European Journal of Scientific Research
ISSN 1450-216X Vol.45 No.2 (2010), pp.162-167

http://www.eurojournals.com/ejsr.htm

Effect of Storm Separation Time on Rainfall Characteristics-A Case Study of Johor, Malaysia

Supiah Shamsudin
Razak School of Engineering and Advanced Technology, Universiti Teknologi Malaysia International Campus, 54100, Kuala Lumpur, Malaysia

Salisu Dan'azumi
Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia
E-mail: sdanazumi@gmail.com
Tel: +60177809907

Azmi Aris
Institute of Environmental and Water Resource Management, Faculty of Civil Engineering Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

Abstract

Planning and design of agricultural, runoff and pollution control systems demand input of rainfall data, mostly, at sub-daily scale. Therefore, the need to explore rainfall characteristics at fine scale becomes important. It is known that, using the same data, the rainfall characteristics may differ depending on the minimum inter-event time definition (MIT) used. Moreover, there is the problem of chosen a criteria for separating the rainfall events as the definition of the MIT separating two rainfall events is vague and arbitrary. This paper is aimed to study the effect of MIT on rainfall parameters. Hourly rainfall data were analysed for MIT values of 2hr, 4hr, 6hr, 9hr, 12hr, 18hr and 24hr. Results indicate that the rainfall frequency per annum is reduced from 199 to 89 when the MIT is altered from 2hr to 24hr. The mean depth, duration and inter-event time were increased with an increase in MIT while the mean intensity is decreased. Similarly, statistical parameters of maximum, standard deviation, CV, skewness and kurtosis were affected as the MIT value is altered. The results highlight the sensitivity of rainfall characteristics to MIT and as such care needs to be taken in the selection of MIT values in any study.

Keywords: Rainfall depth, Rainfall duration, Rainfall intensity, Inter-event time, Storm separation time,

1. Introduction

Statistical analyses of rainfall parameters are largely dependent on the resolution of the actual data. Rainfall data is mostly found at daily time-scale and this makes it possible to estimate rainfall characteristics at daily, weekly, monthly, and even annual levels, depending on the application the data is meant for. However, effective application in the various fields of engineering planning and designs; including agriculture, stormwater management, erosion and runoff control, and many others demands the rainfall data to be at sub-daily scale (Adams and Papa, 2000, Guo, 2002, Adams et al., 1986, Beecham and Chowdhury, 2010). A wide diversity in the criteria employed to identify individual rain events exist, and that limits the meaningful comparison among published works. Furthermore, the uncertainty level is increased when the events once defined are used to determine event based runoff efficiency, soil erosion, interception losses etc (Dunkerley, 2008).

Characterization of rainfall data at sub-daily level is not common, as rainfall data at fine resolution is normally not available. Therefore, the need to explore rainfall characteristics at fine scale becomes important. It is well known that using the same rainfall data; the characteristics may differ significantly, depending on the definition of rainless interval used to separate the rainfall record. For example, the characteristics at daily time-scale may not be the same as that obtained using weekly time-scale; neither will it be the same as that obtained at monthly or annual level. Moreover, there is also the problem of chosen a criteria for separating the rainfall events as the definition of the minimum rainless interval to be used in separating two rainfall events [herein referred to as Minimum Inter-event Time (MIT)] is vague and arbitrary, despite the numerous studies in this area (Wynn, 1994). This makes comparison between different results difficult and therefore the need to also explore the value for MIT that is appropriate to be used becomes important. This paper is aimed at studying the effect of varying MIT on the statistics of rainfall data from a tropical region using a case study in Johor, Malaysia.

Different values of MIT have been reported in literature at different situations. Researches in hydrology dealing with soil erosion, canopy interception losses, continued wetting and drying of soils, design of rainfall harvesting systems, rainfall model fitting and flood generation used values ranging from 15 minutes to 24 hours depending on the phenomenon of their interest (Dunkerley, 2008). Twelve different locations were used to model the distribution of rainfall intensity in Peninsular Malaysia using hourly rainfall data. Six hour storm separation time was used and the rainfall frequency, over the peninsular, was found to vary from 115 to 198 per annum, with a mean intensity ranging from 2.32 to 3.88mm/hr (Dan'azumi et al., 2010). In quantifying the risk of harvesting under semi-arid conditions, thirty years of rainfall intensity data was used to show that about 94 to 96% of the daily totals were in fact the same as event totals for stations in Highveld arid area of South Africa. Three hour storm separation time was used in the study (Tsubo et al., 2005). Cattan et al (2006) used the correlation between rainfall and runoff to define rainfall event as a season in which there was never a gap of more than 15 minutes between two consecutive tips of tipping bucket, and runoff generation as a period during which there was no interruption in water flow for 5 minutes. Other criteria such as canopy drying time were used as means of determining the value that should be used as MIT (Marin et al, 2000).

Rain rate data (resolution of 10s) containing 10,278 events, recorded over a period of 49 years was used to derive statistical properties. A rain intensity of 50mm/hr was used as threshold to separate between heavy and non-heavy storms, and the analysis of annual extreme values of the rain rate and their return period was then conducted (Vilar and Burgueno, 1995).The Spatial and temporal characteristics of annual rainfall frequency was conducted in Cyprus using the data spanning between 1917 to 2006 and results indicated that a distinct change occurs in time and space. Gamma distribution was used and the variation of its parameters was analysed (Michaelides et al., 2009). Thirteen stations spread across Jordan were analyzed for 50 years of annual data. The analyses were based on series of test for consistency, randomness, trend, jump and best fit distribution. The result on the spatial distribution of annual mean, median, maximum and minimum precipitation as well as coefficient of variation and that of symmetry and lag-1 correlation coefficient were analysed (Dahamsheh and Aksoy, 2007). Result of a work with Australian rainfall data at different temporal resolution found that the 2nd, 3rd and 4th statistical moments of rainfall intensities increased with increase in temporal resolution and serial correlation was observed between rainfall intensities at different temporal scales (Beecham and Chowdhury, 2010).

2. Materials and Methods

An automatic recording rain-gauge station; measuring hourly precipitation, located at Larkin, Johor (latitude: 01 28 15; longitude: 103 45 10) was chosen as a case study, and hourly rainfall data covering a period of fourty years (1971-2010) were collected. The data were examined and missing records were removed. A computer programme in Microsoft Visual Basic 6.0 was developed to divide the long term continuous hourly data into individual rainfall events using MIT values of 2hr, 4hr, 6hr, 9hr, 12hr, 18hr and 24hr.

Rainfall duration *(T)* for each event was obtained according to equation 1.

$$T = t_1 - t_2 \quad , \qquad if \;\; b \geq MIT \tag{1}$$

where t_1 and t_2 are the beginning and end of the event respectively, and b is the storm separation time. When $b < MIT$, the storms are merged and considered as one single event.

Rainfall depth *(V)* for each event was obtained according to equation 2.

$$V = \sum_{t1}^{t2} v_i \tag{2}$$

where v_i is the depth of the rain in the *ith* hour of the particular storm event under consideration.

Rain intensity *(I)* was obtained according to equation 3.

$$I = {}^{V}/_{T} \tag{3}$$

The inter-event time between consecutive events was obtained according to equation 4.

$$b = t_j - t_i \qquad if \; b \geq MIT \tag{4}$$

where t_i is the end of last event, and t_j is the beginning of the subsequent event.

The statistical parameters of maximum value, standard deviation, coefficient of variation (CV), skewness and kurtosis for each of the rainfall parameters above were then calculated.

3. Results and Discussions

Tables 1-4 list the basic hourly rainfall statistics of rainfall duration, depth, intensity and inter-event time with varying MIT values.

3.1. Average Annual Number of Events

The total number of events, recorded over the period 1971-2010, ranges between 7359 to 3265 events as the MIT values is altered from 2 to 24hrs (Table 1). Similarly, the average annual number of events (rainfall frequency per annum) decreases from 195 to 87 events as the MIT increases from 2 to 24hrs. It is observed that over this range of MIT, the rainfall frequency is reduced by about 55%. This shows that more rainfall events are merged as single event as temporal resolution of MIT decreases and more storms are separated into individual rainfall events as the temporal resolution increases.

3.2. Rainfall Duration

Statistics of rainfall duration is presented in Table 1. Mean duration ranges between 5.1 to 26.97hr with changing MIT value from 2 to 24hrs, while the highest value of rainfall duration remains constant as the MIT varies over the same range. However, an increase in the highest duration of rainfall was noticed only after 12hrs MIT. This shows that significant variation in highest rainfall duration exist only when the storm separation time is large enough, closer to one day. The standard deviation increases steadily with increasing MIT while the CV, Skewness and kurtosis decrease with the increase in MIT from 2 to 24hrs. This shows that rainfall events separated by shorter MIT have more varied duration and higher peaks as compared to those separated by longer MIT.

Table 1: Basic Statistics of Rainfall Duration

MIT	2hr	4hr	6hr	9hr	12hr	18hr	24hr
Total No of Rainfall Events	7359	6726	6360	5973	5542	4478	3265
Rainfall Frequency per Annum	195	178	169	158	147	119	87
Highest Duration (hr)	200	200	200	200	200	343	568
Mean (hr)	5.10	5.80	6.39	7.26	8.61	14.12	26.97
Standard Deviation (hr)	8.49	9.15	9.78	11.15	13.26	21.53	38.25
CV	1.67	1.58	1.53	1.54	1.54	1.52	1.42
Skewness	8.17	7.34	6.60	5.97	5.32	3.97	3.62
Kurtosis	105.93	85.86	69.91	55.35	44.06	27.81	24.49

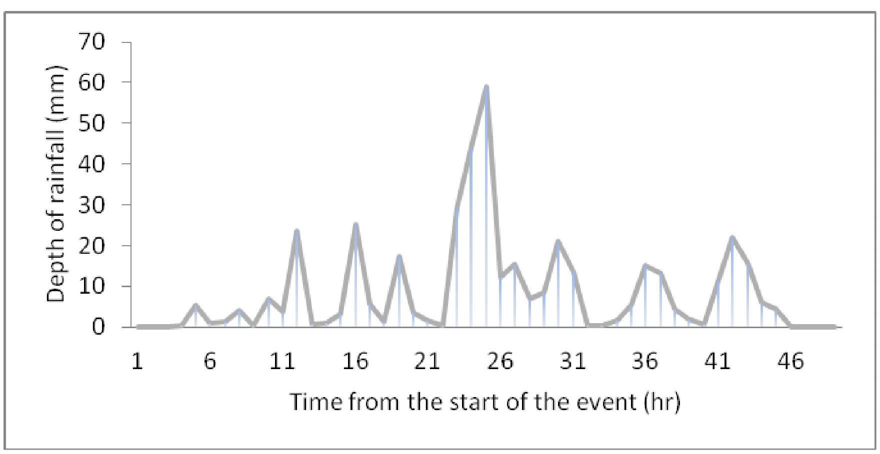
3.3. Rainfall Depth

Table 2 presents the results of rainfall depth statistics with MIT. The mean, highest, and standard deviation of rainfall depth increases from 12.38 to 27.91mm, 419 to 554mm and 19.93 to 40.16mm respectively, as the MIT resolution changes from 2 to 24hrs. With the exception of the highest depth observed; the mean and the standard deviation have more than doubled, as the MIT changes from 2 to 24hrs. However, the CV, skewness and kurtosis decreased from 1.61 to 1.44, 4.84 to 3.85, and 51.9 to 25.49 respectively as the MIT is increased from 2 to 24hrs. As with duration; rainfall events separated by shorter MIT have more varied depth and higher peaks as compared to those separated by longer MIT. Figure 1 displays the time series of the rainfall event with the highest depth observed throughout the 40 years period. The event occurs between 18^{th} to 20^{th} December, 2006, spanning across 2 days and lasting for 49hours.

Table 2: Basic Statistics of Rainfall Depth

MIT	2hr	4hr	6hr	9hr	12hr	18hr	24hr
Highest Depth (mm)	419	419	526	526	546	554	554
Mean (mm)	12.38	13.55	14.33	15.26	16.44	20.35	27.91
Standard Deviation (mm)	19.93	21.03	22.14	23.52	25.42	30.61	40.16
CV	1.61	1.55	1.55	1.54	1.55	1.50	1.44
Skewness	4.84	4.75	5.48	5.66	5.76	4.77	3.85
Kurtosis	51.90	47.96	70.43	70.77	68.76	44.19	25.49

Figure 1: Time series of the highest single rainfall event recorded over the 40 years period



3.4. Rainfall Intensity

Changes in the statistics of rain intensity with MIT are presented in Table 3. The mean rainfall intensity, over the period of observation, ranges from 2.98 to 2.14mm/hr while the highest intensity remains at constant value of 44.90mm/hr. This confirms the fact that unusually high intense rainfall events of high return period occur over a short duration. Values for CV, skewness and kurtosis remain almost constant until the MIT value approaches 12hrs after which a significant increase in these values were observed. This indicates that rainfall intensity at small MIT values is less sensitive as compared to that at higher MIT values. Chances in variation of rainfall intensity property are higher as MIT gets longer.

Table 3: Basic Statistics of Rainfall Intensity

MIT	2hr	4hr	6hr	9hr	12hr	18hr	24hr
Maximum Intensity (mm/hr)	44.90	44.90	44.90	44.90	44.90	44.90	44.90
Mean (mm/hr)	2.98	3.00	3.00	2.97	2.91	2.73	2.14
Standard Deviation (mm/hr)	4.23	4.21	4.24	4.21	4.14	4.03	3.48
CV	1.42	1.41	1.41	1.42	1.42	1.48	1.62
Skewness	3.06	3.10	3.13	3.20	3.26	3.45	4.20
Kurtosis	13.22	13.60	13.80	14.48	15.28	17.08	26.07

3.5. Storm Separation Time

Analysis of the rainless period separating two consecutive events is presented in Table 4. The longest duration of dry period without rain was 971hr (about 40 days). The mean storm separation time ranges from 40.81 to 75.05hrs as the MIT changes from 2 to 24hrs. This is equivalent to an increase of 87%. Similarly, the standard deviation increases from 58.32 to 73.63 with the corresponding change in MIT. However, the CV, skewness and kurtosis decreased from 1.45 to 0.98, 5.12 to 4.29, and 44.28 to 29.41 respectively with a corresponding increase in MIT from 2 to 24hrs. This shows that rainfall events separated by shorter MIT have more varied proportion of rainless period as compared to those separated by longer MIT.

Table 4: Basic Statistics of the Rainless Period Separating Rainfall Events

MIT	2hr	4hr	6hr	9hr	12hr	18hr	24hr
Highest (hr)	971	971	971	971	971	971	971
Mean (hr)	40.18	43.73	45.99	48.52	51.51	60.28	75.05
Standard Deviation (hr)	58.32	59.79	60.72	61.81	63.19	67.39	73.63
CV	1.45	1.37	1.32	1.27	1.23	1.12	0.98
Skewness	5.12	5.05	5.00	4.94	4.86	4.61	4.29
Kurtosis	44.28	42.60	41.58	40.37	38.84	34.53	29.41

4. Conclusions

In this paper, we explored the relationship between the effects of MIT definition on rainfall characteristic using hourly rainfall data recorded at Larkin, Johor Malaysia. The parameters of rainfall duration, depth, intensity and inter-event time were investigated. Statistical parameters of mean, highest value, standard deviation, CV, skewness and kurtosis were analysed. The results highlight the sensitivity of rainfall characteristics to MIT and as such care needs to be taken in the selection of MIT values in any study. The outcome from the research can be used in different fields of studies that deal with rainfall such as agriculture, meteorology, hydrology, etc.

Acknowledgement

Researchers are thankful to University Teknologi Malaysia for their support. We also wish to acknowledge Ministry of Science Technology and Innovation (MOSTI, vote no. 79394) for funding the project. Our special thanks to the staff of the Department of Irrigation and Drainage, Malaysia for the supply of rainfall data.

References

[1] Adams, B. J., Fraser, H. G., Howard, C. D. D. & Hanafy, A. M. S., 1986. "Meteorological Data Analysis for Drainage System Design". *Journal of Environmental Engineering, ASCE,* 112**,** pp 827-848.

[2] Adams, B. J. & Papa, F., 2000. "*Urban Stormwater Management Planning with Analytical Probabilistic Models",* New York, 1st Edition, John Wiley & Sons Inc.

[3] Beecham, S. & Chowdhury, R. K., 2010. "Temporal characteristics and variability of point rainfall: a statistical and wavelet analysis". *Int. J. Climatol. ,* 30**,** pp 458-473.

[4] Cattan, P., Cabidoche, Y.-M., Lacas, J.-G. & C, M. V., 2006. "Effects of tillage and mulching on runoff under banana (Musa spp.) on a tropical Andosol". *Soil & Tillage Research,* 86**,** pp 38-51.

[5] Dahamsheh, A. & Aksoy, H., 2007. "Structural characteristics of annual precipitation data in Jordan". *Theor. Appl. Climatol. ,* 88**,** pp 201-212.

[6] Dan'azumi, S., Shamsudin, S. & Aris, A., 2010. "Modeling the Distribution of Rainfall Intensity using Hourly Data". *American Journal of Environmental Sciences,* 6**,** pp 238-243.

[7] Dunkerley, D., 2008. "Identifying individual rain events from pluviograph records: a review with analysis of data from an Australian dryland site". *Hydrol. Process.,* 22**,** pp 5024-5036.

[8] Guo, J. C. Y., 2002. "Overflow Risk Analysis for Stormwater Quality Control Basins". *Journal of Hydrologic Engineering,* 7**,** pp 428-434.

[9] Marin T. C, Bouten W, Sevink J., 2000. "Gross rainfall and its partitioning into throughfall, stemflow and evaporation of intercepted water in four forest ecosystems in western Amazonia". *Journal of Hydrology* 237: pp 40–57.

[10] Michaelides, S. C., Tymvios, F. S. & Michaelidou, T., 2009. "Spatial and temporal characteristics of the annual rainfall frequency distribution in Cyprus". *Atmospheric Research,* 94**,** pp 606-615.

[11] Tsubo, M., Walker, S. & Hensley, M., 2005. "Quantifying risk for water harvesting under semi-arid conditions Part I. Rainfall intensity generation". *Agricultural Water Management,* 76**,** pp 77-93.

[12] Vilar, E. & Burgueno, A., 1995. "Statistical Properties of 49 Years of Rainfall Rate Event". *Theor. Appl. Climatol. ,* 50**,** pp 213-225.

[13] Wynn, J. K., 1994. "Seasonal and Geographic Variability of Rainstorm Parameter Distributions". *Department of Civil and Environmental Engineering.* MSc Thesis, MIT, Massachusetts, USA.