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Statistical and Spatial Analyses of the Kelantan Big Yellow Flood 2014

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Abstract. Flooding is a yearly phenomenon which is mostly reflected in the Kelantan River basin during the northeast monsoon season due to the heavy rainfall. The December 2014 flood in Kelantan known as 'Kelantan big yellow flood' was unprecedented and the largest recorded flooding event in the century. Flood mitigation, especially in massive floods, should focus on minimizing the risk of severe flooding in one area. A reliable flood extent map is essential to plan proper flood mitigation measures by authorities prior to the extreme flood event (say 1 in 1000 years event). This study is an attempt to resolve the issue of severe flooding in a given area by preparing a map of zones prone to flooding. This was achieved mainly by site visits to the flood-prone area and gathering primary data from face to face interview with local people who were the victims of this flooding. This primary data is also crucial in determining flood vulnerability with respect to economic and social impacts. The integration of primary data with secondary data from several related agencies has resulted in preparing a reliable flood extent map which is slightly different from other such maps developed by Government, NGOs and active researchers in this field. The empirical findings using frequency analysis also helped in preparing a flood vulnerability index based on primary data gathered from the local people who were the flood victims.

1. Introduction

An extreme flooding event with catastrophic impact occurred in the Kelantan State, particularly in towns and city at the end of December 2014. The impact of this flooding paralyzed all aspects of life. These disasters directly affect most of the population, causing damage to homes, infrastructure and public service networks (supply, water, electricity, telephone) as well as the disruption of commercial activities and services. For the flooding event of December 2014, the economic losses were estimated to be 200 million dollars.

Floods are among the most frequent natural disasters causing widespread damage of life and property [1]. As much as 90 percent of the damage related to natural disasters in Malaysia is caused by flood [2]. Average annual flood damage is as high as 100 million dollars. These flooding have caused considerable damage to highways, settlement, agriculture and livelihood. In Malaysia, floods are caused by a combination of natural and human factors. Malaysians are historically river dwellers as early settlements grew on the banks of the major rivers in the peninsula. Coupled with natural factors such as heavy monsoon rainfall, intense convection rainstorms, poor drainage and other local factors, floods have become a common feature in the lives of a significant number of Malaysians. Monsoon rains have a profound influence on many aspects of the lives of the people in the east coast of Peninsular Malaysia [2]. While the rains are needed for agriculture, particularly wet rice cultivation, they are also largely responsible for bringing seasonal floods.

Every year floods in Kelantan causes significant damage. Thus, flooding is a yearly occurring phenomenon especially on the Kelantan River and it may be induced by rainfall. The Kelantan River regularly overspills its banks during the months of November to February because of the northeast monsoon season. The estimate flood volume under the 50 years flood condition at Kusial Bridge is about 6 billion m^3 [3]. Severe flooding occurred in '1926' and '1967'. In the 1967 floods, 84% of the Kelantan population (537,000 people) were badly affected [4]. Some 125,000 people were evacuated and 38 drowned. More recently a telemetric flood forecasting system has been installed to give warning of high river levels [4].

Extreme flood events with catastrophic effect on the effected settlements keep reminding us of the urgent need for the implementation of effective protection concepts which is called resilience concepts. In order to establish a well-defined theoretical and practical framework on flood resilience, it is vital to address the concept of vulnerability in flood prone areas. Although flood impact assessment methods have been around for many years, rapid changes in the contemporary urban environment require the adaptation and development of theory, methods and application in vulnerability assessment. Although, the concept of vulnerability is strongly related to susceptibility (e.g. the protection level provided by primary flood defence system), quantitative starts with impact estimation. Due to the increasing availability of data this hold true not only for retrospective assessment but to a large extent also for prospective cases in which potential flood impact assessment can address disruption of society's socio-economic backbones and their effects on regional, national and even transnational networks. This applies especially to methods used to evaluate the indirect effects [5].

Problems related to flooding have greatly increased, and there is a need for an effective modelling to understand the problem and mitigate its disastrous effects [6]. Human activities such as unplanned rapid settlement development, uncontrolled construction of buildings in general and major land use changes can influence the spatial and temporal pattern of hazards. There are several factors contributing to the flooding problem ranging from topography, geomorphology, drainage, engineering structures, and climate. Most floods are caused by storms in which a lot of precipitation falls in a short period of time, of both types of rainfall, convective and frontal storms. Intensity and duration of the rain are the most influencing factors for flood hazards [7].

In Peninsular Malaysia, the risk of flooding affects a significant section of its population. As floodplains are rapidly developed and being encroached upon, more and more people and property (including public infrastructure, communications and private industries and business) are exposed to flood risk. As population pressures build up in floodplains, the capacity for public response is diluted and reduced, and this increases vulnerability. Floodplain occupants are also largely from the lower income groups [2].

Flood mitigation, especially in large floods, should mitigate the risk of severe flooding in one area. Information about hazards, exposures and extent needs to be known as an effort to take priority action on flood issues. One of the solutions is to provide a precise and reliable flood extent and hazard map to the authorities including the citizen [8]. Currently, food extent and hazard maps are derived from a few sources such as satellite images, areal images and post-flooding food marks. Government and NGOs already made maps and information related with the December 2014 flood but some of them did not integrate with the information gathered from the local people who really stayed in that area although they were victims of flood and had experience the flood. That is the reason why the author tries to configure the flood occurrence in this study area using the data collected from field survey and households' interviews.

The objectives of this study are to gather the primary data through face to face interview with local people which were the flood victims of the Kelantan big yellow flood event, to determine flood vulnerability in the four selected research area using frequency analysis and Chi-square test and to delineate the flood extent map directly from the flood-prone area through site visit observations and interviews.

2. Literature review

In Peninsular Malaysia, the risk of flooding affects a significant section of its population. As floodplains are rapidly developed and being encroached upon, more and more people and property including public infrastructure, communications and private industries and business are exposed to flood risk. As population pressures build up in floodplains, the capacity for public response is diluted and reduced, and this increases vulnerability. Floodplain occupants are also largely from the lower income groups [2].

From historical overview several major flood events experienced in the last few decades at the east-coast of Peninsular Malaysia dates as far back as 1886 where it was reported one severe flood had caused extensive damages to Kelantan. Next was the flood in 1926 and 1967 where disastrous floods surged again at the east- coast across Kelantan, Terengganu and Perak. A few years later in 1971 another catastrophic event were reported with Pahang severely affected [9].

Huge floods are also been observed to occur more frequently nowadays. In November 2005, a flood in Kota Bharu was described as the worst natural flood in history at that time. Due to geographical characteristics, unplanned urbanization and proximity to the South China Sea, city like Kota Bharu has become extremely vulnerable to monsoon flood every year. Afterwards, in the year 2006, 2007 and 2008 heavy monsoons rainfall again have triggered major floods along the east-coast as well as in different parts of the country. The hardest hit areas are again along the east- coast of Peninsular Malaysia in the states of Kelantan, Terengganu and Pahang [7,10].

Flooding is any relatively high flow that goes beyond the river embankment so that the water overflows to the flood plain and cause problems in humans [11,12,13]. The above definition explains that flooding occurs when the river flow capacity has been exceeded and overflow spread to the floodplain, even further causes an inundation and creates problems to people living within the particular area.

Global population growth, more intensive urbanization in flood prone areas and the limited development of sustainable flood-control strategies will increase the potential impacts of floods [13]. Flooding used to be limited to rural areas, but it has now become pervasive in urban areas as well [14]. With their high population densities and concentration of diverse economic activities, cities around the world particularly in developing countries face tremendous challenges in dealing with flood-related problems [15]. Floods in urban areas intensify with the increase of impervious surfaces such as roofs, roads, parking lots, and pavements [16], which cause changes in runoff conveyance networks. Over the past few years, many cities around the world have experienced disastrous floods; notably, a flood in Bangkok, Thailand, lasted for 175 days, took 815 lives, and caused about US$45.7 billion in damage [17].

Flood is called a natural disaster, when they occur in area occupied by human. The disaster can involve the loss of human life and property plus serious disruption to the ongoing activities of large urban and rural communities. Urban and rural areas may be affected by flooding due to rivers, coastal waters, rainfall and groundwater overflow, and the failure of artificial system. Urban flood originated from a combination of causes is the result of a combination of meteorological and hydrological events, such as deposition and extreme flow. But also can often occur due to human activities, including growth and development of the city which is not planned as floodplain, or the failure of dams or levees to protect the development of the city [18]. Rural can be more affected due to their limited coping capacity to the effects of flood [19].

Flooding caused by some factors, namely rain, destruction of Watershed retention, weaknesses in river development planning, river silting factors and river restructuring factors and the effect of construction of facilities and infrastructure [20], besides the factor of land cover that affect the soil infiltration rate also plays an important role in the event of flooding [21]. Floods also occur when soil becomes saturated and its infiltration capacity is zero; runoffs cannot be contained in stream channels, natural ponds and constructed reservoirs, and the land surface becomes submerged, sweeping away all its content. Periodic floods, resulting during heavy rains, occur naturally on many rivers, forming an area known as the flood plain.

Floods affect vast areas, are difficult to contain and cause great destruction, representing a huge threat to lives and property. They are a constant risk facing mankind [22]. The extent of damage depends on the vulnerability of the affected people and infrastructure. Flood vulnerability has its origins in various dimensions that are sometimes hard to capture and to describe precisely and even harder to measure and to evaluate [23].

3. Study area, material and method

3.1 Study area

Figure 1. Location of sampling site at Gua Musang and Kuala Krai district

The data of this study was collected from two districts in Kelantan state namely Kuala Krai and Gua Musang (Figure 1). Those districts have been divided into four specific research area namely Gua Musang, Kuala Krai, Manek Urai and Kuala Pergau (Figure 2) to ensure the primary data can be rigorously collected during the field visit for the purpose of in-depth study on flood hazard. The selection of those specific research areas is based on similarities on administrative status and flooding exposure among locations. Gua musang research area that consists four sub-districts namely Bandar Gua Musang covering 26.75 km^{2,} Ketil covering 128.37 km^{2,} Pulai covering 257.94 km^2 and Batu Papan covering 169.19 km^2 and Kuala Krai research area that consists three sub-districts namely Kenor covering 140.96 km^2, Batu Mengkebang covering 86.15 km^2 and Bandar Kuala Krai covering 5.18 km^2 are represented the urban flood-prone area. Meanwhile, Manek Urai and Kuala Pergau research area which are also another sub-districts in Kuala Krai are represented the rural flood prone area of this study covering 283.7 km^2 and 63.2 km^2 respectively. Those covering areas have been summarised in Table 1.

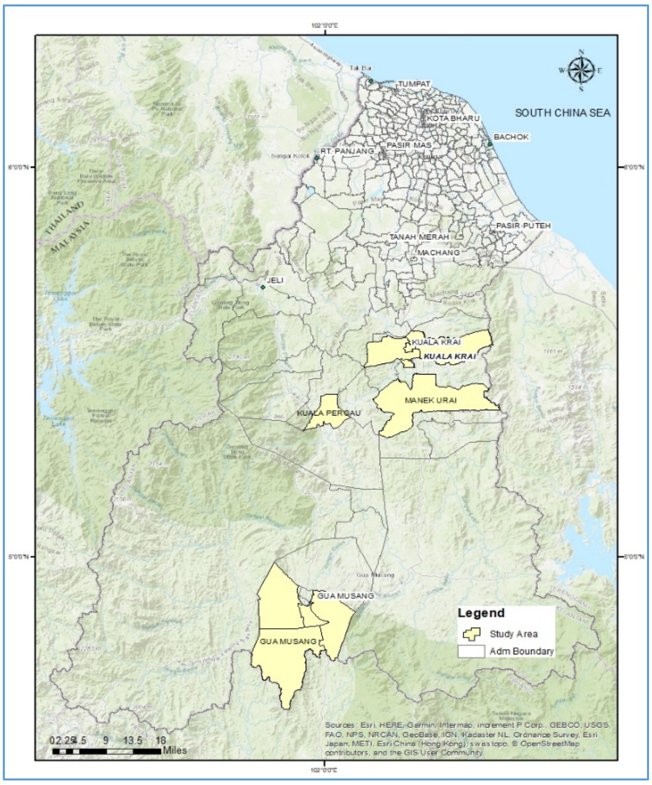

Figure 2. Location of four specific study area: Gua Musang, Kuala Krai, Manek Urai and Kuala Pergau

Table 1. Nine Sub-district of study area

District	Subdistrict	Total area (km²)
Gua Musang (GM)	Bandar GM	26.75
	Batu Papan	169.19
	Ketil	128.37
	Pulai	257.94
Kuala Krai (KK)	Bandar KK	5.18
	Mengkebang	86.15
	Kenor	140.96
	Manek Urai	283.7
	Kuala Pergau	63.2

3.2 Data Collection

Most of the commonly used data in the study related to flood mitigation and flood risk analysis are secondary data from flood-related government agencies and spatial datasets from satellite image without any investigation on the real situation through field visit of the flood-prone area. Therefore, this study has been guided by both type of data which is primary and secondary data in statistical and spatial analysis to ensure trustworthy findings with a high level of reliability.

During a flood event it is often difficult to get accurate information about the flood extent and the people affected. This information is very important for disaster risk reduction management and crisis relief organizations. Most common way to collect that information through a field visit immediately after the flood event. The field visit of this study into the four aforementioned specific flood-prone research area i.e., Gua Musang, Kuala Krai, Manek Urai and Kuala Pergau has been done after sixmonth of 2014 yellow flood event in Kelantan. In this field visit a primary data has been collected through observations, photography and household survey interviews. There were two hundred households where fifty samples that randomly chosen from each prone area have been interviewed during the fieldwork. Through this brief interview from each of the households, data on flood-depths and flood-durations were gathered. The flood depths data was map directly to the indication of flood mark in the building. The position of all sampling location was also recorded using Garmin handheld Global Positioning System (GPS). Hence, using the same device the elevation of each points and distance of each houses to the nearest river were also measured. Other parameters such as demographic information of respondents as flood victims and percentage of damage with the total loss due to the flood event are also gathered through this face to face interview. This field sampling is based on proximity to the flood-prone area, experience with flood, and occupation by infrastructure, properties, housing or settlements. In collaboration with community leaders, flooded areas are delineated using the quick bird satellite image aided by local knowledge about flood extent in the study area.

Meanwhile the secondary spatial datasets that consist of Quickbird multispectral satellite image of Research areas with a resolution of 0.60 cm, existing spatial datasets (boundaries, roads network, contour line, drainage), meteorological data linked to the weather station were also acquired beforehand. The recent version of population, social, economic statistical data of research areas were also gathered. Those secondary data were acquired from an open source website and official interview that involve several governments agencies such as the Department of Irrigation and Drainage, Department of Meteorology Malaysia, Public Work Department, Agency Remote Sensing Malaysia, Kelantan District Council, and District Council in the research areas.

3.3 Statistical analysis on flood vulnerability

Empirical work is very important in applied statistical studies because it deals with real data to solve real problems. Better understanding of real dataset is essential to ensure an appropriate framework of statistical method is applied so that an unbiased statistical inference could be made in particular study [24]. In this study, the observations of nominal or categorical variables that related to social and economic status have been collected through household face to face interview by using the developed survey questionnaire during the field visit into the four selected research area in this study. To analysis those types of variable descriptive and inferential statistics have been used. Descriptive statistics uses the data to provide descriptions of the population, either through numerical calculations such as frequency analysis with graphs or tables. Inferential statistics makes inferences and predictions about a population based on a sample of data taken from the population in question. For inference statistics, Chi-square test of independence will be used to determine if there is a significant relationship between two nominal (categorical) variables. The frequency of each category for one nominal variable is compared across the categories of the second nominal variable through two by two contingency table. This approach consists of four steps: (1) state the hypotheses, (2) formulate an analysis plan, (3) analyze sample data, and (4) interpret results. The hypothesis of this test will be:

H_o: Variable A and Variable B are independent.
H_a: Variable A and Variable B are not independent.

The test statistic is a chi-square random variable (X^2) defined by the following equation.

$$X^2 = \Sigma \left[(O_{r,c} - E_{r,c})^2 / E_{r,c} \right] \qquad (1)$$

where $E_{r,c}$ denoted as ($E_{r,c} = (n_r * n_c) / n$) is the expected frequency count for level *r* of Variable A and level *c* of Variable B, n_r is the total number of sample observations at level r of Variable A, n_c is the total number of sample observations at level *c* of Variable B, and n is the total sample size. This test will automatically be computed by using any statistical software.

3.4 Spatial analysis on flood depth and extent

Flood map represents the flood plain extent which is defines how far a given water level will locally extend. Based on flood level, flood map will be derived from a digital elevation model (DEM) by separating pixel values into areas below and above the high flood level, thereby delineating areas that would or would not be flooded. The flood extent map is generated through the delineation of the flood plain extent using information from local experts at the district level, Digital Elevation Model (DEM) quality improvement, extraction of elevation information at the houses (point location of flood depth), subdivision of the study area in to two zones, flood depth interpolation and flood depth mapping base on average house elevation in each zone. The data uses for flood extent mapping are obtained from official interviews and distribution of Questionnaires at the settlements in flood -prone area. To identify the flood extent, the flood plain is delineated by local experts and digitize from the high-resolution satellite images. The flood depth from household surveys is estimated base on watermarks found on the houses with reference to the ground. To obtain data of flood depth, the observed flood depth at a house location is first aided to the corresponding elevation value from DEM; interpolation is then conducted to generate a flood depth surface.

4. Results and discussion

4.1 Empirical findings on flood vulnerability

Statistical method such as frequency analysis has been used in this study to empirically determine the vulnerability related to social and economic due to the big yellow Kelantan flood 2014. The element of these two types of vulnerability due to flood event have been summarized in Table 1 based on the developed questionnaire that has been distributed to the fifty flood victims in each four selected research area i.e., Gua Musang, Kuala Krai, Manek Urai and Kuala Pergau making the total number of respondents is 200 people.

Table 2: Categorization of distinctive vulnerabilities

Category	Theme	Types
Economics	Total loss	1. Vehicle 2. Household 3. house 4. shop business 5. farm
Social	Age	6. 19 years and below 7. 20 years-39 years 8. 40 years-60 years 9. 61 years an above
	Occupation	10. Business 11. Farmer 12. Government 13. Housewife 14. Labor 15. Pensioner 16. Private 17. self-employed 18. unemployed 19. student
	Gender	20. Male 21. Female

Based on the distributed questionnaire, three variables that related to the economics vulnerability have been asked to the respondents i.e. 'total loss', 'type of damage' and 'percentage of damage'. The collected observations from the variable 'total loss' shows that three classes of economic vulnerability can be determined as High total loss (H) with a range of total loss greater than RM 100 000, Medium (M) between RM 50 000 to RM 100 000 and Low (L) with a smaller range of RM 50 000. Based on this classification, economics vulnerability by four considered flood-prone area is visualized in Figure 3 with the calculated economics vulnerability index summarized in Table 3.

Table 3: Economic vulnerability by area

Area	Total Lost	EVI Level
Gua Musang	2,600,000.00	Medium
Kuala Krai	5,100,000.00	High
Dabong	2,795,000.00	Medium
Manik Urai	4,140,000.00	High

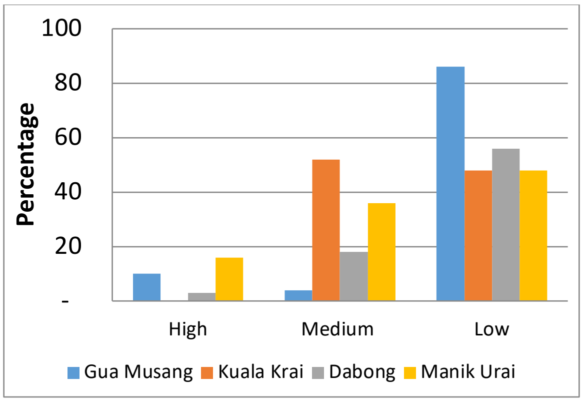

Figure 3. Distribution of total loss by area

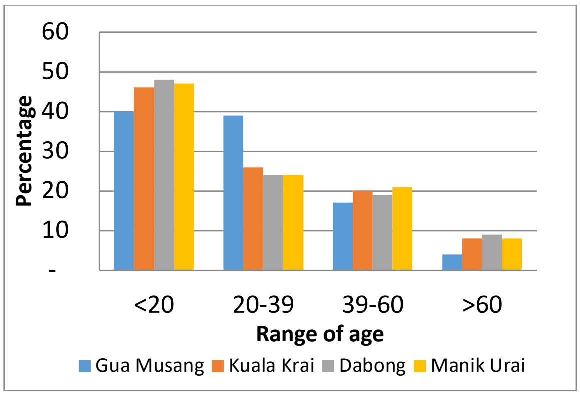

Figure 4. Distribution of respondents' age by area

Social vulnerability focuses on age, gender and occupation as shown in Figure 4, 5 and 6 for each study area. Factor such as age, gender and occupation are important physical or mental characteristic that affect a person's ability to cope and respond to flood. Figure 3 explains that the age below 20 years is most exposed to the Kelantan flood in December 2014. This data also illustrates that young people are more vulnerable to flooding than older people, no matter where they are, in the town or in the village. While the data obtained in Figure 4 does not show a large percentage difference, it means gender status has no effect in determining the level of flood social vulnerability in the Kelantan flood in 2014. Respondents in the study area also can be categorized based on their occupation, Figure 5. Based on data collected in the field shows that business was the occupation most affected by flooding in all Kelantan State in 2014. On the other hands unemployed people also experienced the same impact as businesses. In general, it can be concluded that in the four regions, the study of flood vulnerability can be determined based on the impact experienced by the type of work. As described earlier, business occupation is occupational which has a very high level of vulnerability.

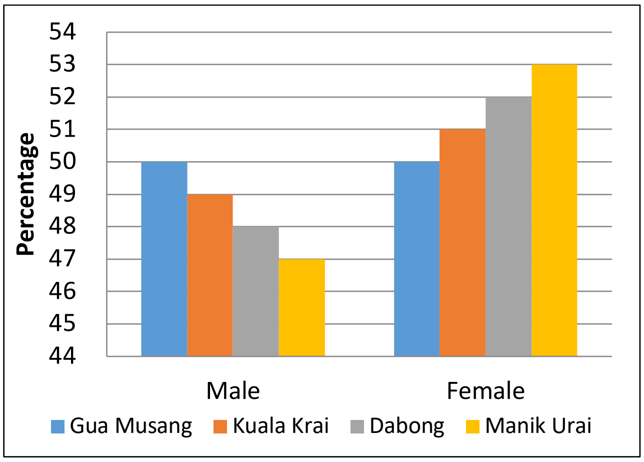

Figure 5. Distribution of gender composition by area

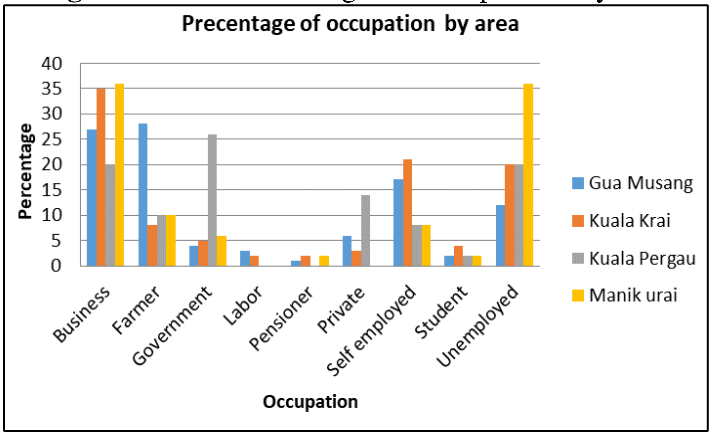

Figure 6. Distribution of occupation composition by area

Some inference statistical method using chi-square test has been used in further analysis of this study to support the descriptive result given by frequency analysis on flood vulnerability. Since the depth of the flood is one of the key elements in the determination flood extent, exposure, hazard and vulnerability, therefore further investigation on the relationship between this variable with another important variables in this study need to be determined. Another three important variables in this study that felt be affected by flood depth are 'type of damage', 'distance from river' and 'total amount of rainfall' that distributed in those selected research areas. Table 4 shows the two by two contingency table between variables 'flood depth' and 'type of damage', while Table 5 and 6 show the two by two contingency table between variable 'flood depth' with variables 'distance from river' and 'total rainfall' respectively. The chi-square statistics are reported together at the bottom of those tables with the p-value at 0.05 level of significant. From the results of chi-square test, it is clearly showing that the variable 'flood depth' has an association with the variable 'type of damage' and 'total rainfall' but not with the 'distance from the river'. Therefore, we can significantly say that, the Kelantan big yellow flood 2014 is totally influence by heavy rainfall where the degree of damage caused by the flood is influenced by the depth of the flood.

Table 4. Two by two contingency table of 'flood depth' and 'type of damage' with chi-square value

Type of damage	Flood depth (m)			
	< 1	1 - 2.5	2.5 - 5	> 5
Destruction	0	0	5	37
Severe	0	2	1	34
Moderate	2	0	6	36
Minor	7	3	16	21
No damage	15	6	4	5

* The chi-square statistics is 85.3586. The p-value is 0.00000.

Table 5. Two by two contingency table of 'flood depth' and distance from river' with chi-square value

Distence from river	Flood depth (m)			
	< 1	1 - 2.5	2.5 - 5	> 5
< 20m	4	2	3	14
20m - 60m	3	1	5	31
60m - 100m	2	8	7	25
> 100m	15	8	17	63

* The chi-square statistics is 12.2614. The p-value is 0.19896.

Table 6. Two by two contingency table of 'flood depth' and 'rainfall distribution' with chi-square value

Total rainfall (mm)/ area	Flood depth (m)			
	< 1	1 - 2.5	2.5 - 5	> 5
195 - 210/ KP	1	1	1	47
210 - 220/ GM	6	13	8	23
210 - 295/ KK	3	5	9	33
210 - 515/ MU	2	6	15	27

* The chi-square statistics is 38.78097. The p-value is 0.00001.
*KP-Kuala Pergau, GM-Gua Musang, KK-Kuala Krai, MU- Manek Urai

4.2 Flood extent map from spatial analysis

Flood extent map for each study area has been obtained from the results of direct mapping in the field which was depicted in a topographic map with interpolation techniques. The information about flood extent by local people in collaboration with community leader during the sampling visit is a based in measuring the reliable flood extent in flood prone area during the big yellow flood 2014 in Kelantan that has been summarized in Table 7. Hence, the flood exposure for each specific research area has been visualized in Figure 7, 8, 9 and 10. Figure 7 shows that the flooding area in Bandar Gua Musang. There are four Mukim in Gua Musang which were affected by flood. The flood affected Mukim Batu Papan, Bandar Gua Musang, Mukim Ketil and Mukim Pulai. Flood inundated 16 out of 75 villages or Kampungs. The result of field data processing using GIS software shows that the largest percentage of flood exposure is Gua Musang subdistrict, while the most widely inundated is Pulai sub-district. Total flood exposure in Gua Musang is 22 km^2, 3% of total area of Gua Musang. Figure 8 shows the result of field data processing using GIS software in Kuala Krai where the largest percentage of flood exposure is Bandar Kuala Krai subdistrict, while the most widely inndated is Batu Mengkebang sub-district. Total flood extent in Kuala Krai is 32.35 km^2 which is 13.92 % of total area of Kuala Krai. Finally, Figure 9 and 10 shows the result of field data processing using GIS software in Manek Urai and Kuala Pergau respectively. The total flood extent in Kuala Pergau is 4.79 km^2 which is 7.86% of the total area of Kuala Pergau while in Manek Urai is 29.56 km^2 which is 10.41% of total area of Manek Urai. Through topographic map analysis that visualized in those figures it is known that flooding occurs in areas that have relatively small slopes or in flat areas.

Table 7. Flood Extent in nine Sub-district of study area

No.	**Subdistrict**	**Total area (km^2)**	**flood Floor extent (km^2)**	**Percentage of Flood extent (%)**
1	Gua Musang	26.75	5.05	18.8
2	Batu Papan	169.19	2.55	1.5
3	Ketil	128.37	4.31	3.33
4	Pulai	257.94	10.11	3.91
5	Kuala Krai	5.18	4.97	95.76
6	Mengkebang	86.15	19.78	22.96
7	Kenor	140.96	7.6	5.39
8	Manek Urai	283.7	29.56	10.41
9	Kuala Pergau	63.2	4.97	7.86

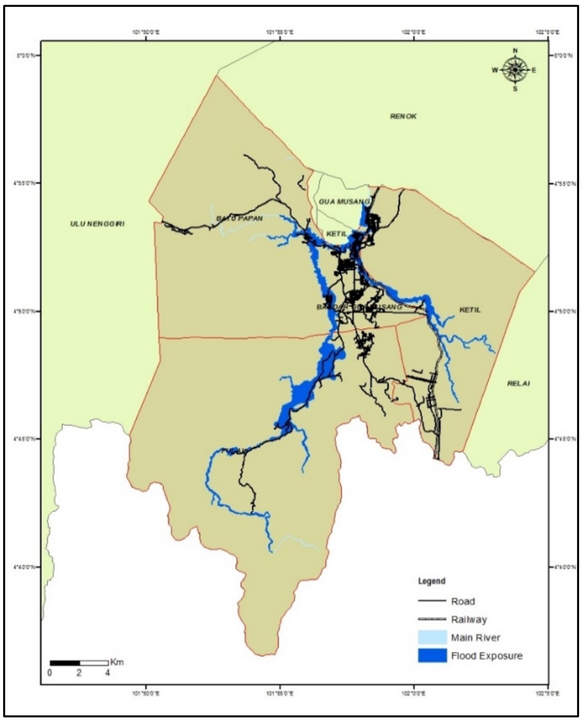

Figure 7. Flood extent in Gua Musang

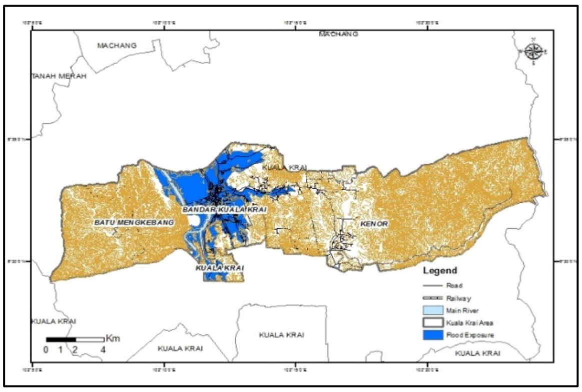

Figure 8. Flood extent in Kuala Krai

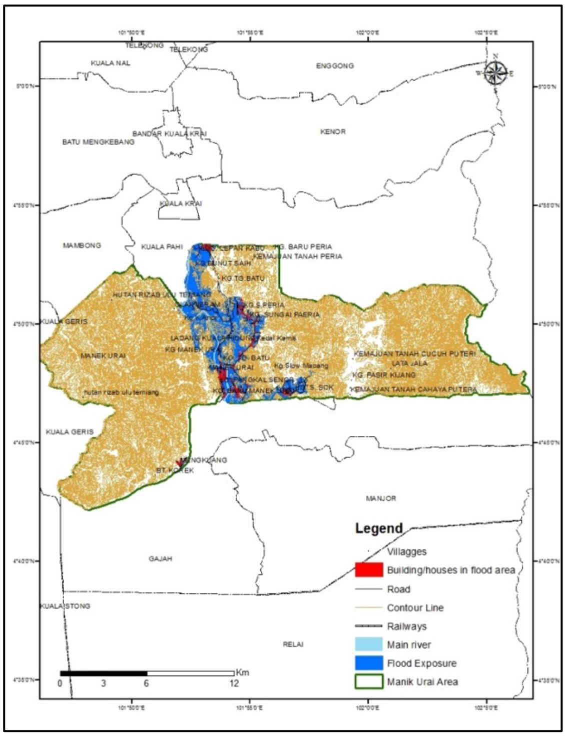

Figure 9: Flood eztent in Manek Urai

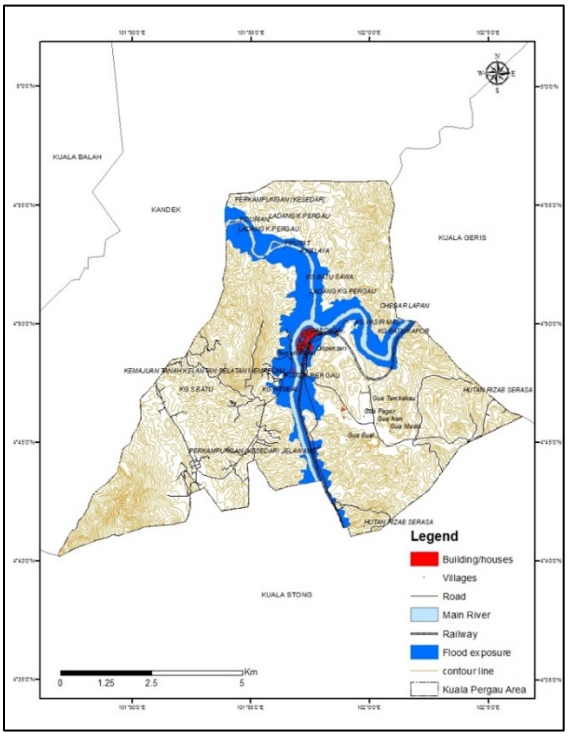

Figure 10: Flood extent in Kuala Pergau

5. Conclusion

Flood mitigation, especially in large floods, should mitigate the risk of severe flooding in one area. Information about hazards, exposures and extent needs to be known as an effort to take priority action on flood issues. One of the solutions is to provide a precise and reliable flood extent and hazard map to the authorities including the citizen [8]. Government and NGOs already made maps and information related with the December 2014 flood but some of them did not integrate with the information gathered from the local who were victims of flood.

The reliable flood extent map is needed and the base for mitigating the hazards of an infrequent extreme flood event (say 1 in 1000 years event) through flood insurance [25]. Great deal of effort by the authorities and the active researchers in this field are needed to construct the reliable flood extant map by directly delineating from the flood-prone area through site visit and primary data gathered from face to face interview with local people which are the flood victims. This valuable primary data is also crucial in determining flood vulnerability in aspect of economics and social. Lead by those primary data and integration with the secondary data from several related agencies this study has successfully construct the reliable flood extent map which is slightly different with other developed flood map by Government, NGOs and active researchers in this field.

Meanwhile the empirical findings using statistical analysis such as frequency analysis with support by chi-square statistical test for categorical variables has lead us to develop an appropriate research framework for further investigation in determining the flood vulnerability index for each category i.e. economics and social using Analytic Hierarchy Process (AHP) analysis. Another category in flood vulnerability such as physical vulnerability can also been considered in the future research. Based on this three expect perhaps the flood vulnerability index can be precisely determine by using AHP analysis.

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