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Accelerated development and changes in rainfall trends and variations in Malaysia: A case study of the Kinta River basin 1960-2006

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Abstract

Environmental impact induced by rapid urbanization and development may be traced from changes in local rainfall trends and variations. This study examined the trends and variations of rainfall in the Kinta River basin, Perak, a region in Malaysia that is rapidly urbanizing and developing. Long-term rainfall data from the year 1960 to 2006 were obtained from the Department of Irrigation and Drainage (DID) involving 15 rainfall stations in the Kinta River basin were employed to analyse long-term variations and precipitation trends. Results of the Mann-Kendall tests show that the Kinta River basin received high rainfall during the Northeast monsoon (950 mm) as compared to that received during the Southwest monsoon (309 mm). The tests also showed that the annual rainfall in the Kinta River basin had an increasing trend from the year 1960-2006 with the value of S=217 as did the monthly rainfall (except in the months of June and July 8) and seasonal rainfall during Northeast monsoon (S = 216) and Southwest monsoon (S = 97). These trends of increasing rainfall appeared to give the early impression that the basin should not have any problems with regard to water supply, in particular, for the purpose of agricultural irrigation and domestic use. However, careful planning should still be undertaken in view of the rapid development of the basin due to rapid urbanisation of the areas surrounding the Ipoh City as there will certainly be growing demand for water in this area in the near future.

Keywords: accelerated development, environmental impact, Mann-Kendall test, Kinta River basin, rainfall trends and variations, rapid urbanisation

Introduction

Rainfall is one of the important hydrological aspects to be studied in the context of a drainage basin. Some features of the rainfall often studied are such as quantity, frequency, distribution, heaviness and rainfall periods (Wan Ruslan, 1994). Variations of rainfall give a very unique perspective about the rainfall condition, especially in tropical areas. In Malaysia, the government agency leading the observation of rainfall data is Malaysian Meteorological Department (MMD) and the Department of Irrigation and Drainage (DID). For the state of Perak alone there are 108 rainfall stations monitored by DID located either in the estate, government offices such as police stations, municipalities, schools and other establishments (DID, 2007).

The trend analysis is a tool or method used to understand variations of a variable over a series of time data. The trend analysis will be able to identify and detect a change and the change is actually occurring in the context of space and time. The trend analysis requires data or information in a long run According

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to Radziejewski and Kundzewicz (2004), one of the things that are important is analyzing time series data for the long term is to detect trend of a variables such as rainfall data, temperature, total discharges, etc. Long-term data are necessary to be used as forecast tor the future. For example, a prediction of long-term rainfall trends will help us to predict the rainfall either increasing or decreasing, and be able to identify phenomena that may occur such as floods, droughts and changes in the variations of discharge in the drainage basin (Zhang et al., 2005; Burn & Elnur, 2002; Yang et al., 2005; Kwarteng et al., 2009; Rehman, 2009; Mohmadisa et al., 2012). This article aims to analyse the long-term rainfall trends in the Kinta River basin either in the amount of annual rainfall, monthly and season of the year 1961-2006. Analysis of rainfall trends over the long term this will help the authorities in the planning and management of water resources, particularly for domestic water supply.

Study area

The study area is in the Kinta River basin. Kinta River Basin area of 2566km2 is a sub-basin of the Perak River. In addition to the Kinta River basin, are other sub basin such as Rui River, Plus River, Batang Padang River and Sungkai River. Figure 1 shows the location of the Kinta River basin in the state.

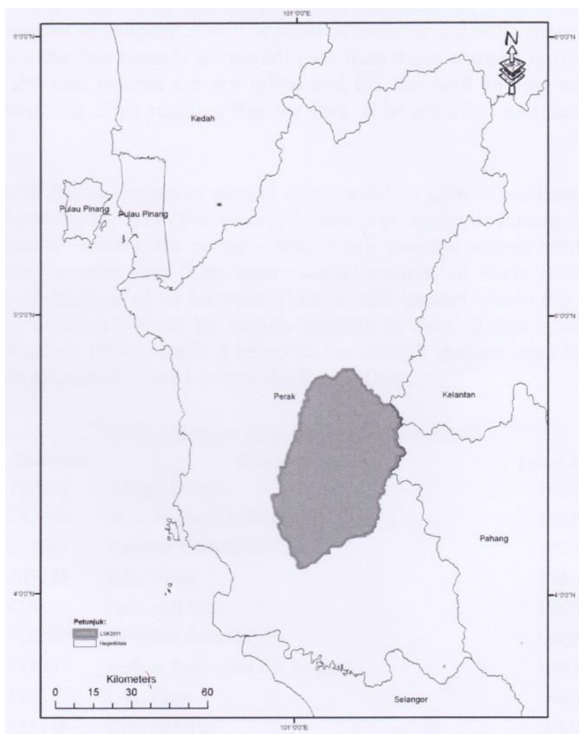

Figure 1. *Location of the Kinta River basin in the State of Perak*

Methodology

The rainfall data for this study were obtained from the DID and used in analysing variations and trends of rainfall occurring in the Kinta River basin. The data were in the form of daily rainfall from 20 stations that have been identified in the study area. However, only 15 rainfall stations were used for the analysis of long-term rainfall. For data analysis emphasise were given on two aspects; to examine the long-term rainfall trends at each station and analyse the average rainfall for the Kinta River basin. The analysis of long-term rainfall was divided into three types, namely annual rainfall, monthly rainfall and rainy seasons.

The rainfall data were tested for reliability; validity and normality test in case it. Factors such as changing the types of rain gauge, gauge location alteration or hindered by the growing vegetations (Wan Ruslan, 1994). In this case, data for all stations located in the Kinta River basin were treated by using a double mass method. This method is very effective in detecting inconsistencies rainfall records and lack of rainfall by comparing nearby rainfall station data within 80 miles and preferably in the same climate (Wan Ruslan, 1994). The rainfall data loss problems were overcome by data interpolation by referencing to the nearby station. At the same time, the rainfall data from meteorological station located at the Sultan Azlan Shah Airport, Ipoh were also used for this purpose. The station has monthly and annual rainfall data are incomplete and do not suffer from the problem of missing data.

The double mass curve analysis was used to plot the cumulative rainfall for a selected rainfall station to test data consistency and then compared to the cumulative rainfall obtained from nearby stations with regular rainfall values (Brooks et al., 2003; Wan Ruslan, 1994). Rainfall data interpolation is necessary if for estimating data lost either due to the technical problems or human error. For this reason the ratio method is used to estimate the missing data. In this case, the nearest rainfall stations are used to estimate the missing rainfall data from other rainfall stations in study area. Data from nearby stations are used because of its location which is still located within the Kinta River and the position is still within 80 miles that can be used to estimate the rainfall data in addition to having the same climate (Wan Ruslan, 1994). Table I refers to the rainfall stations used in the analysis of the distribution and trends of rainfall in the basin of the Kinta River.

Table 1. Station Kinta River basin rainfall

No.	No. Stations	Station Name	Long-time data
1	4110129	Sungai Manik	1960-2006
2	4212128	Sri Kinjang, Chenderiang	1960-2006
3	4311001	Kampar District Office	1974-2006
4	4409121	Ldg. Nalla	1960-1995
5	4410122	Ldg. Hill Rise	1960-1995
6	4410120	Hospital Batu Gajah	1960-1997
7	4411001	Kolam Takungan Air Gopeng	1961-1989
8	4510117	Ldg. Pinji	1960-1994
9	4511118	Kramat Pulai	1960-1982
10	4511111	Politeknik Ungku Omar	1972-2006
11	4610116	Hospital Ipoh	1960-1993
12	4611114	Kerja Air Kinta	1960-1988
13	4611001	Ldg. Kuda Keb. Ulu Kinta	1974-2006
14	4610112	Ldg. Strathisla	1960-1994
15	4711113	Ldg. Chemor	1960-1994

The Theissen polygon method is considered the suitable method for estimating the amount of rainfall in the Kinta River basin from 1960 to 2006. In order to use the method, an ArcView geographic information systems (GIS), was used to determine sub-polygon of the study area as shown in Figure 2. This method used the command-GIS Polygon Thiessen found in CWRW Vector Extension. The constructed polygon is based on the lines that have the same distance between rainfall stations (Shaharuddin & Noorazuan, 2006). Total rainfall for the whole of the Kinta River basin obtained using the following equation:

$$P = [Ps1.A\ 1 + Ps2.A2 + ... + Ps8.A8] / At \qquad \text{(i)}$$

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where:

P = total rainfall for the whole area (area precipitation)
At = area of the Kinta River basin

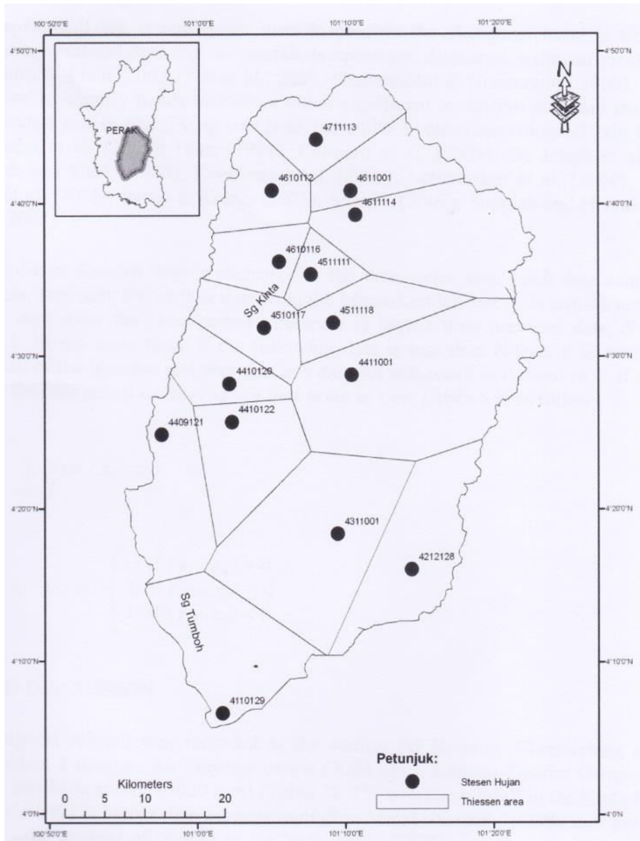

Figure 2. *Position of rainfall stations in the Kinta River basin using the Thiessen Polygon*

The rainfall data from each station is provided in the form of monthly and yearly from 1960 to 2006 (47 years) and were analysed for monthly, seasonal and annual rainfall trends diversity. For the seasonal trends, data were be analysed in term of the Northeast Monsoon (NEM) season, which is from November to March and the Southwest Monsoon (SWM) from May to September and the monsoon transition months of April and October. To analyse the trend of rainfall in the basin, descriptive and non-parametric analysis were used. A non-parametric Mann-Kendall used to test the trend of rainfall for each station and the average long-term rainfall.

Statistical analysis and in particular *t*-test and Mann-Kendall tests were used to identify the significance of rainfall trend in the basin. The linear regression was used identify whether the trend of precipitation is in the form of increase, decrease or no trend. The *t*-test was used to compare significant difference of the amount of rainfall during the NEM and SWM.

The Mann-Kendall test is commonly used to confirm the change of trend in time series data, particularly environmental data such as rainfall, temperature, discharge, sediment yield and water quality (Burn & Elnur, 2002; Yue et al., 2003; Shaharuddin & Noorazuan, 2006). The test was also used to identify trends of either significant or otherwise. Many studies used Mann-Kendall test in identifying trends particularly in hydro-meteorological events (Bae et al.,2008; Basistha et al., 2009; Burn,1994; Caloiero et al., 2009; De Jongh et al., 2006; Gan, 1998; Hirsch & Slack,1984; Kwarteng et al., 2009;

Lettenmaier et al., 1994; Lin & Slack,1999; Luo et al., 2008; Partal & Kahya, 2006; Shahid, 2009; Suppiah & Hennessy, 1998 and Zhang et al., 2001).

In Mann-Kendall test data is measured as time-series each data was compared with all subsequent data. Basically, the earliest data from the Mann-Kendall test *(S)* is considered 0, i.e. no trend. If the data from the time period afterward is higher than previous data, *S* is considered increased by 1. In the same time, if the following data is less than before, it is considered less 1. Results from all of the increase and decrease in a data set will result in the end of *S*. If $x\ 1, x\ 2, x\ 3, \ldots X$ i represents the data points *n* where *xj* is a data point in time *j,* then *S* is as follows:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign\,(x_j - x_k) \qquad \text{(ii)}$$

where:

$$sign\,(x_j - x_k) = \begin{cases} +1 \text{ if } (x_j - x_k) > 0 \\ 0 \text{ if } (x_j - x_k) = 0 \\ -1 \text{ if } (x_j - x_k) < 0 \end{cases}$$

Results and discussion

Overall, the highest rainfall was recorded at the station Sri Kinjang, Chenderiang at 3242 mm, followed by Kolam Takungan Air Gopeng station (3084 mm), Kampar District Office station (3027 mm) and Ldg. Strathisla station (3020 mm) (Table 2). The average rainfall in the basin is 2741 mm and the total is higher than average rainfall in Malaysia, which is 2400 mm per year. This is almost equal to the amount of rainfall in the basin area of 2745 mm Bernam River basin near the watershed (Mohamad Suhaily Yusri, 2007). The high rainfall in the Kinta River basin is related to the basin location, which is located at the foot of the Titiwangsa range and rainfall received is of a hill rain. The variations of the space between the area rain and the rain point are too small based on the coefficient of variation (CV) of less than 0.3. Generally, the smaller the CV will give the impression that the data on the amount of rain in the area are relatively accurate and can overcome the problem of rainfall variations in a drainage basin of rainfall in the CV was 0.17. The total rainfall area also has a standard deviation (SD) lower than rainfall point based on the average value of the rain. In this case, high rainfall variation based on the highest and using a weighted on each region to represent a fairly consistent rainfall in this catchment area reduced lowest rainfall value for each point.

The average annual rainfall in the basin also showed an increasing trend, based on the regression line from year 1960-2006 (Figure 3). The trend analysis based on Mann-Kendall test showed a positive trend or increased rainfall at 99 % confidence level based on the *p* value of 0.0028 (*S* = 327, Z = 2990). The maximum rainfall was recorded in 1999 (4097 mm), while minimum rainfall was in 1978 (2054 mm) and the average annual rainfall is 2741 mm. All recorded annual rainfall exceeding 2000 mm. Abnormal or extreme rainfall can be observed particularly after 1993, where recorded rainfall were exceeding 3000 mm per year as in 1993 (3517 mm), 1995 (3581 mm), 1996 (3167 mm), 1999 (4097 mm), 2000 (3872 mm), 2001 (3257 mm), 2003 (3595 mm) and 2006 (3473 mm). High annual and extreme rainfalls after 1990s could be attributed to the process of land-use change that in the basin. Overall, 72.3% of the total annual rainfall in the basin exceeded 2400 mm. This situation suggests that this basin rainfall is very high and this has undoubtedly contributed to the increase in discharges into the Kinta River drainage system.

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Table 2. Analysis of annual rainfall by data stations in the Kinta River basin, 1960-2006

Stations	Average (Mm)	Standard Error (Mm)	Standard Deviation (Mm)	Range (Mm)	Min. (Mm)	Max. (Mm)	Coefficient of Variation	No. (N)
Sri Kinjang Chenderiang	3242	134	917	4624	1500	6124	0.28	47
Kampar District Office	3027	73	498	2242	1840	4081	0.16	47
Ldg. Nalla	2193	57	388	1887	1171	3058	0.18	47
Hospital Bt.Gajah	2774	112	766	3244	2005	5249	0.28	47
Ldg. HillRise	2634	92	630	3238	1433	4671	0.24	47
Klm.Tkg. Air Gopeng	3048	134	920	3563	1782	5344	0.30	47
Ldg. Pinji	2289	74	504	2382	994	3376	0.22	47
Politeknik Ungku Omar	2423	113	775	3266	1281	4547	0.32	47
Kramat Pulai	2716	83	572	2145	1799	3943	0.21	47
Ldg. Strahisla	3020	141	965	3972	1965	5937	0.32	47
Hospital Ipoh	2391	80	547	2434	1248	3682	0.23	47
Ldg. Kuda Keb. Ulu Kinta	2211	64	439	2674	81 1	3485	0.20	47
Kerja Air Kinta	2424	97	664	2921	1108	4029	0.27	47
Ldg. Chemor	2451	81	557	2639	1516	4155	0.23	47
Sg. Manik	2852	142	975	4723	848	5571	0.34	47
Area Rainfall	2741	68	468	2043	2054	4097	0.17	47

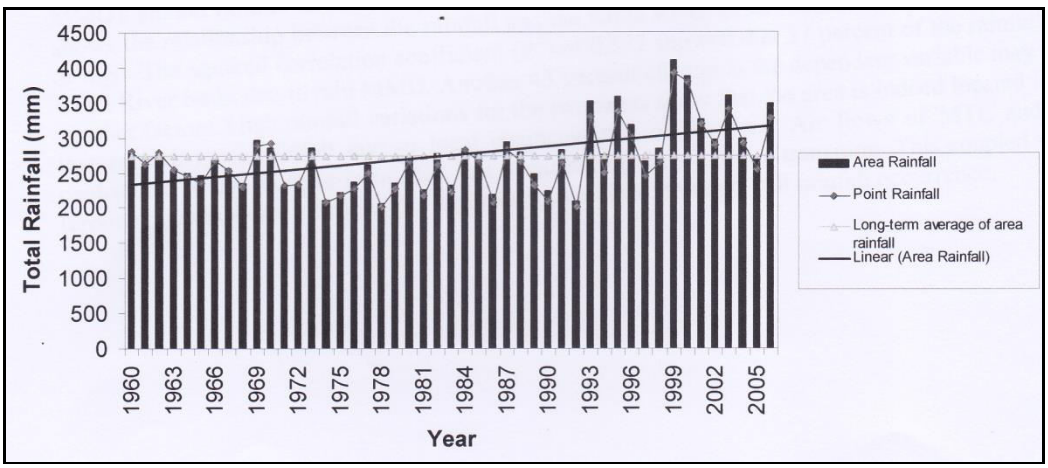

Figure 3. *Trends in annual rainfall in the Kinta River Basin from 1960 to 2006*

Next based on the cumulative analysis of rainfall area and rainfall point shows the variation between rainfall stations is very significant in terms of space and time as the result of the natural characteristics in the tropics which is very localized. Figure 4 shows the cumulative rainfall for each station has high variation due to the annual rainfall data for each station is not in line with each other. Sri Kinjang, Chenderiang rainfall station showed the highest amount of rainfall compared to other rainfall stations.

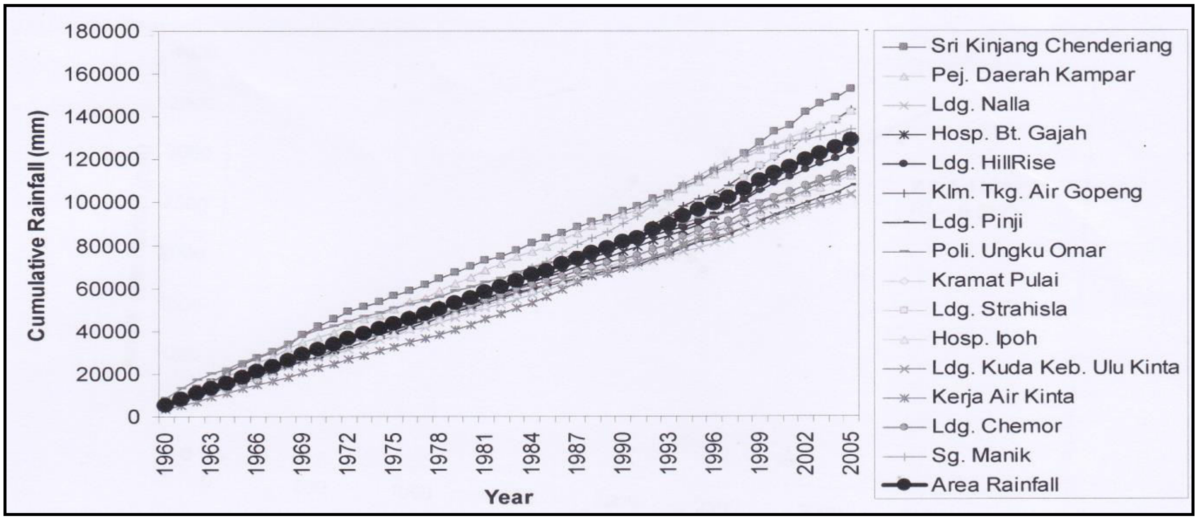

Figure 4. *The cumulative rainfall for each rainfall station in the Kinta River basin from 1960 to 2006*

To confirm the characteristics of rainfall in the basin, total annual rainfall was then compared to rainfall data from the Malaysian Meteorological Department station which is also located in the Kinta River basin. This station represents the central region of the state. Figure 5 shows the correlation of annual rainfall of the basin to rainfall at the stations of MMD from 1980 to 2006. The annual rainfall in the basin is considered as the dependent variable and the MMD's annual rainfall as the independent variable. The coefficient of correlation (R) is 0.76 which shows the relationship between the rainfall in the basin and the rainfall at MMD stations is strong. The correlation coefficient (R^2) of 0.577 showed that 57 % of the rainfall in the Kinta River basin due to rain MMD. Another 43 percent change in the dependent variable may be due to other factors. High rainfall variations for the two areas show that the area is indeed located in areas that receive more rainfall due to local characteristics of the area. Air flows of NEM and SWM contributed to the increase in rainfall that occur during the monsoon transition. This coupled with its terrain which is located close to the Main Range and have frequent hill rainfall occurrence.

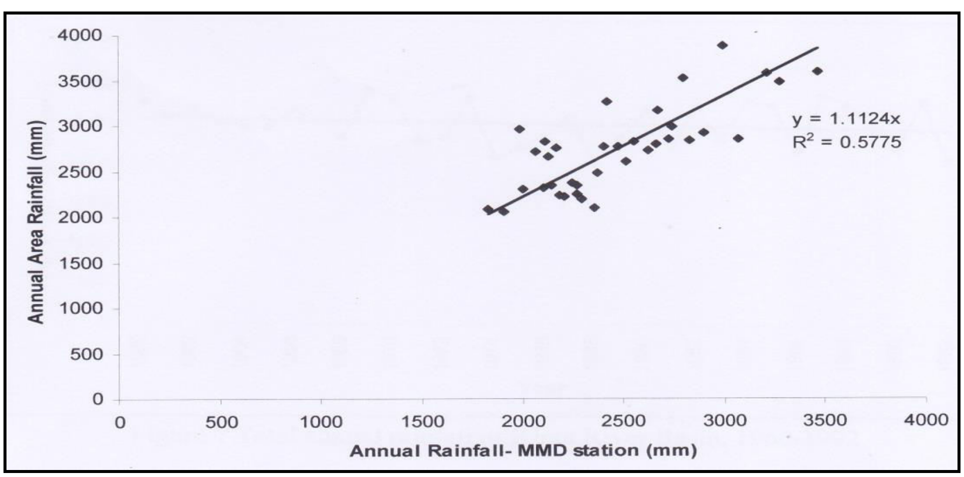

Figure 5. *Comparison of the area rainfall in the Kinta River basin and the Malaysian Meteorological Department, 1980-2005*

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In order to obtain more understanding on the trend of annual rainfall occurrence, total annual rainfall were analysed using the moving average method. Figure 6 summarizes the variation of the annual rainfall for the basin. In the long run, it appears that the trend of annual rainfall increased from 1962 to 2004 and the most significant increase occurred after 1992. Based on Figure 6, it shows that two significant variations for this average annual rainfalls, for the year 1960-1992 and 1993-2006. For the period of 1960-1992, total annual rainfalls were in the range of 2000-2500 mm or an average of 2526 mm (Figure 7) compared to the period 1993-2006 shows whereby annual rainfall of 3000 mm or for the average duration of that period was 3247 mm (Figure 8). However, these two time periods showed a declining trend. This to shows that the rainfall occurrences in basin was strongly influenced by local characteristics of the area such as landform due to its location at the foot of the Main Range and land-use changes that factors occured in the basin.

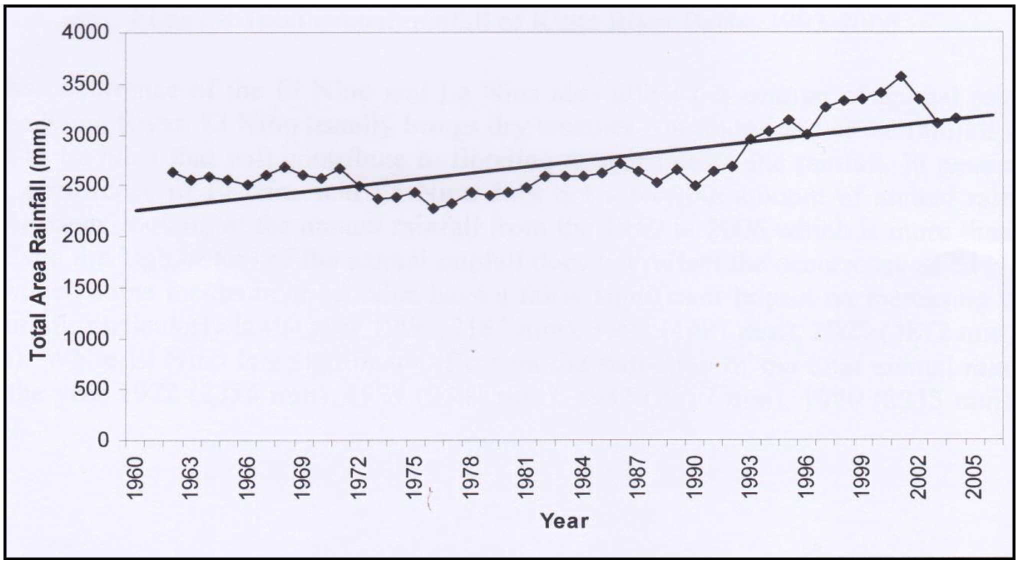

Figure 6. *The sum of rainfall based on the average of rainfall mobility in 5-years in Kinta River basin, 1960-2006*

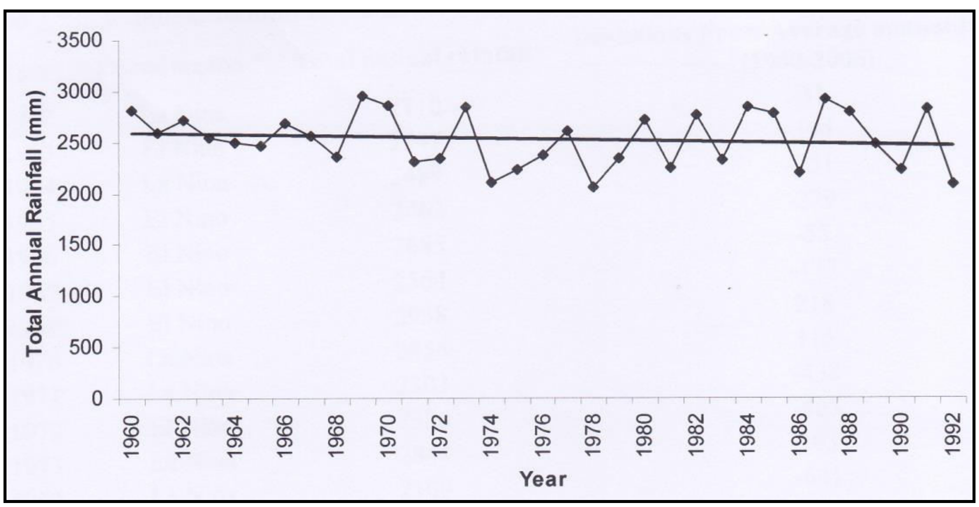

Figure 7. *Total annual rainfall of Kinta River basin, 1960-1992*

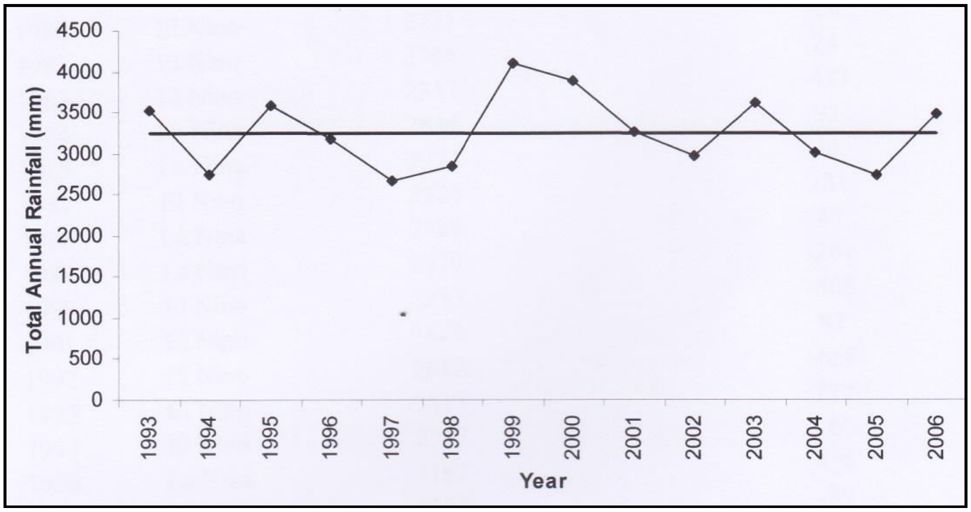

Figure 8. *Total annual rainfall of Kinta River basin, 1993-2006*

The El Nino and La Nina events also affected the amount of annual rainfall in the basin. The El Nino usually brings dry weather conditions and reduced rainfall compared to La Nina that contributed to flooding due to high rainfall. In general the El Nino and La Nina events does not contributed to the amount of annual rainfall in Kinta River basin as indicated in Table 3 and by examining the annual rainfall from the 1960 to 2006 which is more than 2000 mm per year. The highs or a lows of the annual rainfalls does not reflect the occurrence of El Nino and La Nina. However, some incidents of La Nina have shown fairly significant impact on rise of number of high rainfall events, particularly in the year 1996 (3167 mm), 1999 (4097 mm), 2000 (3872 mm) and 2001 (3257 mm) and El Nino have shown significant effects on the reduction of total annual rainfall in the year 1972 (2336 mm), 1979 (2341 mm), 1983 (2317 mm), 1990 (2233 mm) and 1992 (2082 mm).

Table 3. Total annual rainfall in the Kinta River basin and its relation to El Nino and La Nina

Year	Phenomenon*	Total annual rainfall	Deviations From Average annual rainfall (1960-2006)
1962	La Nina	2710	-31
1963	El Nino	2547	-194
1964	La Nina	2489	-251
1965	El Nino	2462	-279
1966	EI Nino	2685	-55
1967	El Nino	2564	-177
1969	El Nino	2958	218
1970	La Nina	2856	115
1971	La Nina	2303	-438
1972	El Nino	2336	-405
1973	La Nina	2844	103
1974	La Nina	2100	-641
1975	La Nina	2222	-519
1977	El Nino	2606	-135
1979	El Nino	2341	-400
1980	El Nino	2721	-20

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Year	Phenomenon*	Total annual rainfall	Deviations From Average annual rainfall (1960-2006)
1982	El Nino	2765	24
1983	El Nino	2317	-423
1984	La Nina	2834	93
1985	La Nina	2774	33
1987	El Nino	2922	181
1988	La Nina	2788	47
1989	La Nina	2479	-261
1990	EI Nino	2233	-508
1991	El Nino	2823	82
1992	El Nino	2082	-658
1993	El Nino	3517	777
1994	El Nino	2747	6
1996	La Nina	3167	426
1997	El Nino	2652	-89
1999	La Nina	4097	1356
2000	La Nina	3872	1131
2001	La Nina	3257	517
2002	El Nino	2962	221
2003	El Nino	3595	854
2004	El Nino	2986	246
2006	El Nino	3473	732

Source: Based on Melesse et al. 2011

Generally, the monthly long-term rainfall trend by in the Kinta River basin is wide and varied in height from 1960 to 2006. Based on the analysis clearly shows the amount of rainfall is high in November with an average of 315.5 mm. In addition, rainfall events were also recorded during the monsoon transition periods in April (262.3 mm) and October (308.6 mm) (Figure 9). Each month of these periods recorded an average rainfall of over 100 mm. The minimum rainfall was recorded in June (30.1 mm) and a maximum in January (563.3 mm). The patterns of monthly rainfall showed two distinct seasons; dry and wet season. The dry season is in January, February, June, July and August, which recorded monthly rainfall of less than 200 mm while the other months is considered as the wet season due to the average monthly rainfall is more than 200 mm.

Table 4 shows the analysis of a long-term monthly rainfall in the basin. The monthly rainfall variation based on CV was nearly constant except in the month of January, July and August. Indirectly, this also explains the nature of the rainfall events for the area that rains throughout the year. Although the basin is located on the west coast of Peninsular Malaysia, the influence of the NEM is strongly dependent on the recorded amount of rainfall which was high during the months of November (323.9 mm) and December (241.3 mm).

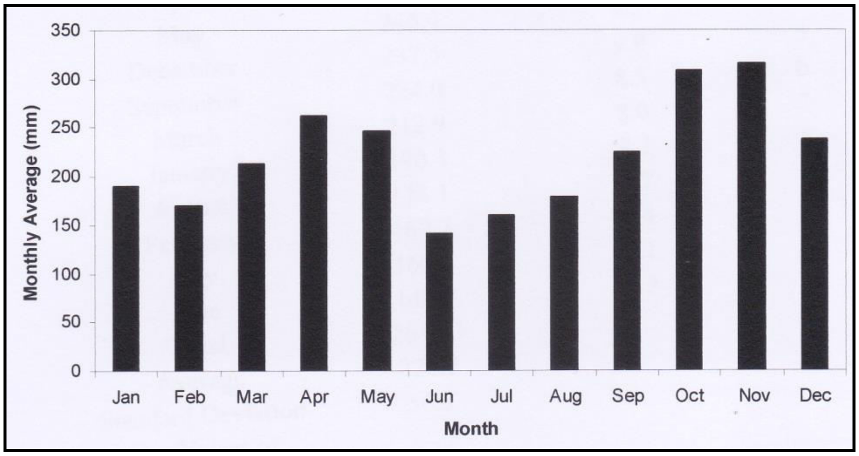

Figure 9. *Average monthly rainfalls in the Kinta River basin from 1960 to 2006*

Table 4. Descriptive analysis of the average monthly rainfall in the Kinta River basin from 1960 to 2006

Month	Average (mm)	Minimum (mm)	Maximum (mm)	Range (mm)	Standard Error (mm)	Standard Deviation (mm)	Coefficient of Variation	N
January	190.3	46.1	563.3	517.2	15.7	107.7	12:57	47
February	169.7	78.3	337.2	259.0	9.1	62.1	12:37	47
March	212.9	101.2	450.7	349.6	10.9	74.9	12:35	47
April	262.3	115.6	441.2	325.6	11.7	80.2	12:31	47
May	246.4	122.0	467.8	345.7	11.1	76.2	12:31	47
June	140.5	30.1	240.3	210.2	7.3	50.1	12:36	47
July	160.6	46.1	415.3	369.2	10.4	71.2	12:44	47
Aug	178.1	51.9	394.7	342.8	10.9	75.0	12:42	47
Boss	224.0	92.5	435.2	342.6	10.2	70.2	12:31	47
October	308.6	96.0	526.8	430.8	14.2	97.5	12:32	47
November	315.5	181.5	507.0	325.5	12.5	85.9	12:27	47
December	237.5	85.7	418.4	332.8	11.3	77.5	12:33	47

Based on the characteristics of the monthly rainfall, clearly showed that high intensities of rainfall in November are within the windy breeze of NEM. Even though the basin is protected by the Titiwangsa range, the monsoons brought heavy rain in this area in November and December. Similarly, the inter monsoon or monsoon breeze transitions brought heavy rains in April and October. Table 5 illustrated the rank of rainfall months from 1960-2006. This information is important for the planning of land use development in this basin as land clearing activities for the upcoming months with high rainfall may contribute to the problem of soil erosion and this situation could also lead to other problems such as landslides, siltation in the rivers and water quality deterioration.

Table 5. Statistics average rainfall point over the long term in Kinta River basin from 1960 to 2006

Month	Average (mm)	Percent (%)	Rank
November	315.5	11.9	1
October	308.6	11.7	2
April	262.3	9.9	3
May	246.4	9.3	4
December	237.5	9.0	5

Month	Average (mm)	Percent (%)	Rank
September	224.0	8.5	6
March	212.9	8.0	7
January	190.3	7.2	8
August	178.1	6.7	9
February	169.7	6.4	10
July	160.6	6.1	11
June	140.5	5.3	12
Total	2646.3		
Average	220.5		
Standard Deviation	56.3		
Coefficient of Variation	0.26		

The total rainfall in Malaysia is heavily influenced by monsoon breeze either NEM or SWM. In NEM, the east coast of Peninsular Malaysia, Sarawak and the coast of western Sabah received heavy rain (Malaysian Meteorological Department, 2011). The rural and areas surrounded by mountain relatively do not received heavy rainfall. Meanwhile, when SWM is said not to bring heavy rain and the wind is drier. Even though sheltered the Kinta River basin received high rainfall during NEM due to its location at the foot of the mountain range and hills remain a factors. The total rainfall during this period is a combined rainfall from November to March. While the total rainfall during the SWM is a combined data from May to September. In contrast, the most abundant rainfall fell during the NEM (November to March) compared to SWM (May to September) is shown in Figure 10.

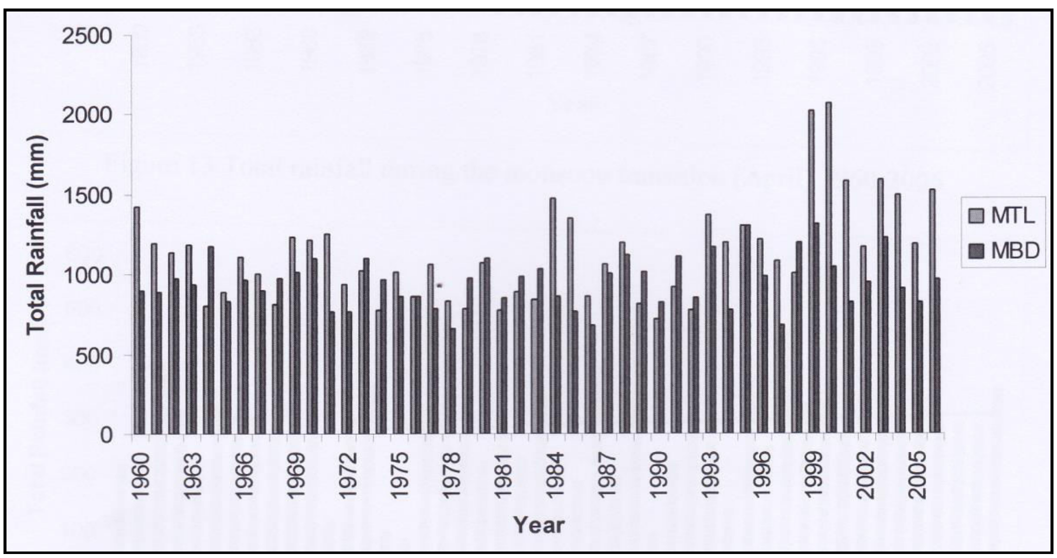

Figure 10. *Comparison of rainfall during the NEM and SWM 1960-2006*

Figure 10 shows the total rainfall during the NEM indicated an increasing trend from 1960 to 2006. The average rainfall recorded for the period was 1126.3 mm with maximum rainfall was recorded in 2000 (2062 mm), ranging between 393 mm to 1337.8 mm and SD (250.9 mm). The Mann-Kendall test showed a positive trend or increase (S = 216, Z = 1.972, p=0.0486). The amount of rainfall during the SWM is a slightly different during the NEM with the average rainfall is 950 mm during SWM, the range of 298.3 mm to 1226.6 mm and SD (215 mm). The Mann-Kendall test (S = 97, Z = 0880) showed an increasing trend (p = 0.3786).

For the transitional monsoon months, April and October showed an increasing trend from 1960 to 2006 (Figure 11 and 12). The average rainfall recorded in the month of April was 262 mm, SD = 100 mm, range = 506 mm while the minimum rainfall recorded in 1985 (116 mm) and the maximum rainfall in 2001 (441 mm). The Mann-Kendall test showed an increase trend with (S = 116, Z = 1.055, p = 0.2916). The trends in rainfall for the months of October also showed an increasing trend from 1960 to 2006. Average annual rainfall is 309 mm, SD =114 mm, range = 489 mm, the minimum rainfall in 1975 (96 mm) and maximum rainfall in 1987 (527 mm). The Mann-Kendall test (S = 178, Z = 1.624, p = 0.1044) showed an increasing trend. Overall, the average rainfall was higher during NEM than SWM as shown in Table 6. Table 7 summaries of the analysis of Mann- Kendall tests for the amount of rain in year, months and seasons in the Kinta River basin from 1960 to 2006.

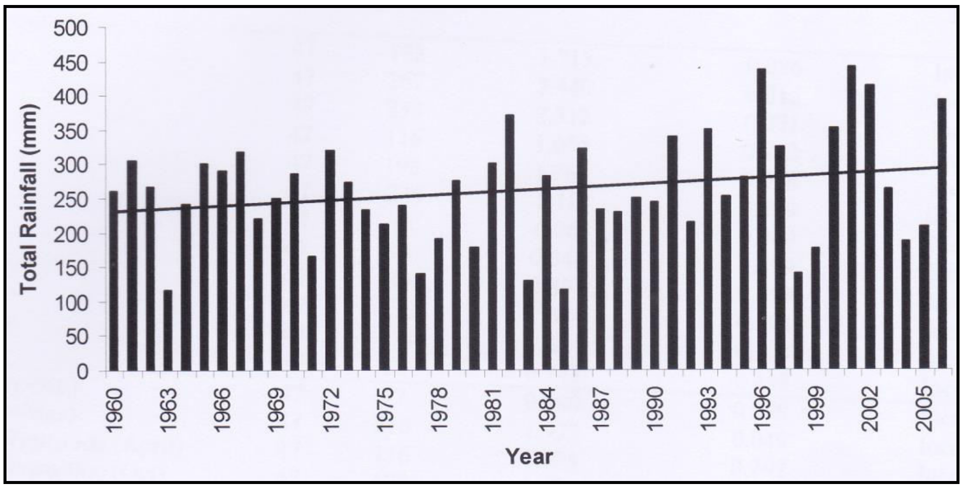

Figure 11. *Total rainfall during the Monsoon transition (April) 1960 to 2006*

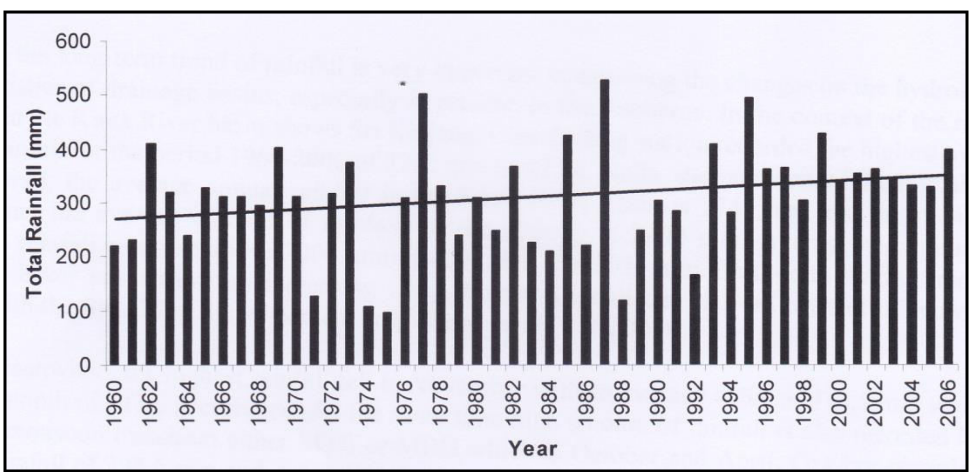

Figure 12. *Total rainfall during the Monsoon transition (October) 1960 to 2006*

Table 6. Seasonal statistics of a long-term rainfall point in the Kinta River basin from 1960 to 2006

Month/ Season	Average Rainfall (mm)	Percentage (%)
MBD	950	36
October	309	12
MTL	1126	42
April	262	10
Average	662	
Standard Deviation	441	
Coefficient of Variation	0.67	

Table 7. Mann- Kendall Test for rainfall trends in Kinta River basin from 1960 to 2006

Month/ Seasonal/ Annual(mm)	No. (*n*)	Statistic Mann-Kendall (S)	Normality Statistic Test (Z)	Probability (P)	Trend (At 99 % Confidence Level)
January	47	188	1.715	0.086	Increased
February	47	267	2.440	0.015	Increased
March	47	253	2.312	0.021	Increased
April	47	116	1.055	0.292	Increased
May	47	193	1.761	0.078	Increased
June	47	-239	-2.183	0.029	Decreased
July	47	-8	-0.068	0.949	Decreased
August	47	93	0.844	0.399	Increased
September	47	89	0.807	0.419	Increased
October	47	178	1.624	0.104	Increased
November	47	178	1.624	0.104	Increased
December	47	82	0.743	0.458	Increased
MBD (May-Sep)	47	97	0.880	0.379	Increased
MTL (Nov-Mac)	47	216	1.972	0.049	Increased
Monsoon Transition (April)	47	116	1.055	0.292	Increased
Monsoon Transition (Oct)	47	178	1.624	0.104	Increased
Annually	47	217	1.981	0.048	Increased

Conclusion

The study of long-term trend of rainfall is very important for assessing the changes on the hydrological characteristics of drainage basins, especially in relation to the river discharge. In the context of the rainfall analysis in the basin, Sri Kinjang in Chenderiang station recorded the highest average annual rainfall for the period 1960-2006 of 3242 mm while Ldg. Nalla station recorded the lowest rainfall of 2193 mm. Overall, the average annual rainfall in the basin is 2741 mm and the amount is higher than the average rainfall for the country at 2400 mm. The average maximum and minimum of rainfall were above 2000 mm of 4097 mm and 2054 mm. Long-term rainfall trends in the basin show an increasing trend. The Mann-Kendall test showed a trend of increasing rainfall with the S = 327 at 99% confidence level (p = 0.0028).

The highest rainfall was recorded in the months of November with an average value of 315.5 mm that is the early month of NEM and the same time, high amount of rainfall were also recorded in the months of monsoon transition either NEM or SWM which is in the months of October and April. The October recorded an average rainfall of 308.6 mm while April recorded 262.3 mm. Although, equatorial climate does not show clearly any seasonal wet and dry but in the context of this study it can be categorised as wet and dry season's months. The dry season is in January, February, June, July and August due to recorded average monthly rainfall of less than 200 mm per month. With high intensity of rainfall in November during NEM, the study concluded that even though the Kinta River basin is sheltered by the Titiwangsa range is not a factor for not receiving high rainfall during the NEM. By using the monthly rainfall data may also assist the authorities to implement land use development activities by taking into account of its nature. As such, any land clearing activities and exploration of new areas for various development activities should not be conducted during the month of November, October and April to reduce erosion problems.

The rainfall amounts in Kinta River basin is highly influenced by NEM, SWM and transition periods breeze. The study showed that NEM has brought more rainfall than SWM even if Kinta River basin is sheltered by Titiwangsa range. In addition, the basin is located at the foot of the range that causes this area to receive high rainfall due to hills rain effects. On average, NEM bring rainfall of 1126 mm compared to SWM (950 mm). The Mann-Kendall test showed all seasonal rainfall trends are increasing at 99 percent confidence level. Indirectly rainfall also contributed to the increase in the number of discharges in the drainage basin. Indirectly, the rainfall also interacts with the exposed surface of the soil without any vegetation cover, allowing route to erosion problem.

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