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ABSTRACT

The widespread increase in flood hazards and the ensuing impacts have guided a change in approach to flood risk management, especially in developed countries. Based on the realization that the integration of non-structural approaches to flood mitigation, understanding the social dimensions of flood risk is an important aspect is needful. Due to changing rainfall patterns and the increased frequency of storm surges in urban development, flooding has become a significant risk in Malaysia's Sarawak State. The most devastating flood event in Malaysian history was recorded in December January 2014,2015, which affected several properties worth millions of dollars and thousands of homes. Therefore, it is essential to address flood vulnerability by developing an integrated approach for modelling flood vulnerability to decrease the flood consequences. Many theories and frameworks present a solution, but no study theoretically develops a framework for flood vulnerable communities using a geographic information system (GIS) for disaster risk reduction in the Malaysian context. The focus of this study is to develop a novel framework for identifying the potential risks and assessing their effects on flood vulnerable communities, as well as to evaluate the role of GISs in risk assessment and overall performance improvement in Malaysian disaster risk reduction policies. To address this issue, we applied the new concept of geographic information capacity and capability, which is used to assess and quantify stakeholders' ability to comprehend, access, and engage with geographic data for disaster risk reduction. This is a conceptual paper; systematic and content analysis has been done for the literature review. For future study, there is a need to empirically verification of this theoretical framework. The proposed methodology to achieve this framework, quantitative research methodology will be employed. The questionnaire will be distributed among Malaysian disaster agencies and flood vulnerable communities from Sarawak. Data will be analyzed through Structural Equation Modelling (SEM) for vulnerability risk assessment and flood disaster mitigation. The theoretical contribution of this study is the support of the theory of flood disaster as underpinning theory.

CCS CONCEPTS

• **General and reference**; • **Document types**; • **General literature**;

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KEYWORDS

Flood vulnerability, Geographic Information System, disaster risk reduction, flood risk perception

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1 INTRODUCTION

Over the last three decades, flooding events worldwide have increased significantly in number and magnitude. However, compared to the 1980s and 1990s, the number of floods was reasonably constant, and the ratio of causalities per incident was minimal. Since 2000, the average fatality ratio has significantly decreased, but floods have increased manifolds [1]. Every year, around 196 million individuals from more than 90 different countries across the globe are exposed to flooding [2]. Countries present on the Asian continent like Malaysia, Bangladesh, Pakistan, India, Myanmar, Iran, Indonesia, and Afghanistan, with a collective population of more than 40 million people or more, are predictably more vulnerable to cataclysmic flooding and such kinds of natural disasters [3]. In the two-decade period between 1998 and 2018, Malaysia experienced 51 natural disasters, and the flood was the highest. It also concluded that Malaysia has endured total damage of US$2 billion due to emergency flooding [2].

The term vulnerability came into the spotlight during these decades [2]. However, there is no universally accepted definition of vulnerability since it is defined as per the purpose. Fernandez et al. [4] described the phenomenon of vulnerability to natural disasters as a characteristic of individual or group parameters. He tested their ability to cope, predict, recover, and resist the implications of any natural disaster. Interventions caused by anthropogenic reasons and climatic changes in land and other scales are the primary causes behind flooding patterns [5]. Urban growth, total and partial cover of torrent banks, improper bridges, erosion, deforestation, and misalignment in watercourses and their management are the few significant anthropogenic interventions [6]. In addition, improper construction of roads, structures, and fats across and upon natural watercourses, blocking their pathways and making the smooth flow of water complex, also add to troubles [7]. Elimination of these problems and potential disasters is not entirely possible. Still, disaster management, evaluation, and administration are possible and can be carried out with proper attention and required measures [8].

Thus, in an attempt to manage destruction caused by floods, vulnerabilities inspired by urbanization, and frequency and severity of both these actions – mapping and improvement in identifying flood hazards are only growing in prominence and are becoming crucial [9]. Therefore, mapping flood vulnerable communities and identifying their risk perception in urban settings can be considered an essential tool for regional planning, in general, and urban planning in particular for effective management [10]. Therefore, this study aspires to establish a vulnerability model by referring to multiple uncertainty theories and criteria evaluation levels. Age, health, gender, education, employment rate, income, and race influence vulnerability on an individual level [11]. On a communal level, population growth size, economic and urban infrastructure, and rate of urbanization are some of the few determining factors [12]. Unfortunately, since the phenomenon is multidimensional, no independent spectrum can measure the scale of flood vulnerability and assess flood communities' GIS and risk perception [13]. Despite this challenge, Jamshed et al. [14] have managed to put in place an approach to quantify it somehow. They apply measurable variables that indicate the degree of community vulnerability to climate change and environmental disasters and use factor analysis to identify factors that make different places more socially vulnerable to natural disasters.

2 LITERATURE REVIEW

2.1 Disaster Risk Reduction

Generally, disaster is comprehended as an artificial or natural hazard that grows or emerges from human and human-system interaction. United Nations International Strategy for Disaster Reduction in 2009 [15] defined disaster as disruption in the functioning of a social set-up or community, including material, economic, human, and environmental depredations, and impacts. Losses of such magnitude and proportion or resources lost cannot quickly be filled by that community or society [16].

A primary objective of disaster risk management is to minimize the adverse implications of disaster with the assistance and active use of modern technology, techniques, and innovations. Technologies such as GIS, and Early Warning Systems (EWS) can timely alert or call for timely evacuation in case of potential disaster [17]. Thus, their deployment can take me critically and most crucial in many cases. Other technological wonders, such as remote sensing gadgets and the global positioning system of GPS technology, are some of the few reliable, cheap, and efficient service providers and are used as monitors to mitigate environmental disasters. For example, the geographical information system creates a combination of sensing and hydrological data, and digital elevation models from several databases to delineate areas directly or indirectly affected by flooding. Bringing such technology will make positive changes in real-time and assess future predictions correctly and more accurately [18]. GIS analysis reports of regions vulnerable to flooding can provide correct estimates of potential floorings in the future and their approximate implications [19].

2.2 Flood Vulnerability

Evaluation of vulnerability is generally carried out by the degree of damage that natural elements endure [20]. It is also implied to refer to an exposed, weak community and still is made to live with natural or otherwise disasters [21]. As per Cova and Church [22], vulnerability estimates the tendency of an area, community, group, object, individual, or country of any entity facing the consequences of natural and man-made disasters. Therefore, it also varies from area to area, entity to entity, never categorized as ordinary or universal for this nature. Control over assets, the status of economic stability, and the opportunity for livelihood are factors that can determine and scale vulnerability from natural hazards and disasters successfully [23].

A considerable amount of literature on the dynamics of disaster vulnerability is available out there. Shrestha, Shah, and Karim [24] carried out considerable research where they explained the vulnerability caused by flash floods. He examined two major factors or reasons of vulnerability: Physical and social. Besides, Liu, Hsieh, and Liu [25] conducted another promising research on Asia's megacities and how these cities are vulnerable to flash floods and environmental disasters. They also look into vulnerability levels among slum dwellers since they are the most illiterate lot and, in many places, the most vulnerable ones as well. Those living in coastal areas, riverbanks, and garbage dumping sites were marked as most vulnerable to hazards. It was also concluded that this lot is vulnerable to flash floods and faces precarious food shortage conditions due to their low incomes and social class. The marginalization cost can only be bridged by democratizing information that can also assist in decent decision-making. This study wished to produce a flood vulnerability assessment framework that can assess the vulnerable communities, their flood risk perception, and the role of GIS in vulnerable communities in terms of capability and capacity building.

2.3 Geographic Information System (GIS)

A geographical Information System is a system that captures, integrates, shares, manages, stores, analyses, and displays data interlinked with GPS for providing geographic information and location [26]. It combines modern computer database technology with cartographic and geo-referenced information, which projects digital maps and databases that later connect with relevant applications in concerned areas [27]. Sites that require management of utility, resources, ecosystem, and environment, in addition to infrastructural planning, on the regional and municipal level. Both kinds of data connected via satellite and taken from integrated and socioeconomic data from tax records are essential for these purposes [28].

Maurya et al. [29] studied hydrology using GIS spatial technique for analysis. They concluded that significant damage to property in vegetation areas had caused considerable destruction in an urbanized area. Aboelghar et al. [30] used SPOT 4 satellite imagery with 20 m expected spatial resolution to explore the land in North Sinai. In addition to this, Chipman [31] preferred to use remote data from sensory technology for mapping flash floods. Hussain et al. [32] established parameters to measure rainfall and estimated hydrological variables in District Shangla. Clime extremes, including precipitation rate and potential temperature, were studied and predicted by Rincón, Khan, and Armenakis [33], using flood risk mapping by integrating GIS and multi-criteria Analysis. Finally, Kia et al. [34] examined the application of GIS multi-layer analysis to study flood simulation of the Johor River, Malaysia. Dano et al. [35] studied flood susceptibility mapping by integrating GIS and analytic processes in Perlis, Malaysia.

2.4 Flood Risk Perception

Developing countries are subject to multi-tier risks where each community and society faces different levels and scales of risk, depending on factors such as their social/political class, exposure, geographical location, and others. Risk perception or assessment is carried out by various groups, including policymakers, politicians, administrators, and managers at both local and government levels [36]. However, conflict arises in their collective perception when each group views a problem through the lens of their interests, experiences, and exposures [37]. This conflict poses a challenge for the final decision-maker, who must incorporate opinions, views, and ideas from all stakeholders, consider every risk perception, and assess individual or collective evaluations brought to the table before determining the best course of action [38].

To explore the complexity of risk perception, it is of utmost importance to clear out the dichotomy between basic knowledge and technical knowledge categorically [39]. Often, the conflict between different actors can provide an opportunity for understanding or comprehending underlying aspects related to risk management and disaster management in society, all together. Furthermore, how all stakeholders perceive risk and reach their independent conclusions tells a lot about the perception of vulnerable communities. Therefore, this entire exercise is necessary for sound decision-making [40].

2.5 Flood Vulnerability Assessment Using GIS

Developing communities face massive risks compared to developed communities of those in the developed world [41]. However, understanding their risk assessment can contribute to building an effective response to a natural disaster. Compression of risks that these communities face is pertinent for developing responses to potential hazards. UNISDR, in 2009, defined risk assessment as the method of exercise of determining the extent and nature of risk by evaluating hazards, existing vulnerabilities, and their potential on multiple levels, for a sound assessment of damages rendered to services, livelihood, people, and their property. Understating vulnerabilities that a specific community or area faces can aid in intelligent risk assessment [2]. Timely interventions and measures can then be planned accordingly. A comprehensive assessment plan can then be implemented with a vulnerability assessment following risk planning [42].

Aven [43] presented two vital components of practical risk assessment: an objective evaluation and one that is primarily based on public perception of risk. Since what may appear dangerous to some may not appear as problematic to others. Nirupama [44] also suggested considering the perception of all stakeholders, even people, for better risk and vulnerability assessment at the social and communal level, which can later be implemented. On the other hand, UNDP emphasizes analysing hazards, looking into vulnerabilities, their extent, and effects, and determining the exact degree of risk. It also went a step ahead and laid down seven-step procedures for reliable assessment of risks:

Step 1: Understanding of needs, causes, and gaps to identify those already existing risks, build an information capacity, and avoid wastage of resources by duplicating efforts. These efforts can be made by systemic evaluation and assessment of risks via available information, data, frameworks, and research abilities.

Step 2: Accurate assessment of disaster or hazard-stricken areas to evaluate the intensity, nature, likelihood, and location of the next potential disaster in a society or community.

Step 3: In an attempt to identify assets at risk and population endangered, an exposure assessment should be carried out. And also, to delineate those areas that are more vulnerable to a calamity.

Step 4: An analysis should be carried out to assess the degree of vulnerability or determine the capacity of elements able to withstand disasters.

Step 5: An analysis for estimating the impact or losses is to be carried out to look into the population, assets, livelihood, and property exposed to disaster.

Step 6: Risk evaluation and identification of cost-effective risk reduction techniques and available options are to be carried out next for a systemic reduction in risk.

Step 7: Revision of DRR techniques, plans, and strategies that involve prioritizing resource allocation and initiating programs like DRR will be the final step in the right direction.

3 THEORETICAL FOUNDATION

Conducting vulnerability assessment using GIS and integrating risk perception is contingent upon both empirical and conceptual investigation. At the same time, empirical research is itself dependent upon non-theory-based and theory-based research. However, theory-based research scope is significantly limited, and for the sake of this study, literature from 1992 to 2020 was reviewed thoroughly. It revealed that 267 studies out of 459 that were consulted were only theory-based or empirical studies. Furthermore, research covering integration, risk, and response relation was almost scarce or very few. Therefore, this study will engage the theory of flood disasters to examine the relationship between flood disasters and GIS and the perception of risk.

3.1 Theory of Flood Disaster

Flood disaster theory is required to enable a deeper understanding of the design of disaster risk reduction policies and generalizations to places with few or no studies and contribute to the developing fields of socio-hydrology and coupled social-ecological systems [45]. While there are several existing conceptual frameworks and putative theories for parts of the complex system, nothing is approaching what might be called a master theory. It is most likely that a master theory can be constructed from the emergent properties of flood disasters. Flood peak discharges, flood sediments, and flood damage and deaths are emergent properties and are fractal. The working hypothesis is that the fractal properties of flood peaks, injury, and fatalities result from the fractal nature of the drainage network that produces floods and the fractal nature of the precipitation that falls on the drainage networks. The hypothesis is sound, and vulnerability is not just a function of human decisions and actions [46]. Therefore, vulnerability and hazard are not independent, throwing into disarray the basis of much flood disaster analysis policy [47].

3.2 Conceptual Framework

Button and Eldridge [48] pointed towards research that views disaster management procedurally and not as an independent activity of responding to any disaster. It includes those processes that lead to the occurrence of that disaster. It can assist in gauging correct responses for vulnerabilities identified in the process and significantly reduce their risk. The study by Tang and Feng [49] supported this processual approach and added to this debate that risk perception can also be an intervening variable. It can have implications for the management of disasters and analysis of vulnerabilities [50]. Thus, it is essential to explore environmental disasters to investigate their root cause and factors that inspire them, and their implications on vulnerable communities [51]. This also calls for characteristics that lead to the frequency of environmental hazards on broader levels. For instance, flash floods that occur in urban areas of Jeddah City make these areas most vulnerable to that hazard [52]. Khan et al. [53] focused on the eminence of identifying the core causes of these vulnerabilities which can range from political, economic, environmental, and social factors – depending on the society, community, and area in question.

A study by Tomaszewski [54] addresses that the GIS is a powerful tool that improves disaster response and disaster recovery activities. Another study by Tomaszewski et al. [55] concluded that GIS continues to gain substantial recognition from disaster practitioners and academic researchers during what is debatably the most publicly visible disaster management stage. A similar study by Kamran Abid et al. [2], and Phengsuwan et al. [56] highlighted the importance of geographic GIS in disaster risk reduction. It now the requirement of common data sharing, and coordination between various administrations to mitigate the impact of disaster by integrating geospatial specialties.

Thus, this study examines the relationship between flood vulnerable communities, GIS, flood risk perception, and disaster risk reduction in the Malaysian context.

H1: There is a positive relationship between flood vulnerable communities and disaster risk reduction

H2: There is a positive relationship between GIS and disaster risk reduction

H3: There is a positive relationship between flood vulnerable communities and flood risk perception

H4: There is a positive relationship between GIS and flood risk perception

H5: Flood risk perception mediates the relationship between flood vulnerable communities, GIS and disaster risk reduction

The ever-evolving and complex dynamics of risk and perception of the risk as the decisive contributor to disasters have heightened the urgency to pursue practical flood vulnerability assessment as a prerequisite to inform the disaster planning and disaster risk reduction processes. A structured and systematic approach to disaster risk assessment assists in maintaining rigor, thus promoting the quality and validity of the process and its outcomes. Appropriate models and skills of the GIS serve as valuable tools in enabling this methodological perspective to undertake a disaster risk assessment. The non-existence of a proper flood vulnerability risk assessment framework (FVRAF) and disaster risk reduction practices in Kuching, Sarawak, Malaysia, has initiated the emphasis and purpose of

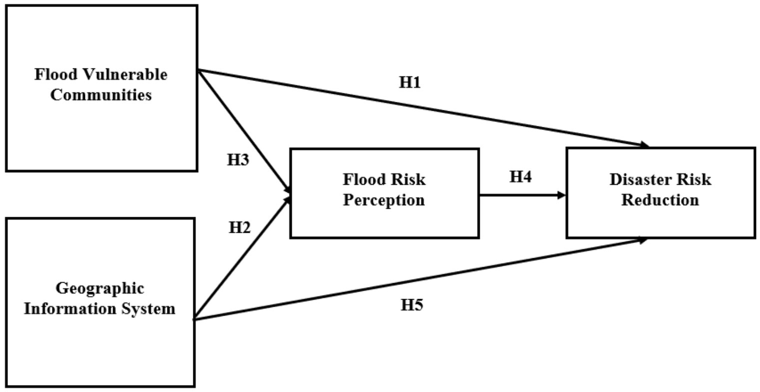

Figure 1: Conceptual Framework

this study. Therefore, emphasizing the critical need to develop a practical, holistic framework for the local government in Figure 1.

4 CONCLUSION

Significant developments related to analyzing, detecting, and monitoring the casting of weather, climate, and water-related disasters have been made over the last few decades, consequently reducing threats, and preventing severe disasters in many areas. For instance, while the number of disasters or environmental hazards has increased globally, the fatality rate or causality ratio resulting from these disasters and the damage they cause have remained majorly low or have only decreased. Although the credit for such a drastic reduction in causalities goes to several factors, monitoring and detection of disasters have played a significant role in the entire procedure. End-to-end warning systems that alter relevant authorities timely have been at the core of these efforts.

The process of decision-making in the entire activity of disaster risk reduction can be categorized into the identification of risk, reduction in risk, and transfer of risk. The identification framework includes the development of strategies and knowledgeable measures that can deal with the threat. Risk reduction included preparedness of response, relief, and recovery systems. While transferring risk was about community risk-sharing mechanisms that would minimize the implication of disaster on all levels. Haiti's earth quacks and the use of DRR technology in predicting the calamity timely, along with preparing for response and recovery, reflect the future. With the help of satellite images, a recovery plan for the Haiti earthquake was put in place. That was crucial in the mobilization of resources. Agencies and volunteer groups are in the right direction at the right time. GIS will be at the core of this new revolution in risk assessment and prediction in developing countries worldwide since they are most vulnerable to natural environmental disasters.

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