Middle-East Journal of Scientific Research 11 (5): 668-673, 2012
ISSN 1990-9233

Rainfall Trend Analysis Using 50 Years Historical Data in Newly Developed Catchment in Peninsular Malaysia

Mohamad Suhaily Yusri Che Ngah, Ian Reid and Mohmadisa Hashim

Department of Geography and Environment, Faculty of Human Sciences,
Sultan Idris Education University, 35900 Tanjong Malim Perak Malaysia

---

Abstract: Rainfall in the humid tropics varies from place to place due to convective precipitation. In this study, historical rainfall data for the years 1948 to 2002 have been analyzed in terms of temporal and spatial characteristics in order to recognize the variability of rainfall. It is important to have a long- and short-term rainfall data in order to understand the water resources availability and hydrological responses within newly urbanized (Bernam) catchments. In this study, the spatial and temporal variability of rainfall has been shown clearly. Temporal variability is related, in large part, to the influence of changes in global circulation brought about by El Nino and La Nina-related phenomena. At an annual scale, wet months in the study catchments occur during inter-monsoon seasons instead of the monsoons themselves. Seasonal factors inevitably play a significant role in the availability of water yield by the river system.

Key words: Rainfall · Spatial · Temporal · Variability · Monsoon · Humid tropics

---

INTRODUCTION

Rainfall in the humid tropics varies from place to place in the short-term (days) and this gives much variation at the local scale, depending on the movement and size of storm cells. Convective precipitation is an important component of the tropical weather system and it contributes to the spatial and seasonal variability of rainfall [1-4]. The dynamic properties of convective precipitation affect runoff response, while the spatial variability of rainfall is important in determining the volume and timing of rain transformed into runoff [5]. Currently, predicting the spatial and temporal distribution of rainfall also important due to climate change [6]. In this study, historical rainfall data for the years 1948 to 2002 have been analyzed in terms of temporal and spatial characteristics after deriving basic statistical properties. Discussion then focuses on the depth, intensity, return period, spottiness and temporal variation of areal rainfall for the catchment.

MATERIALS AND METHODS

The rainfall data were obtained from the Department of Irrigation (DID), Malaysia. They have established many monitoring stations since 1930, especially for rainfall and provide the long historical record required by this study. The Meteorological Office also has a historical data archive, but it does not have many stations, unlike DID and record length is often very limited. The DID standard rain gauge has a 203 mm (8 in) diameter orifice which stands at 1.37 m (4 ft 6 in) above ground level and is fitted with a standard windshield; since 1973 recording has been measured by means of a tipping bucket (0.5 mm/tip). Before that, DID use a 127 mm (5 in) diameter orifice as recommended by the World Meteorological Organisation (WMO). To understand if a change of equipment has affected the record, a double mass curve analysis has been applied. In addition, all of the data had to undergo thorough checking using deductive, analytical time-series analysis.

All rainfall data were obtained as daily point rainfall (mm) recorded at 09.00 hours. Since rainfall is unevenly distributed over the catchment, with rainfall depth decreasing with distance from a storm centre, a large variation can occur over relatively short distances. To overcome this problem, in part, catchment rainfall has been calculated from point rainfall using the Thiessen Polygon method to provide a best estimate of areal rainfall from point rainfall for the Bernam catchment for the period

---

Corresponding Author: Mohamad Suhaily Yusri Che Ngah, Department of Geography and Environment,
Faculty of Human Sciences, Sultan Idris Education University,
35900 Tanjong Malim Perak Malaysia.

from 1960 until 2002 [7]. It is more appropriate and commonly used since the topography of the study catchment in this research is not flat, the number of rain gauges is very limited and the gauges are non-uniformly distributed over the catchment [8].

RESULT AND DISCUSSION

Monthly Rainfall Variation: The monthly rainfall (short-term) inevitably tends to show more variability than annual rainfall. Tables 1 show the statistical properties of monthly rainfall. The coefficient of variation (C_v) for catchment lies between 0.3 and 0.4, except for January and February where the range is 0.4-0.7. The coefficient of variation for January and February seems to be higher as a function of low rainfall but high spottiness. The range of 0.3-0.4 is similar to other areas reported in Malaysia. For example, the Kuala Lumpur area lies at 0.28-0.32 [2] and the Penang catchments lie between 0.4 and 0.8 [9]. This variation of C_v values indicates the existence of strong variability in the rainfall of the study area [10]. This effect is particularly crucial for interpreting the rainfall-runoff relation for hydrological study within tropical region, since the monthly record is a major data source.

Figure 1 shows the temporal pattern of the long-term average monthly rainfall. For Bernam catchment, November is the wettest month with 11.9 % of the average annual total. April is the second wettest month where the percentage of monthly rainfall recorded by Bernam is 11.2%, of the average annual total. Meanwhile, January is the driest month with 5.1% of the average annual total for Bernam. By ranking the mean monthly values, it is shown that the highest three values occur in the months of November, April and October. These months belong to inter-monsoon periods (April and October) and the beginning of the Northeast Monsoon season, which brings a lot of rain to Peninsular Malaysia. The earlier definition by the Malaysian Meteorological Services, which stated that the wet months in Malaysia are associated with monsoon, could not be applied for these areas. However, this circumstance would particularly be relevant for the east coast of the Malaysian Peninsula, which receives direct influence from the Northeast Monsoon.

Annual Rainfall Variation: In this study, rainfall over a catchment area has been estimated from point rainfall using the Thiessen Polygon technique All stations are located in flat-lowland areas where elevation is less than

Table 1: Bernam Catchment-Average monthly areal rainfall characteristics (1948-2002)

Month	Season	Mean (mm)	Minimum (mm)	Maximum (mm)	Range (mm)	Standard Error (mm)	Standard Deviation (mm)	Coeff. Var.	N
Jan	Dry 1	141	44	329	285	10	73	0.51	55
Feb	Dry 1	176	67	366	299	10	72	0.41	55
Mar	Wet 2	235	64	423	360	11	83	0.35	55
Apr	Wet 2	309	99	542	443	13	100	0.32	55
May	Wet 2	265	88	480	391	13	97	0.37	55
Jun	Dry 2	164	31	311	280	9	68	0.42	55
Jul	Dry 3	162	35	373	338	9	70	0.43	55
Aug	Dry 2	175	54	368	314	10	77	0.44	55
Sep	Wet 1	260	99	455	356	11	83	0.32	55
Oct	Wet 1	315	116	569	453	15	110	0.35	55
Nov	Wet 1	330	145	572	427	13	96	0.29	55
Dec	Wet 1	234	52	440	388	12	87	0.37	55

Table 2: Bernam-Annual point and areal rainfall characteristics (1948-2002)

Rain gauge	Mean (mm)	Standard Error (mm)	Minimum (mm)	Maximum (mm)	Range (mm)	Standard Deviation (mm)	Coeff. Var.	N
Hospital	2777	49	2024	3404	1380	361	0.13	55
Gumut	2953	53	2186	3752	1566	393	0.13	55
Trolak	2908	63	1910	3900	1990	467	0.16	55
Bedford	2582	56	1706	3682	1976	412	0.16	55
Behrang	3056	55	2307	4088	1781	408	0.13	55
Areal	2875	42	2213	3496	1283	315	0.11	55
Areal *	2745	35	2213	3247	1053	261	0.10	55

* value after application of correction factor for dataset from 1948-1973

Table 3: Annual average of areal rainfall for catchment: The most coincident year with El Nino and La Nina event, based on deviation of rainfall from long term mean (2468 mm)0

Year	Event	Index*	Average annual rainfall (mm)	Deviation from long term mean (1951-2002)
1954	La Nina	1	2632	164
1956	La Nina	0.5	2430	-38
1958	El Nino	1	2208	-260
1963	El Nino	1	2267	-201
1964	La Nina	1	2469	1
1966	La Nina	1	2615	147
1972	El Nino	1.5	1894	-574
1973	La Nina	1.5	2676	208
1976	El Nino	0.5	2431	-37
1983	El Nino	1	2031	-437
1984	La Nina	0.5	2844	376
1987	El Nino	1	2249	-219
1988	La Nina	1.5	2685	217
1990	El Nino	0.5	2052	-416
1992	El Nino	0.5	2228	-240
1995	La Nina	0.5	2674	206
1997	El Nino	1.5	2379	-89
1998	El Nino	1	2065	-403
2000	La Nina	1	2744	276

* Kaplan index (Kaplan *et al.,* 1998) is based on Sea Surface Temperature (SST); 0.5 - weak; 1 - moderate; 1.5 - strong (Harger, 1995; Kane, 1999 and Severov, *et al.*, 2004).

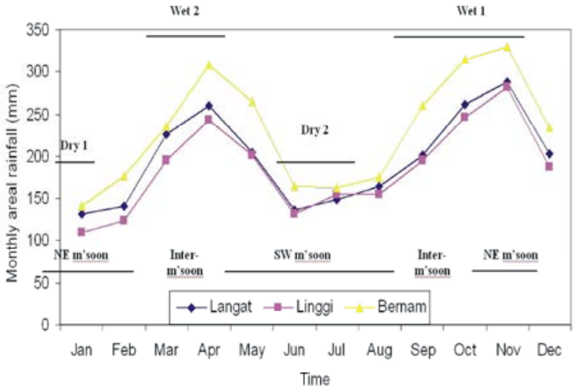

Fig. 1: Bernam catchment: Average monthly areal rainfall (1951-2002)

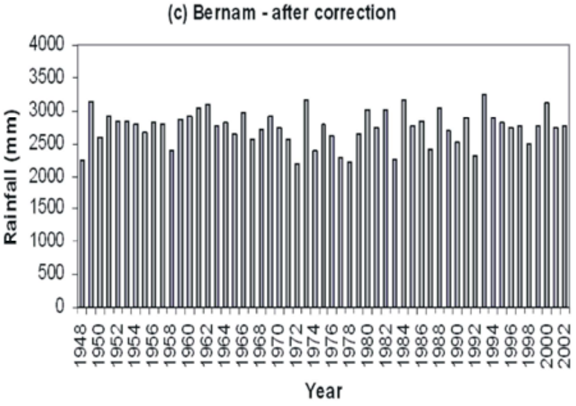

Fig. 2: Bernam catchments - annual areal rainfall

50 m above sea level. Tables 2 show some properties of the long-term annual rainfall depth for all rain gauges available for areal estimation in the Bernam catchment. The highest average annual areal rainfall was recorded at 2745 mm. The highest rainfall of the Bernam arises because of its geographical location at the foot of Malaysian Main range and the orographic effect on precipitation. It has been classified as the second wettest place in the Malaysian Peninsula by the Meteorological Office. The areal rainfall has a lower standard deviation than point rainfall as well as other statistical properties, owing to the averaging technique. The high variability between the highest and lowest values belonging to each point have been reduced and made proportional using each weighted area to represent a fairly consistent areal rainfall for the catchment.

Figure 2, however, shows the long-term average pattern of the annual areal rainfall. In Bernam, it is clearly demonstrated that the period of 1948-1973 had a higher rainfall catch than the later period of 1974-2002, with 9.4% (282 mm). It was found to be statistically significant at the 0.001 level (paired *t*-test). This is probably due to change in rainfall recorder from a 127-mm orifice to a 203-mm orifice in 1973 made by DID throughout Malaysia. According to DID, the latter recorder has a greater performance in rainfall catch. The higher rainfall will cause a higher runoff-rainfall ratio at the beginning, which contrasts with the assumption that the undeveloped catchment should have a low runoff-rainfall coefficient. Therefore, it is necessary to apply a correction factor for that period based on the ratio of the mean(s) of the later (2736 mm) and early (3018 mm) periods. After applying that correction factor (0.9) on the early period of data, the trend shows consistency and the significance test reveals no different between those two periods.

The variations between some point rainfall records within catchments are also significant. In Bernam, point gauges between Hospital and Behrang are separated by 8 km ($r^2 = 0.5$); Gumut and Bedford are separated by 28 km ($r^2 = 0.3$); Trolak and Bedford are separated by 7 km ($r^2 = 0.7$) and Bedford and Behrang are separated by 13 km ($r^2 = 0.2$). The rainfall variation is greater in Bernam despite the closer distance between gauges. Bernam is located in the foothill of the Main Range, there is a strong orographic effect here and, therefore, more rain is received (Figure 3). The strength of relation is moderate, confirming the influence of the spatial variation in convective rainfall. Surprisingly, the variation in this study catchment is higher than arid regions, which are known to possess local variability of rainfall greater than temperate and humid areas of the world. For example, [11] showed that the coefficients of correlation in the rainfall amounts recorded at different pairs of rainfall stations in Southern Israel and Jordan fell from 0.9 at a distance of 2 km to 0.6 at a distance of 5 km and to 0.3 at

The cumulative point rainfall within catchments tends to decrease after 1973 as a function of the changes in equipment. The earlier period witnessed less precision in data gathering from a number of point gauges, owing to a higher rainfall at the beginning of the records. The cumulative rainfall in each catchment also decreases after the 1970s, which can be related with global climate changes associated with El Nino events that significantly affect rainfall, especially in the tropics [12,13] also stressed that urbanization play a role in changing the rainfall trend within developed catchments in Malaysia. Changes in precipitation would cause significant changes in a given runoff-rainfall relation [14]. There is a significant decrease in rain days since 1961 throughout Southeast Asia and western and central South Pacific [15]. The frequency and intensity of drought have been observed to increase in recent years in those regions in recent decades that are dominated by climate variability; i.e., ENSO - shift towards more warm events [16].

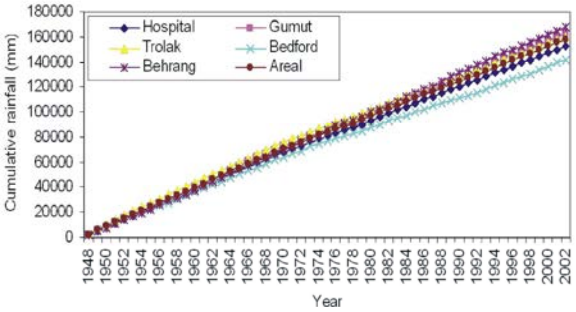

Fig 3: Bernam- Cumulative rainfall

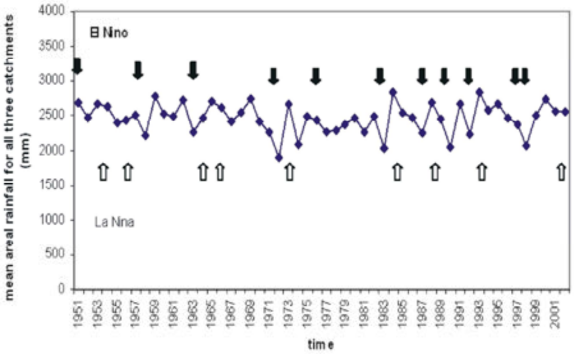

Fig. 4: The El Nino and La Nina event based on average annual areal rainfall for catchment, 1951-2002

The Influence of El-Nino and La-Nina: Figure 4 shows the long-term annual areal rainfall of the catchment. During the 52-year record, it reveals relatively wet and dry periods. Between 1972 and 1983, rainfall is slightly lower when compared with the decades before and after. Dryness could be related to changing global circulation and climate variation. Within the period 1972-2000 there occurred three moderate (1983, 1987 and 1998) and two strong El Nino (1972 and 1997) episodes (Table 3) [17,3,9]. Locally, in addition, there were upland areas within the catchment planted with agricultural crops (palm oil trees and rubber trees) at the expense of natural forest during this period. However, there is no concrete evidence to relate the changes in the local precipitation regime to the changes in land cover type in this area given the geographical scale of Peninsula Malaysia is small. However, [18,19] stated that changes in climate characteristic may cause effect on agriculture. [20] did stress that the establishment of plantations initiates long-term changes at a bigger scale that could modify the distribution of the precipitation and some other elements such as the chemistry and water yield.

The El Nino/Southern Oscillation (ENSO), which is related to the atmospheric-oceanic phenomenon, is a most significant factor, causing global hydro-climatic variability in the equatorial Pacific [21]. The influence of global El Nino and La Nina events within the study area is noticeable. One-way ANOVA reveals a mean different between them at the 0.05 level. There has been no study reported by local meteorologists of the impact on water resources, but [3] reported that Southeast Asia suffered severe drought during the 1997 El Nino, causing widespread fires and damage. Coupled with prevailing winds, smoke haze was being diverted towards Peninsula Malaysia, reducing the amount of solar radiation. Through feedback mechanisms, convective cloud development was suppressed, thus reducing rainfall [22].

Within the 52-year rainfall record, there are 19 events that affect the amount of rainfall caught by the catchments (Table 4 and Figure 4). This is demonstrated by the values of the deviation from the long-term mean of areal rainfall from study area. The long-term mean was chosen to represent the trend for the region. For study catchment, the annual areal rainfall fell significantly in the years 1958, 1972, 1983, 1990 and 1998, which all coincide with an El Nino event. Meanwhile, the La Nina event brought a relatively higher rainfall for catchment during 1966, 1973, 1984, 1995 and 2000. Even though both El Nino and La Nina events made a contribution to the fluctuation of rainfall within catchments, there are a few events that cause an opposite effect for the region or have an impact a year after the event occurs. This could possibly relate to the variation of the global cycle or the circulation between one place and another. It is normally regarded that a stronger El Nino is associated with droughts. Surprisingly, though, this is not so [23]. Floods occurred in some regions and droughts exist in others. This phenomenon has been reported by [24] where there is a location in Peru that suffers huge storms and major floods during severe El Nino events in Southeast Asia. In support of this, it has been reported that during the El Nino in India and Sahel in 1983, 1986 and 1990, these areas received an excess of rainfall; while, during La Nina in 1971, 1973 and 1989, they experienced droughts [23]. Since rainfall in the tropics is extremely variable in both space and time, identifying the precise cause of fluctuations remains problematic [25,26].

CONCLUSION

This study attempts to explain detailed characteristics of rainfall within the study catchment. The spatial and temporal variability of rainfall has been shown clearly. Temporal variability is related, in large part, to the influence of changes in global circulation brought about by El Nino and La Nina-related phenomena. At an annual scale, wet months in the study catchments occur during inter-monsoon seasons instead of the monsoons themselves, contradicting the definition used by The Meteorological Office which is applicable to the wider extent of the Malaysian peninsula. Seasonal factors inevitably play a significant role in the availability of water yield by the river system.

ACKNOWLEDGEMENTS

Thanks are due to Research Management Centre (RMC), Sultan Idris Education University, Malaysia for valuable sponsor.

REFERENCES

1. Calder, I.R., I.R. Wrigth and D. Murdiyarso, 1986. “A study of evaporation from tropical rainforest - west java”. J. Hydrol., 89: 13-33.
2. Desa, M.N. and J. Niemczynowicz, 1996. “Temporal and spatial characteristics of rainfall in Kuala Lumpur, Malaysia”. Atmospheric Res., 42: 263-277.
3. Jetten, V.G., 1996. “Interception of Tropical rain forest: Performance of a canopy water balance model”. Hydrological Processes, 10: 671-685.
4. Ramezani, B.G., 2011. “Identifying dry years by using the dependable rainfall index and its effects on the olive crop in Roudbar Gilan, South Western of Caspian Sea”. Middle-East J. Scientific Res., 7(2): 175-179.
5. Obled, C.H., J. Wendking and K. Beven, 1994. “Sensitivity of hydrological models to spatial rainfall patterns: An evaluation using observed data”. J. Hydrol., 159: 305-333.
6. Rahimi, M., B. Saghafian, M. Azadi and H. Sedgi, 2010. “Flood forecasting in arid and semi arid region using continuous hydrological modeling”. World Applied Sciences J., 10(6): 645-654.
7. Thiessen, A.H., 1911. “Precipitation averages for large areas”. Monthly Weather Rev., 39(7): 1082-1084.
8. Dingman, S.L., 1994. Physical hydrology. Macmillan Publishing Company, New York.
9. Ruslan, W.I., 1995. The impact of hill land clearance and urbanisation on the hydrology and geomorphology of rivers in Pulau Pinang, Malaysia. Unpublished PhD Thesis. Department of Geography, University of Manchester.

10. Dewar, R.E. and J.R. Wallis, 1999. "Geographical Patterning of Interannual Rainfall Variability in the Tropics and Near Tropics: An L-Moments Approach". American Meteorology Society, pp: 3457-3466.
11. Sharon, D., 1981. "The distribution in space of local rainfall in the Namib desert". International J. Climatol., 1: 69-75.
12. Goudie, A., 2006. Climate change: weather effect. London: Unwin Hyman.
13. Shaharuddin, A., M.H. Noorazuan, M.J. Yaakob and A. Noraziah, 2011. "Accelerated urbanization and the changing trend of rainfall in tropical urban areas". World Applied Sciences J., 13: 69-73.
14. Najjar, R.G., 1999. "The water balance of the Susquehanna River Basin and its response to climate change". J. Hydrol., 219: 7-19.
15. Manton, M.J., P.M. Della-Marta, M.R. Haylock, K.J. Hennesy and 23 others. 2001. "Trends in extreme daily rainfall and temperature in Southeast Asia and the South Pacific: 1961-1998". International of Climatol., 21: 269-284.
16. Dore, M.H.I., 2005. "Climate change and changes in global precipitation patterns: what do we know"?. Environment International, 3: 1167-1181.
17. Harger, J.R.E., 1995. "Air temperature variations and ENSO effects in Indonesia, the Philippines and El Salvador. ENSO patterns and changes from 1866-1993". Atmospheric Environment, 29: 1919-1942.
18. Abul Quasem Al-Amin, Walter, L., Josep Maria de la Trinxeria, Abdul Hamid Jaafar and Zabawi Abdul Ghani, 2011. "Assessing the impacts of climate change in the Malaysian Agriculture Sector and its Influences in investment decision". Middle-East J. Scientific Res., 7(2): 225-234.
19. Al-Suhaibani, N.A., 2011. "Yield production of some barley genotypes related to irrigation management under low rainfall conditions in Saudi Arabia". Middle-East J. Scientific Res., 8(1): 191-197.
20. Huber, A. and A. Iroume, 2001. "Variability of annual rainfall partitioning for different sites and forest covers in Chile". J. Hydrol., 248: 78-92.
21. Shrestha, A. and R. Kostaschuk, 2005. El Nino/Southern Oscillation (ENSO)-related variablity in mean-monthly streamflow in Nepal. Journal of Hydrology, 308: 33-49.
22. Lim, J.T. and S.H. Oii, 2004. Impacts of extreme climatic phenomena on water resource management. In Abdul Rahim, N. (Ed.). 2004. Water: Forestry and Land Use Perspectives. IHP-VI/Technical document in Hydrology, No. 70, UNESCO Paris, 16-26.
23. Kane, R.P., 1999. "Some characteristics and precipitation effect of the El Nino of 1997-1998". Journal of Atmospheric and Solar Terrestrial Physics, 61: 1325-1346.
24. Bendix, J., 2000. "Precipitation dynamics in Ecuador and northern Peru during the 1991/92 El Nino: a remote sensing perspective". International J. Remote Sensing, 21: 533- 548.
25. Manton, M.J. and M. Bonell, 1993. "Climate and rainfall variability in the humid tropics". In Hydrology and Water Management in the Humid Tropics - Hydrological Research Issues and Strategies for Water Management eds. M. Bonell, M.M. Hufschmidt and J.S. Gladwell, pp: 13-33. Cambridge: Cambridge University Press.
26. Nieuwolt, S., 1977. Tropical Climatology: An Introduction to the Climates of the Low Latitudes. Wiley, New York.