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Article

Human-Based Adaptive Actions in Flood Disaster Risk Management: A Review of Malaysian Case Events

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Abstract: Flood occurrences in Malaysia are increasing in both frequency and intensity, highlighting the urgent need for effective Disaster Risk Management (DRM) strategies. This paper explores the critical role of human-based adaptive actions in managing flood risks, emphasizing the importance of local communities, social support networks, and grassroots responses. While top-down approaches led by authorities remain essential, this study shifts focus to bottom-up contributions that enhance overall resilience. Using the PRISMA framework for a systematic review, six relevant articles were selected and analyzed thematically. Key themes identified include social support, collective community engagement, and adaptive actions taken before, during, and after flood events. The findings reveal that community-driven preparedness efforts, psychological support systems, and collaborative emergency responses significantly complement formal DRM mechanisms. These human-centered interventions not only strengthen community resilience but also bridge gaps left by institutional responses. The study advocates for an integrated flood management approach that combines national policies with localized adaptive strategies. Such an approach ensures a more inclusive, responsive, and sustainable framework for flood risk reduction in Malaysia. Strengthening social cohesion, encouraging active participation, and building adaptive capacity are essential steps toward creating safer and more resilient urban and rural settlements in the face of escalating flood risks.

Keywords: Disaster Risk Reduction; disaster risk management; human-based adaptive actions; social support; community-led preparedness

Introduction

The frequency and intensity of disasters have increased in recent decades, primarily due to climate change and environmental degradation. Data from the Emergency Events Database (EM-DAT) indicates a 74.4% rise in disaster occurrences from 2000 to 2019 compared to the prior two decades, with floods accounting for nearly half of all weather-related disasters globally (Mizutori & Sapir, 2019; Chan, 2015). Rising global surface temperatures are expected to increase rainfall and increase the frequency of flood occurrences in Southeast Asia, including Malaysia (IPCC, 2022; Nurfashareena & Husna, 2022).

While Malaysia is geographically protected from significant geological hazards such as earthquakes and typhoons, it is notably susceptible to hydro-meteorological disasters, particularly floods (Habibah et al., 2018; CFE-DM, 2022; Raja Noor Afandi, 2022). From 1998 to 2018, floods constituted 75% of disasters in the nation, impacting over 770,000 individuals and resulting in damages beyond RM5.8 billion (NADMA,

2021). The National Risk Register reported by the National Disaster Management Agency Malaysia (NADMA) officially lists Malaysia as being exposed to seven hazards, with floods ranked as the most likely and having the highest impact among others (NADMA, 2021). Although Malaysia may encounter droughts, landslides, earthquakes, and storm surges, the largest portion of its losses is due to flooding (World Bank, 2021; Haziq et al., 2023).

In Malaysia, floods are frequently caused by seasonal monsoons, but depending on the amount, length, and geography of rainfall, they can rapidly worsen into major catastrophes. Significant flood occurrences, including the 2014 Kelantan floods impacting over 200,000 individuals and the 2021 debris floods in Selangor and other regions, causing RM6 billion in losses, exemplify the escalating severity of flood disasters (Nurul Syazwani et al., 2015; Abd Rasid et al., 2023). The recent floods in November–December 2024, deemed the most severe since 2014, impacted around 130,000 residents across nine states, underscoring the necessity for comprehensive flood management strategies (IFRC, 2024).

Although institutional disaster responses and top-down policies are essential, recent research indicates that human-based adaptive actions such as community preparedness, localized knowledge dissemination, and social support systems are equally important in improving flood resilience (Sarina & Nur Hafizah, 2022). Nonetheless, these local strategies are frequently marginalized in policy discussions and scholarly works, particularly in multicultural or economically disadvantaged neighborhoods. In order to determine how grassroots capacities supplement formal disaster administration and how adaptation differs depending on local contexts influenced by cohesion, culture, and ability, it is essential to investigate these characteristics.

This study seeks to investigate the significance of human-centered adaptive strategies in flood disaster risk management in Malaysia. The emphasis is on community-level efforts, social support systems, and locally-driven adaptation techniques, aiming to comprehend how these components interact with and augment formal disaster risk management. The project aims to advance a comprehensive flood management framework that harmonizes top-down policies with community-based resilience strategies.

Literature Review

1. History of Floods Events in Malaysia

The flood data from 2014 to 2024 highlights significant variations in the number of flood incidents, affected individuals, and financial losses across different years in Malaysia. The most devastating flood event occurred in 2014, primarily impacting Peninsular Malaysia states such as Kelantan, Terengganu, Pahang, and Perak. This disaster affected over 200,000 people and resulted in more than RM 1 billion in losses, making it the costliest flood in the decade. In contrast, the following year, 2015, saw 496 total flood cases, which affected 46,000 people, with financial losses exceeding RM 30 million, indicating a significant decrease in both human and economic impact compared to the previous year. However, in 2016, despite a reduction in the number of flood cases to 404, the number of affected individuals nearly doubled to 95,000, with damages increasing to RM 53 million, reflecting the unpredictable nature of flood severity each year.

In 2017, Malaysia faced the highest number of recorded flood cases in the decade, with 1,239 incidents reported, leading to 68,000 affected individuals and five fatalities, with financial damages estimated at RM 63 million (Table 1). In comparison, 2018 saw a slight decline in flood cases to 844, but the severity was lower, with only two fatalities and 12,000 affected individuals, resulting in total damages of RM 44 million. A notable decline occurred in 2019, with flood cases dropping to 535, affecting 49,000 people and causing losses of around RM 26 million, the lowest recorded financial impact in the decade. Meanwhile, 2020 recorded 869 total flood cases, impacting 14,000 individuals, but without available data on financial damages.

A significant turning point came in 2021, where floods across Malaysia resulted in the highest number of fatalities within the decade, with 69 deaths affecting 160,000 people, making it one of the most tragic flood years in recent history. Although financial losses were not provided, the human toll was severe. In 2022, floods primarily impacted Kelantan, Terengganu, and Kedah, with 81 reported flood incidents affecting 50,000 individuals and causing four fatalities, demonstrating the ongoing challenges posed by extreme weather events. Moving into 2023, floods impacted multiple states such as Johor, Pahang, and Sabah, affecting 35,000 people by May. The most recent data from 2024 show a significant increase in flood impact, with 137,410

individuals affected as of December 2 across nine states, including Kelantan, Terengganu, and Johor, pointing to the growing frequency and severity of floods in Malaysia.

Table 1. History of Flood Events in Malaysia

Year	Flood Incident	Impact
2014	Flood in Peninsular Malaysia; Kelantan, Terengganu, Pahang, Perak,	More than 200,000 people affected More than RM 1 billion losses and damages
2015	496 total flood cases	46,000 people affected More than RM30 million in losses and damages
2016	404 total flood cases	95,000 people affected More than RM 53 million in losses and damages
2017	1239 total flood cases	5 people killed 68,000 people affected More than RM 63 million in losses and damages
2018	844 total flood cases	2 people killed 12,000 people affected RM 44 million in losses and damages
2019	535 total flood cases	49,000 people affected More than RM 26 million in losses and damages
2020	869 total flood cases	14,000 people affected
2021	1057 total flood cases	69 people killed 160,000 people affected all around Malaysia
2022	Flood in Kelantan and Terengganu on 25 December Flood in Kedah on 4 July 81 flood incidents reported in Johor, Kelantan, Pahang, Perak, Terengganu on 19 December	4 people killed 50,000 people affected all around Malaysia
2023	Flood in Johor, Pahang, and Sabah on 25 January Flood in Johor, Pahang, Melaka, Negeri Sembilan, Sarawak and Sabah on 1 March	35,000 people affected as of May 2023
2024	Flood in Kelantan, Terengganu, Kedah, Pahang, Negeri Sembilan, Johor, Perak, Melaka and Perlis in November 2024	137,410 people affected as of 2 December 2024

A review of flood occurrences from 2014 to 2024 revealed two principal trends: the escalating severity of floods and the increased vulnerability of at-risk populations. The 2021 floods resulted in 69 deaths and impacted 160,000 individuals, marking the highest human toll in the last decade. Likewise, the 2024 floods affected more than 137,000 residents across nine states, indicating an increase in both impact and magnitude. Flood-prone states like Kelantan, Terengganu, and Pahang continuously report high susceptibility, despite varying annual data. This is due to geographical and socioeconomic variables. These developments emphasize the necessity for both structural and non-structural mitigation strategies.

2. Human-based disaster risk management in Malaysia and Southeast Asia

Human-based disaster risk management in Malaysia and Southeast Asia emphasize active community engagement, enhancing local resilience and promoting collaboration among multiple stakeholders. This strategy has grown increasingly essential due to the region's significant vulnerability to natural hazards and climate-related occurrences. These techniques include community participation, social capital, local knowledge, and participatory governance, indicating a transition from top-down methodologies to more inclusive and adaptive framework, .

According to Chan (2015), disaster management in Malaysia has historically been characterized by government-driven, structural methodologies, especially with flood mitigation. There is an increasing demand for a more holistic strategy that incorporates non-structural measures and promotes wider stakeholder engagement, including the proactive participation of Non-Government Organizations (NGOs). Agencies such as NADMA are encouraged to reassess current flood management strategies to improve their effectiveness at the community level. In Southeast Asia, human-based disaster risk management is facilitated by regional cooperation structures, such the ASEAN Agreement on Disaster Management and Emergency Response

(AADMER) and the ASEAN Coordinating Centre for Humanitarian Assistance (AHA Centre). These structures facilitate cooperative disaster preparedness, response, and recovery initiatives across ASEAN member states, underscoring the significance of coordination, community involvement, and collective accountability in mitigating catastrophe risks (Delfiyanti & Magdariza, 2021).

Chan (2015) underscored the essential importance of social readiness and public knowledge in Malaysia's flood risk mitigation initiatives. Their research in Terengganu revealed that early warning systems, community drills, and household-level adaptations substantially enhanced local resilience. Sarina and Nur Hafizah (2022) examined mental health and social support systems during the 2021 floods in Malaysia, demonstrating that strong interpersonal networks enhanced psychological recovery and strengthened community cohesiveness. A study by Halim et al (2024) highlighted community participation through Community-Based Disaster Risk Management helps to reduce their risks by involving them in hazard identification and risk assessment activities. This approach leverages local knowledge which are crucial for accurately identifying hazards and formulating effective mitigation strategies. The empowering of the Bertam Valley community in Cameron Highlands, Malaysia, through Community-Based Early Warning System has significantly transformed their capacity to address dam-related calamities, mark the critical role of local community engagement (Azril et al, 2023). In Langsa City, Aceh Province Indonesia, the community's reliance on "gotong royong" enabled them to autonomously adapt to tidal floods by raising house levels and building dams without government intervention. This highlights the importance of integrating local wisdom into flood management strategies (Aksa & Afrian, 2022). In Tuban, East Java, social capital was crucial in controlling flood disasters by promoting collaboration among stakeholders, including residents, governmental bodies, and the corporate sector. This underscores the necessity of bolstering social capital to improve the efficacy of flood management initiatives (Rustinsyah et al., 2021).

Methodology

This review article utilized a comprehensive method to gather all relevant resources and process the information so that the content could be used to answer the research objectives. The Problem, Intervention, Comparison, and Outcome (PiCO) framework for this study centers on the increasing frequency and severity of flood events in Malaysia, which demand more effective disaster risk management (DRM) strategies. The identified problem lies in the substantial human and economic losses caused by floods, compounded by the limitations of traditional top-down flood management led primarily by government agencies. To address this, the intervention explored in this review involves human-based adaptive actions, particularly the role of community engagement, local knowledge, and social support systems in enhancing disaster preparedness and response.

A systematic thematic analysis was employed to synthesize findings from the reviewed literature. The process began with open theme searching, where key phrases and concepts relevant to flood DRM were highlighted and categorized across the studies. The study identified resource articles from the Scopus search engine to ensure the selection of high-quality, indexed journal articles for review. A set of Boolean keyword searches was developed and used to retrieve materials from the search engine. The Boolean keywords applied were: (TITLE-ABS-KEY ("Disaster Risk Management" AND "Human-Based Adaptive Actions" AND "Flood" AND "Malaysia") OR ("Disaster Risk Management" AND "Community-Based Management" AND "Flood" AND "Malaysia")). By using these Boolean keywords, the study aimed to obtain more relevant and focused results related to the research topic under discussion. From these core themes were derived inductively reflect recurring insights across the literature and were used to guide the comparative analysis.

A total of 17 relevant articles were found in the Scopus search engine (refer Figure 1.). The study refined the selection criteria to focus only on Malaysia, as the research aimed to examine human-based adaptive actions specific to the country. Additionally, the study set specific criteria, including language (English) and document type (articles only). After applying these criteria, only six (6) articles met the requirements and were considered relevant to the study.

The six selected articles underwent a screening and eligibility process. The study conducted a thorough screening of the overall content to ensure the information was suitable for further analysis to address the research objectives. In addition, the articles were subjected to an eligibility process, which involved sending

them to experts for validation to confirm their significance and relevance to the study. Following the screening and eligibility process, the study successfully selected six articles for further analysis using a terminological method.

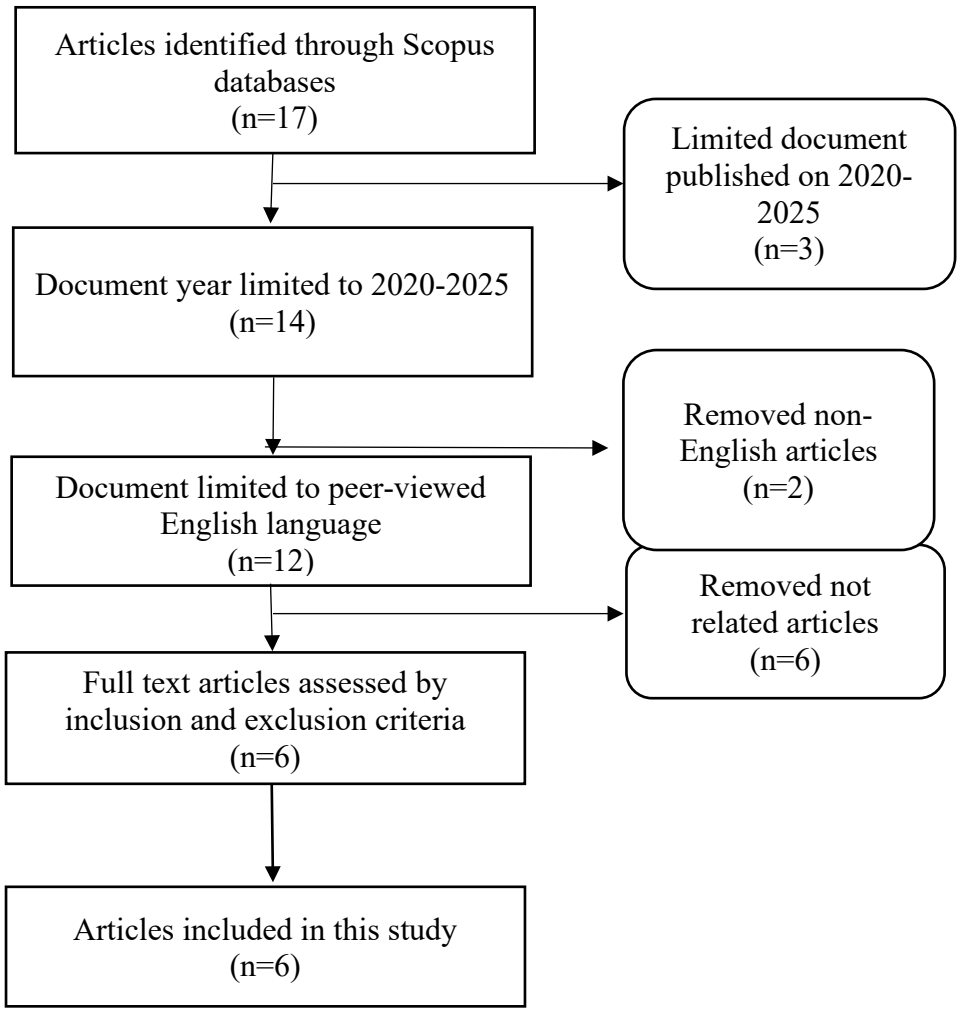

Figure 1. PRISMA Flow Diagram

The Findings

The study derives its thematic findings by analyzing the interplay between institutional frameworks and human-based adaptive actions. Through a systematic review of literature, governance structures, and adaptation measures, the research categorizes themes such as social support, collective community actions, and pre, during, and post-flood adaptation strategies. These findings emphasize that resilient flood management is not solely dependent on infrastructure but also on proactive human interventions, such as community-led preparedness efforts, psychological support systems, and cooperative emergency responses. The thematic analysis highlights the need for synergy between formal DRM mechanisms and local adaptive behaviors, advocating for a paradigm shift in Malaysia's flood management policies. Ultimately, the study underscores the importance of fostering community engagement, strengthening social networks, and integrating local knowledge into national disaster preparedness frameworks to achieve a more comprehensive and sustainable flood risk reduction strategy.

1. Governance of Disaster in Malaysia

Malaysia, as a member to the Hyogo Framework for Action (HFA) 2005-2015, has reiterated its commitment under the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 (NADMA, 2023). This commitment highlights the country conformity with the global DRR framework established by the United Nations Office for Disaster Risk Reduction (UNDRR). The foundation of Malaysia's disaster management

strategies is articulated in the National Security Council Directive No. 20 (NSC Directive No. 20), instituted in 1997 (Izumi et al., 2022).

In light of the intensifying disaster scenario, human activities and the emergence of new threats, disaster management can no longer depend on the current NSC Directive No. 20, which has been superseded by a new directive known as Arahan NADMA No. 1 effective August 1, 2024. Arahan NADMA No. 1 outlines Disaster Management and Disaster Risk Reduction mechanisms more comprehensively. In addition to that, each agency involved in disaster management and DRR are responsible for carrying out their respective roles in accordance with this Directive. Arahan NADMA No.1 will also prevent the occurrence of waste, misunderstanding, conflict and redundancy in disaster management. This directive defines the responsibility of NADMA, encompassing disaster management mechanisms, disaster risk reduction strategies, disaster response protocols, recovery processes and the duties of each agency at all stages of disaster management prior to, during, and following an incident. The Central Disaster Management Committee is in charge of coordinating response and management activities for disasters that impact several states. In the event of disasters limited to one or two districts within a state, the State Disaster Management Committee assumes responsibility. Meanwhile, the District Disaster Management Committee is in charge of operations and supervision for disasters that only affect one district (NADMA, 2024; Izumi et. al, 2022).

The Eleventh Malaysia Plan (RMK-11) and the National Disaster Risk Reduction (DRR) Policy 2030 are interrelated in formulating Malaysia's disaster governance and resilience strategy against climate change and natural hazards. Several aspects illustrates the connection between the two initiatives, particularly in their integration of disaster risk management and climate change adaptation, as well as their emphasis on local resilience and community based disaster risk reduction. The RMK-11 clearly stipulates that strategies for climate change mitigation and adaptation must be incorporated into the national's development goals (Wan Nurul Mardiah, 2020). The Plan also advocates for sustainable development and prioritizes green growth by integrating environmental resilience into development initiatives (Malaysia's 11th Plan, 2016). Similarly, the National DRR Policy 2030 also emphasizes the necessity of tackling both climate related disaster and non-climate disasters, establishing a comprehensive framework between climate change and disaster risk. In particular, the Policy emphasizes the need of preparedness, prevention, and mitigation as critical components in enhancing national resilience. The National DRR Policy 2030 and the RMK-11 both stress how crucial it is to give local communities the authority to take charge of disaster risk management and resilience building at the local level. According to Malaysia's 11th Plan (2016), RMK-11 advocates for the incorporation of local-level disaster management measures that take into account community involvement, adaptive practices, and local knowledge. Meanwhile, the National DRR Policy 2030 emphasizes the importance of community-based disaster risk reduction (CBDRR) in fostering resilience. It recognizes that as local communities are the ones who know the risks they face and are in the greatest position to develop flexible solutions, they frequently have the best ideas for risk reduction (National DRR Policy 2030, Malaysia).

2. Adaptation Actions

The SFDRR promotes DRR strategies and adaptation measures to increase disaster resilience. In Malaysia, NADMA plays a key role in short- and long-term flood recovery efforts, providing material support, financial assistance and manpower. In addition, NADMA oversees and enforces the implementation of DRR measures to reduce the impact of disasters. The agency also conducts training and awareness programmes, including community-based disaster risk management (CBDRM) initiatives, to strengthen preparedness and response capabilities.

Community-based disaster risk reduction (CBDRR) programmes and participatory models have been shown to improve flood management outcomes by actively involving local people in planning, preparedness and response efforts. Abid et al. (2023) conducted a comprehensive evaluation of community-based flood mitigation strategies in Malaysia, highlighting the effectiveness of public participation in the planning process. Their research highlights the important role of community engagement in increasing flood resilience. Similarly, Nur Nafhatun (2022) emphasizes the importance of developing flood preparedness plans through direct community engagement, ensuring that local knowledge and needs are effectively integrated into DRR strategies.The National Risk Register of Malaysia reinforces the critical role of Early Warning Systems (EWS)

and Geographic Information Systems (GIS) in disaster management methods. The register emphasizes the necessity for ongoing technology progress and improved inter-agency cooperation to strengthen these systems for flood risk reduction.

Early Warning System

Flood EWS in Malaysia play a crucial role in mitigating the adverse impacts of flooding by providing timely information to communities and authorities. Malaysia's EWS is primarily managed by the DID, which has developed the National Flood Forecasting and Warning Program (NaFFWS) to enhance flood preparedness (DID, 2020). The system integrates real-time hydrological data, weather forecasts, and remote sensing technologies to predict flood occurrences accurately.

The effectiveness of Malaysia's flood EWS relies on several components, including data collection through rain gauges, river water level sensors, and satellite monitoring. These data sources are processed using hydrological models such as the Infoworks Integrated Catchment Model (ICM) to simulate potential flood scenarios (Chan et al., 2018). The warning dissemination system involves multiple communication channels, including SMS alerts, social media updates, sirens, and the MyPublicInfoBanjir online portal, which provides real-time flood information to the public (Abdullah et al., 2021). Despite advancements, challenges persist in the implementation of EWS in Malaysia, such as data accuracy, system coverage limitations in rural areas, and public awareness regarding response actions. According to (Haziq Sarhan et al., 2023), there is a need for continuous investment in technology and capacity building to enhance the effectiveness of the warning system and ensure timely evacuation and response.

Flood GIS Modelling System in Malaysia

The GIS modelling has become an essential tool in flood risk management in Malaysia, providing spatial analysis and visualization capabilities to identify flood-prone areas and support data-driven decision-making. Government agencies and researchers widely use GIS modeling systems to analyze flood patterns, predict flood levels, and develop mitigation strategies (Khalid et al., 2020). Integration of GIS with hydrological models such as HEC-RAS and MIKE 11 allows authorities to simulate various flood scenarios and assess the impacts of land-use change and climate variability. Malaysia's GIS flood modeling combines data from multiple sources, including topographic maps, river basin models, and historical flood records. The National Flood Hazard Map, developed by the Department of Irrigation and Drainage (DID), uses GIS technology to provide detailed flood hazard information and support urban planning efforts (DID, 2021). In addition, GIS-based flood modeling has been shown to play a key role in community-level risk assessment, enabling local governments to develop targeted disaster response plans (Mohamad et al., 2022).

However, challenges persist in implementing GIS flood modeling in Malaysia, including data accessibility, model calibration complexity, and the need for skilled personnel to effectively interpret and use GIS outputs. Future advances should focus on integrating artificial intelligence and machine learning techniques to improve the accuracy of flood forecasting and resilience planning (Rahman et al., 2023). By incorporating early warning systems (EWS) and GIS into national disaster policies, Malaysia can adopt a proactive and comprehensive approach to disaster risk reduction, ultimately protecting communities and infrastructure from future flood risks.

3. Human-Based Adaptive Actions toward Flood Risk Management

Adaptation measures together with institutional and structural measures, these initiatives highlight the participation of individuals and communities in disaster management initiatives. Social support, cooperative efforts by flood management teams and pre, during, post disaster adaptation actions among the community in Malaysia are a few that are featured in the article.

Social Support

The findings emphasize the significance of social awareness and community assistance in the management of flood disasters in Malaysia such as emotional, instrumental, and informational are essential in mitigating flood-related disturbances and aiding victims' rehabilitation. Social cohesion and active community

involvement enhance resilience and facilitate post-flood recovery. During flood situations, relief items including food, water, clothing, and medication are essential. Instrumental help from governmental and non-governmental organizations (NGOs), community groups, and other agencies is crucial for alleviating the effects of floods. Furthermore, the engagement between flood victims and governmental entities such as Welfare Department and Health profoundly influences mental health rehabilitation. The availability of assistance during the healing phase significantly impacts persons' psychological and emotional resilience.

Collective Actions from the Flood Management Teams

Efficient flood disaster management in Malaysia necessitates strong intergovernmental cooperation, wherein diverse governmental entities exchange resources and synchronize efforts to guarantee prompt evacuations and emergency responses (Siti Nur Aishah et al., 2016). The active participation of NGOs and local communities is equally crucial, as they are vital in the disaster management cycle by enhancing their capacity for effective DRR (Abid et al., 2024; Chan, 2015). A case study in Sarawak shows the essential function of multi-agency cooperation in reducing potential losses and improving recovery. Collaborative initiatives among 39 agencies were essential for effective flood disaster management, facilitating loss mitigation and prompt victim support (Noralfishah et al., 2019).

Government authorities collaborate with NGOs to coordinate evacuations, supply relief materials, and set up temporary shelters, guaranteeing that impacted citizens receive prompt assistance and support (Sandaran & Selvaraj, 2021). Furthermore, in times of disaster, agencies cooperate with entities such fire services, meteorological departments, and healthcare organizations to efficiently mobilize resources and expertise, thereby guaranteeing a thorough and coordinated response (Sandaran & Selvaraj, 2021).

4. Pre, During and Post Disaster Adaptation Actions among the Community in Malaysia

Pre-Flood Adaptation Actions

Non-structural measures, including flood forecasting, early warning systems, public awareness campaigns, and community training programs, are equally crucial in ensuring that people are well-prepared for potential flood events. Community-based initiatives, such as local emergency response plans and evacuation drills, also play a vital role in reducing the impact of flooding and increasing resilience at the grassroots level.

During-Flood Adaptation Actions

During a flood, communities in Malaysia adopt various adaptation actions to minimize the impact and ensure safety. These actions include immediate evacuation to designated safe zones, activation of emergency response teams, and the use of flood forecasting systems to monitor water levels and potential threats (Shazwani & Mohamad Sukeri, 2016). Emergency shelters equipped with basic necessities such as food, water, and medical supplies are established to support affected populations. Coordination among government agencies, NGOs, and local communities is critical to ensuring an effective and timely response. Communication channels, including radio, social media, and public announcements, are utilized to provide real-time updates and guidance to the public.

Post-Flood Adaptation Actions

Post-flood adaptation actions focus on recovery and rebuilding efforts include damage assessment, infrastructure repair, and community rehabilitation programs (Rosmadi et al., 2023). Financial aid and psychological support are also provided to help flood victims cope with losses and trauma. Government agencies work together with NGOs and community organizations to provide assistance and ensure that affected communities receive the necessary support. Additionally, efforts are made to improve flood preparedness by conducting awareness campaigns, revising flood management policies, and incorporating lessons learned from previous flood events into future planning and mitigation strategies. The findings advocate for a thorough reevaluation of Malaysia's disaster risk management strategy. Arahan No. 1 NADMA establishes a more cohesive governance framework and signifies an institutional advancement from the

previous NSC Directive No. 20; however, it must transcend centralization and operational hierarchy to adopt community empowerment, participatory planning, and local expertise.

Discussion

Flood management plays a critical role in reducing the devastating impacts of floods on human lives, properties, and ecosystems. Adaptive actions, such as collective actions, adaptation efforts, and social support, are essential to improving disaster preparedness, response, and recovery. These actions, when implemented effectively, can significantly enhance a community's resilience to flooding. The following table (Table 2.) discuss the various adaptive actions, their strengths, weaknesses, and relevant scholarly perspectives.

Table 2. The Effectiveness of Human-Based Adaptive Action

No.	Adaptive actions	Strengths	Weaknesses	Articles
	Collective actions from the flood management teams	During a flood disaster, cooperation across several authorities allows for the sharing of information and resources.	Potential complexity of multi-agency collaboration, which may lead to communication challenges and differing organizational goals, complicating the decision-making process during emergencies	(Nur Aishah et al., 2016)
	Collective actions from the flood management teams	Highlighted the importance of multi-agency collaboration in reducing potential losses and ensuring rapid recovery	Unwillingness to share information, lack of a common platform, and trust issues among stakeholders, which can hinder effective disaster response	(Noralfishah et al., 2019).
	Collective actions from the flood management teams	Government agencies collaborate with various departments such as the Fire & Rescue Department (BOMBA), Meteorological Department (MET Malaysia), and hospital department to provide a coordinated response. This collaboration ensures that all necessary resources and expertise are mobilized effectively	It highlights a significant limitation regarding the minimal involvement of flood risk communities in disaster preparedness and management, which is often overlooked by government agencies.	(Sandaran & Selvaraj, 2021)
	Collective actions from the flood management teams	Multiple collaboration between government agencies to provide emergency and rescue assistance, relief and support	NA	(Sarina Yusoff & Nur Hafizah Yusoff, 2022)
	Adaptation efforts	Focus on more comprehensive approach that includes both structural and non-structural measures is necessary. This includes better land use planning and the integration of advanced technologies	There is a risk of ignoring local leadership and expertise, which can lead to ineffective distribution of resources and missed opportunities for utilizing valuable local knowledge	(Chan, 2015)
	Collective actions from the flood management teams	Government agencies both at state and federal level, academia, private sectors, community and NGOs work together to raise awareness among communities about disaster preparedness and response. This empowerment is crucial for building community resilience	Underdeveloped communication systems and insufficient trained manpower, may hinder the effectiveness of multi-agency collaboration during disaster management	(Mohamad, 2019)
	Collective actions from the flood management teams	There is a recognized need for greater stakeholder participation, especially from NGOs and local communities, throughout the disaster management cycle. This includes building capacity for these groups to contribute effectively to DRR	Current top-down approaches often overlook local actors' needs and inputs, which leads to gaps in policy effectiveness Lack of awareness and	(Abid et al., 2024)

Adaptive actions	The use of SMART tunnel is to solve the problem of flash floods in Kuala Lumpur	NA	(Fitria & Amalia, 2018)
Social support	Social cohesion and community engagement are important for enhancing resilience and facilitating recovery from floods.	Social cohesion measures are based on individuals' perceptions, which can be influenced by their mental health status.	Greene et al., 2015)
Social support	Collective social support can buffer against the negative effects of flooding on mental health.	It may underestimate the role of interpersonal support, which could also play a significant role in individual recovery post-disaster	Masson et al., 2019)
Social support	Social support plays a crucial role in mental health outcomes, especially in the context of disasters	Social support might not be uniformly accessible to all community members	(Butler et al., 2018)
Social support	Outstanding performance of GOs and NGOs in disseminating information before disasters, which is a crucial component of social support	Improper relief distribution, often influenced by local political leaders and representatives, which undermines the effectiveness of social support systems.	(Hossain, 2020)
Adaptive actions	Structural measures control the river bank erosion and helps to restore the stability of banks	The requirement for ongoing maintenance and monitoring in order to guarantee long-term stability and prevent structural failures.	(Mohd Ekhwan & Haryati, 2007)

An essential element of successful disaster management is multi-agency cooperation in flood response and management. Multi-agency collaboration can improved coordination and resource allocation. According to Nur Aishah et al (2016), collaboration across multiple agencies enables the exchange of resources and information, which is essential during flood disaster. This partnership guarantees the effective delivery of resources, including food, water, medical supplies, and transportation, to impacted regions. In addition to that, a more thorough approach to disaster management is made possible by the integration of many agencies, which lowers the possibility of resource duplication and guarantees that all relevant needs and areas are addressed (Noralfishah et al., 2019). Sarina and Nur Hafizah (2022) emphasized that NADMA, in collaboration with the Special Malaysia Disaster Assistance and Rescue Team (SMART) and other agencies such as BOMBA, the Malaysia Armed Forces, the Royal Malaysia Police, and volunteers, provided assistance to the flood victims. In a study by Mohamad Fazli (2019) also stressed that numerous organizations have been actively involved in planning disaster management-related community initiatives, including National Disaster Management Agency (NADMA), the Universiti Teknologi Malaysia (UTM), the Malaysia Civil Defense Force and Malaysian Medical Relief Society (MERCY Malaysia).

However, a primary concern is the lack of a cohesive framework for information exchange among agencies, which prevents efficient communication and coordination in disaster management initiatives (Noralfishah et al., 2019). Furthermore, a deficiency of trust among stakeholders represent a significant obstacle to the establishment of robust networks for disaster management. In the absence of established trust, agencies frequently hesitate to disclose sensitive information, so constraining the overall efficacy of collaborative disaster response and mitigation methods (Noralfishah et al., 2019). Haziq et al. (2023) reported that the platform utilized by participants in the rescue effort was unsuitable. WhatsApp served as the principal communication medium, and the problem stemmed from unreliable internet connections, hindering the effective execution of rescue efforts.

On the basis of important findings from the cited research studies, this discussion emphasizes the significance of strong social support networks during disasters. Social cohesiveness and community engagement are essential for enhancing resilience and facilitating recovery in flood-affected regions (Greena et al., 2015). By acting as a protective element, collective social support lessens the negative impacts of floods on mental health. Its function in disaster recovery is crucial, markedly affecting individual mental health outcomes and broader community resilience (Masson et al., 2019). For example, many victims have been dealing with trauma, fear and depression after the flood. The Ministry of Health, in collaboration with other NGOs including MERCY Malaysia, has provided many initiatives pertaining to emotional support through

projects including Mental Health and Psychosocial Support Services (MHPSS), Psychological First Aid (PFA) and Child Friendly Spaces (CFS) which are crucial in assisting victims during their recovery (MERCY Malaysia Annual Report, 2021; MalayMail, 2021).

Nonetheless, according the study conducted by Butler et al (2018), social assistance is not uniformly available to all community members. Besides that, the efficacy of social assistance systems can be severely weakened by issues like unfair aid distribution, which is frequently affected by local political leaders and representatives (Hussain, 2020). A study conducted in Bangladesh found that political influence was the primary obstacle to receiving aid during the emergency phase after the 2017 floods (Hussain, 2020).

Effective flood risk management requires a more thorough strategy that incorporates both structural and non-structural elements (Chan, 2012). Better land use planning and the incorporation of cutting-edge technologies are required for this. In particular, structural interventions are essential for reducing riverbank erosion and reestablishing bank stability, highlighting the benefits of adaptive measures in flood risk management (Mohd Ekhwan, 2007; See Too et al, 2022). For example, in Batu Rakit, Terengganu, the floods have been found to have caused erosion along the coastal areas. In the meantime, since the majority of the locals engage in socioeconomic activities near the shore, the stone block fortifications at Teluk Lipat beach and Teluk Gadong beach are continuously monitored and added gradually (Sarina Yusoff & Nur Hafizah Yusoff, 2022).

The discussion makes it clear that human-based adaptive actions, like social support networks, adaptation plans, and agency-wide collaboration, are essential for boosting community resilience to flood disasters. Multi-agency collaboration guarantees the effective delivery of vital resources in times of emergency, improves coordination, and cuts down on redundancy. Robust social networks are crucial for facilitating psychological healing and cultivating a feeling of communal resilience in post-disaster situations. The integration of structural and non-structural solutions improves the adaptability of flood management systems, mitigating physical vulnerabilities and enhancing community readiness.

The findings contradict the effectiveness of top-down techniques, indicating that inadequate community engagement and ineffective communication channels hinder disaster response. Despite their advantages, social support networks are not always available and are frequently jeopardized by corruption and structural injustices. These observations highlight the connection between mental health and disaster recovery, the need of inclusive, locally informed policies, and the challenges of distributing relief fairly, thereby addressing important gaps in the body of existing research on disaster risk management.

The findings address key gaps by emphasizing the necessity for a comprehensive, people-oriented DRM strategy that integrates top-down policy coordination with local community involvement. They highlight the lack of community involvement, insufficient mental health assistance, and unequal resource allocation in contemporary disaster risk management techniques. These insights emphasize the sometimes neglected significance of local knowledge, social cohesiveness, and inclusive decision-making, in accordance with United Nations of Disaster Risk Reduction's (UNDRR) objective of fostering resilient communities against climate-induced disasters.

Conclusion

This study emphasizes the essential function of human-based adaptive actions, including community involvement, social assistance, and cooperative adaptation initiatives, in enhancing disaster preparedness, response, and recovery. These actions, which are based on local knowledge, social networks, and community responsibility, provide adaptable, economical, and culturally relevant alternatives to traditional top-down and technical methodologies. The results indicate that prioritizing people-centered interventions before, during, and after flood disasters significantly helps in fulfilling the goals of the SFDRR and Sustainable Development Goal (SDG) 11, which aims to create inclusive, safe, resilient, and sustainable cities and human settlements.

This study addresses an important research gap in Malaysian disaster risk literature, specifically the lack of sociological emphasis on floods and the humanitarian aspects of disaster management. It emphasizes the necessity of integrating community-driven adaptive methods into formal disaster risk management systems. Fostering local engagement, advancing infrastructure development via community cooperation, and guaranteeing access to timely and pertinent information are critical measures in establishing enduring

resilience. For disaster risk management to be effectively successful and sustainable, it must be built into both national and local governance frameworks and thoroughly integrated into disaster management education and school curriculum. Fostering knowledge and readiness from a young age will build a culture of resilience and enable future generations to respond to disasters proactively and effectively.

In summary, incorporating human-based adaptive measures into standard flood risk management provides an innovative approach to develop disaster resilience strategies that are more responsive, inclusive, and permanent. This methodology conforms to international norms and, crucially, prioritizes communities in disaster risk reduction initiatives where they rightfully belong.

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References

Abdullah, C (2021). Effectiveness of Malaysia's flood early warning system and public response. *Malaysian Journal of Civil Engineering, 33*(2), 45–58. https://www.researchgate.net/publication/354604854

Abid, S. K., Sulaiman, N., Al-Wathinani, A. M., & Goniewicz, K. (2024). Community-based flood mitigation in Malaysia: Enhancing public participation and policy effectiveness for sustainable resilience. *Journal of Global Health, 14*, 04290. https://doi.org/10.7189/jogh.14.04290

Akasah, Z. A., & Doraisamy, S. V. (2015). 2014 Malaysia flood: Impacts & factors contributing towards the restoration of damages. *Journal of Scientific Research and Development*, 2, 53–59.

Aksa, F. I., & Afrian, R. (2022). Community adaptation strategies toward tidal flood: A case study in Langsa,Indonesia. *Jàmbá: Journal of Disaster Risk Studies, 14*(1), a1258.
https://doi.org/10.4102/jamba.v14i1.1258

Arshah, R. A., Hammood, W. A., & Kamaludin, A. (2018). An integrated flood warning and response model for effective flood disaster mitigation management. *Advanced Science Letters*. https://doi.org/10.1166/ASL.2018.13024

Bhuiyan, T. R., Er, A. C., Muhamad, N., & Pereira, J. J. (2021). The socioeconomic impact of climate-related hazards: Flash flood impact assessment in Kuala Lumpur, Malaysia. *Natural Hazards, 109*(2), 1509–1538. https://doi.org/10.1007/s11069-021-04887-3

Butler, C., Walker-Springett, K., & Adger, W. N. (2018). Narratives of recovery after floods: Mental health, institutions, and intervention. *Social Science & Medicine, 216*, 67–73. https://doi.org/10.1016/j.socscimed.2018.09.024

Centre for Excellence in Disaster Management and Humanitarian Assistance. (2022). *Malaysia disaster management reference handbook*. https://reliefweb.int/report/malaysia/malaysia-disaster-management reference-handbook-october-2022

Chan, N. W. (2015). Impacts of disasters and disaster risk management in Malaysia: The case of floods. In D. P. Aldrich, S. Oum, & Y. Sawada (Eds.), *Resilience and recovery in Asian disasters.* (pp. 239–265).Springer. https://doi.org/10.1007/978-4-431-55022-8_12

Chan, N. W. (2018). Flood disaster management in Malaysia: An evaluation of the effectiveness of floodforecasting and warning system. *Journal of Environmental Management, 225*, 60–69.https://www.researchgate.net/publication/337697987

Delfiyanti, & Magdariza. (2021). Juridical review of disaster management policy in ASEAN and the correlationwith the domestic management system of disaster in Indonesia. *E3S Web of Conferences, 331*, 02015.

Department of Irrigation and Drainage (DID). (2020). *National Flood Forecasting and Warning System(NaFFWS)*. https://publicinfobanjir.water.gov.my

Department of Irrigation and Drainage Malaysia (DID). (2023). *Flood mitigation—Activities*. https://www.water.gov.my/index.php/pages/view/419?mid=244

Department of Statistics Malaysia. (2024). *Laporan Banjir Malaysia* [Newsletter].https://www.dosm.gov.my/index.php/portal-main/document_list/newsletter/

Fitria, C., & Amalia, F. (2018). Society perception toward flood prevention in Sentosa Klang Park Selangor,Malaysia. *Sumatra Journal of Disaster, Geography and Geography Education, 2*(2), 39–46. https://doi.org/10.24036/sjdgge.v2i2.164

Ghazali, A., Thiruchelvan, S., Muda, R. S., Mustapha, K. M., Kadir, A. K., Norkhairi, F. F., Yahya, N., Hakimie, H., Isa, A. A. M., Mamat, A. F., Hasini, H., Sahari, K. S. M., Muda, Z. C., Ng, Y. J. (2018). Development of community-based early warning system (CBEWS) in enhancing communitypreparedness for dam-related disasters in Malaysia. *ASM Science Journal, 11*(2), 117–123.

Greene, G., Paranjothy, S., & Palmer, S. R. (2015). Resilience and vulnerability to the psychological harm from flooding: The role of social cohesion. *American Journal of Public Health, 105*(9), 1792–1795.https://doi.org/10.2105/AJPH.2015.302709

Harshita, J. (2024). Leveraging geo-computational innovations for sustainable disaster management to enhanceflood resilience. *Discover Geoscience*. https://doi.org/10.1007/s44288-024-00042-0

Hossain, B. (2020). Role of organizations in preparedness and emergency response to flood disaster inBangladesh. *Geoenvironmental Disasters, 7*(1), 33. https://doi.org/10.1186/s40677-020-00167-7

IPCC. (2022). Pörtner, H.-O., Roberts, D. C., Poloczanska, E. S., Mintenbeck, K., Tignor, M., Alegría, A.,Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A. & Rama, B. Climate Change 2022: Impacts,Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. In Press.

Izumi, T., Matsuura, S., Motoyama, E., Razak, K. A., Supar, L. M., Sardi, M. F., & Kobayashi, S. (2022).Training of Trainers Guidebook for Planning and Implementing Community-Based Disaster RiskReduction Programs. Tohoku University, Universiti Teknologi Malaysia & Selangor Disaster Management Unit.

Izumi, T., Shaw, R., Djalante, R., Ishiwatari, M., & Komino, T. (2019). Disaster risk reduction and innovations. *Progress in Disaster Science, 2*, 100033. https://doi.org/10.1016/j.pdisas.2019.100033

Jaapar, A. R., Aripin, M. F. S., Komoo, I., Ali, C. E., Ramli, Z., Harun, A. R., Bachat, J., Mohamad, Z., Omar, C., Razak, K. A., & Lim, C. S. (2023). The emerging widespread debris flow disasters in tropical R. terrain of Peninsular Malaysia: Understanding the risk and policy intervention. *E3S Web of Conferences, 415*, 05008. https://doi.org/10.1051/e3sconf/202341505008

Khudri, H. B. M., Akma, S. N. N. S., Ruhaida, A., & Hisyam, K. K. (2024). Factors Contributing toParticipation in Community-led DRR Programmes in Malaysia. *Disaster Advances, 17*(8).

Lateh, H., Ahmad, J., & Mohamad, N. A. (2018). The prevalence of post-traumatic stress disorder amonglandslide victims. *Journal of Psychology and Clinical Psychiatry, 9*(2), 160–167. https://doi.org/10.15406/jpcpy.2018.09.00515

Madnor, M. S., Harun, A. N., & Che Ros, F. (2024). Integrating adaptation of climate change to strengthenMalaysia's disaster risk governance. *Environment and Social Psychology, 9*(4).https://doi.org/10.54517/esp.v9i4.2189

MalayMail. (2021). Experts: Flood Victims could be traumatised, in urgent need of mental, emotional support.https://www.malaymail.com/news/malaysia/2021/12/29/experts-flood-victims-could-be-traumatised-inurgent-need-of-mental-emotion/2031745?utm_source=chatgpt.com

Malaysia Flood 2024 - DREF Operational Update (MDRMY011). (2025). ReliefWeb.https://reliefweb.int/report/malaysia/malaysia-flood-2024-dref-operational-update-mdrmy011

Malaysia's 11th Plan (Rancangan Malaysia Ke-11), 2016–2020.Masson, T., Bamberg, S., Stricker, M., & Heidenreich, A. (2019). “We can help ourselves”: Does communityresilience buffer against the negative impact of flooding on mental health?. *Natural Hazards and EarthSystem Sciences, 19*(11), 2371–2384. https://doi.org/10.5194/nhess-19-2371-2019

Md Shariff, N. N., & Hamidi, Z. S. (2019). Community-based approach for a flood preparedness plan inMalaysia. *Journal of Disaster Risk Studies, 11*(1).

MERCY Malaysia. (2021). *Annual report: Recover better, together* (p. 80). https://mercy.org.my/resources/Muhamad, N., & Shaidin, H. A. (2022). Assessment flood events in Selangor, Malaysia. *Journal of AdvancedGeospatial Science & Technology, 2*(2).

National Disaster Management Agency. (2021). *National risk register*. Prime Minister's Department ofMalaysia.

National Disaster Management Agency. (2023). *Garis panduan pelaksanaan pengurusan risiko bencana berasaskan komuniti (CBDRM) di Malaysia*. https://www.nadma.gov.my/bm/penerbitan/nadma

National Disaster Management Agency. (2024). *Dasar pengurangan risiko bencana negara 2030*. https://www.nadma.gov.my/bm/penerbitan/nadma

Rahman, M. A., & Nahian, M. H. (2023). Integration of AHP method in flood risk mapping of Pabna using GISand multicriteria analysis. *Journal of Water and Flood Management–ICWFM*, 13(2), 77–90.

Raja Noor Afandi, R. N. A., Hussain, M. Y., & Muhamad Azian, F. U. (2023). Daya tahan komuniti terhadap bencana banjir di Mukim Dengkil, Sepang. *E-Bangi Journal of Social Science and Humanities, 20*(4).

Ridzuan, M. R., Razali, J. R., Soon Yew, J., & Abd Rahman, N. A. S. (2022). An analysis of Malaysian publicpolicy in disaster risk reduction: An endeavour of mitigating the impacts of flood in Malaysia.*International Journal of Academic Research in Business & Social Sciences*, 12(7), 2006–2021.https://doi.org/10.6007/IJARBSS/v12-i7/14247

Rosmadi, H. S., Ahmed, M. F., Mokhtar, M. B., & Lim, C. K. (2023). Reviewing challenges of flood riskmanagement in Malaysia. *Water, 15*(13), 2390. https://doi.org/10.3390/w15132390

Rustinsyah, R., Prasetyo, R. A., & Adib, M. (2021). Social capital for flood disaster management: Case study of flooding in a village of Bengawan Solo Riverbank, Tuban, East Java Province. *International Journal of Disaster Risk Reduction*, 52.

Sandaran, S. C., & Selvaraj, S. (2021). Government agencies and their discourses of flood disaster preparedness:Impact on response, action and community empowerment. *GEMA Online® Journal of Language Studies,21*(4), 294–313. https://doi.org/10.17576/gema-2021-2104-15

Sardi, M. F., Razak, K. A., & Bakri, R. Z. (2019). Assessing disaster risk and resilience: A case study in urbanflood vulnerable community in Kampung Asahan, Kuala Selangor. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-4/W16, 603–610. https://doi.org/10.5194/isprs-archives-XLII-4-W16-603-2019

See Too, K. L., Er, A. L., & Jaafar, M. (2022). Consequences of massive river bank erosion to the local societyat Pasir Parit, Kelantan. *E-Bangi: Journal of Social Sciences and Humanities, 19*(7).

Shafiai, S., & Khalid, M. S. (2016). Flood disaster management in Malaysia: A review of issues of flooddisaster relief during and post-disaster. *International Soft Science Conference*.https://doi.org/10.15405/epsbs.2016.08.24

Sulaiman, N., Seow, T. W., Fernando, T., WeiChan, S., Roslan, A. F., & Abdul Latib, S. K. K. (2019). Multiagency collaboration in flood disaster management in Sarawak, Malaysia. *International Journal ofInnovative Technology and Exploring Engineering (IJITEE)*, 8(8).

Tahmina, A., Keya, S., Sreeramanan, S. B., Siventhiran, S., Maheswaran, S., Selvan, S., ... Lokeshmaran, A. V.(2024). Flood susceptibility mapping for Kedah State, Malaysia: Geographics information system-based machine learning approach. *Medical Journal of Dr. D.Y. Patil Vidyapeeth*. https://doi.org/10.4103/mjdrdypu.mjdrdypu_985_23

Tamrin, M., Aziz, A., Samsudin, A. R., Sunardi, & Parnomo, A. H. (2024). Sistem Web-GIS untuk zonasi longsor di Lombok Utara menggunakan metode AHP. *Jurnal Pendidikan dan Teknologi (JPTI)*, *4*(12), 699–707.

The World Bank Group. (n.d.). Climatology. *In Climate change knowledge portal*. The World Bank. https://climateknowledgeportal.worldbank.org/country/malaysia

Toriman, M. E., & Che' Lah, H. (2007). Ciri hidrologi dan hakisan tebing sungai di Sungai Lendu, Alor Gajah Melaka. *Jurnal E-Bangi, 2*(2).

Wan Mohd Rani, W. N. M., Kamarudin, K. H., Razak, K. A., & Asmawi, Z. M. (2020). Climate change adaptation and disaster risk reduction in urban development plans for resilient cities. *IOP Conference*

Series: Earth and Environmental Science, 409(1), 012024. https://doi.org/10.1088/17551315/409/1/012024

Yahya, N. S., Lim, C. S., Jamaluddin, U. A., & Pereira, J. J. (2015). The December 2014 flood in Kelantan: A post-event perspective. *Warta Geologi, 41*(3–4).

Yusoff, S., & Yusoff, N. H. (2022). Disaster risk management through adaptive actions from human-based perspective: Case study of 2014 flood disaster. *Sustainability*, *14*(7405). https://doi.org/10.3390/su14127405

Zubir, S. N. A., Thiruchelvam, S., Mustapha, K. N., Che Muda, Z., Ghazali, A., Hakimie, H., Tukiman, I. (2016). Conceptualization of a collaborative decision making for flood disaster management. *IOP Conference Series: Earth and Environmental Science*, 32, 012031. https://doi.org/10.1088/1755 1315/32/1/01203