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Spatio-temporal analysis in determination of flood extent based on rainfall intensity and water level data in Kuala Krai, Kelantan

Spatio-temporal analysis in determination of flood extent based on rainfall intensity and water level data in Kuala Krai, Kelantan

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Abstract. Kuala Krai is one of the districts in Kelantan that affected by flooding almost every year. The recent worse case is during Kelantan big yellow flood event in 2014. The main objective of this paper is to descriptively interpret the relationship between rainfall event and flooding in Kuala Krai, Kelantan using pass data of rainfall intensity and water level. Those data have been verified using ground data collection of flood level six month right after Kelantan big yellow flood event in 2014. Other related primary data also have been collected among the 2014 flood victims in Kuala Krai using survey questionnaire. The observed flood level data and other related primary data have been delineated and spatially analysed using ArcGIS to visualize the flood extent maps of each study area in Kuala Krai based on extreme flooding data on 2014. It can be concluded that urban area gave high percentage of flood extent compared to rural area of Kuala Krai.

1. Introduction

Floods are caused mostly by heavy rainfall in many places of the world, including Malaysia. Floods are widespread in Malaysia due to the country's geographical location, which is near the equator and surrounded by seas, exposing it to a climate with a consistent temperature and high humidity [1]. Therefore, the monsoon seasons have an impact on rainfall distribution in Malaysia. The traditional period of monsoon season, in particular, brings the most rain to Peninsular Malaysia [2]. The two monsoon seasons are the northeast monsoon, which lasts from December to March, and the southeast monsoon, which lasts from June to September. The wettest months of the year are typically April, October, and November [3]. The East Coast and West Coast of the peninsula receive heavy rainfall during these monsoons due to winds transporting moisture from the seas [4].

One of the most frequent hydrological phenomena in Kelantan state, on the east coast of Peninsular Malaysia, are floods brought on by heavy rain events, and they have inflicted damage. In 1967, when 84 percent of the communities in Kelantan were negatively impacted, 125,000 people were evacuated, and 38 people drowned [5], previous floods were deemed serious. The most recent flood, which was the greatest in Kelantan's recorded history and was dubbed the "Kelantan Big Yellow Flood" because of its bright yellow color from the abundance of muck, occurred in 2014 [6]. With 16,734 households evacuated in 83 rescue camps, Kuala Krai, a district of Kelantan, was the worst hit in this recent huge flood event [7]. The floods caused significant damage to the community of Kuala Krai in Kelantan, involving property loss, crop destruction, livestock loss, and human casualties. Additionally, some economic activity was hampered by the damage to communication networks and infrastructure, including power plants, highways, and bridges.

The topographic features of the area and the regular occurrence of rainfall events with significant volume and intensity could both have a role in the cause of floods [8]. In addition to the significant rainfall that occurred during the northeast monsoon period, physical factors such as elevation and the confluence of two major rivers i.e., the Galas River and the Lebir River that form the Kelantan River in Kuala Krai, Kelantan, were also contributing causes [9]. Heavy rainfall over a long period of time caused a river overflows its banks and the water level increased drastically. This study attempts to descriptively investigate the relationship between event of whether activities and flooding in Kuala Krai, Kelantan using pass data of rainfall intensity and water level. The effect of urbanization on flood extent in Kuala Krai was also investigated using spatial analysis and direct mapping in the field for six months after 2014 yellow flood event in Kelantan.

2. Data Source and Study Area

2.1. Data Source

Two types of data have been used in this study which are primary and secondary data. Primary data is acquired directly from the source of the data and is considered the greatest type of data in research. Field observations, photographs, interviews with urban planning authorities at the sector, district, and town levels, and a household survey provided primary data (including GPS location data of housing unit) for this study. The survey sample is drawn from flood-prone locations in the study areas. In partnership with community leaders, sampling is based on proximity to a flood-prone area. Meanwhile, secondary data used for this study is summarized in Table 1.

Table 1: List of secondary data

Data Type	Parameter/Variable	Frequency	Duration	Source/Remark
Hydrological data	Rain fall River Water Level	Daily	2014	Jabatan Pengaliran dan Saliran
Toporaphical data	Elevation and distance Scale 1:50000	Study area	1997	Jabatan Ukur dan Pemetaan
Remote Sensing Data	Ground image, Quickbird Resolution 0.6 cm, Landsat 30 m, and Spot Image 5 m	Study Area	2015, 1998,2010	Agency Remote Sensing Malaysia (ARSM)

2.2. Study Area

This study was carried out at Kuala Krai, Kelantan, which is located roughly 18 miles south of Kota Bharu, the capital of Kelantan that lies between latitude 102° 12' 6.6636" and longitude 5° 31' 50.9268" north. With a total population of 109,461 and a land area of 2287 km^2, Kuala Krai has a comparatively high population density in Kelantan. This district has lowland in the north and low hills in the east, west, and south. Most often, the elevation is between 153 and 305 meters above sea level. The side adjoining Jeli district has the highest level, which is over 915 m. On the Kelantan River in Kuala Krai, the two principal rivers, the Galas River and the Lebir River, converged. Due to its elevation and the junction of the two major rivers that comprise the Kelantan River, Kuala Krai is susceptible to floods every year brought on by heavy rains that fall during the northeast monsoon season.

The topographic features of Kuala Krai, Kelantan, are depicted on a map in Figure 1. ArGIS software has been used to create this map. The map displayed six scattered rainfall stations and three water level stations in Kuala Krai and 150 dwelling locations of flood victims in 2014. The primary river that flows through Kuala Krai was also emphasized on the map, along with a contour line that visualized the

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elevation patent of Kuala Krai. Based on 150 samples representing the residences of 2014 flood victims, the map also highlighted four study sites. The homes of these flood victims are evidently situated along Kuala Krai's main river, and the four study regions that suffered the most during the 2014 floods are Batu Mengkebang, Manek Urai, Kuala Pergau, and Manjor that have been highlighted with pink color in Figure 1.

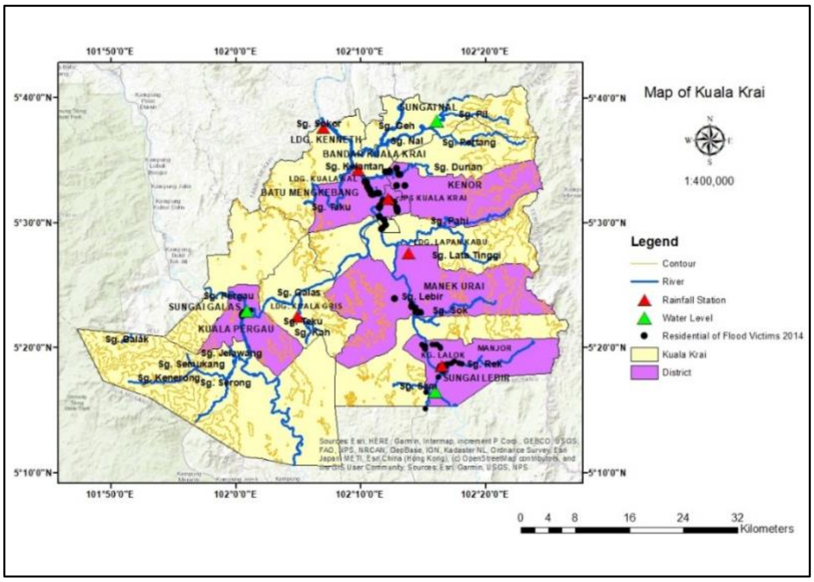

Figure 1: Map of study area indicating six rainfall stations and three water level stations in Kuala Krai, Kelantan

3. Methodology

3.1. Primary Data Collection

In order to develop an effective mitigation and preparedness strategy to lessen the risk from the fury of future floods and for a resilient community, the field survey plays a significant role as they direct towards long-term solutions, including improved flood warning systems. The field survey has been conducted to collect the data by interviewing flood victims using questionnaire and observe/ collect the physical data in the field using measure tools such as GPS and measuring tape. The field survey was carried out along the most severely affected areas in Kuala Krai namely Kuala Krai City, Manek urai and Kuala Pergau. The main components of questionnaire are regarding to flood hazard experience, related to depth, duration, and other flood characteristics such as distance from rivers and physical impressions. Descriptive statistics were used to analyze the data that had been obtained. It was applied to comprehend how intense rainfall affected flood level.

3.2. Descriptive Hyetograph and Hydrograph Analysis

First stage in this research is to analyses the depth and duration of the flood in study area based on the obtained data through direct measurement and data processing using available hyetograph and hydrograph on December 2014 from DID. Hyetograph is a graphical representation of rainfall over time. It is a plot of rainfall depth (Y-axis) against time (X-axis). The entire amount of rainfall for the particular period is indicated by the area beneath the hyetograph. This graph is extremely helpful in illustrating the characteristics of a storm and is crucial when creating a design storm to forecast significant flooding. A hydrograph is a graphic representation of the stream or river's discharge over time. It depicts changes in time at a specific location along a stream. Additionally, it displays the total runoff's time distribution at the measuring site. The corresponding time is represented on the X-axis, while the discharge is plotted on the Y-axis. The method of assessing surface runoff most frequently employed is hydrograph analysis.

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The descriptive interpretation will then be recounted based on those graphs, along with the data obtained through in-person interviews with flood victims and officers from associated agencies.

3.3. Processing Flood Extent Map

The process of making flood extent maps throughout the study area starts from the provision of maps in the form of both digital and hard copy maps taken from Department of Survey and Mapping Malaysia (JUPEM) at a scale 1:50,000 that has been increased so that the contour interval is getting smaller or denser. Then the process is carried out to form a Digital elevation model (DEM) based on the depth values obtained through manual field surveys. Based on field data, a river depth map was created using interpolation techniques. Meanwhile, on the other hand, parallel work is being carried out to analyze the flood boundaries along the river using the help of high-resolution satellite imagery guided by hydrographic data. These two maps are then overlaid, to produce a map that can show a map of the flood depth at a certain area.

Flood maps were produced using a digital elevation model (DEM) field survey based on flood level. Pixel values were split into groups below and above the high flood level using this technique. The flood plain is digitally derived from high-resolution satellite photographs and marked by local experts to determine the extent of the flood. Home surveys that consider the location of watermarks on the structure in relation to the ground can estimate flood depths. The measured flood depth at a housing site is first compared to the related elevation value from the DEM before performing interpolation to construct a flood depth surface.

The flood mapping was carried out using Global positioning system high-resolution satellite imagery (Quick bird with 0.6 m resolution) and a topographic map of the earths at scale 1: 50.000 by direct field mapping activities. Via direct field surveys, mapping of flood borders was carried out and then interpolated on a map. To obtain the flood boundary and its extent, 3-dimensional digital Via available hydrographic analysis, flood depth information was collected. A flood depth map according to the desired classification was generated via the interpolation process. As seen in the image, the approach for performing this survey is to follow the contacts between the flood borders, perform cross-surveys and carry out the river crossing line.

4. Result and Discussion

4.1. Flood depth and duration in Kuala Krai

Flood depth and duration in Kuala Krai is based on processed data of available hyetograph and hydrograph on 19 to 31 December 2014 from DID. The flood become worth in Kuala Krai at this time because of second phase of heavy rainfall in Kelantan that occurred two days after the first phase [10]. The descriptive results have been reported in three categories of area which are urban, suburban, and rural areas. Urban area of Kuala Krai is represented by Batu Mengkebang district that consists of Kuala Krai city as one of the subdistricts. Meanwhile suburban and rural areas are represented by district of Manek Urai and Dabong respectively.

Based on descriptive graphs of these three areas of study in Figure 2, it is clearly shown that the second phase of heavy rainfall in Kelantan occurred on 21 until 24 of December 2014 that caused severe flood starting from 22 to 30 December 2014 in Kuala Krai where the worst hit areas are Kuala Krai city in Batu Mengkebang, Manek Urai and Kuala Pergau in Dabong. Rainfall and water level record breaking was also happened due to this huge flood especially stations at upstream river basin in Dabong district as visualised in Figure 1(c).

These demonstrate that the large-scale, protracted flooding that occurs in Kuala Krai Kelantan is the result of excessive precipitation. Due to heavy rainfall practically everywhere in the nation and increased slope of the Kelantan Basin, there is a very large water storage capacity. the effects of the flooding that occurred throughout the state because of rain that accumulated in the basin starting upstream. This very large water capacity has drowned the whole Kuala Krai because as mentioned above Kuala Krai is vulnerable to flood events especially during the northeast monsoon period due to its physical factors

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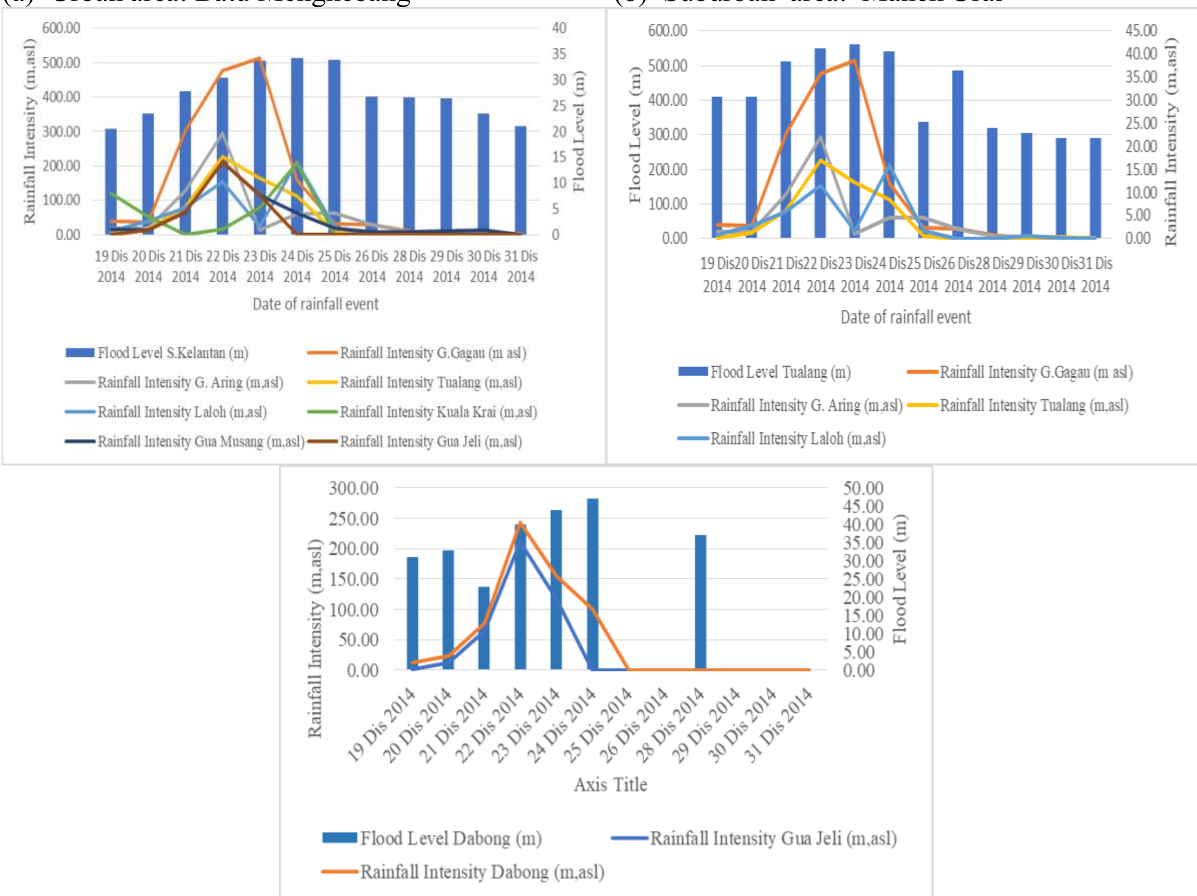
which is the elevation and the collision of two main rivers that form Kelantan River in the middle of Kuala Krai region.

(a) Urban area: Batu Mengkebang (b) Suburban area: Manek Urai



(c) Rural area: Kuala Pergau, Dabong

Figure 2: Descriptive analysis on rainfall intensity and water level in Kuala Krai

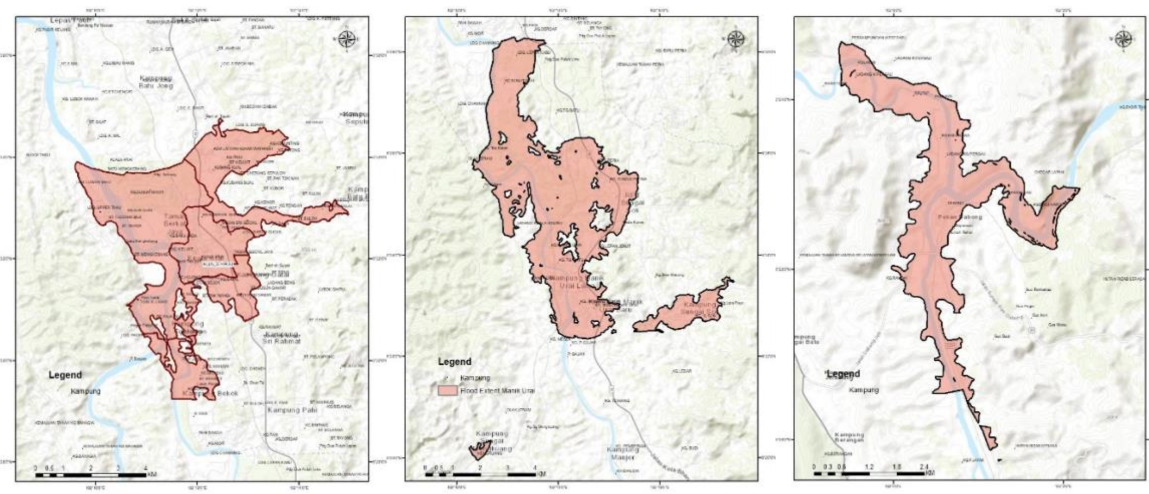
4.2. Flood Extent Map in Kuala Krai

Table 2: Analysis on flood extent in Kuala Krai

No.	District	Type of area	Total study area (km^2)	Flood floor extent (km^2)	Percentage of Flood extent (%)
1	Batu Mengkebang	Urban	232.29	32.35	13.92
2	Manek Urai	Suburban	283.70	29.56	10.41
3	Dabong	Rural	63.20	4.97	7.86

The results of direct mapping in the field, which were subsequently represented on a topographic map using interpolation techniques, were used to construct the flood extent maps for each study area. The information about the magnitude and exposure of the flood were gathered through interviewing session with local peoples and community leaders during the sampling visit. This method gave the reliable flood extent measurement in Kuala Krai during the big yellow flood of 2014 in Kelantan, which is summarized in Table 2. It is clearly shown that, the largest percentage of flood extent in Kuala Krai is at urban area where to be exact, 95.76% of total area Kuala Krai city (5.18 km^2) was inundated by floods. This proof that urbanization gave impact to the flood extent of the particular area.

The results of processing field data using GIS software in Batu Mengkebang are shown in Figure 3. The Kuala Krai City subdistrict has the highest percentage of flood exposure, with a total flood extent of 32.35 km^2, or 13.92% of the entire research area. In Manek Urai and Dabong, the figure also depicts the outcome of GIS software processing field data. Compared to Manek Urai, which has a total flood extent of 29.56 km^2, Dabong has a total flood extent of 4.79 km^2, or 7.86% of Kuala Pergau's entire area. It is known from topographic map study, which is represented in those numbers, that locations with relatively gentle slopes or flat terrain are more prone to floods.



a) Urban: Batu Mengkebang b) Suburban: Manek Urai c) Rural: Dabong

Figure 3: Flood extent map in Kuala Krai

5. Conclusion

Rain is an agent which can lead to flood event. This study has descriptively revealed the huge and long flood at Kuala Krai in 2014 is due to the two phase of heavy rainfall that led a very large capacity of water in Kelantan basin. The whole Kuala Krai inundated by flood for almost 10 days because this region is known as vulnerable area during the northeast monsoon period. The impact of urbanization is also shown in this study from spatial analysis finding of flood extent. Therefore, the reliable flood extent map is needed as a reference to mitigate flood in flood prone area. The construction of a trustworthy flood extant map will require a significant amount of work from the relevant authorities and researchers in the field. This will require direct delineation from the flood-prone area through site visits and primary data gathered from face-to-face interviews with the flood victims. This study has successfully constructed a trustworthy flood extent map that differs differently from previous flood maps made by the government, NGOs, and active researchers in this field. It did this by using those original data and integrating them with secondary data from numerous associated agencies.

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