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RUNOFF TREND AND POTENTIALITY IN MELAKA TENGAH CATCHMENT OF MALAYSIA USING SCS-CN AND STATISTICAL TECHNIQUE

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Abstract. This study is focused to identify the surface runoff trends and potentiality of the five watersheds transforming the discrete runoff pattern to smooth patterns. Runoff potentiality was analyzed by Soil Conservation Service Curve Number (SCS-CN) technique. Considering Hydrologic Soil Group (HSG) and percentage of particular land use pattern, weighted CNs of five watersheds were found between 82 and 85. Monthly surface runoff trends were investigated by statistical autocorrelation, Mann-Kendall, Sen slope and lowess methods. According to the Mann-Kendall method, no statistical significant monotonic trends were found for all the watersheds. Smoothing curve analysis reveals that the monthly mean runoff is 30 mm, 34 mm, 39 mm, 28 mm and 37 mm and the percentage of runoff is 23%, 25%, 31%, 25% and 26% for the watersheds 1, 2, 3, 4 and 5, respectively. Degree of effect of several land use pattern with corresponding soil type was analyzed to assess the total runoff volume for contributing to the surface water resources. Result shows that 26% of the rainwater contributes to the surface runoff of Melaka Tengah catchment and provides the information for planning of surface water management and potentiality of groundwater recharge.

Keywords: curve number, SCS, surface runoff, Mann-Kendall test, Melaka Tengah catchment.

Introduction

The soil conservation service curve number (SCS-CN) technique is widely used in watershed management and environmental sector for calculating the surface runoff from particular rainfall amount. Climatic factors (e.g. precipitations, rainfall intensity, duration and distribution, relative humidity) and physiographic factors (e.g. topographic slope, watershed size, shape of a watershed, land use, soil group and moisture) influence the surface runoff in a watershed. Similarly, watershed characteristics have had a direct influence on the peak flow and runoff volume in any area (Komatsu *et al.* 2011; Zhang *et al.* 2010). High rainfall intensity on less permeable surface resulted in rapid runoff and ultimately causes flash flood in a watershed. Rainfall duration is another factor that increases runoff in a watershed. During the higher rainfall intensity and longer duration, maximum runoff pick is generated at the time of temporally variable of rainfall. Kinetic, spatial, temporal, overland flow of storm rainfall and climate change impact on storm events contribute their effect on surface runoff (Stephenson 1984; Singh 1997; Pourtouiserkani, Rakhshandehroo 2014; Okoli 2014). Increasing rate of urbanization and its adverse effect cause the surface runoff, and deteriorate groundwater and river water quality (Dimitriou, Moussoulis 2011; Khan *et al.* 2011; Shirazi *et al.* 2012). Land use patterns and soil type are also important factors for surface runoff (Wu *et al.* 2011; Bagdziunaite *et al.* 2011). The steep slope surface can produce higher velocity surface runoff due to short period of time for water infiltration. Hillel (1980) defines the infiltration rate into the soil on the basis of infiltration capacity. This infiltration capacity for a dry soil is higher at the initial period but decreases at a rapid rate due to conductivity of the soil layer or soil surfaces. However, textural characteristic of soil controls the infiltration rate as well as surface runoff.

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The SCS-CN method is preferred to calculate the direct runoff due to its flexibility, simplicity and versatility (Melesse, Shih 2002; Gaudin *et al.* 2010; Hawkins 1978; Ragan, Jakson 1980; Slack, Welch 1980; Hawkins 1993; Lewis *et al.* 2000). SCS-CN (SCS 1972) also estimates the runoff volume for a particular rainfall depth of agricultural watershed area (USDA SCS 1985). This method is analyzed to clarify its theoretical and experimental basis (Ponce, Hawkins 1996) and to predict the land use changing effect on surface runoff in urban hydrology (Chen *et al.* 2009). This method along with functional data analysis technique predict the runoff potentiality of a watershed (Adham *et al.* 2014). Remote sensing data are used to derive runoff pattern and watershed evaluation (Zade *et al.* 2005; Kumar *et al.* 2014). The hydrologic soil group (HSG) defines the curve number (CN) which is input of the SCS-CN method. Grove *et al.* (1998) differentiated the effect of storm runoff depth using the composite and distributed curve numbers. Two-CN approach was also used to identify the variation of runoff curve number with rainfall and identification of spatial distribution SCS-CN parameter was analyzed in heterogeneous watersheds (Soulis, Valiantzas 2012, 2013). Individual land use under particular hydrologic soil group exhibits particular curve number and this number depends on several factors representing runoff potentiality of a watershed (Warren, Gray 2003; Carlesso *et al.* 2011; Sarauskiene *et al.* 2015). Due to the watershed complexity, weighted CN is easier to use with many complexes for large watershed area. This is occurred when same land use pattern belongs to different hydrologic soil groups. The CN for C and D soil groups contributes the greater runoff due to soil's textural pattern. However, area under C and D groups is the first indicator for rapid runoff of the watershed area rather than A and B soil groups. The main goal of this study was to define the weighted curve number of Melaka Tengah watershed in SCS-CN method for calculating the surface runoff. This runoff was analyzed by the Mann-Kendall, Sen slope, lowess statistical methods for detecting the trends of the runoff data set of the watersheds. The Mann-Kendall is the most widely used non-parametric method to detect monotonic trends in hydrological parameters (Antonopoulos *et al.* 2001; Caloiero *et al.* 2011; Hirsch *et al.* 1982; Mohsin, Gough 2010; Río *et al.* 2011). This method is less affected by the existence of outliers in the data series. This non-parametric method was used to detect the rainfall trend in Australia (Chowdhury, Beecham 2010, 2012). Jonsdottir *et al.* (2006) applied the Mann-Kendall method to detect long-term variability of rainfall, temperature and discharge of Iceland Rivers. Annual and seasonal rainfall trends of time series data were investigated by using Mann-Kendall method and showed a significant decreasing trend for the time series in Greece (Feidas *et al.* 2007). Henceforth, this study introduced lowess linear fit for smoothing the discrete runoff data for predicting the surface runoff pattern of this region. Finally, monthly mean runoff was calculated from the smooth curve pattern. Therefore, an attempt has been made to find out runoff trend and potentiality of Melaka Tengah catchment for the best water resources management practice in future.

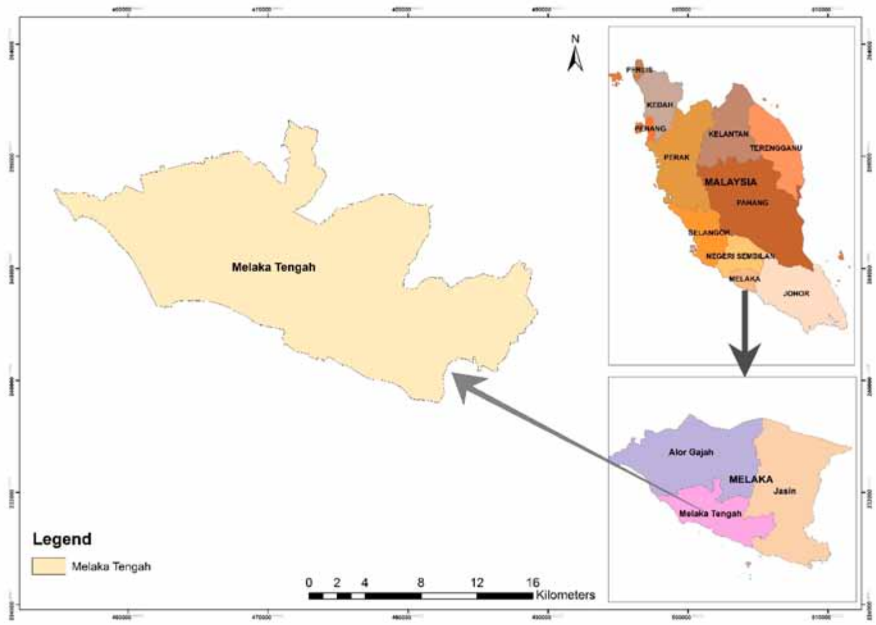

Fig. 1. Location map of the study area

1. Methodology

1.1. Study area

Melaka Tengah catchment with an area of 314 sq. km consists of five watersheds and located in Melaka state of Peninsular Malaysia (Fig. 1). The catchment contains different soils and land use patterns. Elevation of this catchment varied from 20–140 m above sea level. Characteristics of five watersheds are mainly fern shaped in nature (Fig. 2). It also shows the location of rainfall stations (RS) in the Melaka Tengah catchment. Runoff of Melaka Tengah catchment is influenced by practicing ten land use patterns and their land management criteria. Hydrologic soil group was classified into four types A, B, C and D (Mays 2005). These types of soils were grouped on the basis of water infiltration rate through the soil. In general, sandy soil is under the category A having the highest rate of infiltration and less runoff potential. On the contrary, clay soils that have the lowest infiltration rate and high runoff potential were placed in hydrologic soil group D.

The land use and soil group map of Melaka Tengah catchment were collected from the Drainage and Irrigation Department (DID), Malaysia and prepared by using geographical information system (GIS) technique. This soil group with land use pattern exhibits the specific CN values of each category. CN of various land use pattern varies from cultivated land to industrial and residential areas. Surface runoff curve number (CN) depends on soil type, land cover, hydrologic soil group and condition. Based on soil characteristics, soil group is classified for analysis of runoff (Table 1). CN values are used for various land uses on this soil type. Weighted CN can be calculated for a watershed made up of several soil types and land uses.

Table 1. Different hydrologic soil group classification (Mays 2005)

Soil characteristics	Soil Group
Deep sand, deep loess and aggregated silt	A
Shallow loess, sandy loam	B
Clay loams, shallow sandy loam, soils low in organic content and soils usually high in clay	C
Soils that swell significantly when wet, heavy plastic clay and certain saline soils	D

1.2. SCS-CN method

The SCS-CN method is that surface runoff relates to soil-land cover complexes and storm rainfall through a curve number. This method defines that the ratio of actual soil retention after runoff begins to potential maximum retention is equal to the ratio of direct runoff to available rainfall. This method is suitable for the watersheds with area less than 250 square kilometer (Ponce 1989). In this study, five watersheds of Melaka are valid to apply this method to estimate surface runoff due to having area less than 250 square kilometer for each watershed. The Soil Conservation Service Curve Number method (SCS-CN) was used to calculate the runoff of different watersheds in Melaka (Eq. (1)):

$$R_{wi} = \frac{\left\{P - (I_a)_{wi}\right\}^2}{\left\{P - (I_a)_{wi}\right\} + S_{wi}}, \quad (1)$$

where wi indicates different watershed number, R_{wi} – Runoff (mm), P – Precipitation (mm), S_{wi} – Potential

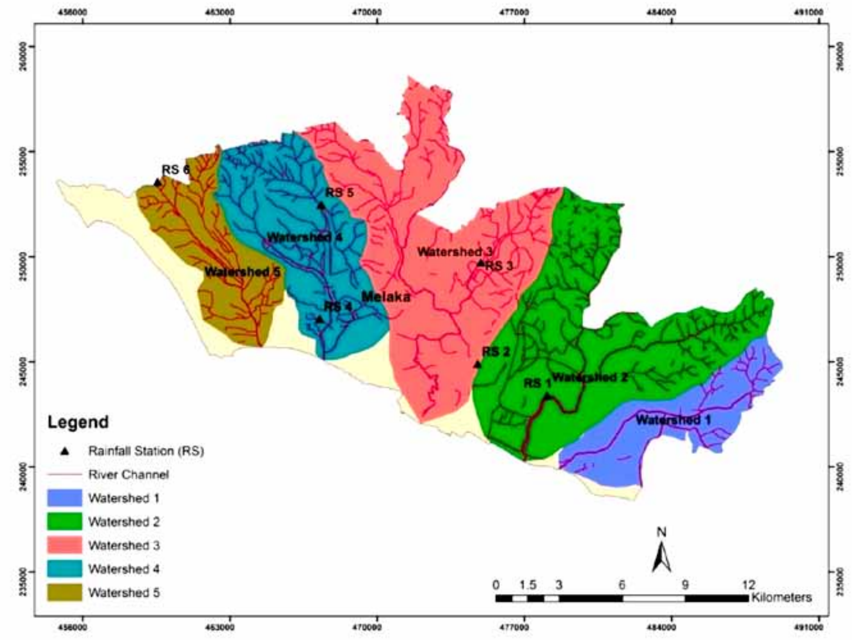

Fig. 2. Watersheds and river channel network at Melaka Tengah catchment

maximum retention after runoff begins (mm) and $(I_a)_{wi}$ – Initial abstraction which is the water losses before surface runoff begins. $(I_a)_{wi}$ is to be approximated in watershed studies by Equation 2:

$$(I_a)_{wi} = 0.2S_{wi}. \quad (2)$$

Therefore, S_{wi} and P are to be allowed to yield the runoff amount and expressed as (Eq. (3)):

$$R_{wi} = \frac{\left(P - 0.2S_{wi}\right)^2}{P + 0.8S_{wi}}. \quad (3)$$

For suitability of Equation 3, S_{wi} is defined in the form of a dimensionless runoff curve number representing the runoff potential of the watershed. It is related to the land cover-soil complex characteristics governed by the soil moisture condition, soil type, and land use and treatment (USDA SCS 1985). In Melaka Tengah watersheds, S_{wi} exhibits this relation through the weighted curve number (CN_{wi}). SCS-CN method estimates the potential retention through empirical studies and the equation is expressed as (Eq. (4)):

$$S_{wi} = \frac{25400}{CN_{wi}} - 254, \quad (4)$$

where CN_{wi} is a weighted runoff curve number. It is a dimensionless number. The higher value of weighted runoff curve number indicates higher runoff factor or runoff potential of a watershed. S_{wi} is an intrinsic model parameter being independent of initial moisture condition, and found that $(I_a)_{wi}$ and S_{wi} are independent of each other for $(I_a)_{wi}$ is not an intrinsic (Michel *et al.* 2005).

1.3. Mann-Kendall method

Mann-Kendall is a non-parametric trend analysis method which is mostly used to detect the trends in climatological and hydrological time series (Mann 1945; Kendall 1975). The Mann-Kendall test statistic S can be given as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(x_j - x_i); \quad (5)$$

$$Sign\left(x_j - x_i\right) = \begin{Bmatrix} +1 if \left(x_j - x_i\right) > 0 \\ 0 if \left(x_j - x_i\right) = 0 \\ -1 if \left(x_j - x_i\right) < 0 \end{Bmatrix}, \quad (6)$$

where x_i and x_j are the ranked values of the data and n is the length of data series. The variance of the statistic is provided for independently and identically distributed data, and is given as:

$$Var\left(S\right) = \frac{n\left(n-1\right)\left(2n+5\right) - \sum_{i=1}^{m} t_i\left(t_i - 1\right)\left(2t_i + 5\right)}{18}, \quad (7)$$

where m is the number of ties values and t_i is the number of ties of extent i. The Mann-Kendall test statistic, Z_s, can be estimated as:

$$Z_s = \begin{Bmatrix} \frac{S-1}{\sqrt{Var\left(s\right)}}, \ if\ S > 0 \\ 0, \ if\ S = 0 \\ \frac{S+1}{\sqrt{Var\left(s\right)}}, \ if\ S < 0 \end{Bmatrix}, \quad (8)$$

positive Z value indicates a positive trend whereas a negative value represents a down word trend in the data series. This test is conducted at the specific significance level (α = 0.05). In order to test the significance of trends at significance level, Z_s is compared with $Z_{1-\alpha/2}$ and if $s > Z_{1-\alpha/2}$, then the trend is significance at that level. Here $Z_{1-\alpha/2}$ is obtained from the standard normal cumulative distribution.

1.4. Lowess method

Lowess method is known as locally weighted polynomial regression (Cleveland 1979). A low degree polynomial is fitted to a sub-set of the data at each point in the data set with explanatory variables values near the point whose response is being estimated. Lowess linear fit method was appliefor smoothing the runoff data set. This method computes the residuals indicating the fitting criterion of the curve and also determines the regression weight function for the data points within the span. This regression uses a first degree polynomial for lowess. The regression weights are shown by the function (Eq. (9)):

$$W_i = \left(1 - \left|\frac{X - X_i}{d\left(X\right)}\right|^3\right)^3, \quad (9)$$

where X – predictor value which is associated with the response value to be smoothed, X_i – nearest neighbors of X as defined by the span, and $d(X)$ – distance along the abscissa from X to the most distance predictor value within the span. In this smoothing procedure, neighboring outlier values reveal the bulk of the data. This provides the goodness of fit resulting in fitting accuracy of the smooth curve.

2. Results and discussion

Five watersheds of Melaka Tengah catchment are associated with eleven soil series. Each soil series exhibits different soil textures and is classified on the basis of soil characteristics and hydrological soil group classification (Table 2). Analyzing the soil characteristics of Melaka Tengah catchment, soil type falls under only C and D hydrological soil groups (Fig. 3). According to the soil characteristics, ten land use patterns are found in the study area. The land use pattern controls the runoff potentiality of catchment area where as tree-palm-permanent crops and urban-settlement occupy 36% and 26% of the total watershed area and contributes the runoff of this region.

Table 2. Hydrological soil group classification of Melaka Tengah catchment

Soil Mapping Unit	Soil Texture	Hydrologic Soil Group (HSG)
Melaka	Clay	D
Kranji	Clay	D
Melaka Prang Association	Clay	D
Rengam	Sandy clay loam	C
Linau-Telok-Local Alluvium Complex	Sandy clay loam	C
Munchong-Melaka-Serdang Association	Clay	D
Melaka-Munchong-Tavy Association	Clay	D
Melaka-Munchong Association	Clay	D
Local Alluvium Complex	Loam to clay	C

Runoff curve numbers were defined on the basis of land cover and hydrological soil condition. CN was computed for various land cover on different hydrologic soil groups in Melaka Tengah catchment (Table 3). This area exhibited only hydrological soil groups C and D, and CN values of these two groups represented less differences among them. Normally runoff estimation should be made with distributed CN values (Grove *et al.* 1998; Soulis, Valiantzas 2012, 2013). However, CN values variation in the land cover and hydrologic soil group complexes present in the studied watershed is generally low. Accordingly, weighted curve number was considered valid for the particular watershed. This weighted runoff curve number can be calculated by weighting the CN's of the different subareas in proportion to the land cover associated with each CN value for a catchment (Wong *et al.* 2001; Gumbo *et al.* 2002). The actual weighted CN_{wi} number of watershed area is the summation of two weighted curve numbers and expressed as (Eq. (10)):

$$CN_{wi} = \sum_{i=1}^{n} \left\{ \sum (CN_{Ci} \times A_{Ci}) + \sum (CN_{Di} \times A_{Di}) \right\}, \quad (10)$$

where, CN_{wi} – Area weighted runoff curve number for particular watershed area; CN_{Ci} – CN for a particular land use for soil group C; CN_{Di} – CN for a particular land use for soil group D; and A_{Ci} and A_{Di} – land use pattern percentage for soil groups C and D.

S_{wi} was calculated by using the equation 4 after getting the weighted CN_{wi} of each watershed. The daily event rainfall data of 2006 to 2012 were considered to analyze the runoff of Melaka Tengah catchment. The runoff depth (R_{wi}) was calculated for each watershed after putting rainfall data and S_{wi} values in Equation 3. The monthly mean runoff, weighted CN_{wi} value and S_{wi} of each watershed of Melaka Tengah catchment are shown in Table 4.

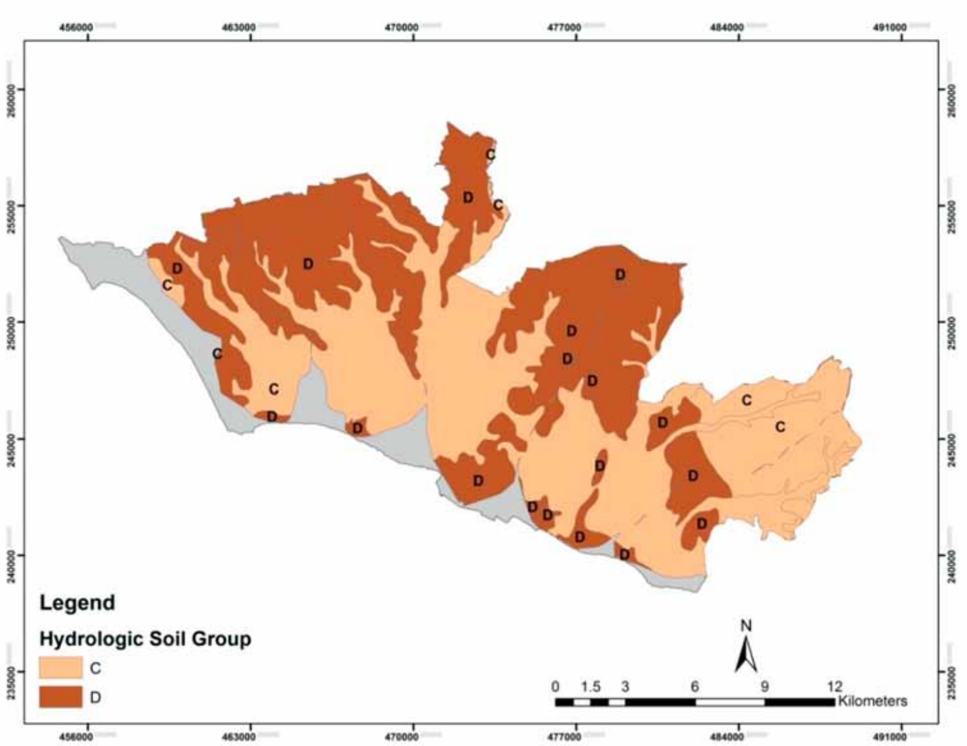

Fig. 3. Hydrologic soil group map of Melaka Tengah catchment

Table 3. CN for particular soil category and percentage of land cover of watershed area

Watershed	Land use Category	Land covered by soil group C (%)	Land covered by soil group D (%)	Total Area (km²)	CN for Hydrologic Soil Group	
					C	D
1	Animal husbandry areas	0.46	0.00	28.29	82	86
	Forest land	1.91	0.00		70	77
	Horticultural lands	11.63	2.55		78	81
	Ideal grassland	3.46	0.81		74	80
	Short-term crops	1.20	0.99		82	86
	Swamps, marshland and wetland forest	1.24	0.57		83	86
	Tree, palm and other permanent crops	48.21	16.19		82	86
	Urban, settlement and associated non-agricultural area	8.40	1.29		90	92
	Others	1.10	0.00		–	–
2	Animal husbandry areas	2.99	0.06	79.73	82	86
	Forest land	0.37	2.06		70	77
	Horticultural lands	11.44	2.87		78	81
	Ideal grassland	2.71	0.83		74	80
	Short-term crops	3.93	0.00		82	86
	Swamps, marshland and wetland forest	5.32	3.43		83	86
	Tree, palm and other permanent crops	32.11	9.98		82	86
	Urban, settlement and associated non-agricultural area	6.61	13.37		90	92
	Water body	0.00	0.60		98	98
	Others	1.30	0.00		–	–
3	Animal husbandry areas	0.08	0.00	85.57	82	86
	Forest land	0.00	8.32		70	77
	Horticultural lands	6.73	4.02		78	81
	Ideal grassland	2.31	1.15		74	80
	Short-term crops	3.82	2.49		82	86
	Swamps, marshland and wetland forest	8.61	0.25		83	86
	Tree, palm and other permanent crops	0.00	18.22		82	86
	Urban, settlement and associated non-agricultural area	26.22	16.27		90	92
	Water body	0.00	0.40		98	98
	Others	0.00	1.11		–	–
4	Animal husbandry areas	0.00	0.23	48.06	82	86
	Forest land	0.00	0.29		70	77
	Horticultural lands	13.84	2.04		78	81
	Ideal grassland	5.20	0.12		74	80
	Short-term crops	9.42	0.65		82	86
	Swamps, marshland and wetland forest	1.92	0.00		83	86
	Tree, palm and other permanent crops	6.67	34.98		82	86
	Urban, settlement and associated non-agricultural area	11.51	12.77		90	92
	Others	0.37	0.00		–	–
5	Animal husbandry areas	0.12	0.00	29.98	82	86
	Forest land	0.00	1.42		70	77
	Horticultural lands	4.87	13.74		78	81
	Ideal grassland	7.47	2.99		74	80
	Short-term crops	17.68	0.47		82	86
	Swamps, marshland and wetland forest	1.08	0.00		83	86
	Tree, palm and other permanent crops	7.97	25.47		82	86
	Urban, settlement and associated non-agricultural area	5.30	10.88		90	92
	Others	0.54	0.00		–	–

End of Table 3

Table 4. Weighted CN_{wi}, S_{wi} and monthly mean runoff for each watershed

Watershed	Weighted CN_{wi}	Value of S_{wi} (mm)	Mean runoff (mm)
1	82	55.76	30
2	83	52.02	34
3	85	44.82	39
4	84	48.38	28
5	83	52.02	37

Daily runoff was calculated using SCS-CN method from the daily rainfall event data for period 2006 to 2012. After calculating the daily runoff, monthly runoff was estimated by summing the daily runoff data (Fig. 4). Eighty four data sets were prepared for monthly runoff analysis. These data sets presented the monthly rainfall-runoff pattern of watersheds in the Melaka Tengah catchment. In watersheds 1, 2, 3, 4 and 5 the rainfall varies 0–333 mm, 0–365 mm, 0–467 mm, 0–322 mm and 0–374 mm, respectively. The corresponding runoff varies 0–97 mm, 0–120 mm, 0–199 mm, 0–125 mm and 0–127 mm, respectively for watersheds 1, 2, 3, 4 and 5. This analysis shows that the changing pattern of monthly runoff varies with the particular monthly rainfall pattern for the watersheds.

2.1. Autocorrelation

It is important to define the autocorrelation properties of the runoff data series before selecting the trend detection test. Figure 5 represents the autocorrelation of monthly surface runoff of five watersheds. From the analysis, it shows that almost all of the autocorrelations fall within the 95% confidence limit. A few lags just fall outside the 95% confidence limit. This analysis indicates that all watersheds

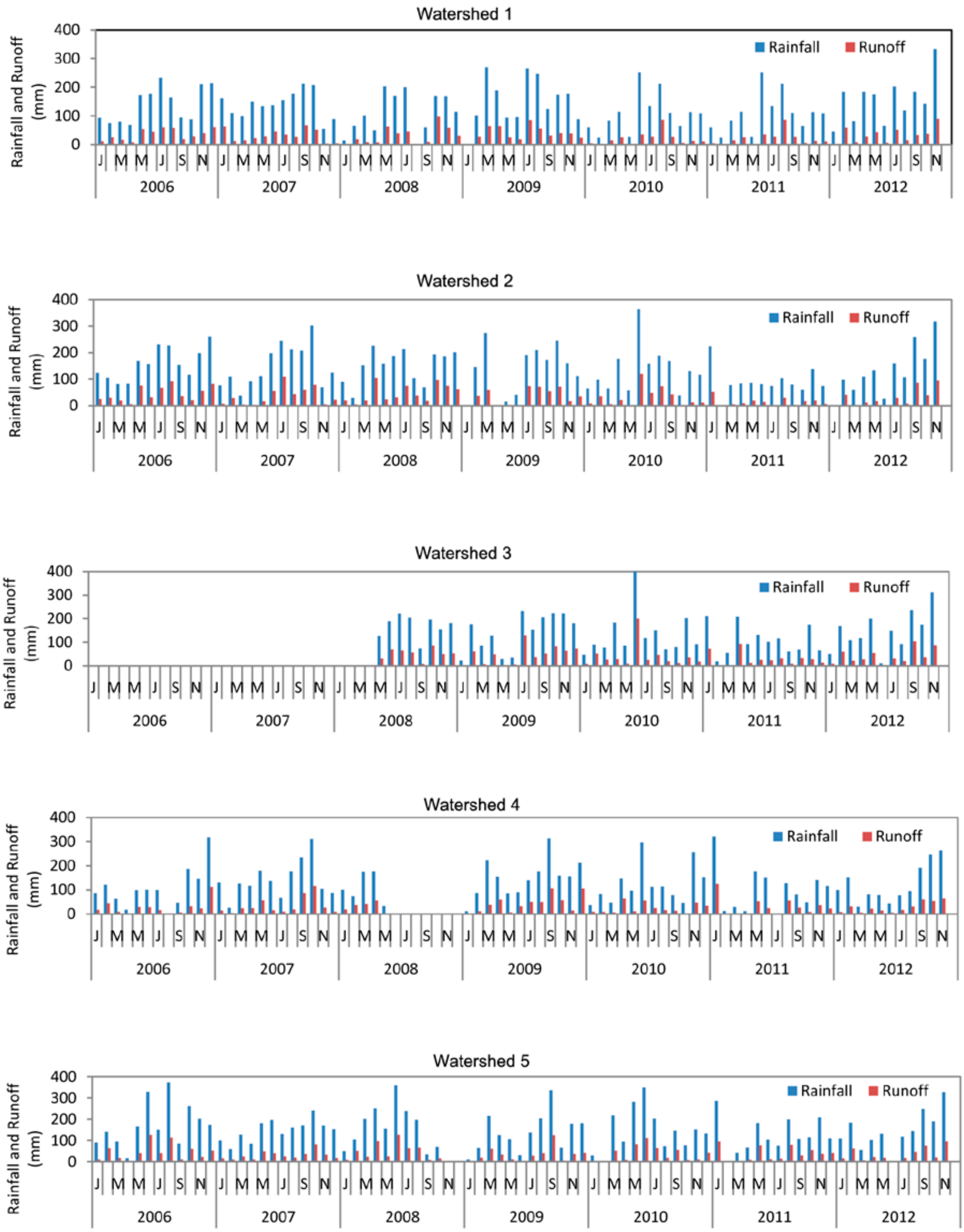

Fig. 4. Monthly rainfall and runoff of watershed area

show non-significant autocorrelation at various lags. Both significant and non-significant lag 1 autocorrelations were conducted for daily, monthly, seasonal and annual temporal resolution rainfall (Rashid *et al.* 2013).

2.2. Monthly runoff trend

Monthly surface runoff trend analysis from 2006 to 2012 was conducted for the watersheds of Melaka Tengah catchment. Monthly values for all watersheds revealed that runoff varies with seasonal effect and most of the values amounted to about high during from November to February and May to August. Runoff peaks in these months and declines thereafter. Therefore, no statistically significant changes in trend line for the monthly runoff during the observed for all the watersheds. The negative trend of monthly runoff was observed for the watersheds 1, 2 and 5 with a Sen slope of about – 0.116, – 0.243 and – 0.036, respectively, while upward runoff trend line was observed for watersheds 3 and 4 with the Sen slope of about 0.312 and 0.009, respectively (Fig. 6).

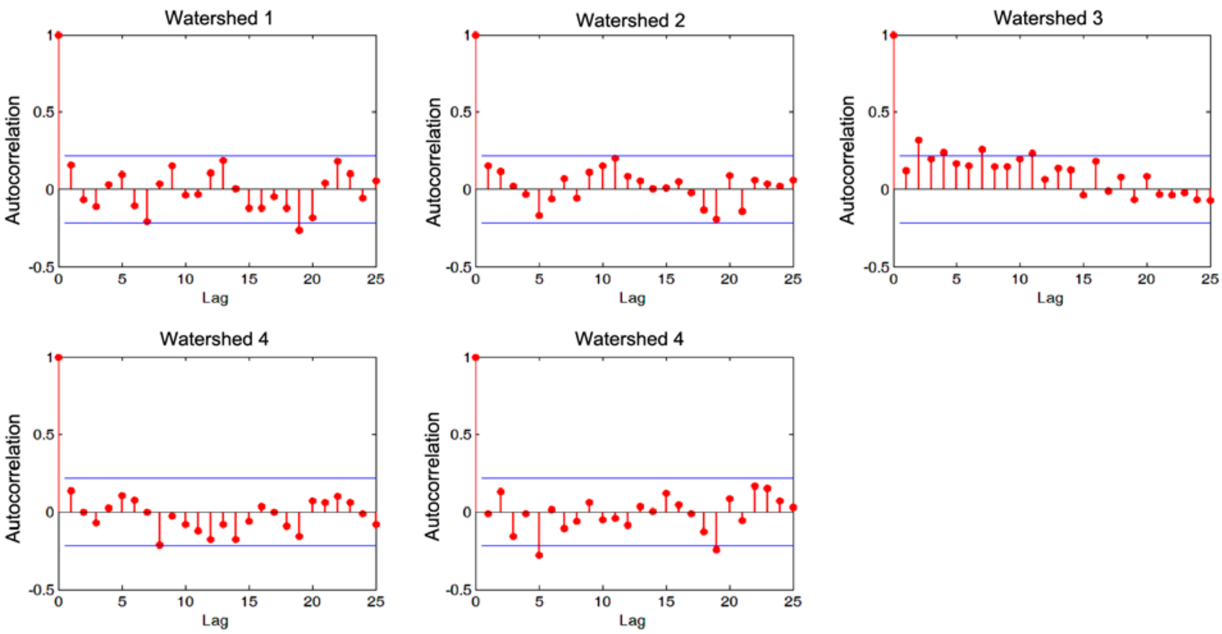

Fig. 5. Autocorrelation function for different lags of monthly runoff of watersheds

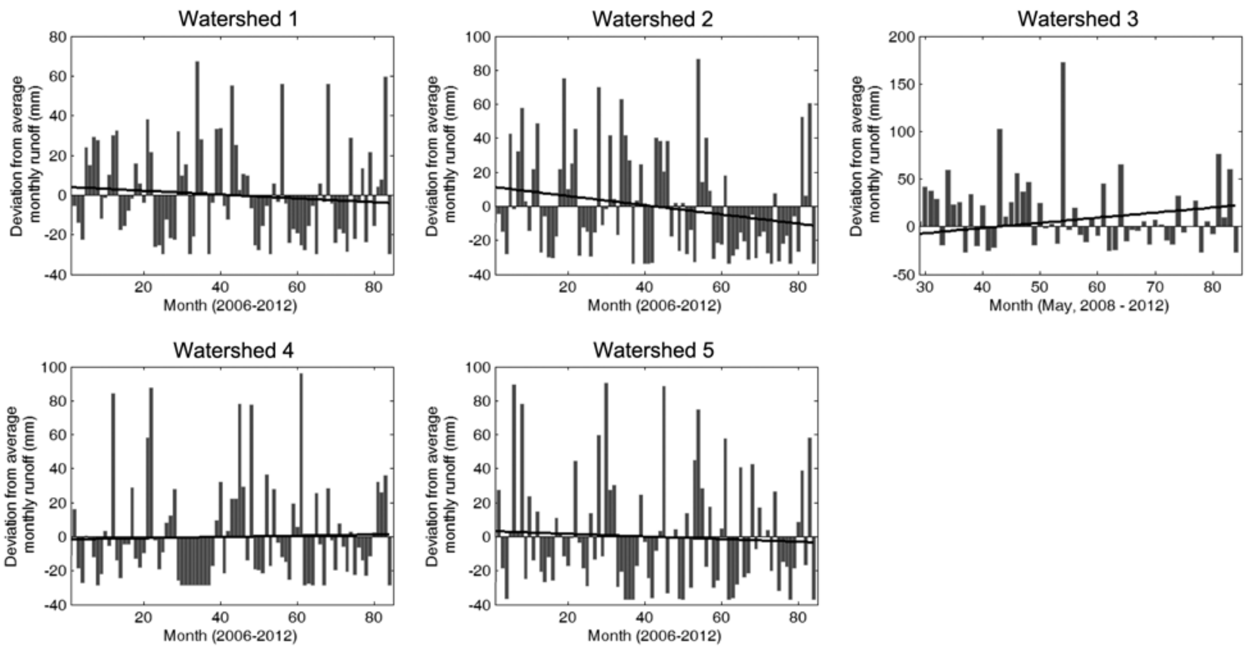

Fig. 6. Monthly deviation from average surface runoff amounts in watershed

2.3. Mann-Kendall trend analysis

The Mann-Kendall test provides the information of existence of monotonic trends either positive or negative. This method was applied to detect any monotonic trend was existing in the runoff data series. Table 5 represents the Mann-Kendall test and Sen slope analysis of the monthly runoff trends. The two-tailed p-value indicates the null (H_0) or alternative (H_1) hypothesis of the test. If the null hypothesis is rejected, alternative hypothesis indicates that there is an increasing or decreasing trend in the runoff data series.

The p-value was greater than the significance level (α = 0.05) for the watersheds 1, 4 and 5. It accepted the null (H_0) hypothesis representing no trends in this time series. However, Sen slope of these trends was –0.116, 0.009 and –0.036 for the watersheds 1, 4 and 5, respectively. On the other hand, the null hypothesis was rejected for watersheds 2 and 3, and it accepted the alternative hypothesis because of the p-value was less than the significance level. This indicated that there was a decreasing and increasing trends which was statistically significance for the watersheds 2 and 3, respectively. Sen slope value of these two watersheds also were –0.243 and 0.312 indicating upward and down ward direction of the runoff trend.

Table 5. Mann-Kendall trend and Sen slope analysis of watersheds

Watershed	Kendall's tau	*p*-value (two-tailed)	H_0 hypothesis (α = 5%)	Mann-Kendall trend (α = 5%)	Sen slope
1	–0.089	0.230	Accept	No	–0.116
2	–0.178	0.017	Reject	Yes (–)	–0.243
3	0.414	<0.0001	Reject	Yes (+)	0.312
4	0.031	0.673	Accept	No	0.009
5	–0.037	0.624	Accept	No	–0.036

2.4. Smooth curve and runoff potentiality

Figure 7 shows the smooth curve runoff for five watersheds. It reveals that the runoff values varied from one peak to another peak but all peaks occurred during the months of November to February and May to August when most of the rainfall occurred. From this analysis it implies that this runoff exhibits the watershed characteristics in the form of different degree of effect for the study area. The estimated monthly rainfall-runoff relation for the watershed area indicated a good correlation between both criteria (Fig. 8). Relation was found to be linear (R^2 = 0.73

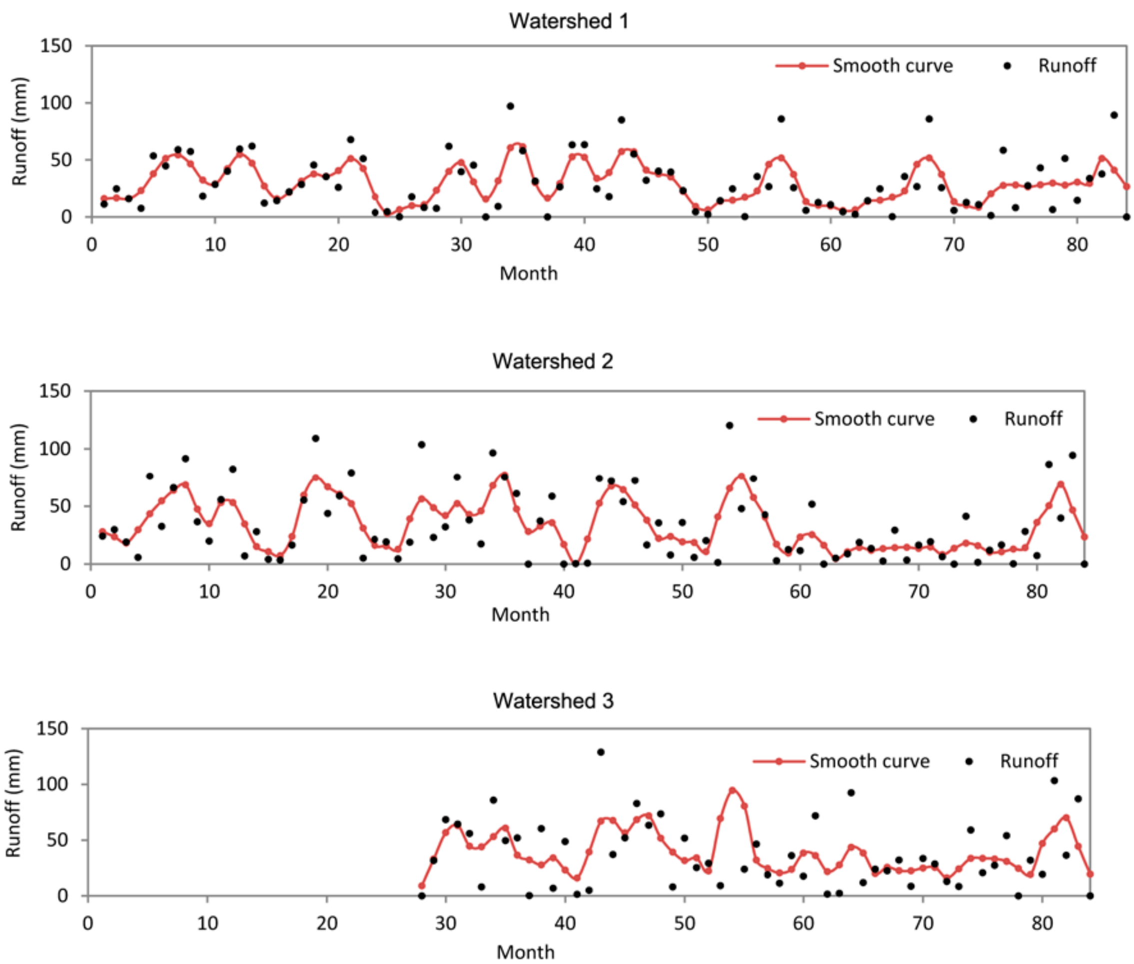

Fig. 7 →

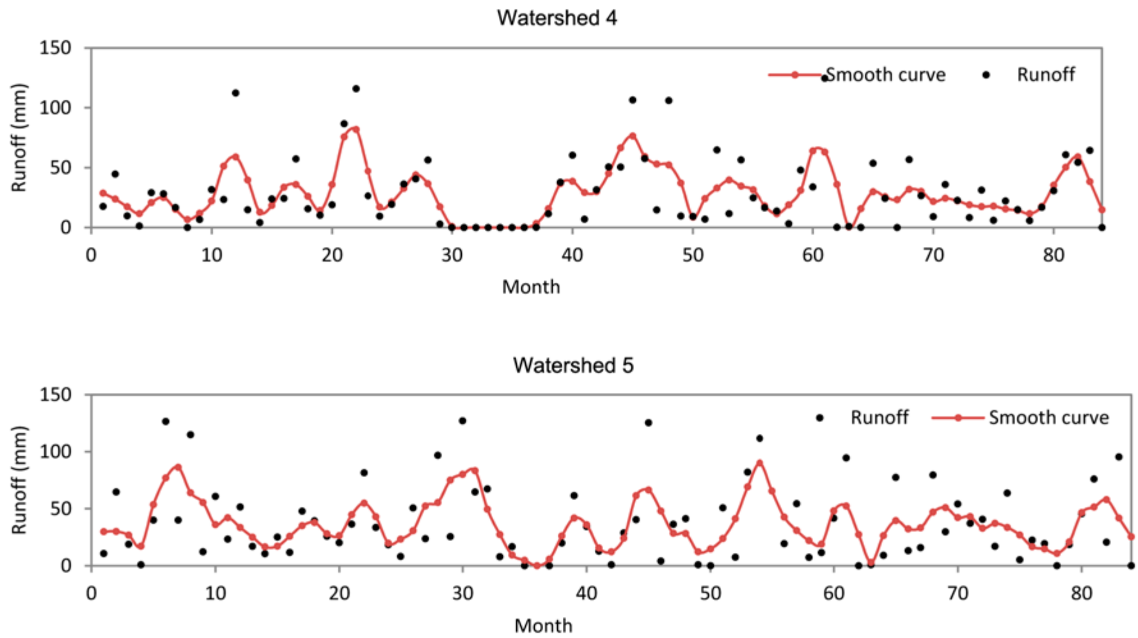

Fig. 7. Runoff and smoothing curve of five watersheds

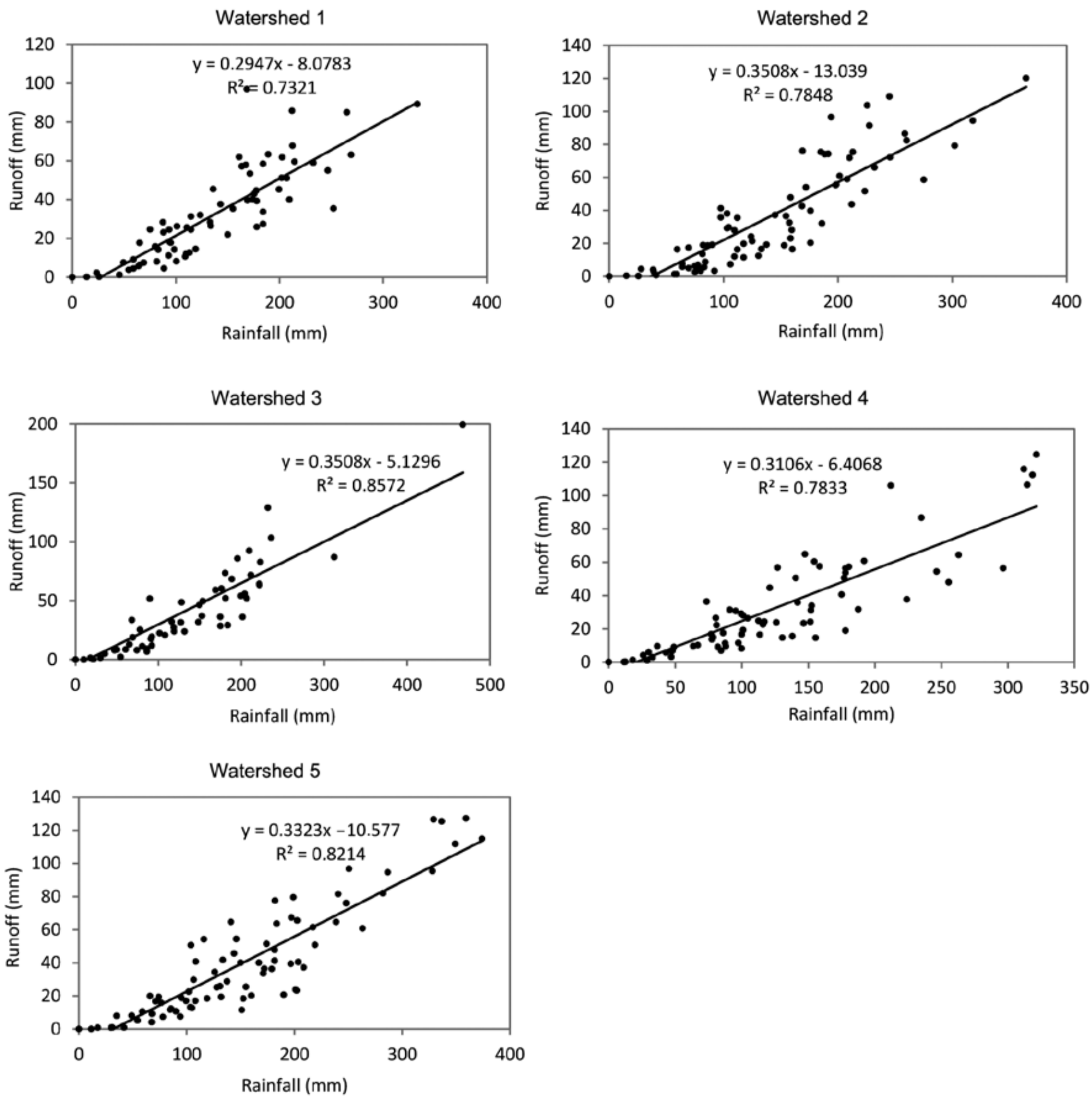

Fig. 8. Estimated monthly rainfall runoff relationship of the study area

to 0.85). This analysis indicated that the surface runoff due to rainfall in Melaka Tengah catchment may be predicted using SCS-CN method. The runoff varied with the different value of CN in Melaka Tengah catchment. Henceforth, runoff volume was calculated for a particular watershed, and total runoff volume in Melaka Tengah catchment was calculated (Table 6) and it revealed that watershed 3 contributes monthly 3.34 Mm^3 of surface runoff.

Table 6. Monthly runoff of particular watershed area of Melaka

Watershed	Runoff R_{wi} (m)	Rainfall P (m)	Watershed Area A (m^2)	Rainfall Volume $P \times A$ (Mm^3)	Runoff Volume $R_{wi} \times A$ (Mm^3)	Runoff (%)
1	0.030	0.13	2829×10^4	3.65	0.85	23
2	0.034	0.13	7973×10^4	10.68	2.71	25
3	0.039	0.13	8557×10^4	10.87	3.34	31
4	0.028	0.11	4806×10^4	5.38	1.35	25
5	0.037	0.14	2998×10^4	4.29	1.11	26
			Average			26

Conclusions

The SCS-CN method was considered to assess the surface runoff of five watersheds in Melaka Tengah catchment. Soil of this region falls mostly under C and D soil groups on the subject of soil texture and hydrological condition. Considering of several sub-catchments with different CNs, the area averaged weighted curve number was computed for the entire watershed and varied between 82 and 85 for different watersheds. It is recommended that weighted curve number may apply for the hydrological soil groups C and D, and less differences of CN values among them. Whereas, distributed CN value is the consideration of hydrological soil groups for accurate surface runoff. Monthly runoff trends over the time period were investigated by using autocorrelation, Mann-Kendall and Sen slope estimation methods. According to the Mann-Kendall test, watersheds 1, 4 and 5 showed no trend at the significant level ($\alpha = 0.05$), while watersheds 2 and 3 showed a trend with Sen slope – 0.243 and 0.312, respectively. The trend analysis revealed that there was no significantly increasing and decreasing trend for these runoff data series. Moreover, the runoff value varied with seasonal and indicated the discrete pattern of the data set. Lowess linear fit method was applied for discrete runoff data and to provide the smoothing of curves. Five smooth curves one for each watershed indicated the surface runoff pattern and these patterns were compared among the watersheds. These curves fluctuated due to the seasonal variation of monsoonal rainfall. As a result, most of the highest peaks of the curve were observed during November to February and May to August, when maximum rainfall occurred. Based on the smoothing curves, the monthly mean runoff was identified and the value is 30 mm, 34 mm, 39 mm, 28 mm and 37 mm for the watersheds 1, 2, 3, 4 and 5, respectively. Watershed 3 had most of the surface runoff of this region to contribute runoff water to the river. About 26% volume of water from rainfall directly goes to the river through surface runoff. This trend and volume of water provides the firsthand information for rainwater distribution and contribution. It may be helpful for planning of surface water management and for contribution and potentiality of groundwater recharge.

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