Multicriteria Analysis for Flood Mapping of Sungai Pahang

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Abstract: The occurrence of floods is a natural disaster incidence that depends on the geographical, physical and rainfall. This study aims to investigate the geospatial analysis of flood in Sungai Pahang, Pahang. The objectives of the study are i) to analyse the use of factors for multi criteria analysis, and ii) to prepare a flood hazard mapping in Sungai Pahang, Pahang. Method used for this study is a multi-criteria analysis using Geographical Information System. Four important factors were used in this research; distance from the river, gradient, land cover and height of the land form. The finding show that the highly dense areas (such as Pekan and Kuantan) located close to the river are located inside the highest susceptible areas, which can give a high loss to the inhabitants in those particular areas. Thus, the recommendation suggests that determination of flood-prone areas of flood level 1 (protected area), level 2 (moderate sensitive rank), level 3 (controlled development area) and level 4 (development area) can be implement by the local authority in practice of development planning work.

Keywords: flood map, multi criteria, Geographical Information System (GIS).

Introduction

Flooding in Malaysia is worsening, with the huge spending towards material and life loss. The incidence of floods as either monsoon floods or flash floods is a natural disaster incident whose main feature depends on geographical, physical and local factors, especially rainfall. Flood incidents involve property loss as well as loss of life and natural assets. In terms of environmental conservation, flood events also involve the destruction of natural resources such as wildlife and forestry. Malaysia has had several disaster incidents involving the loss of lives and property damage on a large scale such as major floods in Pahang, Kelantan and Terengganu (2014). In order to mitigate the flood problem, several methods were applied by using GIS as the main platform. The method such as multi-criteria decision making (MCDM), Simple Additive Weighting (SAW), Monte Carlo AHP approach and weighting approach.

Multi-criteria decision making (MCDM) used for flood management by providing several alternatives. Several researchers that have conducted this kind of method are Ahmadisharaf et al. 2015 and Tang et al (2018). There are also a massive application by using this technique, such as flood risk mapping (Marco, 1994; Sinnakaudan, Ab Ghani, Ahmad, & Zakaria, 2003; Tam, 2014), flood hazard zoning (Nur Aisyah Sulaiman, Thuaibatul Aslamiah Mastor, & Samad, 2015; Rahmati, Zeinivand, & Besharat, 2016), flood risk assessment (Priest et al., 2016) and flood mitigation strategies.

The AHP method is widely used to develop the relative weighting of criteria for specific variables. The steps including 1) producing criteria weight samples, ii) perform uncertainty analysis and computing multiple realizations of the susceptibility assessment and iii) perform sensitivity analysis (Tang, Zhang, Yi, & Xiao, 2018). The result shows an average (AVG) susceptibility map and the standard deviation. Another technique is the ordered weighted averaging (OWA) is a family of multi-criteria aggregation technique (Tang et al., 2018), which provides a general class of parameterized aggregation operators between the minimum and maximum. There are also research that used several methods; i) Spatial Multicriteria Evaluation technique, ii) Pairwise Comparison (Analytical Hierarchy Process-AHP) and iii) Ranking Method (Yahaya, 2008). This research purpose is to examine how sensitive the choices are to the changes in criteria weights. This research found that MCDA techniques using GIS technology have proved to be powerful methods to generate hazard maps with a good degree of accuracy.

The review of literature has identified the main factors that are contributed to flooding. The factors of flood analysis was derived from i) flow accumulation, rainfall density, elevation, geology, land use and slope (Kourgialas & Karatzas, 2016) and all of these factors are overlaid together to determine the final flood risk map. The paper also stated that correlation analysis with different weights for each factor was applied to minus the major and minor effect of flood generation. There is other paper (Tang et al., 2018) had mentioned the six conditioning factors were selected for flood susceptibility mapping are digital elevation model, slope, distance from the river, maximum three-day precipitation, topographic wetness index, Soil Conservation Service Curve Number. A study in Semarang, had identified factors such as data of rainfall, drainage, land use, and topography (Setyani & Saputra, 2016). A local study in Johor Malaysia had include these factors that contributed to flood, such as rainfall distribution, slope, distance from river, land use, drainage density and road density (Nur Aisyah Sulaiman et al., 2015). An AHP methods used by this researcher, whereas using 10 variables are for a flood analysis; flow accumulation, annual rainfall, slope, runoff, land use/cover, elevation, geology, soil type, distance from the drainage network, and drainage density (Mahmoud & Gan, 2018).

Factors of human activities; unplanned rapid settlement development, uncontrolled construction of buildings in general and major land use changes can influence the spatial and temporal pattern of hazards (Pradhan, 2009). Topography is an important role to process flooding map. Two factors that is related to topographic factors are elevation and slope. Areas of the low elevation are more prone to flooding than areas at high elevations because water flows downhill. Steep slopes tend to retard infiltration and continue increased risk of flooding In general, the greater the precipitation intensity, the greater the resultant overland flow and waterflow, and the greater the resultant flooding (Tang et al., 2018). Other than topography, rainfall is also an important factors that contributing to flood. Flood usually occurs during the monsoonal season is the season where majority of rainfall amount. This is the time when the average annual rainfall become higher than the other period. (Tang et al., 2018) has reported that heavy monsoon rainfall on the 4th to 6th August 2012 caused destructive flooding in Gucheng County.

The objective of this study are hence twofold; i) to analyse the use of factors for multi criteria analysis, and ii) to prepare a flood hazard mapping in Pahang. Method used in this study is the multi-criteria analysis by distributing weightage according to the guidelines provided in the Environmental Sensitive Area (ESAs) Sensitivity.

Environmental Sensitive Areas (ESAs)

Environmentally Sensitive Areas (ESAs) are natural features that identified as areas at greatest risk. It has become the hope of the government to protect and preserve these fragile areas from any development depending on its level of sensitivity (Asmawi & Paiman, 2016). The Manual of Standards and Guidelines provided by the Town and Country Planning Department, Federal Malaysia, the definition of Environmentally Sensitive Areas (ESA) is a "special area that is very sensitive to any activity or development and need to be preserved for its heritage value, preserve life and minimize support disaster risk due to land use changes". Table 1 shows the rank distribution using ESA Sensitivity.

Table 1: Rank distribution using ESA Sensitivity

High Sensitive Rank: Protected Area	Moderate Sensitive Rank: Limited Development Area	Low Sensitive Rank: Controlled Development Area	Outskirt of ESA: Development Area
No development of urbanization and agriculture, except sustainable logging and works involving conservation and preservation, limited eco-tourism activities and any eco-tourism related support and authorized research and development (R & D) activities without affecting the nature of carrying capacity.	No development of urbanization except recreational area/tourism activities based on minimal environmental impact; waterbodies and forest waste are allowed without affecting the nature of carrying capacity.	Only restricted development subject to compliance with specific requirement as in the guidelines set out for development such as housing, industrial and business involving low or moderate density only.	This area is suitable for all development for urbanization by taking into account the land use zoning and following the terms and guidelines.

(Source: (PLANMalaysia@Pahang, 2017))

Study area

The state of Pahang is located at the east coast of Peninsular Malaysia is exposed to heavy rainfall and strong winds from the South China Sea. This situation is influenced by the winds of the Northeast Monsoon at the end of the year. Every year, the monsoon flood incidents are recorded in Pahang had resulted in the residents being forced to move to the relief center while waiting for the floods to recede. The environment is also affected by floods such as agricultural areas which have decreased production and livestock that destroyed from floods. The neighbouring state of Pahang includes Kelantan (north), Perak (west), Negeri Sembilan (south west), Johor (south) and Terengganu (north east). The Pahang River Basin and the Kuantan River, which covers an area of 2,860,000 hectares, constitute 70% of the total area of Pahang State. The Pahang River is located in the interior of Pahang State in the west and north of the state. Amongst the main towns along the river are Jerantut, Temerloh and Pekan. Fig. 1 shows the River Basins in Pahang.

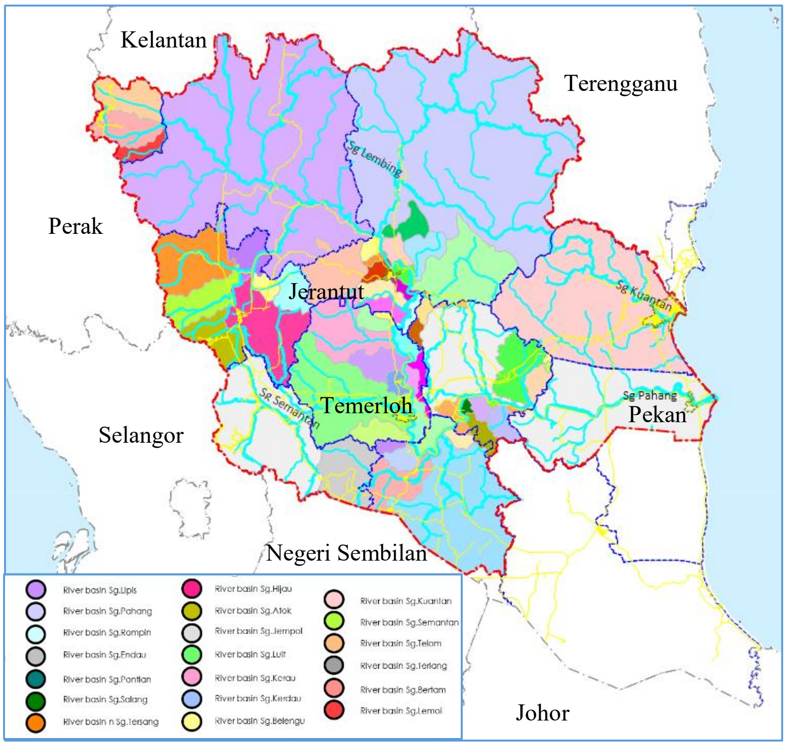


Figure 1: Pahang river basin and the Pahang river (Source: PlanMalaysia@Pahang, 2017)

Methodology

The susceptibility defined as 'flood prone areas' includes factors of climate, geography, distribution of rainfall, natural irrigation system and etc. The combination of all factors resulted the flood prone areas mapping and this mapping helps in the integrated land use planning in the Pahang River Basin areas. The used of thematic layers modelling has a weightage for each factors through GIS processing. In order to recognised the susceptibility areas, five factors used in this research.

The rainfall data was gathered from Meteorological Department. The annual mean of rainfall amount are collected from 2000 until the recent one (2015). All MET station located in Pahang was collected, and also include the neighbouring states; such as Perak, Selangor, Negeri Sembilan, Johor, Terengganu and Kelantan. Graph based analysis were used in this research; using mean maximum and minimum annual temperature from 2011 to 2015 and rainfall datasets.

The method adopted in this research was using multi-criteria analysis using weightage according to ESAs. Ranks was distributed according to the definition of Sensitivity Areas according to the definition of each ESAs; protected areas (Rank 1), limited development area (Rank 2), controlled development area (Rank 3) and development area. Two types of final maps were generated; the ARI 1 year (yearly event) and ARI 100 year (extreme event).

The factors are selected from the review done from the previous studies. These are, i) land use, ii) slope and iii) elevation and iv) distance from the river. The land use data was collected from the Department of Planning, Malaysia. The slope and elevation are derived from the Digital Elevation Model (DEM) datasets that was downloaded from ForestWatch.com. Each of these factors are presented in a form of grid map and the method of preparing all of the grid is different. The slope and elevation can be derived from the Digital Elevation Model (DEM data), but the rainfall was derived from the annual mean of rainfall distribution from neighbouring meteorological station.

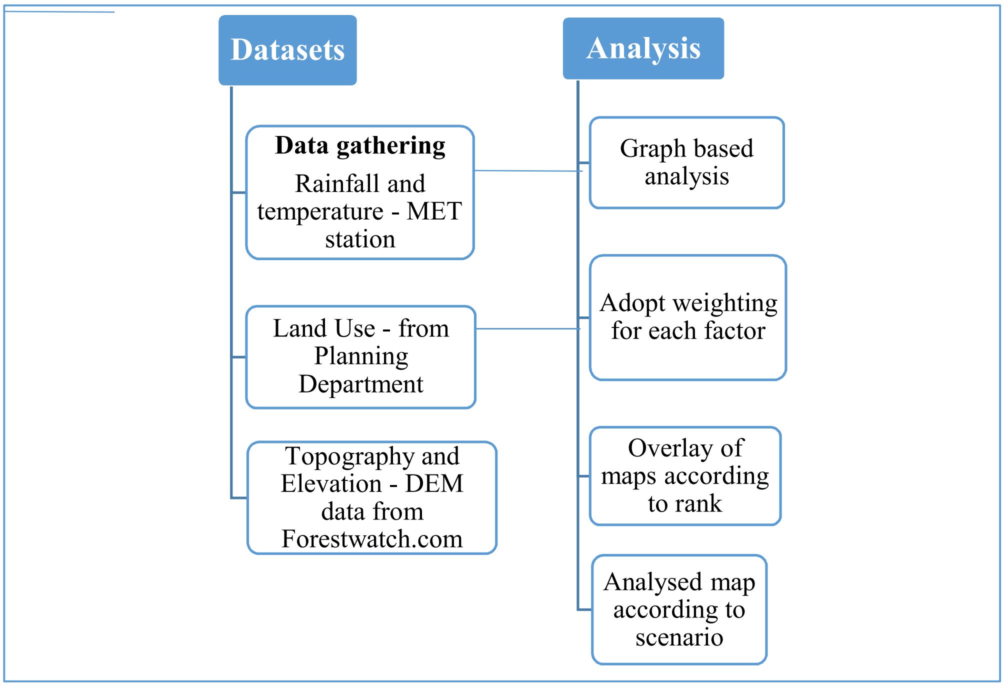


Figure 2: The methodology of this research

Every factor were mapped in the format of grid file and each rows of the factors were recorded using the calculator tool according to the categories ESA Sensitivity, as it was divided into three different sensitive rank. All of the factors are overlaid to produce a flood susceptibility map. Two types of final maps were generated; i) map with flood area ARI 1 year and ii) map with flood area ARI 100. ARI 1 year is the occurrences of flooding for 1 year and ARI 100 year represent occurrence of flooding for 100 year. The map shows a level of exposure that refers to generate a distribution of flood-prone areas according to different levels.

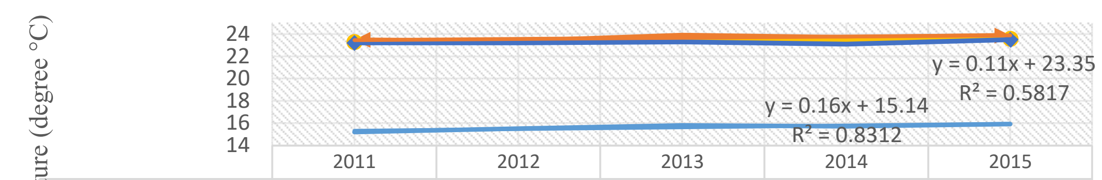
Table 2: The Flood Susceptibility Ranking

Flood Factor	**Susceptibility Rank 1 (Highest)**	**Susceptibility Rank 2 (Moderate)**	**Susceptibility Rank 3 (Low)**
Topography condition and & DEM	< 300 m	301- 600 m	601 - 800 m
Slope Classification	$< 15^0$	$16 - 30^0$	$31^0 - 40^0$
Land Use Types 2015	Urbanization Residential Industrial Commercial	Infrastructure Road	Forest Agriculture Open space
Distance from the River	< 500m	500m – 1,000m	1,001 – 1,500 m
Flood Area ARI 1 Year and ARI 100 Year	ARI 1 year	ARI 100 year	-

(Source: PlanMalaysia@Pahang, 2017).

Climate Change Trends and Rainfall

The Malaysian Meteorological Department has five (5) meteorological stations in Cameron Highlands, Jerantut, Kuantan, Muadzam Shah and Temerloh. The lowest temperature was recorded at Cameron Highland, which is about 15 degrees Celsius, which is a highland area. While four (4) meteorological stations in low land area recorded a reading of about 23 degrees Celsius. Analytical trends for minimum temperatures at all meteorological stations show that they are increasing in five (5) years. Surprised result showed from the trend of minimum temperature of Cameron (0.16) that was increasing faster compared to the increased of minimum temperature of Kuantan (0.11). This finding show that the Urban Heat Island (UHI) has occurred faster in Cameron Highlands.

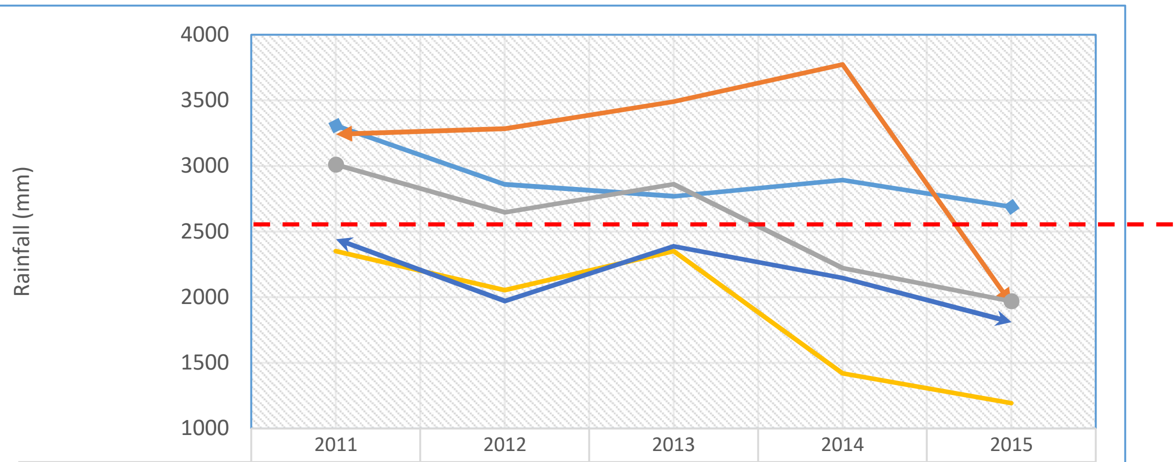


	2011	2012	2013	2014	2015
Cameron Highland	15.2	15.5	15.8	15.7	15.9
Kuantan	23.5	23.4	23.9	23.7	23.9
Muadzam Shah	23.2	23.4	23.4	23.3	23.6
Temerloh	23.3	23.4	23.5	23.4	23.6
Jerantut	23.2	23.2	23.3	23.1	23.5

Cameron Highland | Kuantan | Muadzam Shah | Temerloh | Jerantut | Linear (Cameron Highland) | Linear (Kuantan)

Figure 3: The minimum temperature in Pahang from 2011 to 2015.
(Source: PlanMalaysia@Pahang, 2017).

In general, the average annual rainfall in Peninsular Malaysia is 2,500 mm/year. The annual average rainfall trends in Pahang State for the period 2011-2015 showed a decrease in all the meteorological stations (Fig. 4). In 2011, there were three (3) stations recording more than 2,500 mm/year but in 2015 only weather station in Cameron Highlands had rainfall over 2,500 mm/year. High number of rain flows remain in the monsoon season at the end of the year. Figure 5 shows the pattern of annual rainfall in Pahang State and its surrounding meteorological station. In general, it also shows the trend of decreasing the amount of annual rainfall.



	2011	2012	2013	2014	2015
Cameron Highland	3310.1	2,861.4	2,770.8	2,894.6	2,688.6
Kuantan	3,242.6	3,283.8	3,492.2	3,776.0	1,947.4
Muadzam Shah	3,011.7	2,647.6	2,863.3	2,223.0	1,968.9
Temerloh	2,350.6	2,053.8	2,352.2	1,420.6	1,193.2
Jerantut	2,442.0	1,971.2	2,388.6	2,148.2	1,811.6

Cameron Highland | Kuantan | Muadzam Shah | Temerloh | Jerantut

Figure 5: The annual rainfall distribution in Pahang from 2011 to 2015.
(Source: PlanMalaysia@Pahang, 2017).

Four types of maps were produced; land use map, distance from the river map, the elevation and slope map. The land use mapping shows that the forest located at the high elevated areas at the north part of Pahang. The river map shows that the pattern of the river are from the uphill areas at the North west side of Pahang. This analysis has been designed to create polygon of distance from river and streams to differentiate the solution of each of these ranks.

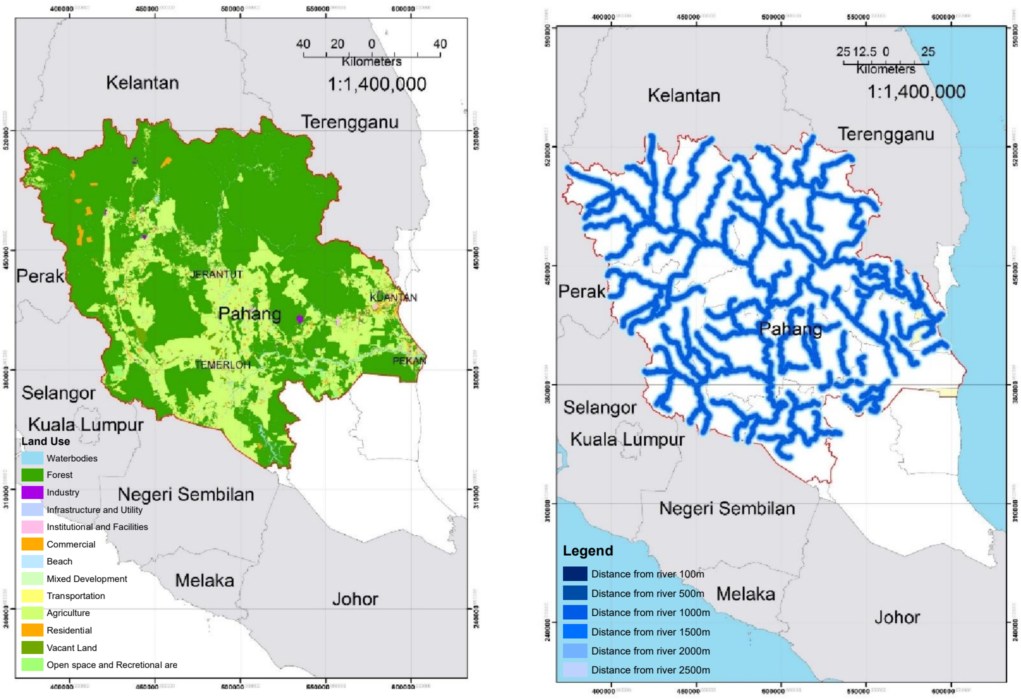


Figure 6: The land use map (left) and distance from river map (right).
(Source: PlanMalaysia@Pahang, 2017)

The elevation and slope map shows the high land values (Cameron Highlands) at the North West side of Pahang (Fig. 7). According to several reports (Barrow, Chan, & Masron, 2008; Razali, Syed Ismail, Awang, Praveena, & Zainal Abidin, 2018) claimed that many flash flood problems had occurred in Cameron Highlands due to clearing of land for agriculture activities. Thus, it causes mudflow from the upstream areas to the downstream areas. The sedimentation loads are trapped along the river. This process makes the volume of the river decrease because the depth of the river becomes small, as a result, the water will overflow from the river and the flood continuous to the lower stream areas.

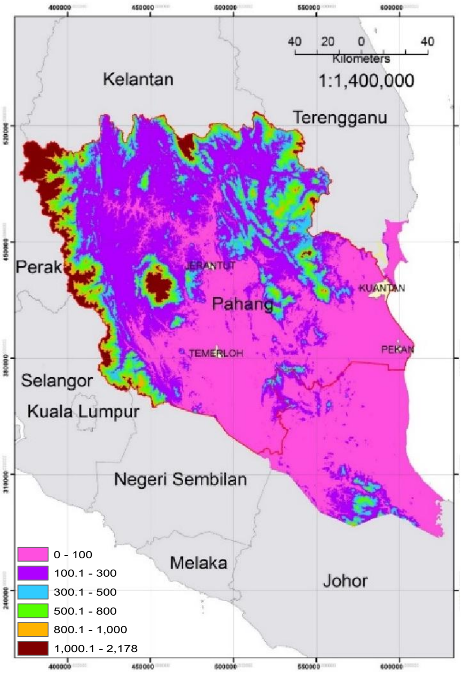
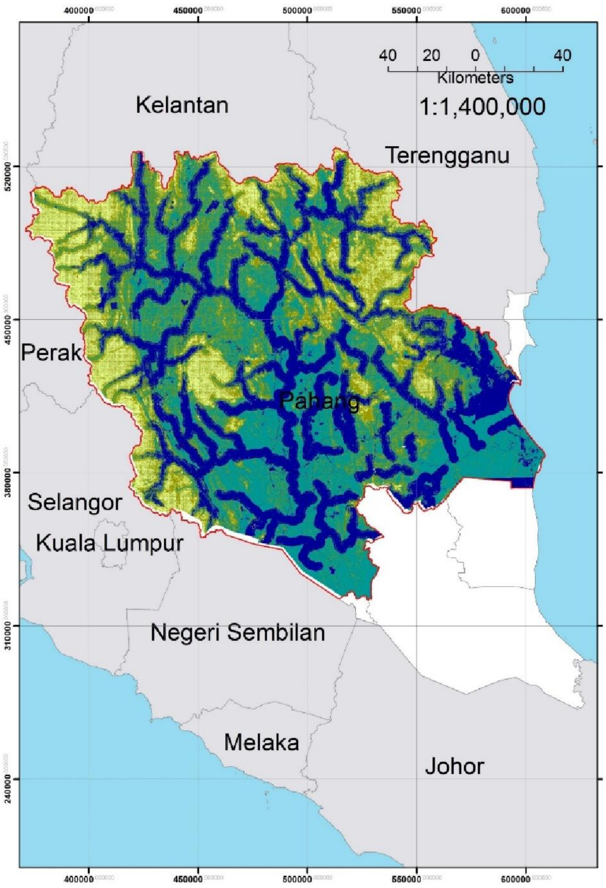


Figure 7: The elevation map (left) and slope map (right)
(Source: PlanMalaysia@Pahang, 2017)



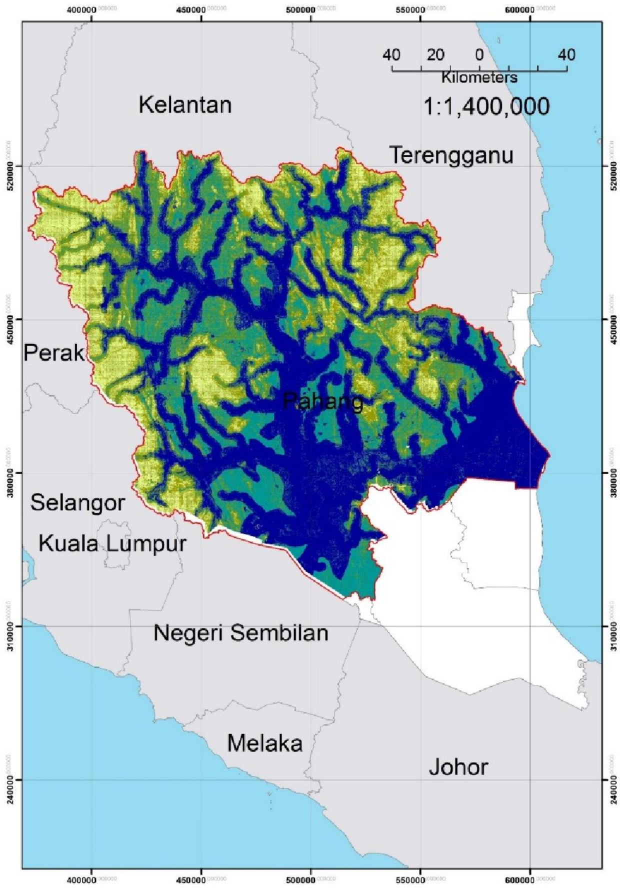


Figure 8: The ARI 1 year (left) and ARI 100 years (right).
(Source: PlanMalaysia@Pahang, 2017)

Fig. 8 shows the flood susceptibility according to different susceptible; according to ARI 1 year (yearly) and 100 years (extreme cases). The susceptible rank includes susceptible rank 1 (highest), susceptible rank 2 (moderate), susceptible rank 3 (low), while other areas are those areas that has no exposure to flood. This spatial distribution is referring to the environment factors and geography that linked with the riverine monsoon flood that usually happens at the end of the year. The finding in the form of plan is import as to assist the authority to prepare the flood prone risk management plan.

Conclusion

This research concludes that GIS and Remote Sensing can assist the planner to prepare maps for the mitigation of flood prone areas. Especially those urban areas such as Kuantan, Pekan and Temerloh, a careful examination of the urban areas need to be crucially been done as the location of these urban areas close to the river. The upper areas, such as Cameron Highlands can give a negative impact to the environment if a clearing activities been done without proper mitigation.

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