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Pattern of Rainfall Distribution in Kuala Krai, Kelantan, Malaysia

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ABSTRACT

Rainfall in Malaysia is associated to the convectional rains which has its own pattern that mostly affected by climatic change. A heavy rainfall can cause flooding which is one of the most common natural disasters in Malaysia that happens almost every year. The only difference is that they can either be "normal" or "extreme". Such calamity can threaten people lives, health, crops, livestock and economy. There are several factors that can contribute to this flooding which are heavy monsoonal and convectional rain fall, climatic change effects and La Nina and El Nino. The study area of this research is in Kuala Krai with the purpose of study to determine on how the rainfall pattern can affects flooding as this area is vulnerable to flood disaster. Hence, the record of monthly annual rainfall amounts and number of rain days from year 1985 to 2014 were obtained from the Malaysian Meteorological Department. Both of the data were analysed using descriptive statistic, graph plotting and data tabulation in order to determine its rainfall pattern. The results of this study revealed that the pattern of rainfall and number of raindays varies in different months, season and annually. The highest rainfall amount and number of raindays are in December that has the highest possibility of flooding, while the lowest are in January and February. Apart from that, the total amount of annual rainfall showed a significant increase from year to years which exceeded the average amount of rainfall. Therefore, the findings may be used as a guidance for flood preparation or in any daily human activity and process.

KEYWORDS: Pattern of Rainfall, Flood Disaster, Monsoonal Season, La Nina, El Nino, Kuala Krai.

INTRODUCTION

Floods are common natural disasters which can be defined as the presence of excess water in areas that are usually dry beyond its normal limit [1]. Floods associated with extreme rain events are one of the most hydrological phenomena in Kelantan state on the east coast of Peninsular Malaysia which has brought massive destruction. Previous floods, were considered significant in Kelantan's history. In the 1967 flood, 84% of the villages in Kelantan were badly affected with 125,000 people were evacuated and 38 drowned [2]. The 2014 flood was the largest recorded flood in the history of Kelantan. It was considered to be a "tsunami-like disaster" and this flood was called 'Bah Kuning' (yellow-coloured flood) because of its high mud content [3]. Kuala Krai, a district of Kelantan was the worst hit with 16,734families were displaced in 83 relief centres [4]. The community of Kuala Krai, Kelantan has suffered a huge loss from the floods including the loss of human life, property damage, destruction of crops and loss of livestock. Furthermore, communication links and infrastructure such as power plants, roads and bridges are damaged causing some economic activities disrupted.

The cause of floods maybe due to topographic features of the region as well as the frequency of occurrence of high magnitude and intensity rainfall events [5]. Unfortunately, factors causing floods in the Kuala Krai district of Kelantan are a combination of physical factors such as elevation and its close proximity to the sea, apart from the heavy rainfall experienced during the north east monsoon period [6]. Among these factors, studies on rainfall events have received increased attention from scientist in the last few years to investigate the characteristic of rainfall in Malaysia.

Rainfall is defined as a critical index of climatological investigation and has major impacts on flora and fauna, as well as ecological setting and water resources management of any area[7]. The changing trend of rainfall of Kelantan River by using statistical tests based on monthly, seasonal and annual and secondly has been quantified [8]. From the analysis, the study found that rainfall differs for each of the months, seasons and annually. September was recorded as the driest month as well as June to September season. Besides that, December to January always the wettest month in Kelantan where the extreme rainfall always occurred during these months. The amount of rainfall keep on increasing upon increasing year where it can be forecasted that the following years will be higher than the previous years. Furthermore, the spatial rainfall patterns in Kelantan showed high amounts of rainfall accumulated by 2 phases (Phase 1-daily rainfall up to 300 mm; Phase 2-daily rainfall up to 500 mm) [9]. Extreme rainfall occurred in December 2014 were due to the combined effect of the monsoon season, Madden Julian Oscillation and temperature below anomalies at the Siberian High.

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The current pattern of rainfall in Malaysia has been a source of concern to the citizens, especially those who live in flood prone areas. Many research has been conducted to analyse the rainfall pattern in Malaysia, but limited research has been done on Kuala Krai, Kelantan region as this place is vulnerable to flooding. Therefore, it is on this basis that this study intends to provide a trend analysis of rainfall behaviour in Kuala Krai, Kelantan state over the past 30 years. This study will come out with the latest estimated extreme rainfall data for Kuala Krai, Kelantan so that it can be used towards flood preparation and in future infrastructure design.

MATERIALS AND METHODS

Kelantan is one of the largest states in Peninsular Malaysia with 15, 022 km^2 total area (4.4% of the area of Malaysia) and total population of 1,530,700 [10]. For this study, Kuala Krai, Kelantan (station 48616) located at 5° 32' N latitude 102° 12' E longitude with the elevation of 63.8 m was chosen because this place has become extremely vulnerable to monsoon flood every year. Due to its geographical characteristics, unplanned urbanization and proximity to the South China Sea, Kuala Krai, Kelantan has become extremely vulnerable to Northeast monsoon flood that occurs from November to Mac every year. To determine the trend of rainfall in Kuala Krai, Kelantan, the data on the monthly amount of rainfall in Kuala Krai, Kelantan (station 48616) was obtained from the Malaysian Meteorological Department for 30 years (1985 to 2014). The data was then analyzed by using descriptive statistic method and the graphs of rainfall distribution for each 30 consecutive years were plotted. The graphs were further analyzed by recognizing the pattern and the month with the lowest and highest rainfall amounts.

RESULTS AND DISCUSSION

Monthly Trend Analysis of Rainfall Amount in Kuala Krai, Kelantan State (December 1984 to November 2014)

Based on the raw data provided by Malaysian Meteorological Department (Table 1), monthly rainfall series data was recorded from the December 1984 to November 2014. For this study, the data selected ranged from January 1985 until December 2014 with the duration of 30 years. The data showed that the total amount of monthly rainfall annually ranged from 1542.8 mm to 3305.5 mm.

- Minimum monthly rainfall amount (annual) = 1542.8 mm
- Maximum monthly rainfall amount (annual) = 3306.5 mm

Table 1: Records of monthly rainfall amount in Kuala Krai (1985-2014)

Records of Monthly Rainfall Amount													
Year	Month											Annual	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1984												**660.9**	**Def.**
1985	55.7	130.4	427.3	137.5	233.9	16.0	179.9	197.4	338.9	286.6	200.1	216.2	2419.9
1986	82.2	5.1	66.1	49.4	81.1	178.8	205.1	114.5	262.8	239.2	597.4	316.2	2197.9
1987	87.7	0.6	128.3	160.5	108.2	180.3	95.7	113.7	341.5	158.4	319.3	776.4	2470.6
1988	92.4	94.4	93.1	105.8	117.0	138.5	197.7	102.1	332.4	178.8	1173.9	324.2	2950.3
1989	137.5	10.1	47.7	146.4	30.4	106.9	136.6	70.3	188.7	327.0	197.6	161.8	1561.0
1990	222.7	56.5	20.2	98.7	148.4	76.2	230.3	159.1	344.5	262.6	364.1	575.4	2558.7
1991	318.4	22.7	55.6	35.4	143.6	88.8	87.0	278.3	264.7	178.4	381.4	557.2	2411.5
1992	26.1	59.1	11.2	40.6	55.7	310.5	212.3	178.3	110.4	240.4	544.4	357.1	2146.1
1993	66.2	58.5	178.4	93.1	87.1	161.1	160.4	240.5	397.7	518.5	201.1	787.3	2949.9
1994	34.8	74.9	244.4	67.8	350.7	304.1	89.0	194.6	231.3	141.4	1151.5	128.0	3012.5
1995	198.5	67.0	71.5	19.8	92.9	203.7	81.7	141.6	335.5	114.4	268.8	412.2	2007.6
1996	71.8	47.3	72.2	96.5	196.2	59.3	209.0	264.2	234.4	225.3	186.0	597.1	2259.3
1997	3.3	160.6	34.7	231.2	85.7	304.8	191.5	192.0	90.6	123.2	217.6	639.8	2275.0
1998	89.7	3.6	17.7	31.7	210.9	127.8	155.3	310.5	246.4	220.0	114.7	728.2	2256.5
1999	241.6	193.2	115.3	218.8	216.0	230.8	55.4	346.5	114.3	275.8	379.4	460.1	2847.2
2000	231.2	90.9	203.9	102.7	150.2	133.6	52.1	78.7	246.6	246.2	520.5	308.3	2364.9
2001	317.6	94.2	195.2	113.3	101.1	134.0	80.3	153.8	297.7	324.8	192.8	558.2	2563.0
2002	66.8	14.1	98.4	32.9	110.2	152.4	139.5	117.7	127.5	230.4	212.6	240.3	1542.8
2003	153.5	51.3	122.1	123.2	60.8	181.7	248.8	263.8	152.6	344.5	267.5	758.8	2728.6
2004	289.5	17.4	131.7	82.7	141.3	56.7	183.9	226.2	335.0	315.8	302.6	669.3	2752.1
2005	34.8	12.6	116.3	48.8	285.8	227.6	108.6	202.0	306.0	235.3	537.4	602.4	2717.6
2006	156.8	468.6	45.0	69.0	204.4	182.0	275.6	237.4	163.4	182.2	199.4	313.8	2497.6
2007	324.2	16.6	166.0	81.0	238.7	104.6	188.8	198.8	162.6	258.4	194.2	1110.7	3044.6
2008	99.0	249.0	151.6	222.6	156.9	244.2	108.0	253.4	192.2	316.4	634.6	504.4	3132.3
2009	186.2	54.2	135.8	159.2	240.4	108.9	244.6	182.6	240.6	155.2	1062.2	536.6	3306.5
2010	192.2	13.2	55.8	74.2	64.4	233.4	192.8	99.6	138.8	363.6	425.0	503.6	2356.6
2011	524.4	50.4	284.0	73.0	113.2	258.0	201.4	166.4	153.2	363.8	676.2	402.2	3266.2
2012	275.4	71.4	116.0	137.0	206.0	56.6	138.4	135.2	258.8	148.0	88.0	824.0	2454.8
2013	228.2	766.4	49.2	145.2	215.4	107.6	142.6	213.6	208.8	238.0	252.6	566.4	3134.0
2014	244.4	Trace	120.8	43.0	163.2	77.0	136.8	209.0	167.2	152.4	417.4	1386.6	3117.8

Source: Malaysian Meteorological Department

The maximum and minimum of monthly rainfall amount were also analysed from the raw data by tabulating the minimum and maximum rainfall amount for each month throughout the 30 years data as shown in Table 2. From the analysis, November and December were recorded as the highest amount of minimum and maximum monthly rainfall amount while January and February were recorded as the lowest amount of minimum and maximum monthly rainfall amount.

Table 2: The maximum and minimum of monthly rainfall amount for each consecutive month (1985-2014)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum Monthly Rainfall Amount (mm)	3.3	0.6	11.2	19.8	30.4	16.0	52.1	70.3	90.6	114.4	88.0	128.0
Maximum Monthly Rainfall Amount (mm)	524.4	766.4	427.3	231.2	350.7	310.5	275.6	346.5	397.7	518.5	1173.9	1386.6

Furthermore, rainfall trend analysis of Kuala Krai, Kelantan has been investigated for north east monsoon season over 30 years. The time series graph has been constructed for the northeast monsoon season because major hydrological disaster of flood was related to extreme rain event that usually occurred in Peninsular Malaysia during this season [5]. Figure 1 showed the rainfall amount pattern. The pattern of lowest and highest of rainfall amount is not uniform but it is predictable. The trend analysis revealed that the highest amount of rainfall is on December 2014 (1386.6 mm) and the lowest amount of rainfall is on February 1987 (0.6 mm). The amount of rainfall is generally high on November and December except for November 2012 (88.0 mm). Meanwhile, the amount of rainfall is usually low on January and February except for February 2013 (766.4 mm).

The monthly rainfall amount data in Kuala Krai Kelantan are influenced by the four major rainy seasons namely two monsoon seasons and two inter-monsoon seasons. The two monsoon seasons are the Northeast Monsoon (NEM) and Southwest Monsoon (SWM). The Northeast monsoon usually causes heavy rain to the east coastal area of the Peninsular Malaysia including the states of Kelantan whereas the Southwest monsoon usually common with drier weather. The NEM is usually ranges from November to March and the SWM usually ranges from May to September. Based on graph plotted of the monthly rainfall amount for 30 consecutive years, the monthly rainfall amount is low for month February and the monthly rainfall amount is high for December [11].

Other factors that contribute to the effects of the total rainfall amount from January to December in Kuala Krai are the El Nino and La Nina event [12]. El Nino is known as the “Southern Oscillation”, a phenomenon where the atmosphere and ocean collaborate together. It corresponds to the warm phase of ENSO. La Nina is the opposite of El Nino, which is a phase consist of a basin wide cooling of the tropical Pacific [13]. It corresponds to the cold phase of ENSO. They caused the drought to the study are which indirectly affects the amount of rainfall next arises the temperature. The years associated with El Nino and La Nina Events includes 1986, 1987, 1988, 1990, 1991, 1992, 1994, 1995, 1997, 1998, 2000, 2002, 2004, 2006, 2009 and 2010.

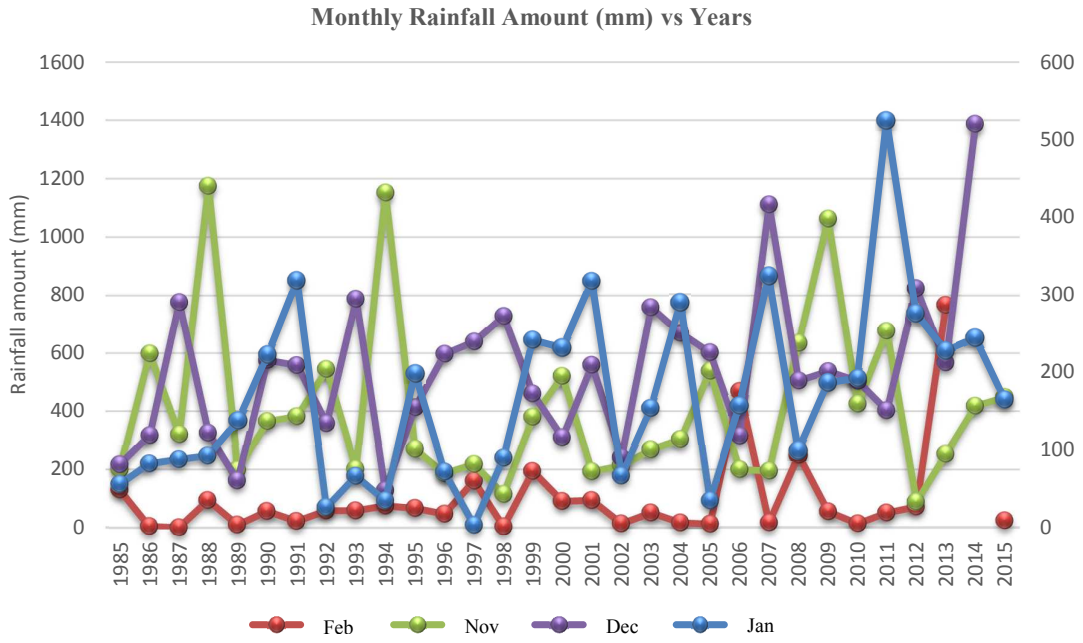

Figure 1: Monthly rainfall amount during north east monsoon season from 1985 to 2014

Annually Trend Analysis of Rainfall Amount in Kuala Krai, Kelantan State (December 1984 to November 2014)

Figure 2 represents the trend of total annual rainfall amount for 30 years in Kuala Krai, Kelantan with maximum total annual rainfall occurrence in the year 2009 (3306.5 mm) and minimum total annual rainfall in 2002 (1542.8 mm). The average rainfall for 30 years is 2576.78 mm. The trend analysis revealed that the total annual rainfall varies in different years. However, since 2003, the total amount of annual rainfall showed a significant increase from year to years which exceeded the average amount of rainfall except for year 2010 and 2012. This finding supports [8] who found that the rainfall keeps on increasing from year to years where it can be predicted that the following years will be higher than the previous years.

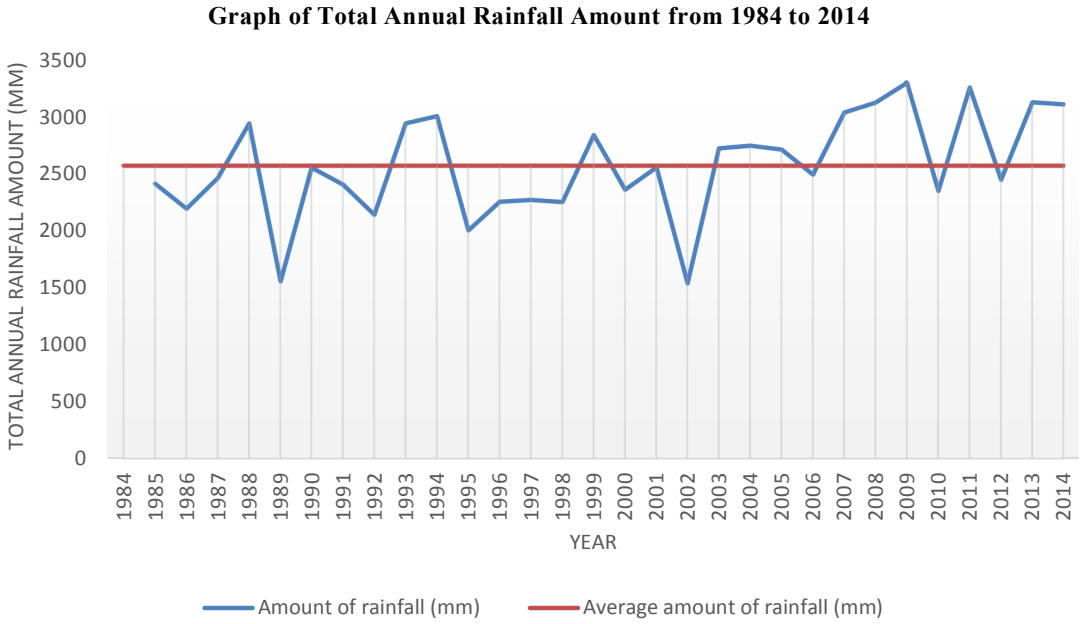

Figure 2: The trend of total annual rainfall amount for 30 years in Kuala Krai, Kelantan from 1985 to 2014

Annually Trend Analysis of Number of Raindays in Kuala Krai, Kelantan State (December 1984 to November 2014)

Based on the raw data provided by Malaysian Meteorological Department (Table 3), the number of raindays for each month were recorded from the December 1984 to November 2014. The data showed that the number of raindays rainfall annually ranged from 163 days to 221 days.

- Minimum monthly raindays (annual) = 157 days
- Maximum monthly raindays (annual) = 221 days

Table 3: The number of raindays for each month were recorded from the December 1984 to November 2014

Records of Number of Rain days													
Year	Month												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1984												21	Def.
1985	15	11	20	11	17	4	13	20	23	20	23	22	199
1986	12	2	12	6	11	18	12	12	24	18	20	22	169
1987	17	2	15	12	15	11	12	18	20	16	21	23	182
1988	13	14	7	13	15	15	19	18	17	19	26	15	191
1989	19	3	11	8	12	12	14	19	19	19	21	18	175
1990	14	8	5	15	16	12	18	12	18	24	16	22	180
1991	18	4	7	7	16	12	8	20	18	20	26	26	182
1992	12	9	7	11	10	16	12	13	16	25	27	24	182
1993	18	8	14	11	8	12	12	17	19	20	19	24	182
1994	13	10	23	11	24	24	13	21	21	16	30	15	221
1995	22	14	10	7	14	16	17	23	20	16	23	21	203
1996	12	11	9	9	18	12	17	19	20	23	21	20	191
1997	4	9	6	19	7	15	16	14	11	17	21	24	163
1998	17	1	5	4	15	18	11	19	23	19	19	26	177
1999	18	11	12	18	15	14	12	18	18	27	17	24	204
2000	23	15	12	12	14	16	9	17	21	18	21	15	193
2001	19	4	19	14	18	9	12	12	16	27	21	19	190
2002	16	5	5	12	13	12	15	16	18	20	21	23	176
2003	19	10	15	6	13	15	13	18	17	25	21	23	195
2004	16	3	11	13	14	9	17	17	18	22	18	16	174
2005	11	3	11	7	19	15	16	13	17	22	20	24	178
2006	13	15	10	10	15	12	16	15	18	17	25	20	186
2007	22	4	14	14	18	12	16	16	20	23	18	22	199
2008	14	6	19	13	14	19	18	23	12	22	21	24	205
2009	13	6	13	16	18	8	15	20	17	14	24	18	182
2010	10	2	8	10	11	16	15	13	20	15	23	23	166
2011	18	6	19	8	16	17	17	16	17	27	23	26	210
2012	21	12	15	12	14	6	18	13	18	20	19	25	193
2013	12	18	6	18	19	8	16	16	11	23	19	20	186
2014	11	0	7	3	13	8	15	17	17	18	23	25	157

The maximum and minimum number of monthly raindays for each month starting from January to December for over 30 years were also analysed. The results as represented in Table 4 indicates that November recorded the highest number of minimum and maximum number of raindays, followed by December.

Figure 3 represents the trend of total annual raindays for 30 years in Kuala Krai, Kelantan. The maximum total annual raindays recorded was 221 days in 1994 and the minimum total annual raindays was 157 days in 2014. The average raindays for 30 years is 186 days. The trend analysis showed clear fluctuations in the pattern of total annual raindays for the period of study. However, years from 2011 to 2014 showed decline in the pattern of total annual raindays compared to previous years. Since the result shows inconsistency in the pattern of rainfall, it will be difficult to rely for the pattern of total annual raindays for any process or activity such as agriculture activity that depends on rainfall.

Table 4: The maximum and minimum of monthly raindays for each consecutive month (1985-2014)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum Monthly Rain days (day)	4	1	5	3	7	4	8	12	11	14	16	15
Maximum Monthly Rain days (day)	23	18	23	19	24	24	19	23	24	27	30	26

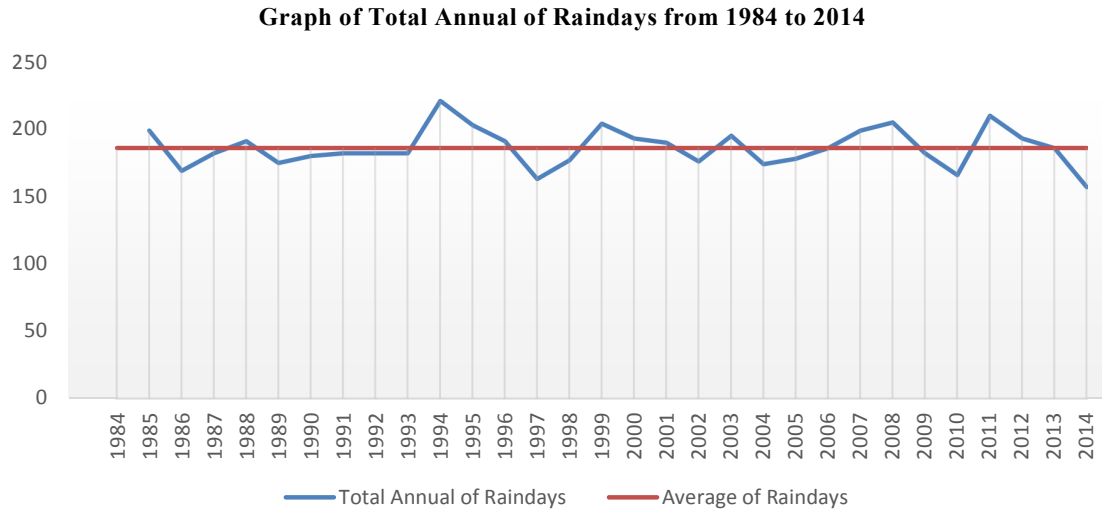

Figure 3: The trend of number of raindays for 30 years in Kuala Krai, Kelantan from 1985 to 2014

CONCLUSION

The results of this study revealed that the pattern of rainfall and number of raindays varies in different months, season and annually. December recorded as the wettest month in Kuala Krai with the highest rainfall amount and number of raindays while the driest months are January and February. Apart from that, the total amount of annual rainfall showed a significant increase from year to years which exceeded the average amount of rainfall. Therefore, these information may be used as a guidance for flood management policy and decision and will help the government to find ways on how to reduce floods in Kuala Krai.

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