INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN BUSINESS & SOCIAL SCIENCES

Vol 14, Issue 7, (2024) E-ISSN: 2222-6990

An Analysis of Malaysia's Flood Vulnerability Study Using the Geographical Information System Technique

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To Link this Article: http://dx.doi.org/10.6007/IJARBSS/v14-i7/21831 DOI:10.6007/IJARBSS/v14-i7/21831

Published Date: 07 July 2024

Abstract

Floods are a natural disaster phenomenon in most parts of the world. Floods, like Malaysia, are frequent natural disasters in most parts of the world. This natural disaster related to weather in Malaysia has two major types (i) flash flood and (ii) monsoon flood. The monsoon rains also caused flooding in other parts of Malaysia e.g. in Johor, Terengganu, Kelantan, Sabah, and Sarawak, forcing hundreds to evacuate. Floods hit the state of Pahang every year, causing significant loss to the socio-economic of vulnerable stakeholders living in flood-prone areas. This study conducts a systematic literature review on vulnerability towards flood events and the use of GIS applications by previous researchers for flood mapping from 2009 to 2019. Two main concepts were applied during the literature search and review phase to explore the dimension of vulnerability and to analyse the GIS technique in flood studies of Pahang State. To date, there are only six studies related to the preferred criteria of this review. Vulnerability studies done in the past ten years focused on the dimension of socio-economic rather than the geophysical dimension. Only two studies applied GIS techniques for flood vulnerability mapping in Pahang. Thus, to create a local vulnerability map, the socioeconomic vulnerability assessment findings are integrated with the flood area's geographic data, which are essential and motivation for further study. It has a guideline for policymakers to prepare and manage natural disasters, especially in the flood-prone area.

Keywords: Flood, Vulnerability, Geographical Information System (GIS), Pahang, Malaysia

Introduction

Flood Disaster in the World

The losses from floods globally are increasing due to several factors, including changes in climate patterns as well as the growing populations and development activities in flood-prone areas (Ashley, 2005; Muis, 2015). According to The United Nations (UN), floods have caused

47% of all weather-related disasters in the world, affecting almost 2.3 billion people, and it includes 157,000 fatalities from 1995–2015 along with the high occurrences in Asian countries, including Malaysia (Wahlstrom 2015). Due to its magnitude and scale in Malaysia's 189 river basins, including the Peninsular, Sabah and Sarawak (Figure 1), flood is the most important natural disaster in Malaysia (Hussaini, 2017). Moreover, the impact of floods on the socio-economic condition of Malaysia is also significant. Flooding has a severe effect on 9% land of the country (i.e., 29720 km2) and 21% population (i.e., 4.915 million) that cost around RM915 million a year with the additional economic sequential cost of RM1.83 billion (Department of Irrigation and Drainage, 2009). According to Department of Irrigation and Drainage, there were several major floods in the history of Malaysia such as the flood incidences of 1886, 1926, 1931, 1947, 1954, 1957, 1963, 1965, 1967, 1969, 1971, 1973, 1979, 1983, 1988, 1993, 1998, 2001, 2003, 2004, 2006 and 2007 (DID 2009). Therefore, the incidences of floods in Malaysia are not a recent phenomenon; instead, there was historical evidence of floods (BEM 2004 & DID 2009). Nevertheless, the intensity and frequency of flooding in Malaysia have increased considerably due to changes in climate and

Figure 1. Map of Malaysia (UoTA 2020)

rainfall patterns (Abd Majid et al., 2019). Since the widely discussed phenomenon of climate change at the global level, it has opened a new perspective vulnerability mainly related to the rural population. This phenomenon refers to global climate change that directly and indirectly impacts humans and ecosystems. A scientific report published by the Malaysia Meteorological Department (MMD) predicts significant annual changes in rainfall and temperature for Peninsular Malaysia over the years 2020-2029, 2050-2059 and 2090-2099. According to the report, the yearly average temperature and precipitation in some areas of Peninsular Malaysia, namely northwest, northeast and central west coast, are predicted (Table 1).

Table 1
Forecast for rainfall and temperature (annual average) in the northwest, northeast and central west coast for the period 2020-2029, 2050-2059 and 2090-2099

Period	Average annual rainfall	Average annual temperature
2020-2029	-13.4	+1.3
2050-2059	+2.7	+1.9
2090-2099	+10.3	+3.1

Note: Rain is in% change and the temperature are in change ^{o}C.
Source: Malaysia Meteorology Department, 2009

Statistically, it indicates that rainfall increases over more than 70 years will increase with average annual temperatures. Climate change can affect crop production and disrupt human activities to meet daily needs. These incidents have also led to declines in agricultural products such as rice, affecting soil fertility levels, spreading disease and pesticides (Siwar et al., 2009). An empirical study (Abulquasem 2010) found that rice production declined between 4.6% and 6.1% as a result of an increase of 1^{o}C temperature at the current carbon dioxide (CO2) concentration level. This phenomenon is expecting to reduce national rice production productivity by 34.8% per hectare by 2060.1.2. Monsoon Flood in Malaysia

Malaysia is extremely vulnerable to flooding due to its geographical location in the equator and the weather (Ainullotfi et al., 2014; Islam, 2016). It has experienced floods since 1886, according to existing records (IPCC 2014). Generally, two types of significant floods, i.e., the monsoon flood and the flash flood, are observed in Malaysia. The monsoon flood is the seasonal flood as it occurs annually during the monsoon seasons (Kamarulzaman et al., 2015). In Malaysia, two monsoons are found i.e. northeast monsoon from November to March and southwest monsoon from May to September (MMD 2020). The monsoon winds specifically the stronger northeast monsoon, bring heavy rains to the states of the east coast in the Peninsular Malaysia, the northern part of Sabah and Southern part of Sarawak (Ainullotfi et al., 2014). Monsoon flood is the result of intense monsoon rainfall which ranges between 2000 to 3000 mm annually and produces a higher amount of run-off to exceed the absorptive capability of the natural drainage system (Toriman et al., 2009). The low land area that is not able to accommodate the overflow of river water will have a higher probability of flooding and the flooding situations are worsened due to the rising sea level. According to Malaysia's Department of Irrigation and Drainage, the responsible agency of flood management, around 29,000 km^2 of land area along with the residents of low-lying areas, especially close to riverbanks, being the most susceptible to flash floods (Department of Irrigation and Drainage 2016; Toriman et al., 2009). The local community suffered from severe damage as their settlements were flooded, traffic flow was blocked, agricultural productions were ruined, and lives were lost in extreme cases (The Straits Times 2018). Over 4.82 million people or 22% of the total population are affected by floods annually in Malaysia.

Additionally, about 90% of injuries caused by flood-related disasters in Malaysia cost around an average of USD100 million every year (Pradhan, 2010). However, the worst flood event in this country ever recorded was between December 2014 and January 2015. The total damage caused by this flood cost up to RM1 billion to repair the infrastructure, facilities, plantations, property and such. The Malaysian government must spend large sums of its annual budget for possible floods. Under the Malaysia Five Year Plan for the development

sector, the allocation for the design and construction of flood mitigation projects was RM18.93 billion in First Malaysia Plan, 1966-1970 (Malaysia, 1966), RM40.56 million in Second Malaysia Plan, 1971-1975 Malaysia (1971), RM135.21 in Third Malaysia Plan, 1976-1980 Malaysia (1976), RM270.42 million in Fourth Malaysia Plan, 1981-1985 (Malaysia, 1981), RM405.63 million in Fifth Malaysia Plan, 1986-1990 (Malaysia, 1986), RM 946.46 million in Sixth Malaysia Plan, 1991 -1995 Malaysia (1991), RM 12709.60 million in Seventh Malaysia Plan, 1996-2000 (Malaysia, 1996), RM1646.56 million in Eighth Malaysia Plan, 2001-2005 (Malaysia, 2001) RM5.18 billion in Ninth Malaysia Plan 2006-2010 (Malaysia, 2006) RM4.85 billion in Tenth Malaysia Plan, 2011-2015 Malaysia (2011) and RM 2 million in Mid-Term Review Eleventh Malaysia Plan, 2016-2020 (Malaysia, 2016). This shows that the program has always been an agenda in implementing development initiatives in response to state and global challenges especially in flood disasters.

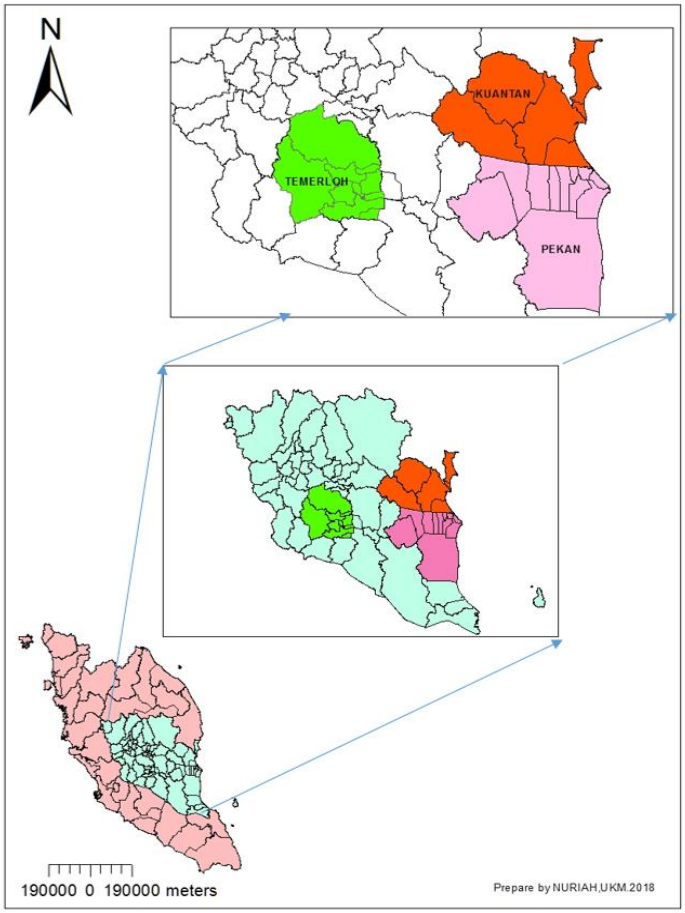

Figure 2. Map of Pahang State in Peninsular Malaysia

Annual Flooding in the state of Pahang, Malaysia

The state of Pahang, located along the eastern coast of Peninsular Malaysia, is one of the worst flood-prone areas in Malaysia (Figure 2). In Peninsular Malaysia's eastern region, the Pahang River basin is situated between latitudes N 2° 48' 45" and N 3° 40' 24" and longitudes E 101° 16' 31" and E 103° 29' 34". The catchment's maximum length and width are 205 km and 236 km, respectively. The Pahang River Basin in the largest catchment area in the Pahang state and the annual flood incidents severely affecting the residents as well as their economic activities, specifically those who are residing in Pekan up to Temerloh district. However, the

Kuantan district, adjacent to the Pahang river basin and the capital city of Pahang State, has separated the Pahang river basin and it's located close to the South China Sea (Figure 3) (Siwar et al., 2017; Reza et al., 2017).

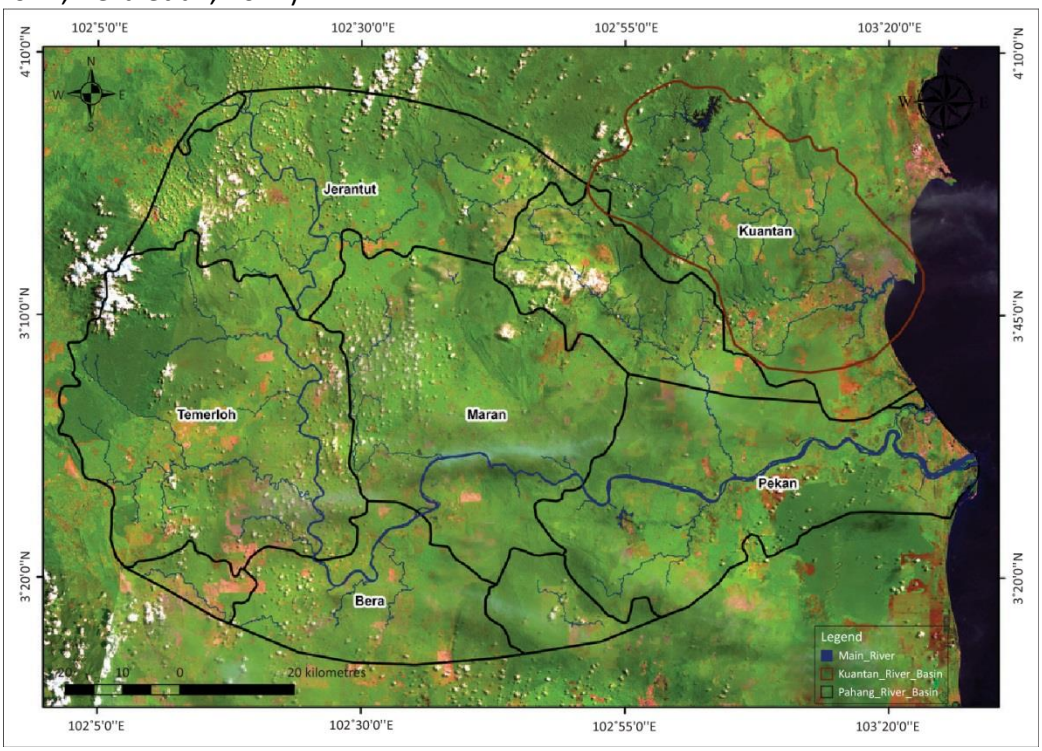

Figure 3. Pahang river basin (Isahak et al., 2018)

During the flood incidents at the end of 2014 in Pahang, it was recorded that a total of 116 villages had been flooded and it was affecting approximately 80,000 people who were living in the district of Pekan, Kuantan and Temerloh (The Star, 2015). Unalarmed communities residing in these flood-prone districts are not prepared to withstand the sudden shock generating from the considerable floods and ultimately, the number of vulnerable groups are increasing among the communities of those areas (Idrus et al., 2014). Loss of assets and mortalities made it hard for the communities to reconstruct their livelihood following a disaster (Ahmed et al., 2018).

Flood, Society, and Vulnerability

Flood is categorized as one of the vulnerability forms for the communities (UNISDR, 2009). In the case of floods, the vulnerability can be categorized in two dimensions: (i) the geophysical perspective which depends on the characteristics of the hazard and the physical landscape over which it occurs, and (ii) the socio-economic perspective which is a function of institutional and socio-economic characteristics (Hamblen, 2006). Vulnerability is a situation determined by factors such as physical, social, economic, and environmental processes that increase the tendency for a community towards disaster impact (Ho, 2009; Moher, 2009). These components can be assessed by different indicators to understand the vulnerability of the flood impacts. Thus, assessment of vulnerability is defined to measure the degree of loss to a given element at risk or set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss).

Vulnerability Mapping using GIS

Vulnerability mapping using GIS (Geospatial Information System) is a new approach to assess the disaster risk of an area. Different aspects of vulnerability have been evaluated globally. However, there are only a few studies on flood vulnerability mapping. The Geospatial Information System (GIS) datasets have been introduced a few decades ago and widely used for variables and analyses to put on the map (Moher, 2009). Therefore, this study provides an overview of vulnerability analysis studies done within the scope of GIS techniques applied by previous researches in the flood-prone areas in Pahang state.

2. Methodology

A systematic literature review was performed to identify current research on the application of GIS within the scope of vulnerability towards flood disaster in Malaysia and to analyze these studies with regards to the vulnerability indices, types of GIS analysis conducted, data source, and the study area. This review focused on defining clear and specific research questions as follows:

- Research question 1 (RQ1): Which vulnerability component towards flooding was studied in Pahang State?
- Research question 2 (RQ2): What analyses have been done using GIS technique for the vulnerability studies in Pahang?

Thus, the two basic concepts of vulnerability and GIS analysis are connected in this review. The overall method consists of a literature search, data screening, information extraction, and synthesis, which are further described as follows.

Literature Search

Literature searches were conducted across 13 electronic databases (Table 2) with full access to articles. Additional relevant works from other sources were also considered by gathering scientific newsletters, theses and dissertations on this subject. Therefore, the other 3 databases were included in this search. The following criteria were applied to search the literature. (1)The search date for references only includes articles published from January 2009 to July 2019. (2) The articles published only in English or Malay language were selected for review due to practical reasons. This resulted in the identification of 2,513 digital sources (Table 2). All the selected studies were stored and managed using the Mendeley Reference Management Software (Mendeley, 2019)

Table 2
Electronic databases used during the review process.

SOURCE	URL	DATE OF SEARCH	SEARCH RESULT
MyCite	http://www.mycite.my/	14 June 2019	137
MDPI	https://www.mdpi.com/	14 June 2019	23
DOAJ	https://doaj.org/	14 June 2019	138
NDLTD Global ETD Search	http://search.ndltd.org/	14 June 2019	4
BASE	https://www.base-search.net/	2 July 2019	484

UKM Journal Article Repository	http://journalarticle.ukm.my/	2 July 2019	205
Cambridge Journal Online	https://www.cambridge.org/core/	2 July 2019	88
Elsevier	https://www.elsevier.com/en-xs	2 July 2019	1,112
Springer	https://www.springer.com/gp	2 July 2019	11
ScienceDirect	https://www.sciencedirect.com/	2 July 2019	67
Pure UKM Expert	https://www.ukm.my/portal/ukm-experts/	2 July 2019	15
Oxford Journals	http://www.oxfordjournals.org/%20%20	2 July 2019	43
IEEE Xplore Digital Library	https://ieeexplore.ieee.org/Xplore/home.jsp	2 July 2019	18
Environmental Research Letters	https://iopscience.iop.org/journal/1748-9326	14 June 2019	145
Open Access Theses and Dissertations	https://oatd.org/	14 June 2019	21
UM Students Repository	http://studentsrepo.um.edu.my/	14 June 2019	2

Query Terms

Search strings for each database include the terms 'flood', 'vulnerability', 'GIS' and 'Pahang' with an intention to link the basic concepts of vulnerability and GIS. Different search string combinations were used for each electronic database with the aim of increasing the query's sensitivity and specificity. Synonyms, various spelling forms of the keywords in both English and Malay language were also included.

Data Screening

Duplicate search results of preferred databases were removed. All references identified in electronic databases were screened by applying guidelines of 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses' (PRISMA) (Shariff et al., 2019). Reference lists of these eligible studies were manually checked to ensure no potentially relevant articles were missed.

Data Extraction and Analysis

As the purpose of this study is to identify the vulnerability towards flood events and the use of GIS application by previous researchers for flood mapping from the year 2009 to 2019, the full-text manuscripts were then reviewed to find three types of information which are flood disaster in Pahang, types of vulnerabilities towards flood and the use of spatial technologies during applied period. Bibliographic information that includes the year of publication, study design, and use of methods, study duration and results gained was extracted from selected full-text literature and arranged in table form (Table 3). After that, selected full-text manuscripts were analyzed to answer research questions and discussed in the subsequent section.

Table 3
Studies on vulnerability towards flood done in Pahang between years 2009-2019

Author	Year Published	Methods	Area of study	Study Duration	Result
Ho	2009	Flood risk assessment model (GIS)	Seberang Perai, Penang Kuantan-Pekan coast	2009-2200	Climate change and anthropogenic activities increase the risk of coastal flood in the long term within the coastal zone. "Flood insurance" strategy could effectively reduce coastal flood risk at both study locations.
Shariff, & Hamidi	2019	Qualitative analysis (Field interview)	Machang, Kelantan Kuala Lipis, Pahang	2016	Flood preparedness plan that is based on community-based approach determined by (1) flood frequency; (2) flood severity; (3) population understanding of flood danger, knowledge and experience that translates into desire or cooperative activity; and (4) social unit groups, village preparedness program. Such preparedness activities are (1) to identify main players in delivering emergency relief and (2) to map out the villages ' advantages and disadvantages.
Mustaffa	2014	Quantitative analysis (Questionnaire)	Pahang Terengganu	2014	Flood survivors who accepted the help they got will also affect their well-being. This research has established the aspect that influences well-being among Malaysian flood victims, such as social support and handling impression.
Nor Diana et al.	2019	Livelihood Vulnerability Index	Pekan & Temerloh, Pahang	2007-2014	The LVI-IPCC as alternative methods for determining the relative sensitivity of the population to the impacts of climate fluctuations indicates that the Pahang River Basin is most susceptible to climate change due to the high intensity and relatively low degree of environmental adaptability in Temerloh compared to the most resilient Pekan District with the most economical financial support during flooding This work has described the dimension that affects welfare among Malaysian flood victims, such as social support and experience management.
Isahak et al.	2018	Flood disaster risk map	Temerloh, Kuantan &Pekan, Pahang	2014	The methods shown in this analysis may be used as a decision-making device to identify areas requiring shelter

					centres. The approach used to determine shelter centers can be used to evaluate potential locations or infrastructures for the selection and naming of existing shelter centres.
Weng	2011	Literature review	Malaysia	2009	This paper argues that a mix of natural and human causes in Malaysia has led to the elevated flood hazards. This also means flood risk, pollution and insecurity in Malaysia are all rising. Greater exposure and vulnerability will result in higher potential for damage and flood hazard intensification.

Results

A systematic search of 13 electronic databases identified 3,488 records, and another 3 additional databases consisting of a scientific newsletter, theses and dissertations also identified another 237 records of relevant work. A total of 2,718 records were screened after its duplicates were removed. Full texts of the remaining 2,513 records were retrieved and assessed in detail after excluding 26 records. Another 2 records were also excluded from further review due to their inadequacy to provide the study duration according to this study range (Figure 4).

A total of 6 studies met the preferred criteria. 5 quantitative studies, which include one thesis dissertation, were conducted. One qualitative research performed field interviews and systematic review.

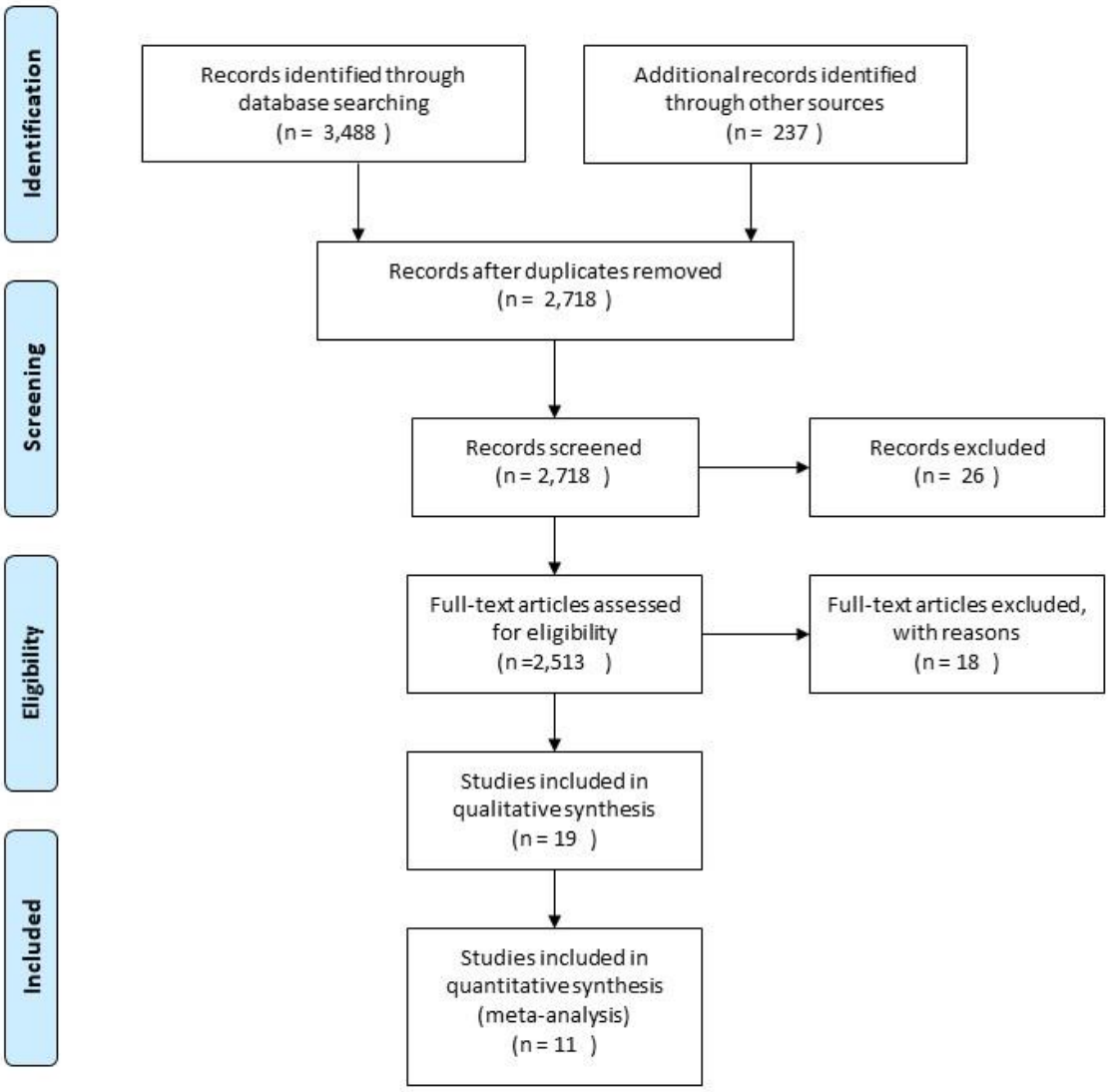

Figure 4. Literature searches based on PRISMA guidelines (Moher et al., 2009)

To answer the research questions proposed in this study, 6 studies were analyzed thoroughly. It is found that only one study related to this review's preferred criteria was published in the years 2009, 2011, 2014 and 2018, respectively. Recently, another 2 relevant articles were published in the year 2019 (Table 3). Other study areas at the east coastline such as the states of Kelantan and Terengganu and another one in Penang Island were also covered by previous researchers for compare purposes (Mustaffa et al., 2014; Weng, 2011). The analysis of all the 6 studies provides answers to RQ1 (Table 4) about the vulnerability component towards flooding. Vulnerability studies in the context of social and communities towards floods were commonly used by previous researchers (Siwar et al., 2017; Reza et al., 2017; Mustaffa et al., 2014; Ho, 2009; Weng, 2011). However, only one study of vulnerability that covers geographic and economic components focused on Malaysia coastline as mentioned by Nor Diana et al. (2021). On the other hand, it is found that only 2 reviews related to flood vulnerability mapping using GIS technique which addressed the RQ2 (Siwar et al., 2017; Mustaffa et al., 2014).

Table 4
Studies scored research questions.

Reference ID	RQ1	RQ2
Ho	Flood vulnerability (coastal flood)	Flood risk assessment model
Shariff, & Hamidi	Social vulnerability	Not applicable
Mustaffa et al.	Social vulnerability	Not applicable
Nor Diana et al.	Social vulnerability	Not applicable
Isahak et al.	Social vulnerability	Flood disaster risk map
Weng	Social vulnerability	Not applicable

Discussion

The purpose of this review is to identify studies on the vulnerability of flood disaster events and to focus on the application of GIS techniques in those specific studies to map the vulnerability findings. Only six studies out of 2,513 references for the results, during this systematic literature search within 16 electronic databases, are dealing with such topics. The limitations in geographic regions of the selected studies also seem to be the consequences. Overall, the number of studies on this topic has been increasing since the year 2009 to 2019. Focusing on the social aspect of risk in the studied research suggests that the susceptibility to flooding is higher in persons primarily associated with socio-economic and health variables (Lowe, 2013).

Vulnerability assessment in flood-prone areas in Pahang State was focused on the river basin where it accommodates many populations at the low land area. Flood victims in Pahang experienced the loss of property, damage of plantation, destruction of livestock and such. Pahang is the largest state in Peninsular Malaysia and the strategic location for shipping and trading at the port, rapid development to cater to the economic bloom at Pahang seems to be severely affected by the frequent flood events in the coming years. This situation will develop more vulnerable communities that reside in the Pahang River basin because of their exposure to monsoon floods. Continuous heavy rainfall for several days can result in floods in low-lying areas and flood-prone areas. If heavy rainfall coincides with high tide, the risk of flooding may be worse. In addition, continuous northeasterly winds can cause turbulent seas and bear waves in the South China Sea. This could has caused more severe flooding in the East Coast area than any other state in Peninsular Malaysia. The unsustainable urbanization which involves land clearing at the higher land area also increased the flood impacts at these areas.

The review of literature on flooding has also recognized the importance of incorporating institutional and socio-economic factors in determining the vulnerability to flooding, as well as applying GIS to the mapping of flood vulnerability. Most of the results show that researchers are more interested in the qualitative approach to study the community response and preparedness during flooding rather than spatial research on flood disasters.

However, the impacts of the flood can be mitigated by identifying social groups vulnerable to flooding and by assisting them through preparedness and emergency planning processes. Thus, preparation requires detailed information at a local scale that can help local government to develop specific and differentiated mitigation plans.

Conclusions

This study presents a systematic literature review regarding vulnerability studies on the flood with a focus on GIS analysis application in Pahang State, Malaysia. The analysis of most of the full texts provides flood management approaches which aimed to lower the vulnerability within communities living in the flood-prone areas.

Intense rainfall might be the main factor that causes flooding. However, it is undeniable that anthropogenic influences are the catalyst towards severe annual flood events in Pahang State. Rapid urbanization in recent years leads to land use degradation, ignoring the protective strategy to save natural resources from overexploitation and as such, will increase the impacts of climate change (Zaidi et al., 2014). The risk of flooding will always be there no matter how many precautions had been taken. The best step to act prior to flooding and during the disaster is to lower the risk of flooding to minimize the damage. A strong foundation of the flood knowledge process could facilitate good interaction between management and stakeholders. Proper river restoration and upgrade to a better drainage system for the efficient flow of suddenly increased amount of surface runoff during intense rainfall might prevent flooding.

A wide range of GIS technique applications has been used by researchers to produce flood maps. However, the vulnerability towards flooding is geographically and socially different. Thus, it's essential to understand better the vulnerability of populations and properties when a geophysical disaster event occurs. The study of vulnerability mapping is essential to provide information on the degree of social and economic disorganization that may take place after the occurrence of a natural disaster. Thus, results from the vulnerability assessment are combined with geographic information of the flood areas to produce the vulnerability map at a local scale.

Conflicts of Interest

The authors declare no conflict of interest

Acknowledgment

This work was supported by Universiti Kebangsaan Malaysia (grant number DPP-2018-008). Authors gratefully and appreciated to the Prof Emeritus Mohd. Raihan Taha for his support and guidance for this project.

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