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# Spatio-temporal analysis of rainfall data in Kuala Krai Kelantan

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**Abstract.** This paper interpreted spatio-temporally the relationship between event of weather activities and flooding in Kuala Krai Kelantan. During the Kelantan big yellow flood event in December 2014, Kuala Krai was one of the worst affected area with the rarity of the return period approximately 1 in 1000 years. Many say this is due to the unusual occurrence of extreme rainfall. Therefore, this research work on spatio-temporal analysis of the time series rainfall data in Kuala Krai Kelantan, to describe and determine the behaviour and pattern of the data. The data on the monthly amount of rainfall between (2013-2019), were collected from Department Irrigation and Drainage (DID). The main aim of this study is to statistically determine whether it is true the flooding in Kuala Krai Kelantan on 2014 is because of heavy rainfall. The collected rainfall data had been spatially analysed using ArcGIS to compare the distribution of rainfall from year 2013 to 2019. Then, the trend pattern of the data had been determined using Mann Kendall Test and Sen's slope Test. From those analysis it can be concluded that the huge amount of rainfall intensity is the major factor that contribute the extreme flood event in Kuala Krai Kelantan on December 2014.

## 1. Introduction

Extreme rainfall events in Malaysia have become more common in recent years. It reveals by [1], where the frequency of heavy rain events on the east coast of Peninsular Malaysia have increased over 40 years. Various developed models by active researchers in this field also predicted that rainfall will continue to increase, which will cause an increase of heavy rainfall events in the East Coast of Peninsular Malaysia [2]. Increased rainfall and extreme rainfall events can increase the frequency of flood events. There are a number of studies in extreme rainfall event over Malaysia but there are still large knowledge gaps with regard to extreme rainfall events [3].

Floods caused by heavy rain events are one of the most common hydrological occurrences in Kelantan state on Peninsular Malaysia's east coast, and they have wreaked havoc. Previous floods in Kelantan's history were regarded serious in 1967, when 84 percent of the villages were adversely affected, 125,000 people were evacuated, and 38 people drowned. [4]. Recently, the 2014 flood was the largest recorded flood in the history of Kelantan and was called as the Kelantan big yellow flood because the yellow color of the flood due to its high mud content [5]. Kuala Krai one of a district in Kelantan was the hardest hit with 16,734 families were displaced in 83 relief centres [6]. The floods wreaked havoc on the Kuala Krai community in Kelantan, resulting in human deaths, property damage, crop destruction, and livestock losses. Additionally, communication networks as well as infrastructure such as power plants, highways, and bridges were damaged, disrupting some economic activity.



Floods may be caused by topographic factors in the area, as well as the regularity with which high magnitude and intensity rainfall events occur. [7]. A combination of physical factors, such as elevation and the collision of two main rivers, the Galas River and the Lebir River, which form the Kelantan River in Kuala Krai, as well as heavy rainfall experienced during the north east monsoon period, contributed to floods in the Kuala Krai district of Kelantan. [8]. Among these aspects, scientists have paid more attention to study on rainfall events in recent years to examine the characteristics of rainfall in Malaysia.

One of the most important statistical methods for applications involving hydrology and the environment that focus on rainfall is time series analysis. It has a significant link to the amount of rain that falls in different locations. The model incorporated into a map using GIS technique after passing two statistical tests, Mann-Kendall test and Sen's Slope estimator, is one of the most successful approaches for analyzing time series data. The models are used to illustrate monthly rainfall patterns, as well as the ability to view areas with high rainfall data. This study has two objectives: first, to quantify the changing trend of Kelantan River rainfall using descriptive analysis and statistical tests (i.e. Mann-Kendall test and Sen's Slope test) based on monthly and annual rainfall data, and second, to map rainfall distribution in Kuala Krai and thus make a comparison on average rainfall amounts received between years 2014 and 2019.

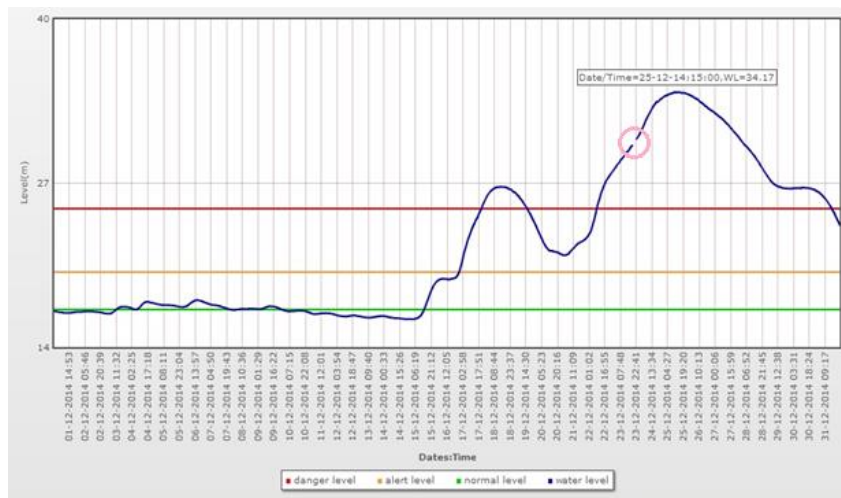
## 2. Motivation and Study Area

### 2.1. Motivation

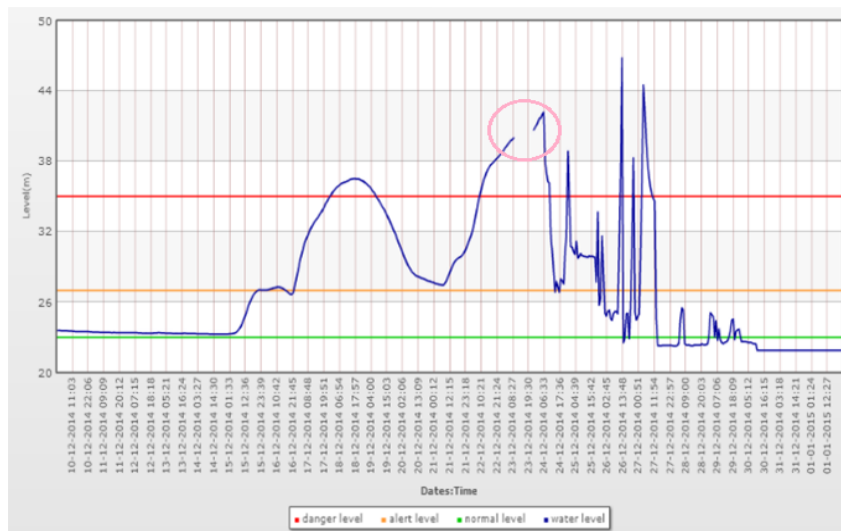
Many studies have been done on floods in Kelantan and use Kuala Krai as a case study or study area. A study by [9] that has been conducted six months after flood event on 2014 is one of the related study that has been done with the respondents consisting the flood victims from four sub-discripts in Kuala Krai namely Bandar Kuala Krai, Batu Mengkebang, Kenor, Manek Urai, Kuala Pergau dan Manjor. This previous study has shown that the flood events in Kuala Krai during the Kelantan big yellow flood 2014 is totally influence by two phases of heavy rainfall.

The first phase, which took place from December 15 to 19, caused to the raise of water levels in the Galas, Lebir, and Kelantan rivers. Thus, flooding occurred in the areas of Kota Bharu, Tualang, Kursial, and Kuala Krai from the 17th to the 19th of December 2014. A second bout of rainfall occurred from December 20 to 24, 2014. Rainfall intensity was higher at this time, particularly at the upstream of the River basin in Gunung Gagau. Flooding has become more severe due to the full capacity of soils, rivers, and drainage systems. From December 22 to December 30, 2014, Kuala Krai, Dabong, and Manek Urai were the hardest damaged areas. The researchers also discovered that during the second phase of the flood, there was a lot of record-breaking rainfall data, notably at upstream stations of the river basin, with ARIs reading over 100 years and several of them having more than 500 years ARIs reading. As a result of the high amount of river discharge, certain river monitoring stations have been damaged and are unable to record the water level as shown in hydrographs of Figure 1, 2 and 3. The record breaking has been highlighted with pink circle where happened on 23 December 2014 at Kelantan river, Lebir river in Manek Urai and Galas river in Kuala Pergau respectively. These findings had motivated us to study on rainfall events in Kuala Krai before and after the big yellow flood of Kelantan 2014.

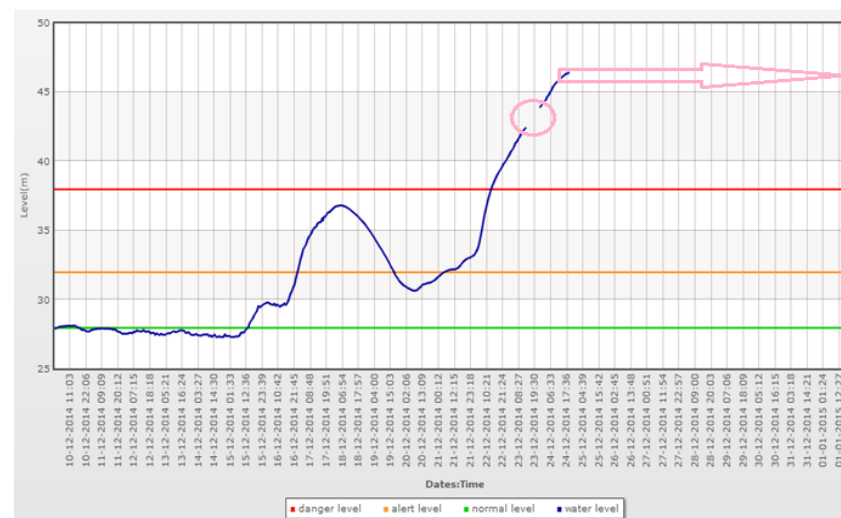
For this further study, five rainfall stations which are JPS Kuala Krai (station 36), Ladang Kuala Nal (Station 37), Ladang Lapan Kabu (Station 39), Kampung Lalok (station 41) and Ladang Kuala Gris (station 42) were chosen based on the residential location of 2014 flood victims. Kuala Krai has grown very vulnerable to the Northeast monsoon flood, which happens every year from November to Mac, due to its geographical characteristics, uncontrolled urbanization, and the convergence of two major rivers, the Galas and Lebir rivers, which create the Kelantan River. This is another issue that prompted us to investigate the spatiotemporal trend of rainfall in Kuala Krai, Kelantan. For this purpose the data on the monthly amount of rainfall in Kuala Krai based on aforementioned stations were obtained from the Department of Irrigation and Drainage (DID) Malaysia from 2013 to 2019.



**Figure 1.** Hydrograph for Kelantan river at Kuala Krai from 10 - 31 Dec 2014.



**Figure 2.** Hydrograph for Lebir river at Tualang,Manek Urai from 10 - 31 Dec 2014.

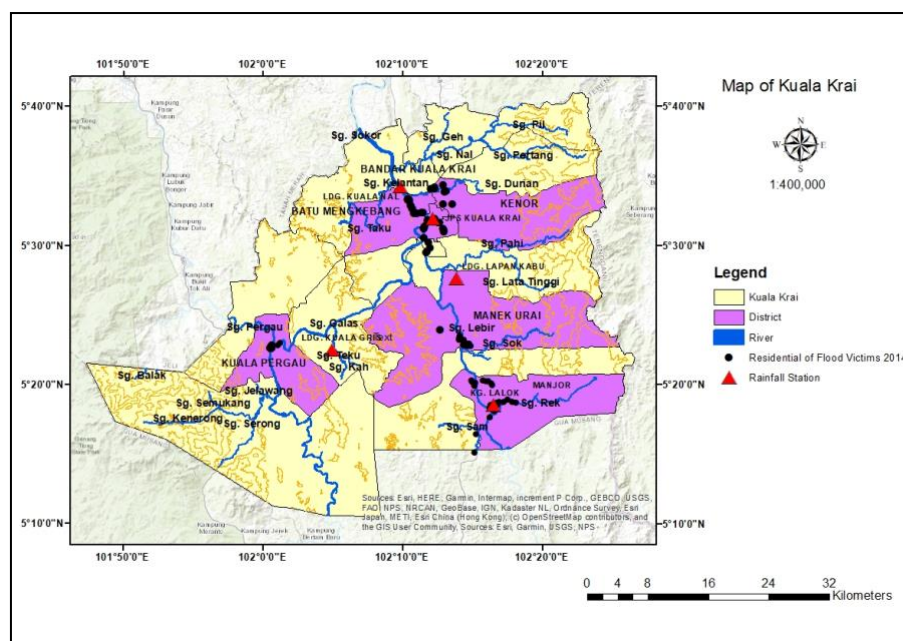


**Figure 3.** Hydrograph for Galas river at Kuala Pergau from 10 - 24 Dec 2014.

## 2.2. Study Area

This study has been conducted in Kuala Krai, Kelantan which is situated about 18 miles south of Kelantan city, Kota Bharu. lies between the longitude  $5^{\circ} 31' 50.9268''$  N and latitude  $102^{\circ} 12' 6.6636''$  E. It covers an area of 2287 km<sup>2</sup> with a total population of 109,461 people that make Kuala Krai relatively high population density in Kelantan (Department of Town and Country Planning, 2011). The terrain of this district is hilly in the East, West and South and lowland in the North. The elevation above sea level is mostly between 153m - 305m. While the highest level is more than 915m which is the side bordering Jeli district. The two main rivers namely Galas River and Lebir River met on Kelantan River in Kuala Krai. Due to these physical factors which is the elevation and the collision of these two main rivers that form Kelantan river in Kuala Krai, making this district vulnerable to flood events causing by heavy rainfall occurrence during the north east monsoon period every year.

Figure 4 shows a map of Kuala Krai, Kelantan with the aforementioned topographic features visualized. This map has been developed using ArGIS software. The map shown 150 residential locations of flood victims in 2014 and five rainfall station scatted in Kuala Krai. The map also highlighted the main river that situated in Kuala Krai together with the contour line to get an idea of the elevation patent in the study area which is Kuala Krai. The map also highlighted four sub -districts based on 150 samples of 2014 flood victims 'residential locations. It is clearly showing, the houses of these flood victims are located along the main river in Kuala Krai and the four sub-discrits that were severely affected during the 2014 floods are Manek Urai, Batu Mengkebang, Kenor, Kuala Pergau and Manjor



**Figure 4.** Physical map indicating five rainfall stations in Kuala Krai, Kelantan.

## 3. Materials and Method

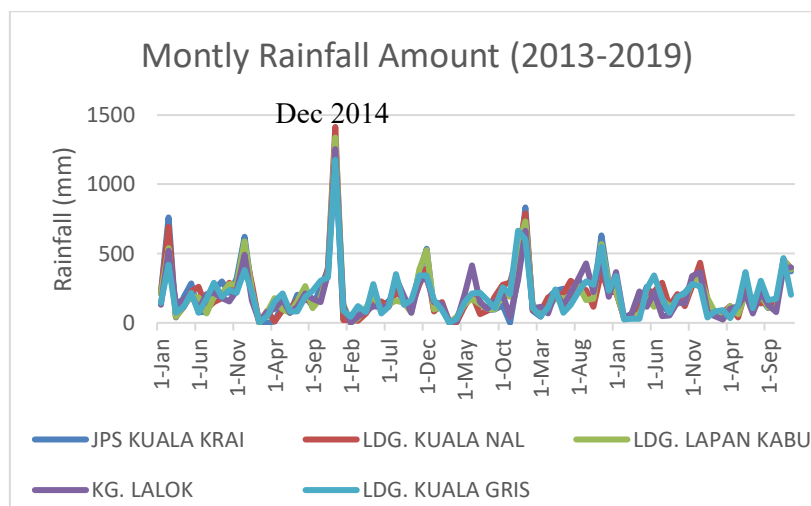
To produce map in Figure 4, the materials needed are shapefile of Kuala Krai that contain a data of main rivers, contour layering, coordinates of DID rainfall stations and residential of 2014 flood victims. All aforementioned data have been added in ArcGIS software and standard setting need to be done to ensure the colors, symbols and label will visualize correctly on the map. Finally, the map will be transfer to layout view to add grid, scale, compass and legend. The similar materials and method have been used to produce Figure 5, but a yearly total rainfall intensity data at five chosen rainfall stations has also been added in ArcGIS software to develop this rainfall distribution map for year 2014 to 2019.

Based on the developed map in Figure 4, the rainfall stations of DID that should be considered in this study were identified. Those rainfall stations namely JPS Kuala Krai (R5522047), Ladang Kuala Nal (R5521050), Ladang Lapan Kabu (R5422046), Kampung Lalok (R5322044) and Ladang Kuala Gris (R5320039). The data on the monthly amount of rainfall in Kuala Krai based on aforementioned stations were obtained from the Department of Irrigation and Drainage (DID) Malaysia from 2013 to 2019. The data was then analyzed spatially using ARGIS software to produce the rainfall distribution maps of Kuala Krai from 2014 to 2019. The data was also analyzed temporally by using descriptive statistics method and the graphs of rainfall distribution for each 7 consecutive years were plotted. The graphs were further analyzed by recognizing the trend pattern using Mann Kendal test and sen's slope. The non-parametric Mann-Kendall test and sen's slope analysis are widely used in detecting trends of variables in meteorology and hydrology fields. [10,11].

## 4. Results and Discussion

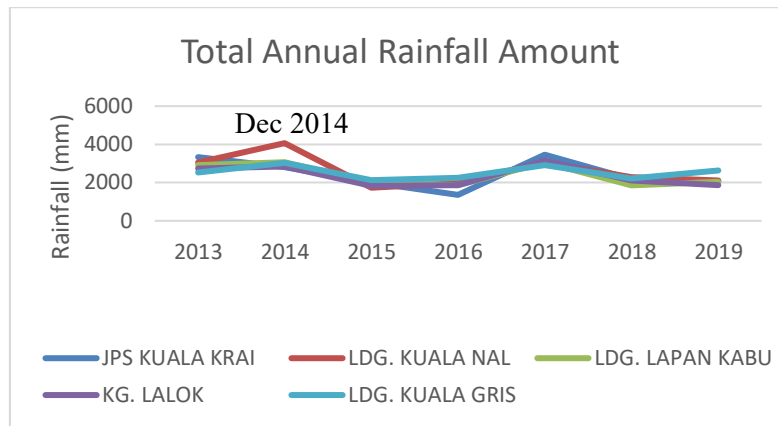
### 4.1. Temporal Analysis

Based on hyetographs from five DID rainfall stations in Kuala Krai that have been published in [9], the raw data of daily rainfall distribution of these five stations has been updated especially for missing values due to record breaking caused by Kelantan big yellow flood 2014. Figure 5 shows the graph of monthly rainfall amount starting from Jan 2013 till December 2019 of five rainfall stations in Kuala Krai. It is clearly shown that, there is no trend exists in monthly rainfall amount data for Kuala Krai in that particular period that also supported with results of Mann Kendal test and sen's slope in Table 1 where the listed p values are greater than a level significance,  $\alpha=0.05$ . Therefore, it is proven that the monthly rainfall amount of five considered stations in Kuala Krai have significantly no trend. However, based on Figure 5 there are clearly shown that, a seasonality effect on the amount of rainfall in these five stations where it is generally high on November and December each year. Meanwhile, the amount of rainfall is usually low on January and February in each station for these particular years.



**Figure 5.** Monthly rainfall amount for five stations in Kuala Krai from 2013 to 2019.

Figure 6 represents the graph of total annual rainfall amount for 7 years for five stations in Kuala Krai, Kelantan with maximum total annual rainfall occurrence in the year 2014 (3066.5 mm) that was recorded at station Ladang Lapan Kabu and minimum total annual rainfall in 2016 (1357.1 mm) that was recorded at station JPS Kuala Krai. The average rainfall for these 7 years is 2469.08 mm. The analysis revealed that the total annual rainfall varies in different years where for year 2014 rainfall amounts at five considered stations are exceeded the average amount of rainfall. This finding supports [9] who found that the flooding in Kuala Krai Kelantan on 2014 is because of heavy rainfall.

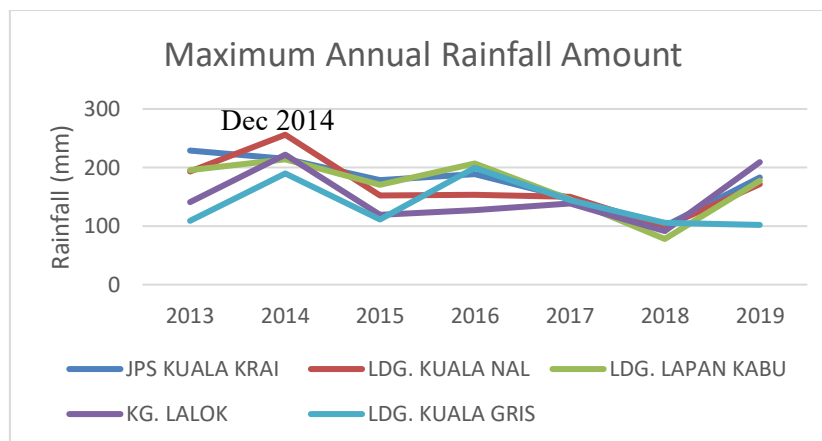


**Figure 6.** Total annual rainfall amount for five stations in Kuala Krai from 2013 to 2019.

The maximum rainfall amount for each month starting from January to December for over 7 years were also analyzed. The average maximum rainfall amount for these 7 years is 160.46 mm. The results as represented in Figure 7 indicates that the maximum rainfall amount in 2014 exceeded the average maximum amount of rainfall at all five stations that not happened for other years in this period. This shown that Kuala Krai received and extreme rainfall amount in year 2014 that cause a huge flooding in this district due to overflow of water at Kelantan River, Galas River and Lebir River where these three main rivers are situated at Kuala Krai.

**Table 1.** Summary of Mann Kendal Test and Sen's Slope Test.

Station	Kendall's tau	p-value	Sen's slope
Jps Kuala Krai	-0.238	0.562	-159.850
Ldg. Kuala Nal	-0.238	0.562	-158.167
Ldg. Lapan Kabu	-0.333	0.381	-107.000
Kg. Lalok	-0.143	0.773	-122.800
Ldg. Kuala Gris	-0.048	1.000	-29.250



**Figure 7.** Maximum annual rainfall amount for five stations in Kuala Krai from 2013 to 2019.



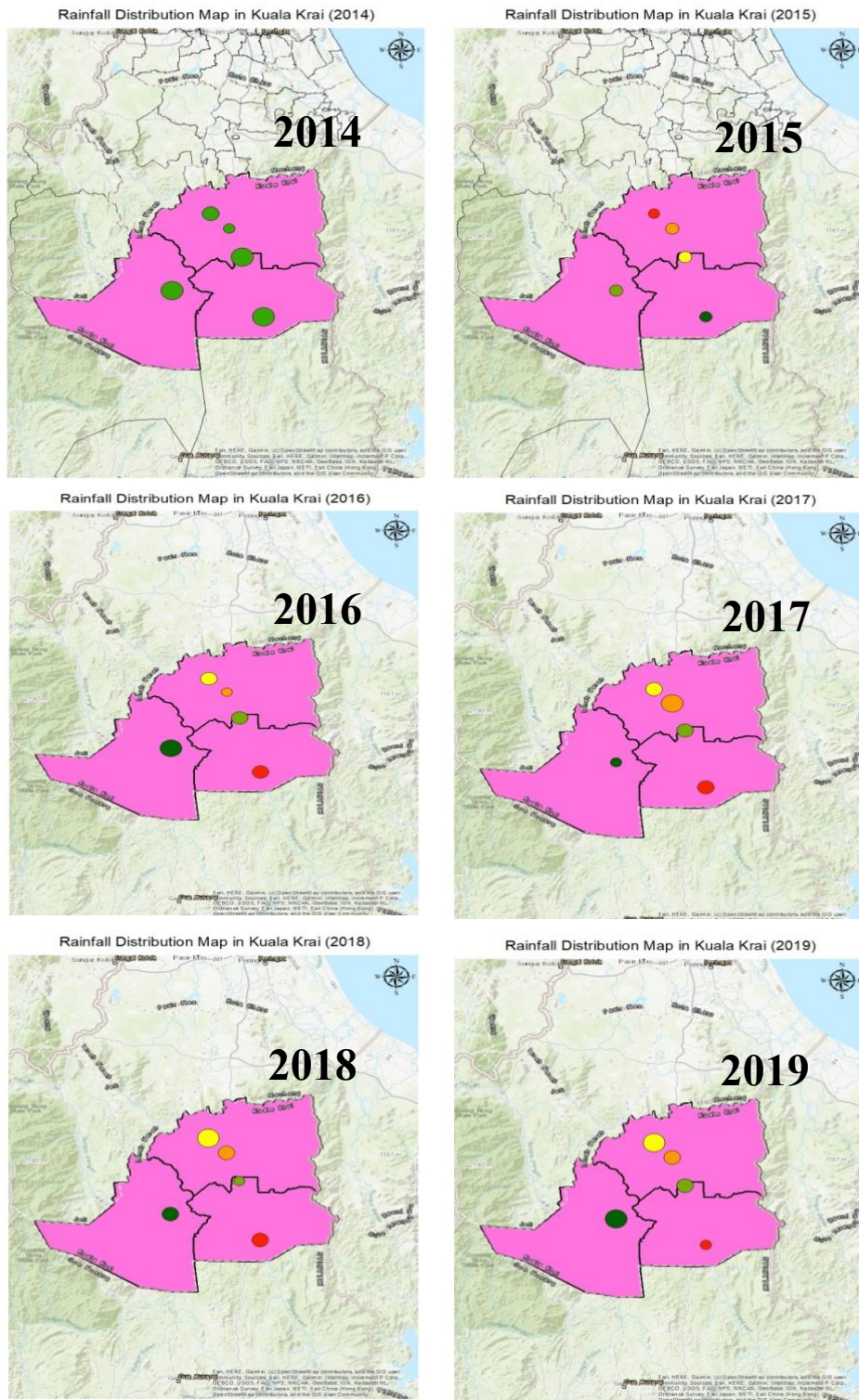


Figure 8. Spatial average rainfall distribution map in Kuala Krai from 2014 to 2019.



#### 4.2. Spatial Analysis

The spatial analysis was conducted by produce 6 rainfall distribution maps of five stations in Kuala Krai, that have been putted together in Figure 8. The average rainfall data has been used and classified by year from 2014 to 2019. Based on Figure 8, Kuala Krai received a huge amount of rainfall as compared to other years based on the size of five dots in the maps. This support the findings in [9] where the huge flood of 2014 occurred in Kuala Krai due to the two phases of extreme rainfall occurred in Kelantan river basin in that particular year.

### 5. Conclusion

The findings of this research demonstrated that rainfall patterns varies by month, season, and year. The wettest month in Kuala Krai is December, with the highest total rainfall, while the driest months are January and February. Aside from that, the overall amount of annual rainfall varied dramatically from year to year. However, when the yearly rainfall amount of three years exceeded the average amount of rainfall in seven years of rainfall data, heavy rain occurrences on Peninsular Malaysia's east coast intensified. Therefore, this information concluded that the extreme flood is unpredictable, nevertheless its occurrence may increase because of the influence by the pattern of extreme rainfall events that have increased in recent years. However, the further pattern analysis of rainfall using long-term data is needed to ensure precise prediction on extreme rainfall pattern for flood mitigation.

### Acknowledgement

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