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Flood disaster in Malaysia: approach review, causes and application of geographic information system (GIS) for Mapping of flood risk area

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ABSTRACT

The study conducted through the method of approach review is to identify the dominant causes affecting the occurrence of floods in Malaysia. In addition, this approach review focuses on the importance and effectiveness of the Geographic Information System (GIS) in flood studies in Malaysia. An approach review study was conducted by screening and analyzing research on flood risk mapping using GIS technique done in Malaysia. The findings show that the floods occurring in Malaysia over the last few years have clearly shown that the risk of flooding has worsened. The flood risk levels from year to year are parallel with human-modified environmental changes. Hence the combination of natural factors such as heavy rain and anthropogenic factors have resulted in extreme flood events.This research adds to the body of knowledge about integration of GIS application with factors studies on flooding, based on what previous research has found in that field. This is important to improve the field of GIS spatial analysis as a tool in flood mitigation in Malaysia. This review records on studies in flood risk mapping derived from GIS application by previous researchers in Malaysia and identified gaps that could give a different perspective in flood risk mitigation study in the future.

Key words : *Disaster, Floods, Malaysia, Geographic Information System (GIS)*

Introduction

Natural disasters such as floods are common in Malaysia. Flooding is an annual event in Malaysia. The east coast and the western part in Peninsular Malaysia are the flood-prone areas (Figure 1). Meanwhile, the flood-prone areas in Sabah are in the east and north and in Sarawak, the flood-prone areas are east and west. Floods in Malaysia have caused a lot of loss of lives, infrastructure destruction and loss to the country. The flood occurs due to several factors such as climatology, hydrology and anthropogenic causes. Floods are associated with severe rainfall events and annual rainfall (Tekolla, 2010; Elfithri *et al.*, 2011; Ibrahim *et al.*, 2014). When there is an increase in water level and discharge in river drainage then water will flow out until it lowers the low surrounding area found in valley water. Despite its recurrent nature, the research on flood in Malaysia has been very limited.

Floods were caused by three factors namely local heavy rain, water level rise and waves from southern China (Tekolla, 2010). In addition, land-use change also affects the incidence of floods. The land-use change increases the rate of runoff to the drainage system and causes flood events. Among other

factors affecting flood events are the slope of the basin, the drainage system, the soil type (Kursh, 2013), topography (Pradhan, 2009; Forko, 2011), and climate change (Morita, 2014; Abdul-Rahman, 2009).

Furthermore, the anthropogenic activity of natural surroundings to meet the demands of life promotes further development in the land-use sector such as urbanization, housing, tourism and recreation, public utilities and agricultural (Hussain *et al.*, 2010; Taib *et al.*, 2015; Abdullah *et al.*, 2017; Udinand Malek, 2018; Ng *et al.*, 2018). This situation also contributes to flooding events. This is happening due to deforestation and land clearing which causes the role of forests was impaired. Hence, it improves the surface of the runway and increases the air level and river discharge.

In order to mitigate the effects of flood hazards, various studies and efforts have been undertaken. Among them are estimating and mapping flood sanitation areas using geographic information systems (GIS). GIS has been reliable tools and been used in the evaluation of geo-environmental catastrophes by providing a sort of synoptic coverage of a very broad area in a cost effective way, which overcomes the bottle-neck and limitations caused by the conventional ground stations in recording an extreme hydrological information during an extreme event. GIS is a tool to illustrate flood events, flood analysis, problem-solving and provide rational and precise decisions.

Hence, the various techniques and techniques used by researchers to map, analyze and predict flood risk areas such as GIS techniques as well as remote sensing techniques (Ab.-Ghani *et al.*, 2012; Ozkan and Tarhan, 2016; Hussain and Ismail, 2016; Kursh, 2013; Darwin *et al.*, 2018; Md-Hashim and Ahmad, 2007; Abu-Bakar and Alias, 2014). Meanwhile, a combination of GIS and analysis such as Principal Component Analysis (PCA), Analytical Hierarchy Process (AHP), Multicriteria Decision Analysis (MCDA), and Multicriteria Evaluation (MCE) were used in different studies (Tekolla, 2010; Hussain and Ismail, 2016). On the other hand, combination method of GIS with modelling such as hydrodynamic, hydraulic, hydrological and water balance models were done by other researchers (Bukari *et al.*, 2016; Pradhan, 2009; Büchele *et al.*, 2006). The study of this approach focuses on the importance and effectiveness of the Geographic Information System (GIS) in flood studies in Malaysia.

In addition, flood modelling was also developed and used by researchers to map flood risk areas such as hydrodynamic models using info works RS software to simulate the flood and Flood Damage Prediction Model (FDPM) to predict the flood (Ibrahim *et al.*, 2014; Alaghmand *et al.*, 2010; Morita, 2014; Amin and Othman, 2018). Sulaiman *et al.* (2015); Hashim *et al.* (2012), and Md-Hashim and Ahmad (2007) uses the non-parametric analysis method of the Mann-Kendall Test, and Kruskal-Wallis rank analysis while Temrinand Awang (2017), Khan *et al.* (2014), and Md-Hashim and Ahmad (2007) used questionnaires and interviews and then analyzed using statistical analysis test (SPSS).

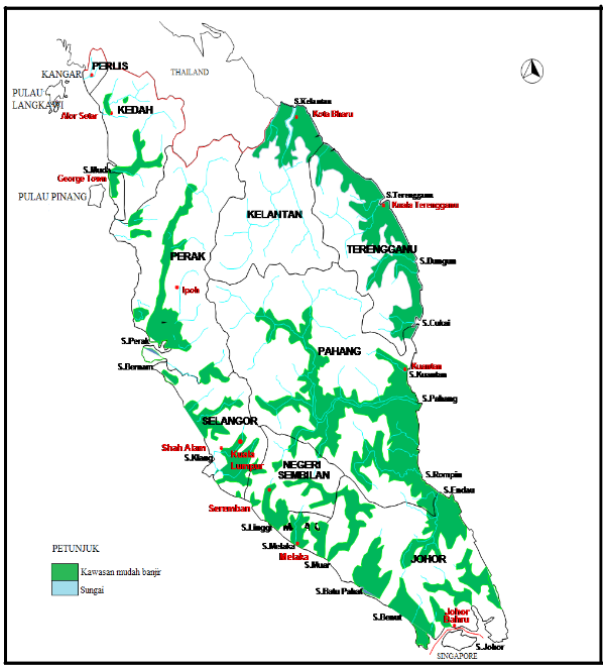

Fig. 1. Areas prone to flooding in Peninsular Malaysia. *Source:* Department of Irrigation and Drainage Malaysia, 2012

Methodology

This paper aims to review and discover the dominant causes affecting the occurrence of floods in Malaysia and to identify the application of GIS used in flood risk mapping studies done by previous researchers. This study applied the concept of reviewing relevant records of research conducted in Malaysia according the objective of this paper. Analysis of this review will focus on the factors related to flooding event, areas affected with floods and

method used in mapping flood risk areas. This review only analyzes selected studies carried out within 10 years from year 2008 until 2019.

Study Area

This study is more focused on the occurrence of floods in Malaysia. Malaysia is bordered by Thailand, Indonesia and Brunei on land, whilst overseas borders Singapore, Indonesia, and the Philippines. Malaysia is at latitude 4 ° 08'26.28 "North and longitude 109 ° 37'5.33" West. In addition, Malaysia has an equatorial climate characterized by the annual southwest monsoon from May to October and northeast from November to March. Furthermore, Malaysia has a uniform temperature, high humidity, and abundant annual rainfall. Such climatic characteristics led to the occurrence of floods that easily hit Malaysia. The floods will be more extreme when the monsoon season arrives around November to March.

On the east coast of Malaysia, the floods are heavily influenced by the northeastern monsoon winds that bring heavy rain around November to March (Khan *et al.*, 2014; Elfithri *et al.*, 2017).

Results

Flood Relationship Connection with Related Factors

Table 1 shows the review case flooding in Malaysia from 2009 to 2018. Table 1 shows the review of the flood studies in Malaysia from 2008 to 2018. This analysis is based on the factors that cause floods in Malaysia, there are three major factors analyzed, namely climatology, hydrology and anthropogenic factors. This review also covers the methods used by researchers during the period 2008-2018.

Floods are natural disasters that occur due to climatic factors such as precipitation, resulting in increased water levels and river discharge (Barriendos and Rodrigo, 2006; Pradhan, 2009; Alaghmand *et al.*, 2010; Haryani *et al.*, 2012; Ab.-Ghani *et al.*, 2012; Jamil *et al.*, 2012; Mohsen *et al.*, 2014; Basarudin *et al.*, 2014; Morita, 2014; Sulaiman *et al.*, 2015; Bukari *et al.*, 2016; Ozkan and Tarhan, 2016; Muhammad-Amin, 2017; Rimba *et al.*, 2017). Floods also occur due to the annual rainfall down continuously with high-intensity rates (Tekolla, 2010; Hashim *et al.*, 2012; Ibrahim *et al.*, 2014; Hussain *et al.*, 2015; Temrin and Awang, 2017).

The cause of flood disaster in the interior of Kedah is due to changes in land use which directly affect the rainfall distribution (Hussain *et al.*, 2015). The result of rainfall data analysis using monthly bar graph from 1990-2013 found that land-use change was associated with an incredible rainfall event that eventually caused a major flood disaster. Based on the history of floods, the worst floods have been experienced in several rural areas of Kedah, back in year 2005 and 2010. The magnitude of rain events is closely related to land-use changes in river basins in influencing flood hazard patterns in the Kayu Ara river basin (Alaghmand *et al.*, 2010).

In the study by Gasim *et al.* (2010), it is also found that the cause of flooding in Segamat from 17 to 21 December 2006 was due to the overwhelming heavy rainfall. The condition of the heavy rain caused the flood to worsen due to the lowly and undulating topographic form in Segamat. From the results of this study, floods occur easily when the monsoon season begins. There was a significant increase in rainfall from October to December 2006, from 118 mm to 435 mm / month, but dropped to 392 mm in January 2007.

Furthermore, the frequent phenomenon of floods in Malaysia, especially in the east coast of Peninsular Malaysia is closely linked to the occurrence of Northeast Monsoon that begins in November to March (Elfithri *et al.*, 2017). Despite the heavy rains that were the main cause of the floods, it was not anticipated that the occurrence of more extreme floods compared to previous years was due to environmental changes in the river basin. This, obviously proves that anthropogenic factors are the cause of flood events occurring at higher magnitudes. Flood disaster also occurs if there is any change to the physical channel form of the river. Sedimentation processes was found related in influencing the availability of river channels to accommodate high quantities of discharge (Jamil *et al.*, 2012). This is because the ongoing sedimentation process will cause the drainage to become shallow. Then this condition will have a flood impact on the nearby river area.

Since 2000, the Sungai Menggatal Basin, Sabah has been experiencing rapid development activities. Such a situation, resulting in the inability of the river flow to accommodate the continuous increase of inputs at any one time. When land-use characteristics are changed to development activities then it has disrupted the hydrological system of the basin.

Table 1. Relevant records of flood studies in Malaysia from 2008 to 2018.

Author	Factor			Study Method
	Climatology	Hydrology	Anthropogenic	
Gasim *et al.* (2010)		/		Analyze daily telemetry data and river discharge and is associated with rain data sets
Hussain *et al.* (2015)		/	/	GIS & secondary data
Ab.-Ghani *et al.* (2012)		/		GIS (DEM)
Alaghmand *et al.* (2010)		/	/	Hydrologic and hydraulic models
Bukari *et al.* (2016)		/		GIS & AHP (Hydrological model+ water balance model & Analytical Hierarchy Process)
Elsheikh *et al.* (2015)		/	/	GIS (Multicriteria Decision Analysis (MCDA) & AHP)
Darwin *et al.* (2018)		/		GIS (Chi-square Automatic interaction detection (CHAID) & ROC method. (Receiver operating Characteristic)
Elfithri *et al.* (2017)		/	/	Data collectionLiterature reviewFlood reports from DID
Abdul-Rahman (2009)	/			Research through data
Yusri *et al.* (2010)			/	Land use 1992 and 2004software ArcView GIS version 3.2
Jamil *et al.* (2012)		/		Sampling method
Mohd Ekhwan *et al.* (2012)		/		Sampling method
Hussain *et al.* (2016)		/	/	Secondary data
Said *et al.* (2013)		/	/	Focus group discussion approach (FGD)
Temrinand Awang (2017)		/	/	survey
Jafar *et al.* (2012)			/	GIS analysis Field work/observation / survey method.Analyze rational method
Weng (2011)	/	/	/	Review through previous articles, reports and data.
Ibrahim *et al.* (2014)	/			Hydrodynamic model
Tekolla (2010)	/	/		GIS & PCA
Forko (2011)			/	Image ASTER & GIS
Ghorbani *et al.* (2015)	/			SCS & HEC-HMs
Kursh (2013)		/		GIS
Khan *et al.* (2014)	/			survey
Abu-Bakar and Alias (2014)	/			GIS
Haryani *et al.* (2012)	/		/	GIS (Composite mapping analysis)
Sulaiman *et al.* (2015)		/		Mann-Kendall Trend Test
Sulaiman *et al.* (2017)	/	/		GIS
Basarudin *et al.* (2014)	/		/	HEC-HMs

This is a condition that causes flood events to occur easily (Jafar *et al.*, 2012).

The inability of the riverbed to accommodate the increase of input discharge at any one time, not only due to the constant pouring rain factor (Temrinand Awang, 2017). Other factors such as drainage system, drainage or rafting, low land area, and development activities have caused river water to flood and flood events occur. The findings showed that floods in the Padang Terap, Kedah districts were due to prolonged heavy rain, flooding became worse due to uncontrolled development, unmanaged and blocked drainage systems (Said *et al.*, 2013).

Another study showed that when the variation in plantation and forest areas decreases, but the in-

crease in settlement land-use variables in Pekanbaru city, Indonesia, it will indirectly have a negative impact on the environment. Percentage of flood disaster events will record a high level of bad (Yusri *et al.*, 2010).

Toriman *et al.* (2012) discovered that the sedimentation problem will usually cause the river to be shallow and ultimately bring flood risk to a river basin. It was found in the normal season estimated that the sediment load per day was 318,329 tons/day and will increase to 3,192,155 tons/day during the rainy season at Sungai Chini, Pekan, Pahang. The suspended sediment concentration is not only caused by the occurrence of rainfall which increases the value of river discharge, but the anthropogenic factor that is being carried out around the basin is also a factor in the incidence of flood events. Among the examples of activities carried out are boat movement activities that erode riverbanks, deforestation, agriculture, and mining.

Human excitement in development has opened a high vulnerability to the risk of major floods in the Kelantan river basin. A research was conducted to study the relationship between land-use change in influencing the increasing frequency and intensity of the flood disaster and found that changes in land use since the last 26 years have caused frequent flood events with increasing intensity of rain every year (Hussain and Ismail, 2016).

Researcher concluded that natural combinations and human factors have led to higher levels of flood danger in Malaysia (Weng, 2011). This is because, when monsoon rains carry excessive and prolonged rain intensity coupled with the direct surface exposure conditions then the river flow capacity of the overflow at one time will shrink.

Another researcher also pointed out that such floods were affected by today's climate change. Malaysia is included in the list which receives a temporarily increased temperature record from 30 to 50 years ago (Abdul-Rahman, 2009). The record proves that temperature changes in Malaysia are between + 0.70 °C to 2.60 °C, while precipitation changes are between -30% and + 30%. Such a situation, resulting in increased frequency and intensity of extreme weather events. As well-known climate change is due to the generation of heat traps. Increased gas such as carbon dioxide (CO_2) emanating from vehicles, industries, power stations, and deforestation acts as thick blankets.

The occurrence of floods in Malaysia is usually due to the constant downpour. Increasingly heavy raindrops cause a rise in river water levels leading to overflowing of rivers, causing floods to occur. The occurrence of floods in Malaysia is due to the northeastern monsoon that begins from November to March, however, the major contributing factor is human activity and natural explosive factors contributing to flood events in Malaysia.

Application Geographical Information System in Flood Risk Mapping Approach

The Geographic Information System (GIS) was used to map flood areas in the Pahang River including in Mentakab, Temerloh, Maran and Pekan throughout 2009 to obtain information on flood areas, flood depths, river floods, and water levels for floods during the year 2007 by developing a digital elevation model (DEM) (Ab.-Ghani *et al.*, 2012). The visual height of DEM was then used to develop the actual level of flood in 2007 in the study area.

In Sungai Sembrong, Johor, the use of GIS techniques and Hierarchical Process Analysis (AHP) is effective in determining the area of flood sanitation. GIS serves as a spatial analysis that creates new information based on the data analysis contained in the system. Hence, GIS is used to map flood aviation areas especially in the district of Batu Pahat while AHP is used as a means of deciding on existing data. Using AHP, the preparation and positioning of the required parameters in the GIS are more robust and easier to analyze (Bukari *et al.*, 2016).

Flood risk areas in urban areas was mapped as a case study conducted on the Kayu Ara River basin using HEC-HMS and HEC-RAS as hydrological and hydraulic models (Alaghmand *et al.*, 2010). The mapping of flood-prone areas is based on the water depth and flow velocity maps prepared according to hydraulic model results in GIS. The findings show that the magnitude of rainfall events and the development of Sungai Kayu Ara River Basin is a significant influence on the flood patterns in the rivers, the magnitude of the rain influences flood events as compared to land use in the Kayu Ara River basin.

In addition, Kaamin *et al.* (2015) using GIS and a combination of hydrological models and water balance models to predict flood events in Sungai Sembrong, Batu Pahat, Johor. By using these models, it is able to illustrate flood events in potential flood areas in the future. Data such as rain, contours, land use, soil type, river, and all basins are

GIS data used. The combination of hydrological models and water balance models shows that these models are a great tool for getting immediate information about floods immediately while GIS is a tool that helps to illustrate flood events, flood analysis, problem-solving and provide rational and accurate results.

The mapping of flood hazards in Terengganu was integrated with GIS using Multicriteria Decision Analysis (MCDA) to map the area of flood sanitation (Elsheikh *et al.*, 2015). Some of the factors that cause flooding include the rain, the slope of the basin, the drainage system, and the soil type. Using AHP, the study shows the percentage of factors affecting flood events where rain factor is 38.7 percent, drainage system (27.5%), basin slope (19.8%) and soil type (14%).

Discussion

The occurrence of floods is indeed a disaster that cannot be avoided by humans. This is because, when the monsoon season is coming, naturally the river will rise. However, extreme flood events can be mitigated if ecosystems in the river valleys are not excessively exploited. Guided by the guidelines, which have been determined by the government should be anthropogenic factors around the river basin should meet the specified conditions. Land use for development should be carefully planned so as not to have a bad impact on the physical condition of the nearby river.

Through this case study, it can be concluded that aggressive anthropogenic factors greatly influence the more severe flood events in the future. Therefore, many studies are conducted using GIS to analyze, identify and understand the occurrence of flood events. Immediately this alternative is used to prevent the risk of increased mortality during floods, destruction of buildings and property.

The disaster has left quite a profound impact on the communities involved in Pahang, Kelantan Kedah in Malaysia. There are many aspects of the lives of the people here who are affected by the floods, especially the impacts of economics such as income, expenses, property ownership, damages and losses However, floods have socioeconomic impacts that are also influenced by the elements of advancement such as age, sex, educational level of education, type of employment, total income, housing materials, and clean water sources. These vulnerable groups will receive a deeper impact than those that are not influenced by aspects of flood warning. Floods that occur annually in certain areas of Malaysia have health effects on humans. The impact on this health can be seen in the short term such as injury or death or long-term such as infectious diseases, mental stress or malnutrition effects. This effect if left untreated can increase the rate of morbidity and mortality of Malaysians. Precautionary measures should take precedence. It should happen before the flood, which is a precautionary measure by providing adequate medical equipment or during floods where management towards a cleaner should be carried out. After the floods, there are still many preventative measures to be followed to ensure that health effects are reduced and have less impact on humans. The past flood experience has given a great deal of awareness of the importance of preventive measures to prevent the health effects of death. Based on the study, contributing factors to flood events are due to the intensity of rainfall and rising water levels. However, the issues and issues related to the basin and the community are well-known in the management of floods and river basins. Things raised are like flood warning system problems, flood preparedness, sedimentation, river bank change, food supply, and clean water. GIS systems can integrate weather factors and river basins in order to create a flood-prone zone. From the identified zones, various socio-economic information can be linked and presented in visual form and facilitates understanding of flood risk and impact on the affected communities. Finally, building a database that can help flood management decision-makers based on flood risk taking into consideration various aspects.

Conclusion

Typically, floods occurring in Malaysia are caused by monsoon winds. Monsoon winds usually carry a large amount of rainwater. The level of flooding that is getting worse from year to year is influenced by the anthropogenic factor and the condition of a drainage system. This is because, when the occurrence of rain occurs over a long period then there will be a rise in water level in a drainage system. The situation will be worse when the drainage system is active sedimentation due to anthropogenic and natural factors in upstream areas. Therefore, it can be concluded that flood events will be worse for

humans when the nuisance of humans to nature, especially the environment in the river basins, is not systematically preserved. By utilizing the latest technologies such as implementing GIS applications in flood control, the impacts and flood management will be mitigated.

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