three strategies is necessary to create a comprehensive and sustainable flood mitigation framework, taking into account the high urbanization and climate change that continue to increase flood risks in the Kuala Lumpur metropolitan area.

Keywords: Analytic hierarchy process; Flood disaster; Mitigation strategy

Introduction

Flooding is one of the most serious environmental threats facing major cities in Southeast Asia, including Kuala Lumpur, the capital of Malaysia (Luo et al., 2022). Rapid urbanization, global climate change, and increasingly extreme rainfall intensity have placed Kuala Lumpur at risk of flooding, with increasing frequency and impact (Ghalehteimouri et al., 2024). This phenomenon not only threatens the safety of people's lives and property, but also disrupts economic activity, urban mobility, and the stability of vital infrastructure that is the backbone of metropolitan life (Arrighi et al., 2019).

As an economic and administrative center, Kuala Lumpur has undergone a massive urban transformation in recent decades (Kozlowski et al., 2022). Rapid population growth, coupled with intensive development expansion, has drastically altered the region's natural hydrological characteristics. The conversion of green areas to built-up areas, the construction of high-rise buildings, and the expansion of the road network reduce the soil's natural ability to absorb rainwater, increase surface runoff, and accelerate water flow towards major rivers such as the Klang River and Gombak River. Global climate change is further exacerbating the situation by increasing the intensity and frequency of extreme weather events in tropical regions (Thomas et al., 2024).

Climatological data shows that Kuala Lumpur is experiencing an increase in the incidence of short-duration, high-intensity heavy rainfall, triggering sudden and unpredictable flash floods (Bhuiyan et al., 2022). The combination of anthropogenic factors such as unplanned urbanization and climatic factors makes Kuala Lumpur one of the most vulnerable cities to flooding in Southeast Asia. According to Bahari et al. (2023), continuous heavy rainfall lasting several hours is the main trigger for flash floods in the metropolitan area. Flooding in Kuala Lumpur is also exacerbated by dense and uncontrolled development. Furthermore, soil

How to Cite:
Dewi, P. T., Umar, I., Hermon, D., & Febriandi. (2026). Flood Disaster Mitigation Strategy in Kuala Lumpur. *Jurnal Penelitian Pendidikan IPA*, *12*(4), 243–253. https://doi.org/10.29303/jppipa.v12i4.14202

erosion due to development activities accelerates the accumulation of silt in riverbeds, resulting in silting that reduces the river's capacity. Shallower rivers have a smaller capacity and are unable to accommodate the additional volume of water during heavy rain, causing them to overflow into surrounding residential areas and roads. Ongoing development projects in river basins also prevent the continuous flow of water into rivers, causing water to become trapped in certain areas and worsening flooding conditions (Guo, 2023).

Kuala Lumpur faces a significant increase in flood risk due to rapid urbanization, climate change, and increasingly frequent extreme rainfall events. Flood management in Kuala Lumpur should not be solely reactive but should adopt a comprehensive approach encompassing short-, medium-, and long-term mitigation strategies (Saad et al., 2024a). The importance of constructing retention ponds, implementing water diversion tunnels such as SMART (Stormwater Management and Road Tunnel), and creating an early warning system to reduce flood risk in vulnerable areas using high-resolution forecast models and real-time rainfall data (Dong et al., 2024). SMART, which doubles as a stormwater channel and road, is one of the most significant flood mitigation infrastructures in Kuala Lumpur. According to Ahmad & Ayob (2023), the SMART Tunnel has significantly reduced the frequency of flash floods in the city center since its opening in 2007. However, problems such as waterlogging in some locations still persist, highlighting the need for a holistic, ecologically based approach such as the sponge city concept to overcome the limitations of existing conventional systems (Kaiser & Akter, 2025).

Kuala Lumpur City Hall (DBKL) has implemented various structural and non-structural mitigation projects, including upgrading drainage systems, installing water level sensors at 30 high-risk locations, and constructing strategic pumping stations. These strategies are complemented by CCTV monitoring systems and the deployment of mobile pumps to mitigate the impact of flash floods quickly and responsively (Pereira et al., 2024). At the national policy level, the Malaysian Department of Irrigation and Drainage (JPS) has integrated the concepts of Water Sensitive Urban Design (WSD) and the Manual Saliran Mesra Alam (MSMA), which incorporate features such as bio-swales and rain gardens into new developments, aligning with globally recommended climate adaptation measures (Juiani et al., 2022). The importance of large-scale hydraulic modeling that integrates flood defense infrastructure to reduce river flood risk by up to 40%, as well as the use of GIS (Geographic Information System)-based vulnerability mapping for more targeted and spatial data-based planning (Zhao et al., 2023).

Based on flood data across Malaysia in 2020, Perlis province recorded the highest number of flood events, with an average maximum rainfall of 70 mm, a maximum flood duration of 60 hours, and a maximum flood depth of 0.6 meters (Ahmed et al., 2021). Meanwhile, Selangor province experienced 132 flood events with flood depths reaching 1.2 meters, making it the most severely affected region. From November 2020 to early 2021, several provinces in Malaysia were hit by devastating floods, forcing the evacuation of more than 40,000 residents to shelters. These floods not only caused loss of life but also paralyzed almost all forms of land transportation in the affected areas, resulting in enormous economic and social losses (Citaristi, 2022).

In this context, flood vulnerability maps play a crucial role in identifying flood-prone areas so that the government and community can take targeted preventive and mitigative measures (Ibrahim et al., 2024). Flood vulnerability maps in Kuala Lumpur also serve as an effective spatial planning tool to avoid infrastructure and housing development in high-risk locations. Furthermore, vulnerability maps can serve as strategic guidance in building better, more planned, and more climate-adaptive drainage infrastructure and flood control systems (Cea & Costabile, 2022). By utilizing these flood vulnerability maps, we can determine appropriate and measurable flood disaster mitigation strategies for the Kuala Lumpur region. These strategies will provide significant benefits in reducing the risk and impact of flood disasters, protecting lives and property, and increasing the city's resilience to extreme weather events. With proper planning, adequate infrastructure, sophisticated early warning systems, and education and active community involvement in mitigation efforts, these strategies can foster collective awareness of the importance of protecting the environment and minimizing damage caused by flood disasters (Uddin & Matin, 2021).

However, community attitudes toward disaster mitigation remain relatively low, contributing to the significant negative impacts of disasters (Que et al., 2022). Disasters often experience the greatest impacts on vulnerable groups, such as children, as their understanding of disaster mitigation remains limited (Wight et al., 2025). Floods not only have physical impacts but also affect the mental and psychological well-being of children who experience them. In crisis management procedures, community knowledge and skills significantly influence the effectiveness of post-disaster response and recovery. Therefore, increasing community capacity and awareness is a crucial component of a comprehensive disaster mitigation strategy (Akram & Mushtaq, 2024).

Previous research on flooding in Kuala Lumpur has largely focused on technical evaluations of infrastructure, such as the effectiveness of the SMART Tunnel drainage system or spatial-based hazard mapping. However, analysis of mitigation strategies from an integrated risk governance perspective, involving the role of spatial planning regulations, community participation, and institutional preparedness, remains limited and requires further study. This study aims to address this gap by examining the effectiveness and sustainability of flood mitigation strategies in Kuala Lumpur, particularly through non-structural approaches such as regulations, spatial planning, and community preparedness, as well as their integration with existing structural solutions. By focusing on cross-sectoral policy integration, this research is expected to produce more holistic, measurable, and implementable policy recommendations to strengthen Kuala Lumpur's resilience to future flood threats (Abegaz et al., 2026).

Kuala Lumpur's current flood mitigation strategy relies on an integrated approach that combines non-structural measures such as early warning systems, ecologically based urban design, and public education with structural solutions such as SMART Tunnels, retention ponds, and continuously improved drainage systems (Saad et al., 2024b). A key challenge going forward is ensuring the sustainability and effectiveness of these techniques in the face of anticipated increases in rainfall intensity and frequency due to climate change. This research is expected to make a significant contribution to formulating more adaptive, responsive, and sustainable mitigation strategies to protect Kuala Lumpur's communities and infrastructure from the threat of flooding.

Method

Research Design

This study adopts an integrated approach with the primary objective of mapping flood vulnerability and formulating effective mitigation strategies in Kuala Lumpur, Malaysia. This research is quantitative and descriptive, explaining the flood disaster phenomenon through comprehensive spatial mapping results. The core of this study lies in the analysis of flood mitigation strategies, which are processed quantitatively using the Analytic Hierarchy Process (AHP) method to determine the importance weight of each criterion and prioritize the most optimal mitigation alternatives based on expert assessment.

The use of a quantitative descriptive approach integrated with spatial mapping and AHP in this disaster mitigation research aligns with contemporary best practices supported by expert consensus. Spatial mapping using a Geographic Information System (GIS) provides a fundamental framework for generating coherent spatial vulnerability models and serves as a quantitative basis for mitigation decision-making. The AHP method complements spatial analysis by systematically structuring complex multi-criteria decision-making problems, allowing for the measurement of the relative weight of each criterion and the prioritization of mitigation strategies based on expert judgment and consensus. The integration of these two methods ensures that the resulting strategies are not only technically accurate based on vulnerability maps, but also managerially relevant and acceptable based on established policy priorities (Thammaboribal et al., 2025).

Research Site

This research was conducted in Kuala Lumpur, Malaysia in October 2025. The following is a map of the research location in Kuala Lumpur, Malaysia.

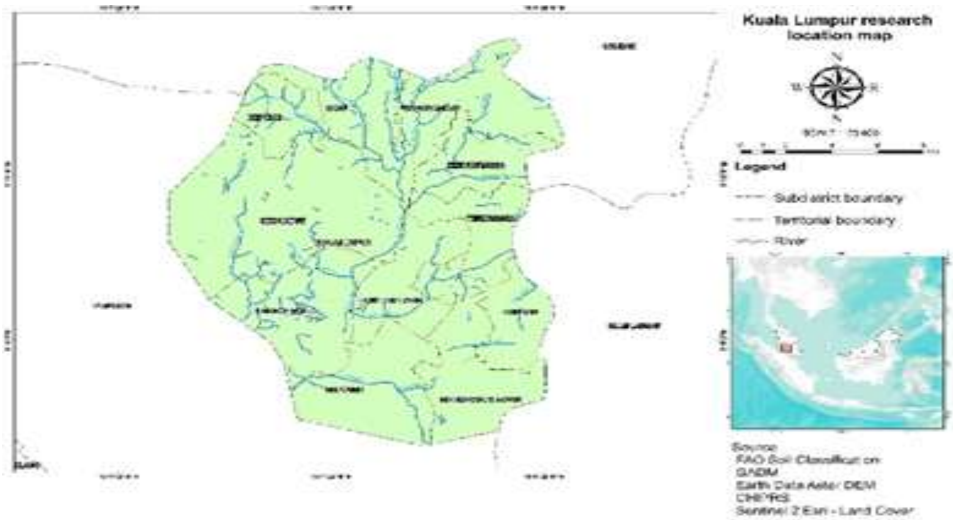


Figure 1. Map of research locations Kuala Lumpur, Malaysia

Sampling Strategy

Sampling in this descriptive quantitative study adopted an integrated approach in data collection and processing to ensure validity and strategic relevance. Purposive sampling, a subset of non-probability sampling, was used to collect qualitative data that served as input for the quantitative analysis. Key informants were selected based on strict criteria, namely having at least 10 years of practical experience in disaster management, urban planning, or Klang River hydrology in Kuala Lumpur, as well as holding strategic decision-making positions in relevant institutions such as the Department of Irrigation and Drainage (JPS/DID), the Kuala Lumpur City Council (DBKL), or senior academics in relevant fields (Fulop & Avvisati, 2022).

Qualitative primary data obtained from in-depth interviews with experts were then processed quantitatively using the Analytic Hierarchy Process (AHP) method to transform the experts' subjective assessments of mitigation criteria and alternatives into rational and structured priority weights. In the flood vulnerability mapping phase, secondary spatial data including elevation, rainfall, and land cover were analyzed using ArcGIS software through a spatial multi-criteria decision analysis approach. The results of this analysis produced a flood vulnerability map that served as a quantitative descriptive basis for the research as well as factual validation for the strategic priorities generated by the AHP, thus creating a strong integration between qualitative and quantitative analysis in this study.

Data Collection Technique

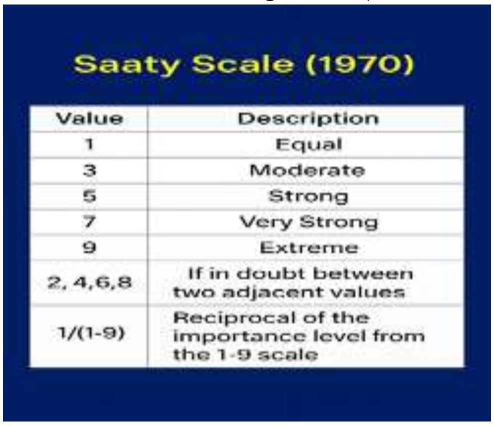
This study employed three primary data collection methods: field observations, in-depth interviews, and documentation. Field observations were conducted to obtain a direct overview of the geographic conditions and characteristics of flood-prone areas in Kuala Lumpur, Malaysia. The collected data were then interpreted using ArcGIS software to produce accurate and detailed maps of flood-prone zones. The primary objective of this study was to identify effective flood mitigation techniques and comprehensively assess locations with high flood vulnerability in the Kuala Lumpur region. In analyzing flood potential, three primary criteria were the focus of the assessment. The first criterion is rainfall, which is a crucial factor in determining and planning flood control strategies. Rainfall data is used to calculate the volume of water entering an area, enabling more precise flood mitigation planning (Mishra et al., 2022).

The second criterion analyzed is land use, which reflects land use planning in an area based on specific characteristics such as residential, commercial, or industrial zones. Land use planning plays a strategic role in determining decisions regarding development locations, road infrastructure, the provision of public spaces, and other urban aspects (Kalfas et al., 2023). The third criterion is slope, which has a significant influence on the discharge, volume, and velocity of surface water flow, and is closely related to land use and erosion rates. Slope gradient is directly proportional to water flow velocity; the steeper the slope, the faster water flows to lower areas, thereby increasing the risk of flooding (Barrocu & Eslamian, 2022).

AHP Data Processing Technique

Primary qualitative data obtained from in-depth interviews with experts and stakeholders in Kuala Lumpur were quantitatively processed using the Analytic Hierarchy Process (AHP) method. This process begins with developing a hierarchical structure consisting of research objectives, mitigation criteria, and alternative strategies, all derived from the interview analysis. The core of the data processing involves pairwise comparisons, where each expert rates the relative importance of elements in the hierarchy using the Saaty scale (1-9). These assessments are then transformed into a reciprocal Pairwise Comparison Matrix for mathematical calculations to obtain Priority Vectors (Eigenvectors) that represent the quantitative importance weights of each mitigation criterion and alternative.

Once the priority weights are obtained, the next crucial step is to conduct a Consistency Ratio (CR) Test to validate the reliability of the assessment. The matrix is considered consistent and valid if the CR value is ≤ 0.10, indicating that the experts' assessments are logical and reliable. The final result of the AHP data processing is a synthesis of global weights that rationally identify and prioritize the most effective and optimal flood disaster mitigation strategies for implementation in Kuala Lumpur. This method ensures that the resulting strategic decisions are not based solely on subjective opinions, but have undergone a systematic and scientific quantification and validation process (Mitra et al., 2022).


Saaty Scale (1970)

Value	Description
1	Equal
3	Moderate
5	Strong
7	Very Strong
9	Extreme
2, 4,6,8	If in doubt between two adjacent values
1/(1-9)	Reciprocal of the importance level from the 1-9 scale

Figure 2. Saaty scale, (HARIS) (1970)

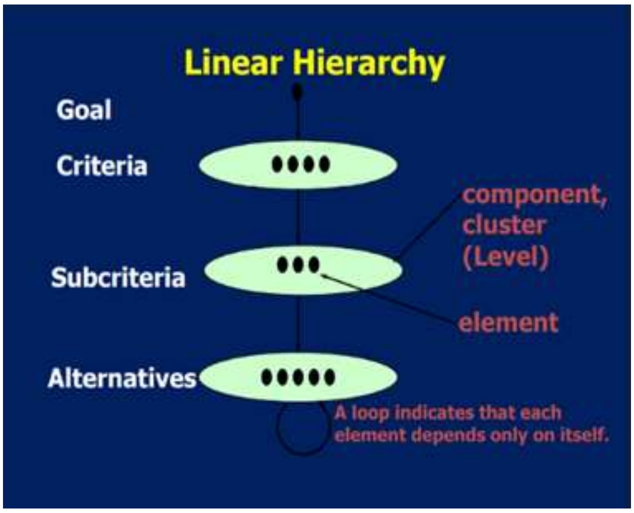


Figure 3. Linear hierarchy

Results and Discussion

Results

Flood Vulnerability Maps

The flood hazard vulnerability map is a spatial representation that illustrates the level of risk and vulnerability of various areas in the Malaysian capital to the threat of flooding. This map is compiled based on a multi-criteria analysis that integrates various important parameters such as rainfall, slope gradient, land use, topographic elevation, distance from major rivers, and the capacity of the existing drainage system. Using a Geographic Information System (GIS) approach and hydrological modeling, the Kuala Lumpur region is classified into several vulnerability zones ranging from low, medium, to high, marked with color gradients to facilitate the identification of priority areas. With clear visualization and based on scientific data, this vulnerability map serves as a strategic foundation for efforts to increase the city's resilience to flood disasters (Sarmah et al., 2020). The flood hazard vulnerability map can be seen in Figure 4.

Table 1. Flood-prone areas in Kuala Lumpur

Classification	Area (ha)	Percentage of Area (%)
Not Vulnerable	22.33	0.08
Less Vulnerable	2747.20	10.10
Vulnerable	15972.95	58.73
Highly Vulnerable	8452.99	31.08
Area at Risk of Flooding (ha)	27195.47	100.00

Source: Processed Data, 2025

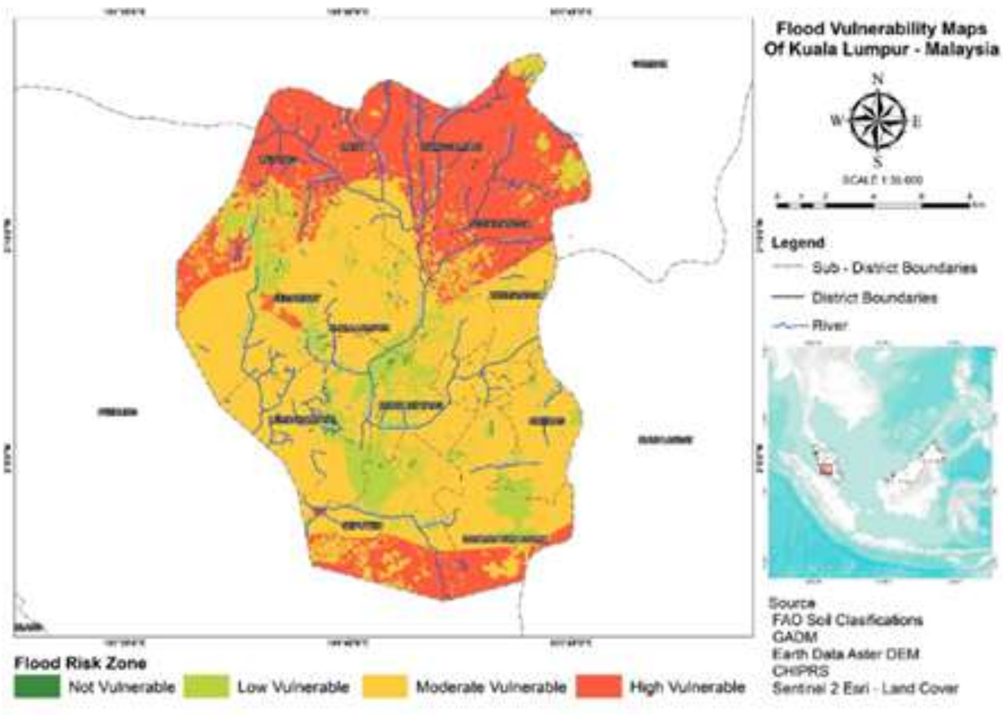


Figure 4. Flood hazard vulnerability map of Kuala Lumpur, Malaysia

Based on the results of the flood vulnerability classification, a total area of 27.195.47 hectares was identified as potentially affected by flooding. The distribution of vulnerability shows an alarming pattern, where the Vulnerable category dominates with an area of 15.972.95 hectares (58.73% of the total area), followed by the Very Vulnerable category covering 8.452.99 hectares (31.08%). Meanwhile, areas with a low level of vulnerability are relatively limited, namely the Less Vulnerable category covering only 2.747.20 hectares

(10.10%), and the Not Vulnerable category is almost insignificant with an area of 22.33 hectares (0.08%).

These findings indicate a critical situation, with nearly 90% of the total study area categorized as Vulnerable to Highly Vulnerable to flooding. This situation underscores the urgency of intervention through comprehensive flood risk mitigation and management strategies. The results of this flood-prone area mapping provide a crucial foundation for the next phase, namely the development and implementation of targeted and sustainable flood mitigation strategies.

Flood Disaster Mitigation Strategy

In an interview, a 60-year-old resident named Pakcik Abdullah, who lives in Kuala Lumpur, expressed deep concern about the frequent flooding in his neighborhood. He explained that heavy rainfall is always followed by a rapid rise in water levels. This situation not only disrupts residents' daily activities but also causes damage to household items.

According to Uncle Abdullah's observations, the root of the problem lies in the inability of the existing drainage system to accommodate the large volume of water. This infrastructure failure causes flooding to recur at a very high frequency, even almost monthly during the rainy season. This situation highlights the urgent need for improvements to a more adequate drainage system.

Similar concerns were expressed by Makcik Latha, a 45-year-old resident, who highlighted the broader impact of flooding. She emphasized that the flooding problem extends beyond material losses, but also poses a serious threat to public health due to stagnant, dirty water that can potentially become a source of disease. Makcik Latha hopes the government will take immediate concrete action by improving drainage infrastructure and providing sustainable solutions so that the community does not continue to suffer from the destructive impacts of recurring flooding.

Figure 5. interview evidence

Based on the results of interviews and flood cases that occurred in Kuala Lumpur, it can be concluded that 10 alternatives will be processed in the AHP.

Table 2. Alternative strategy

Alternative	Strategy
1	Sustainable implementation of the River of Life (RoL) project for river and ecosystem rehabilitation.
2	Increased water infiltration area to reduce surface runoff and increase groundwater absorption.
3	Implementation of Integrated Stormwater Management System (MSMA) in all new developments.
4	Strict oversight of building permits to ensure compliance with flood mitigation standards.
5	Revision of Kuala Lumpur Structural Plan to define and regulate flood prone zones.
6	Mandatory construction of drainage systems and retention ponds in new residential and commercial areas.
7	Increased public awareness campaigns and disaster simulations in densely populated areas.
8	Optimization of SMART Tunnel operations as a major flood control infrastructure.
9	Educate the public to monitor river water levels through official portals such as Public Flood Information.
10	Incentive program for building adaptation in high-risk areas to encourage flood-resistant development.

From the 10 strategies above, then processed using the AHP technique, the results can be seen as follows.

Figure 6. Priorities with respect to: Goal Flood Mitigation Strategy

The Analytic Hierarchy Process (AHP) method was used to prioritize flood mitigation strategies in Kuala Lumpur. The results showed the following weightings.

Analysis using the Analytical Hierarchy Process (AHP) method identified that Regulation is the highest priority in flood mitigation efforts in Kuala Lumpur with a weighting of 57.7%, followed by Education with a weighting of 25.8%, and Conservation with 16.5%. The dominance of Regulation as the main priority is based on its effectiveness in implementing firm policies and ensuring compliance of various related parties in the implementation of flood mitigation programs. Consistent enforcement of regulations is seen as a crucial foundation for systematically controlling the factors that trigger flooding.

Table 3. Flood mitigation priority strategy results

Priority Strategy	Weight	Information
Regulation	0.577	This is the highest priority, accounting for approximately 57.7% of the total weight. It indicates that policy enforcement and regulatory measures are considered the most effective in reducing flood risk. Examples include implementing and auditing compliance with the Integrated Stormwater Management Manual (MSMA), designing flood-prone zones in the city's structural plan, limiting impervious surfaces, and mandating drainage and retention ponds in new developments.
Education	0.258	The second priority, with about 25.8% weight. This highlights the importance of community awareness and capacity building. Activities include public campaigns, disaster simulations in high-density areas, training for local communities, promoting the use of official flood monitoring portals, and incentive programs for building adaptation.
Conservation	0.165	The third priority, with 16.5% weight. Although less emphasized compared to regulation and education, ecological restoration remains crucial for long-term resilience. Actions include river rehabilitation projects such as River of Life, expanding water infiltration zones, and implementing green infrastructure such as bioswales, rain gardens, and permeable pavements.

Despite its lower weighting, education still plays a strategic role in strengthening community capacity by increasing awareness and preparedness for flood threats. Meanwhile, conservation contributes as a supporting pillar for long-term sustainability through ecological restoration approaches and green infrastructure development. These three priorities complement each other and form a comprehensive framework for effective and sustainable flood risk management in the Kuala Lumpur region.

Discussion

Analysis of Kuala Lumpur's flood hazard vulnerability map shows a very worrying situation, where almost 90% of the total at-risk area (27.195.47 hectares) is categorized as vulnerable to very vulnerable to flooding. The dominance of the "Vulnerable" category covering 58.73% of the area (15.972.95 hectares) and the "Very Vulnerable" category at 31.08% (8.452.99 hectares) indicates that most areas of Kuala Lumpur have high structural and geographic vulnerability to flood threats. This finding is in line with research by D'Ayala et al. (2020) which identified that the lowland areas of Kuala Lumpur, especially along the Klang River and its tributaries, have a very high level of vulnerability due to a combination of topographic factors, extreme rainfall intensity, and high surface impermeability due to massive urbanization.

Zhou et al. (2021) confirmed that a GIS-based hydraulic modeling approach can identify critical zones with high accuracy, enabling policymakers to prioritize the allocation of flood control infrastructure resources more effectively. The small number of areas in the "Less Vulnerable" (10.10%) and "Not Vulnerable" (0.08%) categories indicates that almost the entire Kuala Lumpur metropolitan area is under significant flood threat and requires comprehensive and comprehensive mitigation interventions. This provides a strong basis for the government to immediately implement measurable and sustainable mitigation strategies to protect communities and urban assets from the increasing risk of flooding.

The high percentage of flood-prone areas is inextricably linked to the rapid urbanization and drastic land-use changes in Kuala Lumpur over the past few decades. The conversion of green spaces to built-up areas has reduced the soil's natural infiltration capacity and increased the volume and velocity of surface runoff. Wu et al. (2023) highlighted that infrastructure development that fails to consider Water Sensitive Urban Design (WSUD) principles significantly contributes to the increasing frequency and intensity of flash floods in the city center. While infrastructure such as the SMART Tunnel has made a positive contribution to flooding reduction in certain areas since its opening in 2007, the system has limited capacity to cope with extreme rainfall, the intensity of which continues to increase due to climate change. Boogaard et al. (2024) added that the implementation of the Second Edition of the Natural Drainage Manual (MSMA), which integrates green elements such as bio-swales, rain gardens, and retention ponds into new developments, is a progressive step, but its implementation remains uneven and inconsistent across Kuala Lumpur.

Based on the vulnerability conditions identified through GIS mapping, an Analytic Hierarchy Process (AHP) analysis was conducted to prioritize the most effective mitigation strategies. The AHP analysis results showed that the Regulation strategy received the highest priority weighting of 57.7%, indicating that policy enforcement is the most effective approach to reducing flood risk in Kuala Lumpur. Regulatory priorities include the implementation of the MSMA, the designation of flood-prone zones in the City Structure Plan, restrictions on impervious surfaces, and the mandatory construction of drainage systems and retention ponds in new developments. Without a strong regulatory framework and consistent enforcement, other structural and non-structural solutions will not be optimally implemented. Strict monitoring of building permits is crucial as a preventive measure to prevent the deterioration of urban hydrological conditions (Piyumi et al., 2021).

The Education Strategy ranks second with a weighting of 25.8%, highlighting the importance of increasing community awareness and capacity in flood management. This strategy includes public campaigns, disaster simulations, community training, promotion of official flood monitoring portals, and building adaptation incentive programs. Community attitudes toward disaster mitigation remain low, a major factor in the perceived negative impacts (Kurata et al., 2023). Interviews with local residents such as Pakcik Abdullah and Makcik Latha reinforce this finding, stating that the community expects not only technical solutions but also a better understanding of how to reduce risks and respond appropriately to flooding. Olsen et al. (2023) emphasize that community knowledge and skills significantly influence crisis management, suggesting that investment in education can enhance overall community resilience.

The Conservation Strategy received third priority with a weighting of 16.5%. Although lower, it still plays a crucial role in long-term resilience. This strategy includes river rehabilitation, such as the River of Life (RoL) project, expanding water infiltration zones, and implementing green infrastructure such as bioswales, rain gardens, and permeable pavements. Ecologically based approaches, such as the sponge city concept, are crucial to address the limitations of conventional systems that rely solely on gray infrastructure (Nguyen et al., 2020). Integrating green infrastructure with conventional flood defense systems can reduce flood risk by up to 40%. Despite its lower weighting, ecological conservation provides long-term benefits such as improved water quality, reduced urban heat islands, and increased biodiversity, contributing to the sustainability of urban environments (Green et al., 2021).

The integration of three strategies: regulation as a policy foundation, education as community empowerment, and conservation as an ecological solution, creates a comprehensive, adaptive, and sustainable flood mitigation framework for Kuala Lumpur. With nearly 90% of the area categorized as vulnerable to highly vulnerable, strategic priorities should be directed towards a comprehensive revision of the Spatial Plan to limit development in highly vulnerable zones, the development of green infrastructure and sustainable drainage systems, optimization of existing infrastructure operations such as the SMART Tunnel, and strengthening early warning systems and community preparedness (Pangesti et al., 2024). The results of this vulnerability mapping and strategic priority analysis provide strong empirical evidence to encourage political commitment and adequate budget allocation in efforts to increase Kuala Lumpur's resilience to future flood threats, especially in the face of the increasingly real challenges of climate change.

Conclusion

Based on the research results, flood vulnerability mapping in Kuala Lumpur shows a critical condition with a total area of 24.425.94 ha (89.81%) categorized as Vulnerable (15.972.95 ha) and Very Vulnerable (8.452.99 ha) to flooding. Analysis using the Analytic Hierarchy Process (AHP) method identified three priority mitigation strategies, namely Regulation (57.7%) as the highest priority which includes policy enforcement and implementation of MSMA, followed by Education (25.8%) to increase public awareness and preparedness, and Conservation (16.5%) through ecological rehabilitation and green infrastructure. The integration of these three strategies is needed to create a comprehensive and sustainable flood mitigation framework, considering the high urbanization and climate change that continue to increase flood risks in the Kuala Lumpur metropolitan area.

Acknowledgements

During the research, the author received a lot of support, guidance, direction and input from various parties, therefore on this occasion the author would like to thank colleagues and lecturers in the Department of Geography, Universitas Negeri Padang.

Author Contribution

P.T.D.: preparation of original draft, results, discussion, methodology, conclusion; I.U., D.H., and F.: analysis, review, proofreading and editing.

Funding

This research did not receive any external funding.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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