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Hydrological Investigations in Red Soils of a Micro Catchment Area for Dugout Farm Pond at UAS Raichur Campus

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To measure and characterize storm wise runoff for the catchment area of the farm pond and to correlate rainfall intensity and runoff relationship for the catchment area will help to design the appropriate size of the farm pond and waste weirs of the bunding system.
Place and Duration of Study: The study was conducted in a micro catchment (field sized area) of a dugout farm pond, having an area of 6 ha located in the new area of UAS campus Raichur, which

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comes under Zone II in Region-I of Karnataka state. Geographically it is located at 16° 12′ N latitude and 77° 20′ E longitude and at an elevation of 389 m above the mean sea level (MSL). The study was conducted for a period of one year during 2019.
Methodology: The existing farm pond constructed was used for conducting hydrological studies. The detailed soil and rainfall characterization of the study area has been made through appropriate methods. The rainfall intensity for each storm has been measured using self-recording rain gauge. The runoff has been measured at the out let of the field sized micro catchment area of farm pond using hydraulic structures coupled with automatic runoff recorder. The event wise rainfall, rainfall intensity and runoff have been measured and analysed to see the relationship between rainfall intensity and runoff with prevailing soil and topographical characteristics of the study area.
Results: The percent runoff varied from 6.79 to 50.42 and highest was 50.42 per cent occurred on 25-10-2019 followed by 44.03, 39.36 and 37.46 per cent. The data shows that the individual storm wise percent runoff was quite high as compared to annual percent runoff of 15.99 per cent. The storm wise high runoff percent was due to the fact that high intensity of rainfall followed by high AMC in the soil. Further the minimum runoff yield of 142.66 m^3 was observed on 18-07-2019 against the rainfall of 35.00 mm and maximum of 2985.48 m^3 was yielded on 25-09-2109 against rainfall of 113.00 mm and followed by 1086.64 m^3, 944.24 m^3, 665.61 m^3 and 431.25 m^3 against rainfall of 46.00 mm, 42.00 mm, 22.00 mm and 48.00 mm respectively. The total annual runoff yield was found to be 6255.90 m^3 against the rainfall of 651.50 mm. Therefore, there is a scope for harvesting excess quantity of runoff which is going as a waste. The existing pond capacity of 547.77 m^3 is insufficient to store prevailing runoff generated in the catchment area and hence, pond capacity may be enhanced. The maximum intensity of rainfall and runoff during six events were showed statistically insignificant relationship with R^2 value of 0.370. There is no correlation between intensity of rainfall and runoff.

Keywords: Soil; rainwater harvesting; soil moisture; rainfed agriculture.

1. INTRODUCTION

The average annual rainfall of India is about 1194 mm considered over the geographical area of 328 M ha, amounts to 392 M ha-m of surface water. A part of this that is around 150 M ha-m flows as surface and subsurface runoff and is not useful form the point of agriculture production.

The scientific study on the quantum, intensity and distribution of rainfall would help enable the farming community to adjust or modify the cropping programs as well as the relevant cultural operations [1]. The rainy season in semi-arid topics is characterized by short duration and variable intensity rains, interspersed with unpredictable dry spells.

Rainwater management is the most critical component of rainfed farming. India has a long history of rainwater harvesting through a variety of a structures and systems (tanks, ponds), which are built by the Government and local bodies and managed by the community and village level institutions [2]. Rainfed agriculture in India is practiced under a variety of soil type, agro-climatic and rainfall conditions ranging from 400 mm to 1600 mm per annum [3].

Rainwater harvesting either runoff collection from a catchment area upslope or through conservation of rainfall where it falls in the cropped area or pasture has received increasing attention in rainfed systems [4]. The probable increases in runoff generally occur during high flow seasons and may not alleviate dry season problems, the extra water should be stored during the wet seasons and utilized during dry spells or the dry season. Apart from that, small scale rainwater harvesting and management technologies are important to address environmental such as soil erosion and flooding [5].

Understanding hydrological processes helps to identify water resource potentials, runoff source areas, and erosion danger zones. This in turn helps with the estimation of runoff and sediment yield, which is the basis for developing watershed management plans involving soil and water conservation measures [6]. It helps to represent and simulate the actual hydrological processes so that areas most prone to severe damage and in need of greater soil and water conservation measures can be prioritized. This is the key step to better target finite resources for enhanced soil conservation measures.

Runoff recorders and sediment samples have been extensively used for measuring runoff and soil loss from the fields and during the last decade digital runoff recorders for measuring runoff and microprocessor based runoff samplers for measuring soil loss have gained considerable acceptance over the mechanical type recorders because of their higher accuracy, reliability and operational efficiency [7].

The quantification of hydrological parameters particularly runoff and its peak discharge and volume is very important aspect in the present context of climate change and global warming scenarios. The runoff flow parameters are being used in the hydrologic design of soil and water conservation structures and also in the design of farm pond. The realistic data on runoff helps in arriving accurate hydrologic design of soil and water conservation structures.

The hydrologic parameters namely, intensity of rainfall, runoff could be used for assessing the runoff yield from the pond catchment. Studying rainfall-runoff relationships in field size micro watershed will help to better understand the potential ability of micro catchment to runoff production and water balance in the proposed area and will offer a good scientific knowledge for the decision makers in order to enhance the usage of the limited available water resources by maximizing water collection and storage and minimizing losses due to evaporation and seepage [8]. The present study is undertaken to characterize soil, topography, rainfall characteristic and also storm wise runoff behaviour in the catchment area.

2. MATERIALS AND METHODS

2.1 Description of the Experimental Micro Catchment Area

The study was conducted in a micro catchment (field sized area) of a dugout farm pond, having an area of 6 ha located in the new area of UAS campus Raichur, which comes under Zone II in region-I of Karnataka state. Geographically it is located at 16° 12′ N latitude and 77° 20′ E longitude and at an elevation of 389 m above the mean sea level (MSL). The location map of the study area is shown in Fig. 1a and 1b.

Agroclimatically, the micro watershed is a part of the Northern dry zone of Karnataka and also a part of the agro ecological region of the country. The climate is semi-arid and the average annual rainfall is 682.40 mm. The study area belongs to the North-Eastern Dry Zone (Zone-2 of region-1) under semi-arid region with subtropical climate and consists of parts of Raichur, Gulbarga and Bellary districts in Karnataka.

During the study period, the highest one-day rainfall of 113 mm was recorded in the month of September 25th, 2019 (Fig. 2) and minimum 8.60 mm in the month of May and the total annual rainfall recorded was 651.50 mm during. The average maximum and minimum temperature of 43ºC and 19ºC were recorded in the month of May and December 2019 respectively. Day temperature shows a slight increase in October. From November, both day and night temperature gradually decreases till December. The mean maximum relative humidity (RH) was noticed during August and September months (83 per cent) whereas mean minimum RH was noticed during March month (24 per cent).

2.2 Installation of Self Recording rain Gauge at the Experimental Site

A self recording rain gauge was installed near the farm pond, UAS, campus Raichur by following the installation protocol. The event wise rainfall depth and intensities were recorded during the study period 2019.

2.3 Rainfall Characteristics of the Study Area

The rainfall intensity is one of the prime factors affecting runoff, is a very important parameter to understand rainfall-runoff relationships especially in semi-arid areas where high intense short duration rainfall is a common phenomenon [9,10]. The rainfall intensities for each storm event were recorded and the storm patterns were classified into constant rainfall intensity, high intensity and low intensity. The rainfall intensity types were classified by following the standard methodologies shown in Table 1. The event wise rainfall depth (mm) and intensities were recorded during the study period of 2019-20 (Plate 1). Using the rain gauge charts, the intensity was calculated by knowing the start and end time of an event which is marked on x-axis and counting the number of pen marked lines on y-axis and two such lines on y-axis is equivalent to 10 mm of rainfall and accordingly depth and intensities.

2.4 Cropping Pattern in the Study Area

The cropping pattern in the study area confined to a few field crops. During kharif season the red gram (*Cajanus cajan*) crop was sown in the month of July 17th, 2019 and followed by Jowar crop was grown in the entire 6 ha area. During the runoff events, the red gram crop was sixty days old.

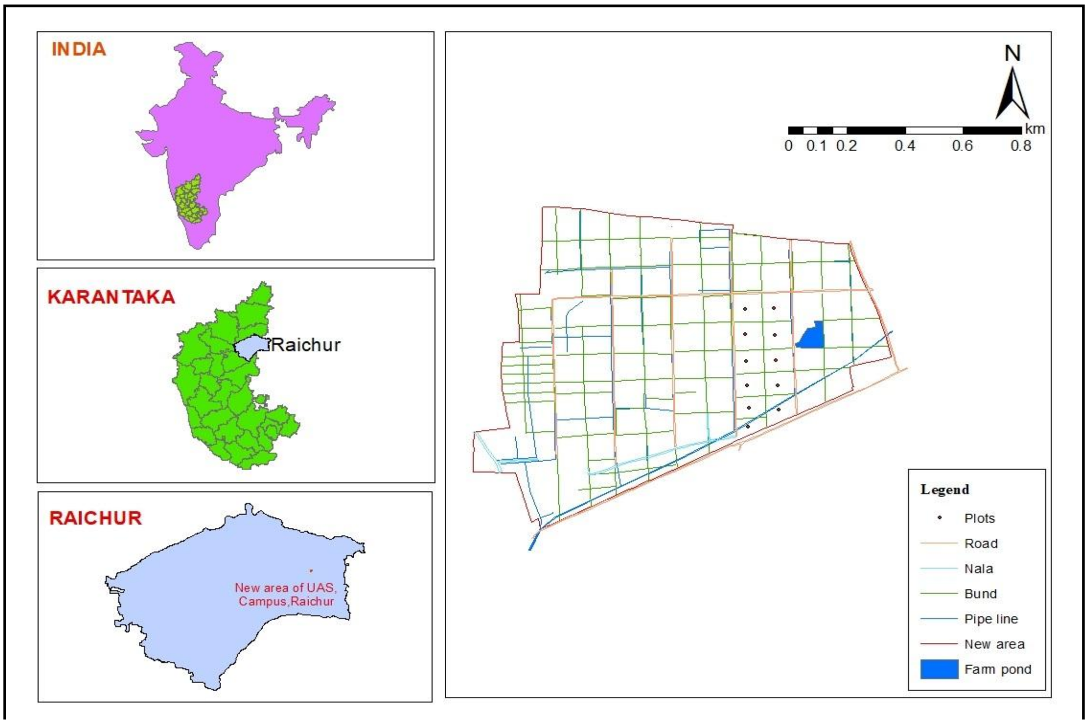

Fig. 1a. Location map of study area in the UAS, campus Raichur

Fig. 1b. Google earth satellite image showing the boundary of the study area and farm pond at UAS, Raihur campus

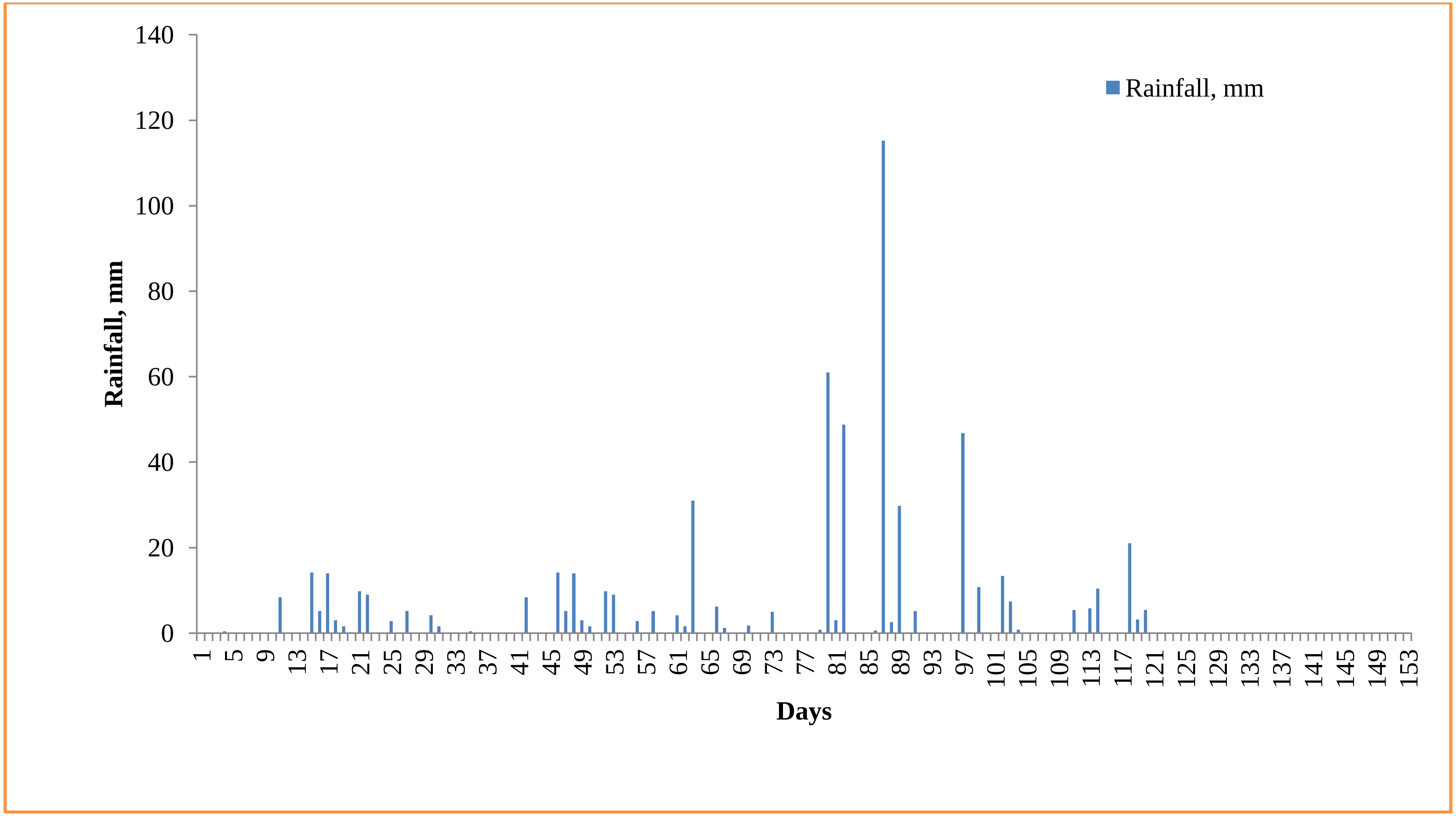

Fig. 2. Daily rainfall (mm) recorded from July to November during the period of 2019-20

2.5 Topographic Features of the Study Area

In this study, the new version of SURFER 8.0 was used. The details of the contour map of the catchment area along with 3D map are shown in Fig. 3a and 3b respectively. The highest and lowest elevation was 100.7 m and 99.75 m and the average elevation of the study area is 99.5 m and with elevation difference of 0.95 m from head to toe of the watershed. The average slope of the area is 0.25 per cent.

From the Fig. 3 a and 3b it is clearly understood that, the study area topographically covered with low and high spots where part of the runoff is accumulating and further flow towards farm pond which is being located at the lowest elevation of the study area. Therefore, identify the farm pond is at the outlet point of the micro catchment where all the runoff was drained and collected.

Table 1. Classification of rainfall intensity based on rainfall

Sl. No.	Method 1	Method 2
1	Light soil < 2.5 mm	Very light drizzle< 0.25 mm/hr
2	Moderate rain 2.5 to 10 mm	Light rain 0.25 to 1.00 mm/hr
3	Heavy rain 10 to 50 mm	Moderate rain 1 to 4 mm/hr
4	Very heavy > 50 mm	Heavy rain 4 to 16 mm/hr
		Very heavy rain 16 to 50 mm/hr
		Extreme rain > 50 mm/hr

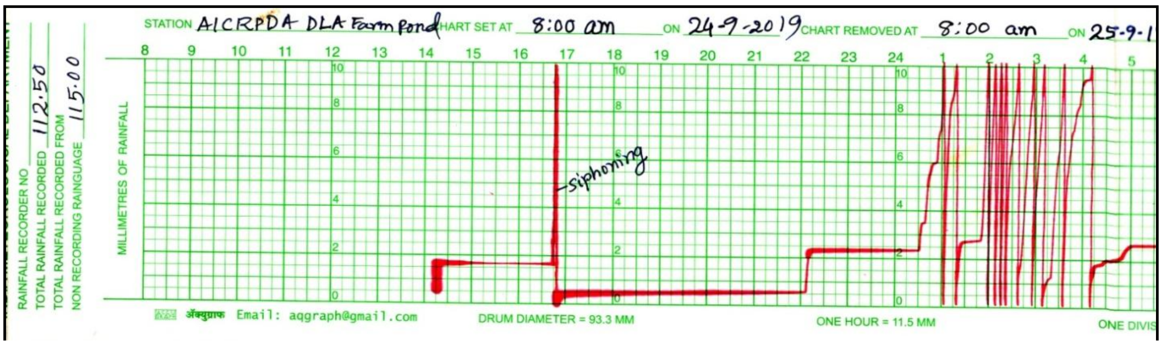

Plate 1. Rainfall chart recorded on 25-09-2019 with rainfall 113 mm

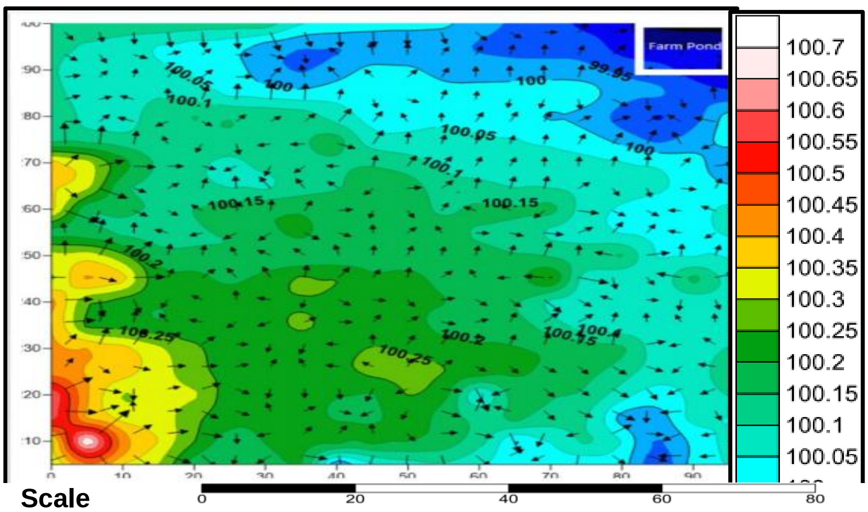

Fig. 3a. Map showing the contours, flow direction and topographic features of the study area

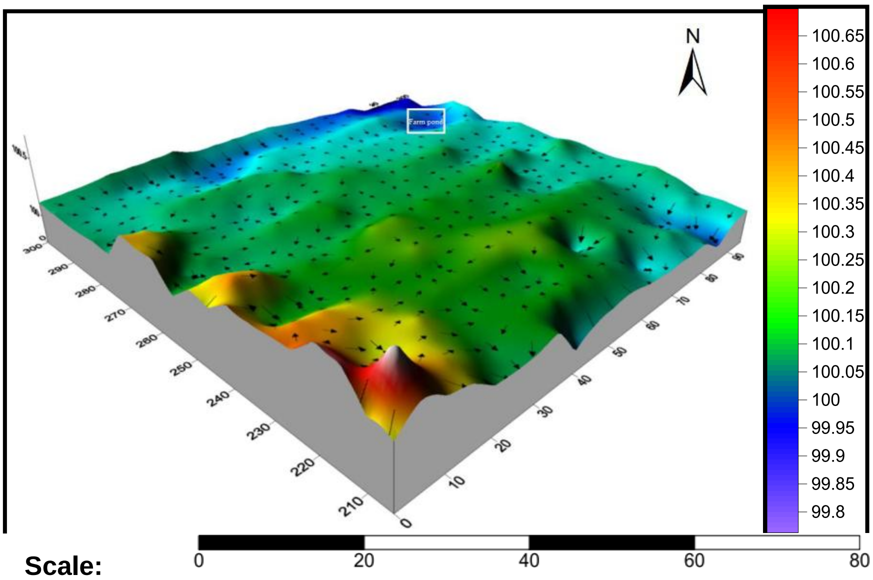

Fig. 3b. Map showing the 3D map depicting the topographic feature of the catchment area

2.6 Determination of Soil Characteristics of the Study Area

The average depth was recorded as < 50 cm for the study area. The soil characteristic of the study area is shown in Table 2. The distribution of particles sizes was determined by following standard sieve analysis method, followed by International pipette method [11]. The results of the textural analysis of soil samples at different depths are given in Table 3. Soil infiltration rate was measured at the micro watershed using double-ring infiltrometer [12]. The infiltration values were observed at increasing intervals of 5,10,15,30 and 60 minutes, for a total period of 8 hours. Infiltration characteristics of the study area is shown in Fig. 4. The average infiltration rate of the soil is 9 cm/hr.

The average bulk density of the soil was found to be 1.52, 1.56 and 1.60 g/cc at above mentioned locations.

Soil samples were collected on daily basis from the field using screw auger at different depths. Daily antecedent soil moisture contents were determined at layer-I (0-30 cm) and layer-II (30-60 cm) of the study area. The samples moisture content was determined in the laboratory by means of gravimetric method [13].

2.7 Farm Pond Constructed at the Outlet of the Micro Catchment

Farm pond is a dug out structure with definite shape and size having proper inlet and out let structure for collecting the surface runoff flowing from the farm area. It is one of the most important rain water harvesting structures constructed at the lowest portion of the farm area. The stored water can be used for supplemental irrigation. The design details and capacity of the farm pond is shown in Table 4 and Fig. 5.

Table 2. Site characteristics of the study area by profile study

Sl. No.	Soil properties	Details
1	Topography	Undulating
2	Gradient (%)	1-3
3	Drainage	Medium well
4	Erosion	Moderate
5	Runoff	Medium
6	Texture	Sandy loam

Table 3. Soil textural classification of study area

Sl. No.		Soil depth (cm)					
	Soil separates	**0-11**	**11-23**	**23-48**	**48-73**	**78-102**	**>102**
1	Clay (%)	14.8	10.0	13.2	15.0	18.2	15.4
2	Silt (%)	3.60	11.40	26.80	25.0	41.8	21.8
3	Sand (%)	81.60	78.6	60.0	60.0	40.0	62.8
Soil textural class		Sandy loam	Sandy loam	Silty loam	Silty loam	Silty loam	Loam

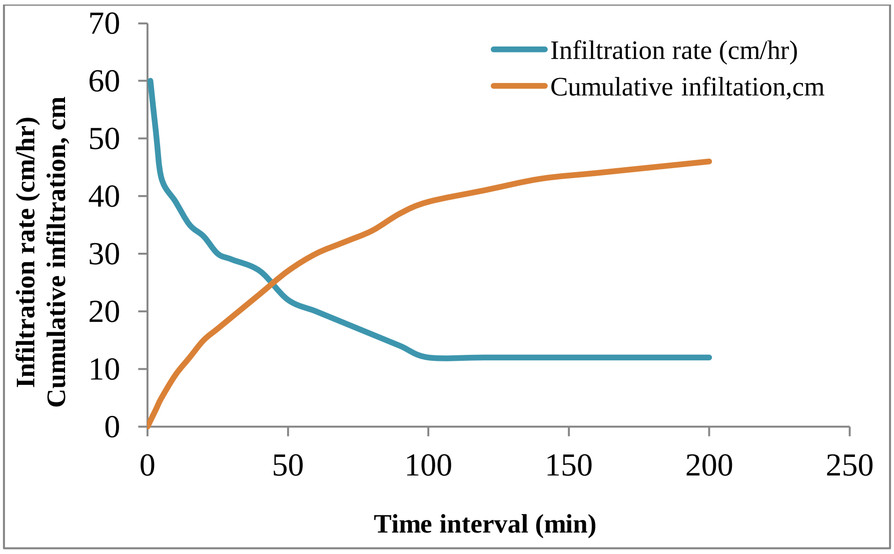

Fig. 4. Infiltration characteristics of the study area

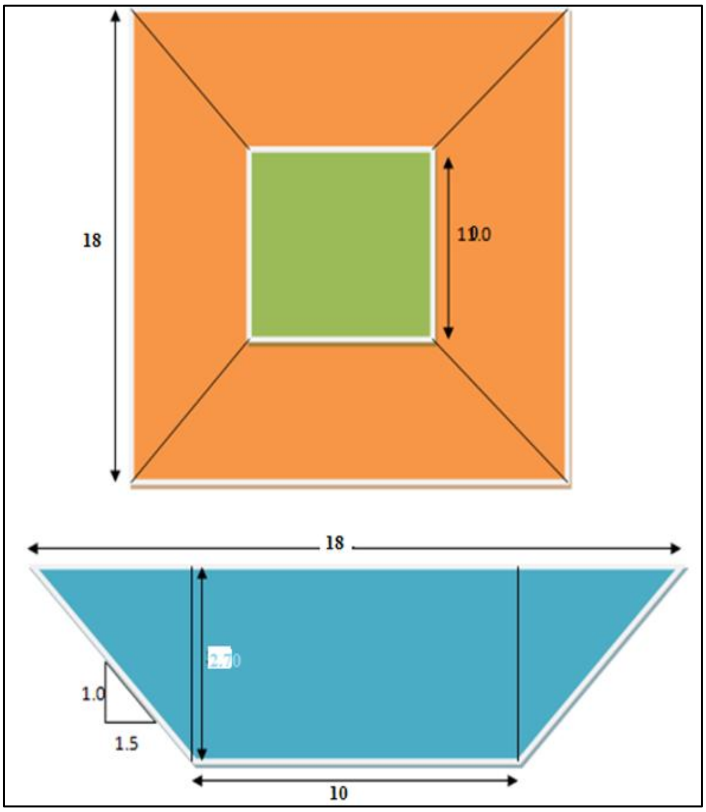

Fig. 5. Plan and sectional view of Farm Pond showing design dimensions

2.8 Instrumentation Setup and Data Collection for Runoff and Sediment Yield

2.8.1 Measurement of runoff

The experimental setup consisted of a Thalimede data encoder type digital water level recoreder for recording continuous and uninterrupted measurements of changes in the water level over long period of time have been installed at the inlet section of the farm pond which is the outlet point of the micro catchment area (Plate 2a and 2b). The whole experimental setup was created under the “All India Coordinate Research Project on Dry land

Agriculture" (AICRPDA) project, UAS, Campus, Raichur.

2.8.2 Thalimede data encoder digital water level recoreder

Thalimede is a float operated shaft encoder with integral digital data logger was used to continuously monitor the water level in the discharge measuring structure namely weirs and flumes. In the present study a rectangular weir with crest length 0.9 m, crest width 0.3 m and depth of weir 0.7 m was constructed and its plan and section is shown in Fig. 6.

2.8.3 Setting and data downloading from Thalimede

The instantaneous head over crest data has been downloaded from the Thalimede using proper procedure. Further, analysis was carried out and runoff was calculated using rectangular weir formula as shown in below.

$$Q=C_d\sqrt{2gh}\frac{2}{3}LH^{\frac{3}{2}} \quad (1)$$

Where,

Q = Peak discharge rate, m^3/s
C_d= Coefficient of discharge (0.6)
L = Length of weir, m
H = Head of flow, m

Using the above formula, the instantaneous discharge at one-minute interval throughout the individual runoff event was calculated. Then, the runoff in cubic meter as well as in mm and peak rate of runoff events was calculated. The Cd value was chosen 0.60 for the broad crested weir based on the calibration of Cd value using discharge values determined by velocity meter (current meter).

Table 4. Design details of farm pond at AICRPDA centre UAS, Campus, Raichur, Karnataka

Sl. No.	Particulars	Details
1	Shape	Square
2	Bottom dimensions	10×10 m
3	Top dimensions	18×18 m
4	Depth	2.70 m
5	Side slope	1.5:1
6	Storage capacity	547.77 m^3
7	Lining	RCC concrete
8	Total cost including lining	Rs. 3,20,000
9	Catchment area	6.0 ha
10	Command area	1.0 ha
11	Soil type	Sandy loam

Plate 2a. Image showing setup of Thalimede data encoder, data logger and self recording rain gauge at the inlet section of form pond

Plate 2b. Close view of thalimede data encoder and data logger used in the study area

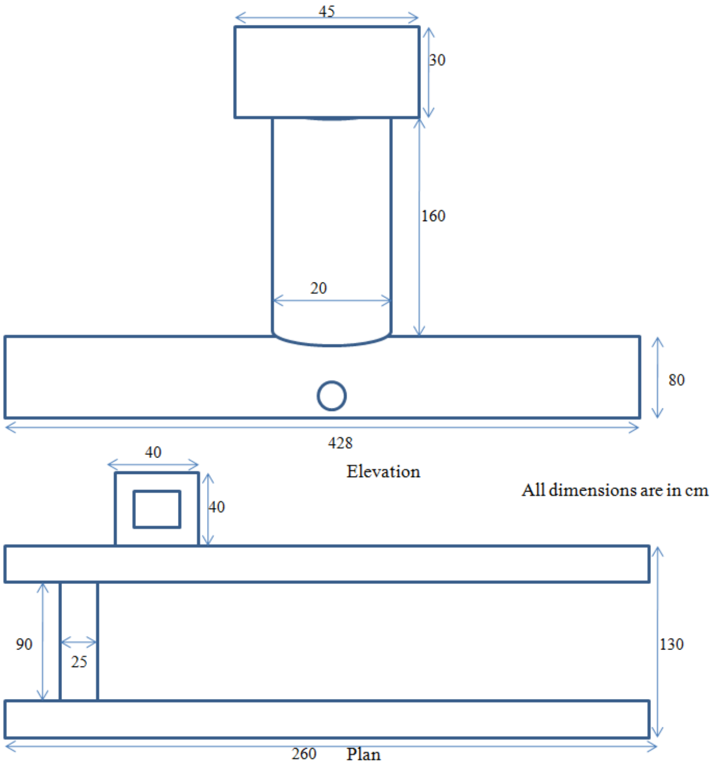

Fig. 6. Drawing details of weir, stilling well, channel, shelter box of thalimede and their dimension

3. RESULTS AND DISCUSSION

3.1 Rainfall Analysis

The present investigation was taken extensively in a field size micro watershed having an area of 6 ha located in the new area of UAS campus Raichur, Karnataka. The area receives average annual rainfall of 682.4 mm. The metrological data for the year 2019 and for the past 37 years (1982-2019) were recorded at weather station, MARS, UAS Raichur and is furnished in Table 5. The total actual rainfall received during the year 2019 was 651.50 mm as against the normal rainfall of 622.8 mm. However, rainfall during the experimental period varied from seasonally. The rainfall was lower than the normal in the month of Feb (0.00 mm), March (0.00 mm), April (13.5 mm) May (8.60 mm) June (67.00 mm), July (107.80 mm), August (34.00 mm), Nov (0.00 mm) and Dec (0.00 mm) while it was higher than the normal in the month of Jan (10.00 mm), September (280.80 mm) and October (129.80 mm) during 2019. The highest monthly rainfall was received during September (280.80 mm) followed by October (129.80 mm), July (107.80 mm) and August (34.00 mm) during 2019 and is shown in Table 5. The daily rainfall distribution is also shown in the Table 5. Similarly, the highest maximum monthly rainfall was observed in September (280.80 mm) against the normal rainfall of 77.8 mm in the year 2019 and the lowest minimum monthly rainfall was observed in January (10.0 mm) against the normal rainfall 3.0 mm and is shown in Fig. 7.

Monthly rainfall distribution of the study area during the period of 2019 is shown in Table 5. More than 85% of the total annual rainfall is received during the southwest monsoon season (July to September). The highest rainfall occurs in the month of September 25th was 113.2 mm and in the end of October the rainfall ceases. In the month of November and December no rainfall occurred.

The monthly maximum and minimum temperature during the study period of 2019 was 41.39ºC (May) and 10.00ºC (February) respectively The highest relative humidity of 78 per cent was received in the month of October and minimum of 35 per cent was received in April month. The maximum wind velocity of 16 km/hr and minimum of 4.8 km/hr was observed in the month of July and November.

3.2 Soil Characteristics of the Micro-watershed

3.2.1 Analysis of daily moisture data

To correlate antecedent moisture content over the runoff, the daily soil moisture content was measured at three locations in the micro catchment area at two depths namely, 0-30 and 30-60 cm from 1st September to 31st November 2019 as most of the runoff events were occurred during this period. The collected soil moisture data helps to assess its effect on the runoff generation. The fluctuation of daily soil moisture content as a result of soil evaporation and replenishment through rainfall is shown in Table 6 and Fig. 8 (a) – Fig. 8 (c). The soil moisture level at location I (lower reach) at 0-30 and 30-60 cm ranged from 5.10 to 26.30 and 7.10 to 30.20 per cent respectively. Similarly, at location II (middle reach) at 0-30 and 30-60 cm depth the moisture content varied from 5.00 to 25.50 and 7.60 to 30.50 per cent respectively. Further, at location III (upper reach) at 0-30 and 30-60 cm was varied from 5.30 to 21.40 and 7.70 to 27.60 per cent respectively. The high moisture value was due to replenishment through rainfall event or supplemental irrigation provided to the crops and low moisture content was due to evaporation losses during dry period which is clearly depicted in Fig. 8 (a) – Fig. 8 (c). From September 18th to September 29th and October 17th to 24th, there is increase in soil moisture indicates occurrence of rainfall. However, during 13-10-2019 to 20-10-2019, 30-10-2019 to 5-11-2019 and from 20-11-2019 onwards soil moisture observation found to be decreasing indicates dry period and recession of rainfall. The relevance of antecedent moisture content (AMC) over runoff generation will be discussed in the subsequent sub headings of this chapter.

Similarly, these findings were consistent with a previous study conducted by Shukla *et al*., 2014 at Jodhpur, Bharatpur, India. They measure soil moisture at the depth of 5cm, 10 cm and 30 cm and concluded that at 10 cm depth the soil moisture was 10.37, 13.16 and 14.13 per cent. In this study the highest soil moisture was observed to be 30.2 per cent at 30-60 cm depth.

Antecedent soil moisture plays an important role for generation of runoff. The relationship between antecedent soil moisture condition and runoff events is shown in Fig. 9. There were six runoff generating events recorded during the experimental period. During the rainy season runoff was generated when the antecedent soil moisture was more than 15 per cent. The average Antecedent soil moisture on September 24th at 0-30 cm and 30-60 cm was observed to be 11.5 and 15.37 per cent respectively before the runoff event occurred on 25-09-2019 There was a significant correlation between runoff and antecedent soil moisture measured during 2019 with R^2 value 0.701 is shown in Fig. 10.

3.3 Measured Runoff at the Outlet of Micro Watershed

3.3.1 Measured runoff

The runoff was measured by using hydraulic structures coupled with digital stage level

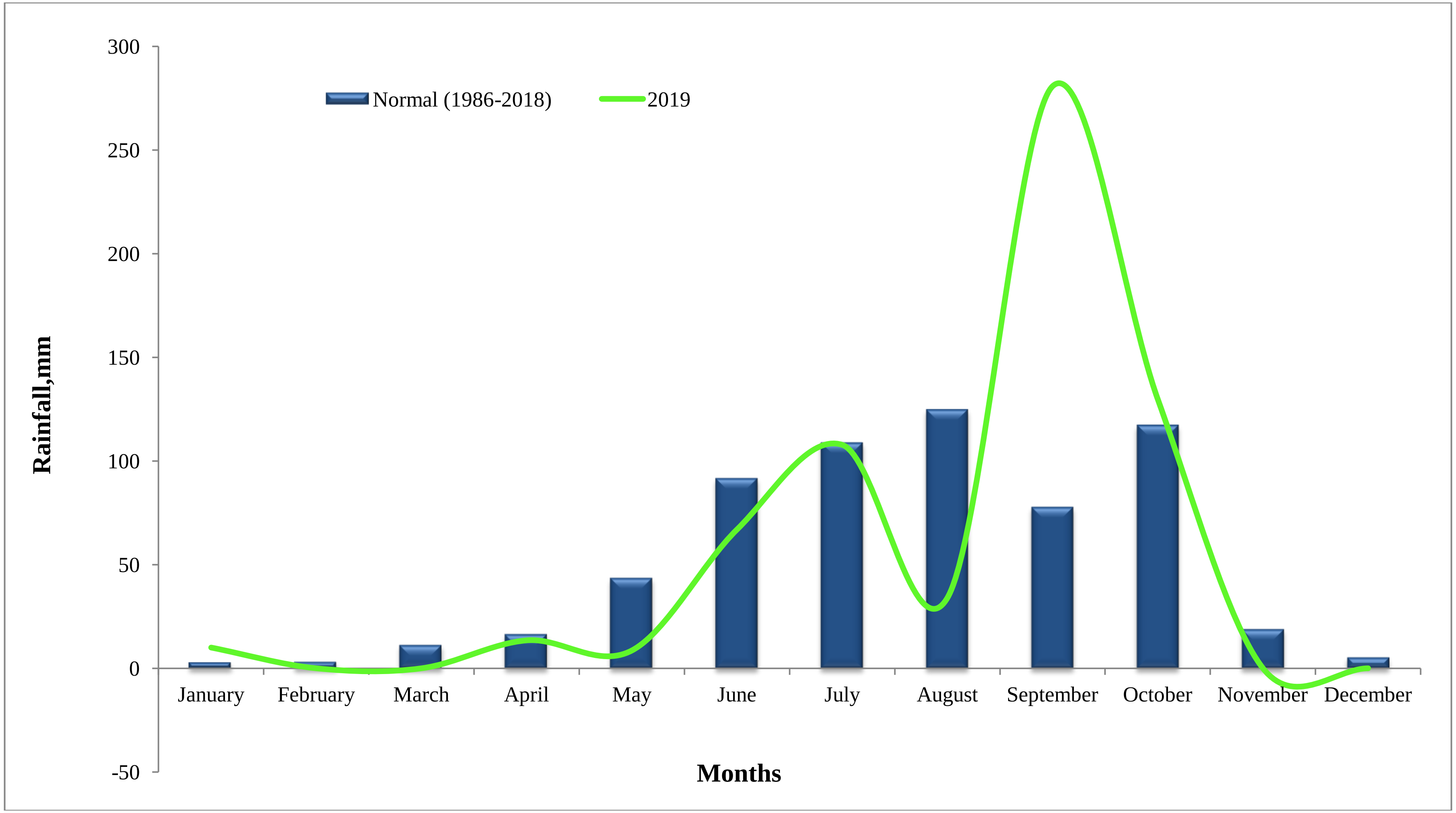

Fig. 7. Comparison of monthly rainfall pattern of MARS, Raichur

Table 5. Rainfall distribution at the experimental site during the year 2019

Date	Months											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	0.00	0.00	0.00	0.00	0.00	26.6	0.00	0.00	31.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.80	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	5.8	0.00	12.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	4.10	0.00	0.00	0.40	0.00	6.20	46.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.60	1.20	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	7.40	0.00	23.4	0.00	0.00	0.00	10.80	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.80	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.40	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	8.40	0.00	5.00	7.40	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	14.20	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	5.20	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00	0.80	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	35.00	0.00	48.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	42.00	5.40	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	3.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	5.00	9.80	0.00	0.00	5.80	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	2.20	9.00	9.20	0.00	10.40	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	2.80	1.80	113.20	22.00	0.00	0.00
26	0.00	0.00	0.00	0.00	3.80	0.00	0.00	0.00	2.60	0.00	0.00	0.00
27	10.00	0.00	0.00	0.00	0.00	0.00	5.20	0.00	29.80	3.20	0.00	0.00
28	0.00	0.00	0.00	0.00	4.8	4.00	0.00	0.00	0.00	5.40	0.00	0.00
29	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	1.00	5.20	0.00	0.00	0.00
30	0.00	**0.00**	0.00	2.0	0.00	0.00	4.20	0.00	0.00	0.00	0.00	0.00
31	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	1.60	0.00	**0.00**	0.00	**0.00**	0.00
Total	**10.00**	**0.00**	**0.00**	**1 3.50**	**8.60**	**67.00**	**107.80**	**34.00**	**280.80**	**129.80**	**0.00**	**0.00**

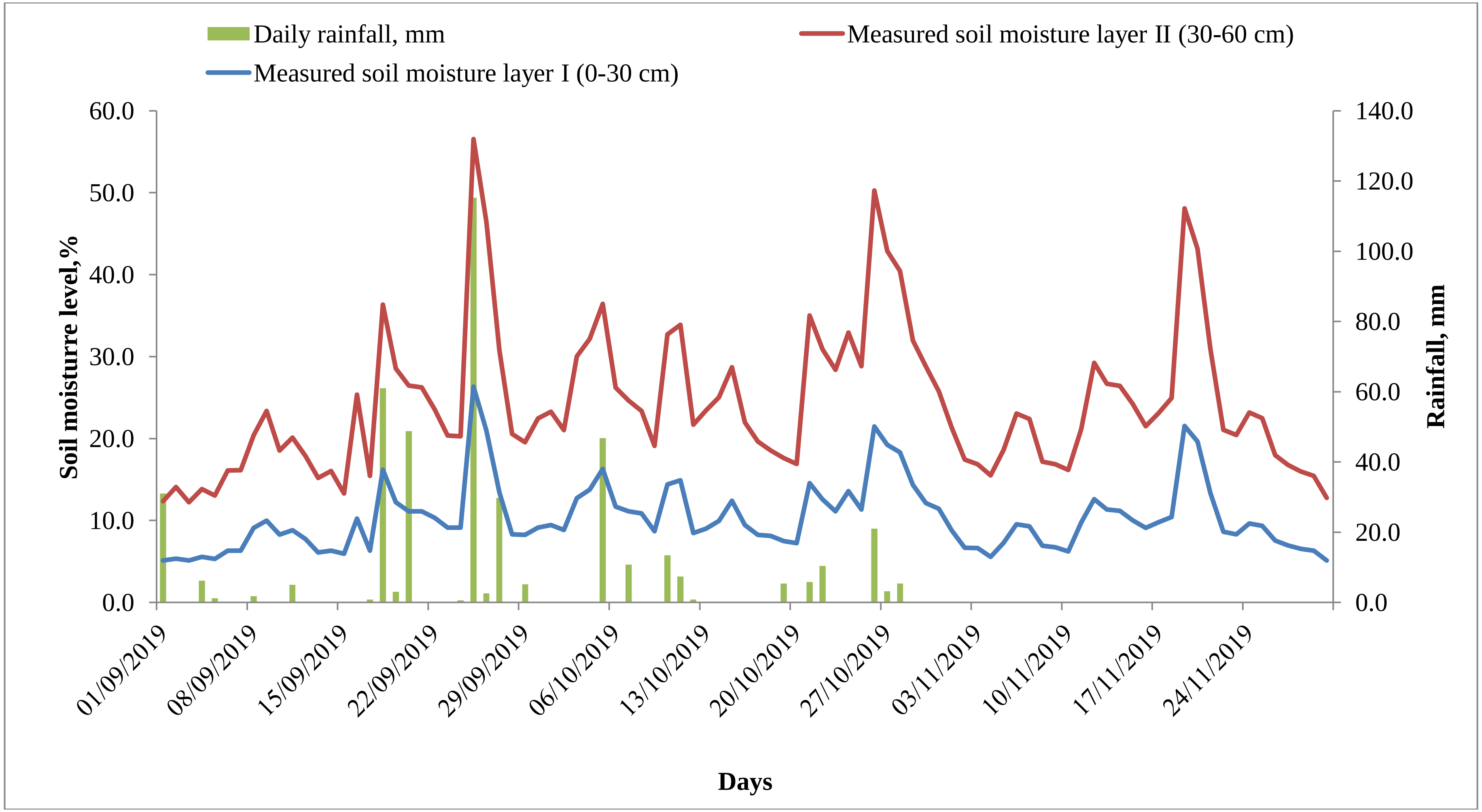

Fig. 8a. Measured soil moisture content on mass basis in location I at layer I and layer II

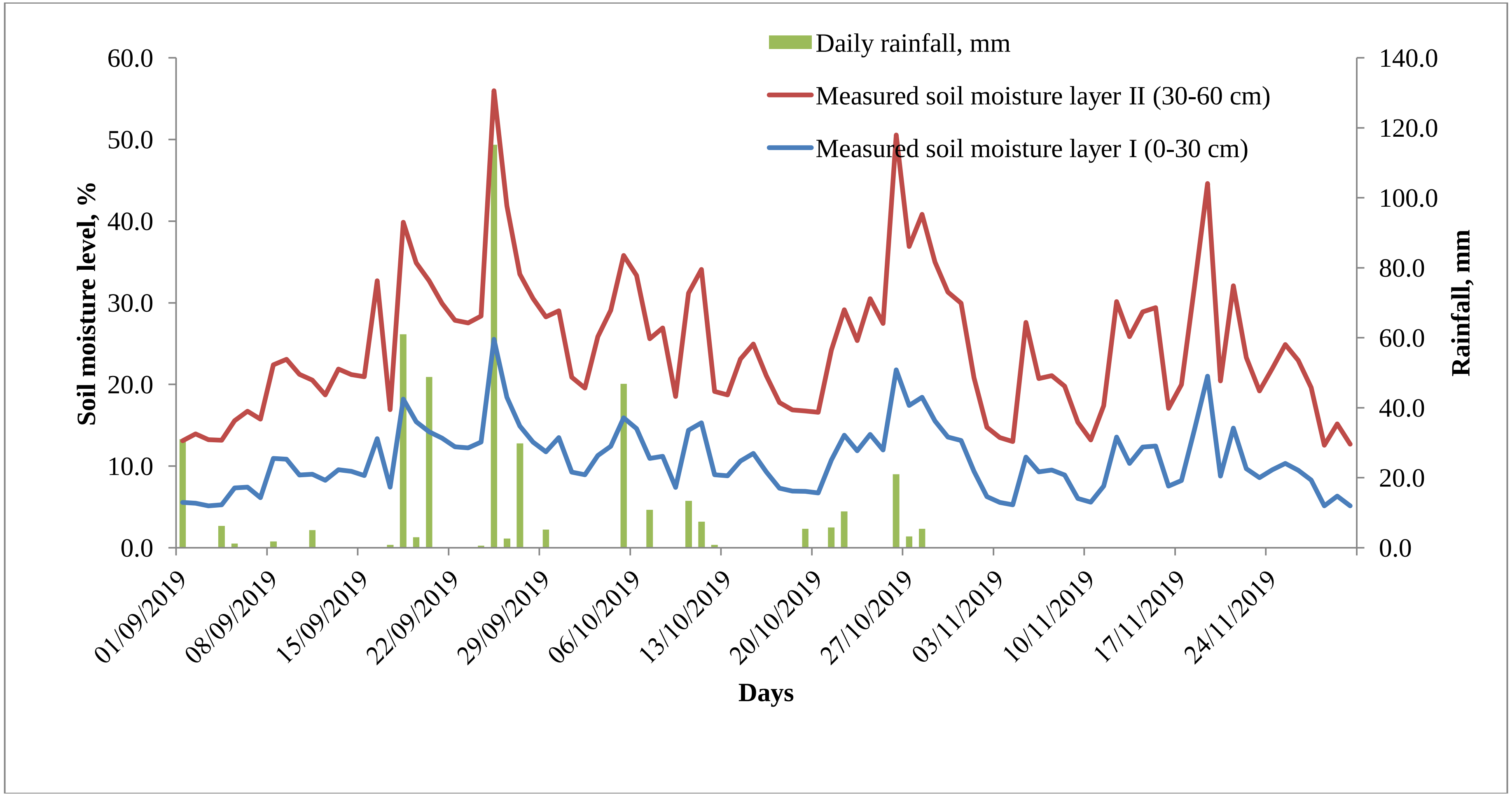

Fig. 8b. Measured soil moisture content on mass basis in location II at layer I and layer II

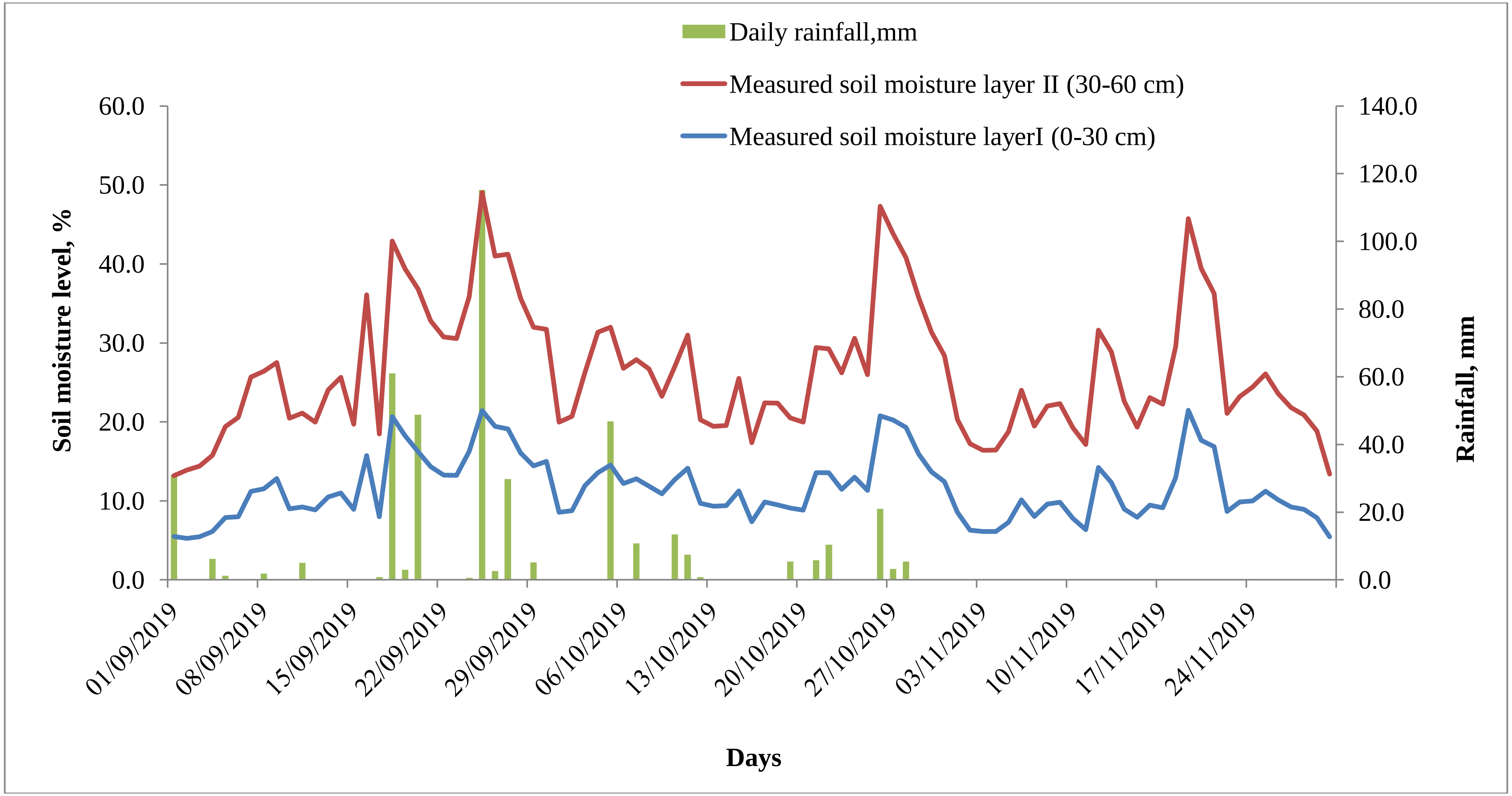

Fig. 8c. Measured soil moisture content on mass basis in location III at layer I and layer II

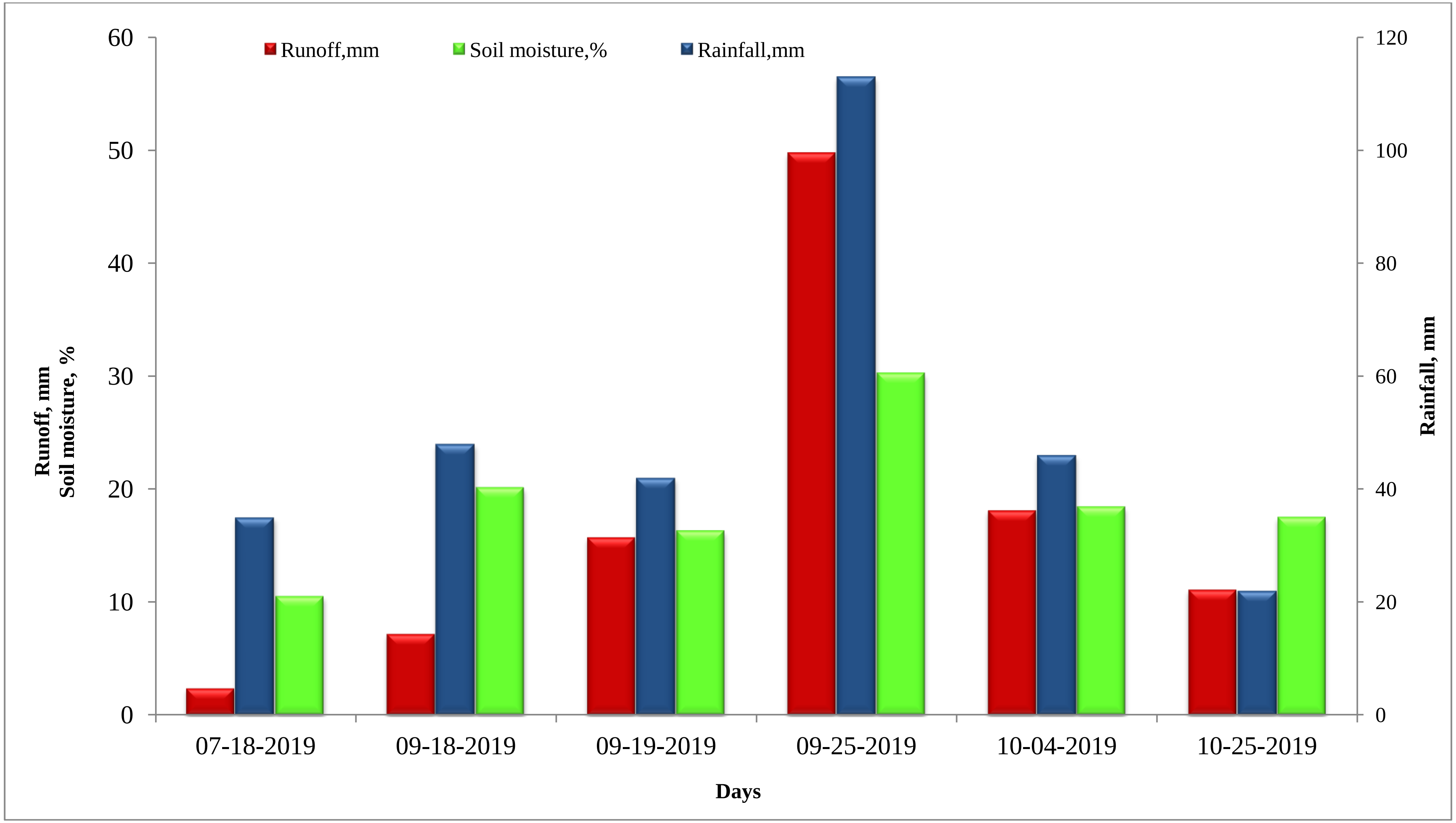

Fig. 9. Measured runoff and soil moisture during the study period

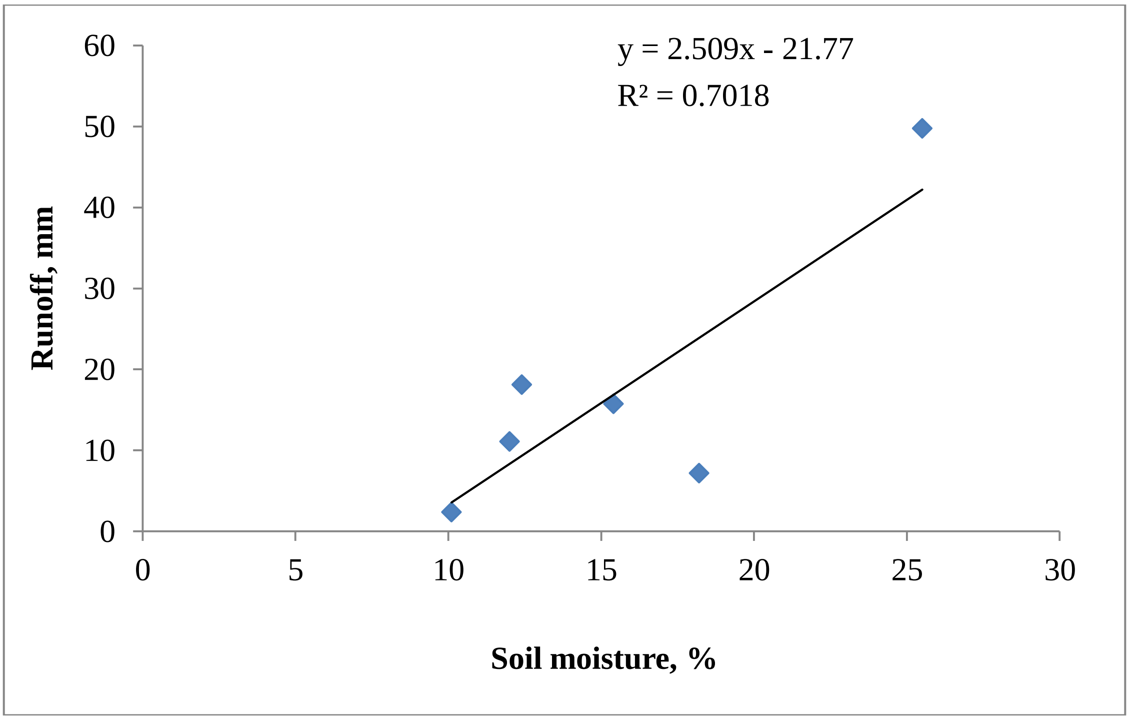

Fig. 10. Scatter plot of soil moisture and measured runoff during study period

recorder (Thalimede) from 01-01-2019 to 31-01-2019 at the outlet of the micro catchment area. The event wise discharge (m^3/s) and runoff depth (mm) was calculated using height data of runoff flow by applying broad crested weir formula and further runoff hydrographs were derived for the micro catchment area and results are presented in the Table 6. The total rainfall from June to October 2019 was 619.40 mm which is more than the long term seasonal average of 520.60 mm and 15.99 per cent of total annual rainfall of 651.50 mm was discharged as runoff during 2019. The remaining 84.01 per cent or 547.27 mm was distributed among evapotranspiration, ground water recharge or change in unsaturated soil storage. From June 1st to July 17th total of 108.80 mm rainfall was recorded, while stable mean moisture content was 25.2 per cent between the 30-60 cm soil layers from all locations but runoff was absent for most of this period. Runoff events occurred on 18-09-2019 and 19-09-2109 was shown in Plate 9a and 9b. Total precipitation between the runoff events from July 18th to end of the study period ie on October 25th was 503.60 mm of which 104.23 mm (20.70 per cent) was discharged as runoff. It was observed from the results, that there were total six runoff events occurred during the year 2019. Among these events, the highest runoff of 49.75 mm (44.03 % of rainfall) was produced on 25th, September 2019 against the rainfall depth of 113.00 mm and lowest runoff of 2.37 mm (6.79 % of rainfall) was recorded on 18th, July 2019 against 35.00 mm rainfall and event wise details is shown in Table 7.

The percent runoff varied from 6.79 to 50.42 and highest was 50.42 per cent occurred on 25-10-2019 followed by 44.03, 39.36 and 37.46 per cent. The data shows that the individual storm wise percent runoff was quite high as compared to annual percent runoff of 15.99 per cent. The storm wise high runoff percent was due to the fact that high intensity of rainfall followed by high AMC in the soil. Further the minimum runoff yield of 142.66 m^3 was observed on 18-07-2019 against the rainfall of 35.00 mm and maximum of 2985.48 m^3 was yielded on 25-09-2109 against rainfall of 113.00 mm and followed by 1086.64 m^3, 944.24 m^3, 665.61 m^3 and 431.25 m^3 against rainfall of 46.00 mm, 42.00 mm, 22.00 mm and 48.00 mm respectively. The total annual runoff yield was found to be 6255.90 m^3 against the rainfall of 651.50 mm. Therefore, there is a scope for harvesting excess quantity of runoff which is going as a waste. The existing pond capacity of 547.77 m^3 is insufficient to store prevailing runoff generated in the catchment area and hence, pond capacity may be enhanced. This kind of information for designing the farm pond would essentially helps to harvest more quantity of runoff and it is need of the hour.

Table 6. Storm wise details of measured runoff in the study area during 2019

Sl. No.	Storm event	Rainfall (mm)	Runoff (mm)	Peak discharge (m^3/s)	Time to peak (min)	Runoff (m^3)	Runoff (%)	Annual runoff (%)
1	18-07-2019	35	2.37	0.08	26	142.66	6.79	**15.99**
2	18-09-2019	48	7.18	0.16	47	431.25	14.95	
3	19-09-2019	42	15.73	0.14	53	944.24	37.45	
4	25-09-2019	113	49.75	0.45	60	2985.48	44.03	
5	04-10-2019	46	18.11	0.29	72	1086.65	39.36	
6	25-10-2019	22	11.09	0.08	30	665.62	50.42	
Total		**306**	**104.23**			**6255.90**		

Note: Annual rainfall of 2019 is 651.50 therefore, annual runoff per cent (104.23x100/651.50)=15.99 per cent
***Time to peak recorded individual runoff event. It is the only time at which the maximum discharge rates attain from individual event. But it is not significant value with reference to time of concentration*

Several factors are likely responsible for the relatively higher runoff from the Alfisols (Sandy loam). The alfisols have non-stable soil structure, which enhances the soil tendency to develop surface seals that reduces the infiltration and profile recharge even under moderate or mild rains. The surface seal hardens into crusts during intermitted dry periods, which further influence the runoff behaviour of the Alfisols. Also because of low structural stability, the smoothing of the soil surface roughness following rainfall events was found to much quicker in the Alfisols. This contributed to fast decline in the surface depression storage, resulting in a relatively higher runoff. The similar studies have been conducted in ICRISAT Patenchuru, Hyderbad and the results were found to be in the same line [14].

Runoff and rainfall was measured doring study period 2019 was depicted in Fig. 11. The relationship between rainfall (mm) and runoff (mm) depicted by the scattered plot in Fig. 12. The storm wise rainfall runoff showed a statistically significant linear relationship with R^2 value of 0.850. It clearly showed that there is a close relationship between rainfall and runoff.

Similar results were observed by Premanand et al. [15] in Madubhavi micro watershed. They measured that runoff from each storm in the range of 15 to 49 per cent in case of fallow conditions and 10 to 36 per cent in case of cropped conditions and Pathak et al. [7] also found that mean annual rainfall, runoff and peak discharge for Alfisols were 890, 199.70 mm and $0.21 m^3 s^{-1} ha^{-1}$ respectively at ICRISAT centre, Patancheru, AP, India. In our respective study area (Raichur) the measured runoff for different runoff events ranged from 6.79 to 50.49 per cent.

Further event wise hydrographs derived from the micro watershed are shown in Fig. 13(a) to Fig. 13(f), it was revealed that the peak discharge ranged from 0.080 $m^3 s^{-1}$ (18th, July 2019) to 0.45 $m^3 s^{-1}$ (25th, September 2019). However, with progress in rainy season, the month of September recorded relatively higher runoff of 76.66 mm compared to other months. Besides, it was also observed that in July and October months less amount of runoff was recorded. Further, the hydrographs had also revealed that, the time to peak varied from 26 min to 72 min which is due to change in rainfall intensity, AMC of soil and management practices.

Besides, it was also observed that during early season of monsoon in the month of July discharge was low, the reason for this variation in average discharge and time to peak from event to event was due to low intensity of rainfall along with low AMC of soil. The rainfall occurred in July was captured completely by the watershed by increasing the soil moisture content and recharging the groundwater. Once the soil storage and deep storage compartments were filled, the rainfall was sufficient to generate a surplus flow from the watershed area which was particularly occurred in September and October months. Low value for time to peak 30 min could also be attributed to the fact that, geomorphologically the watershed is small and the outlet receives discharge simultaneously from all parts of the watershed. Rainfall is the most important factor which affects the runoff and intensity of rainfall also influences the low value of time to peak. Changes in rainfall can significantly change the runoff either a decrease or increase of runoff.

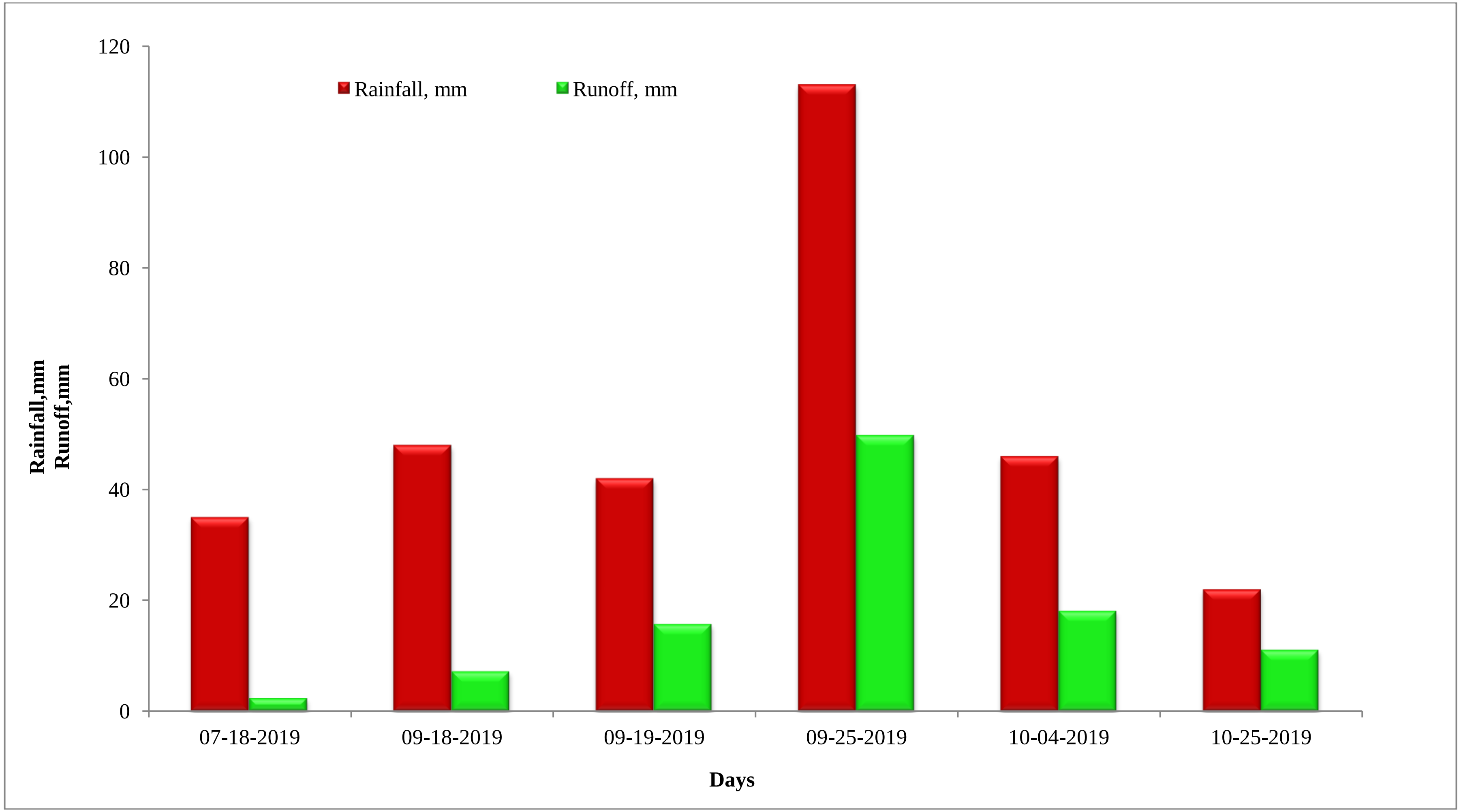

Fig. 11. Measured runoff and rainfall during study period

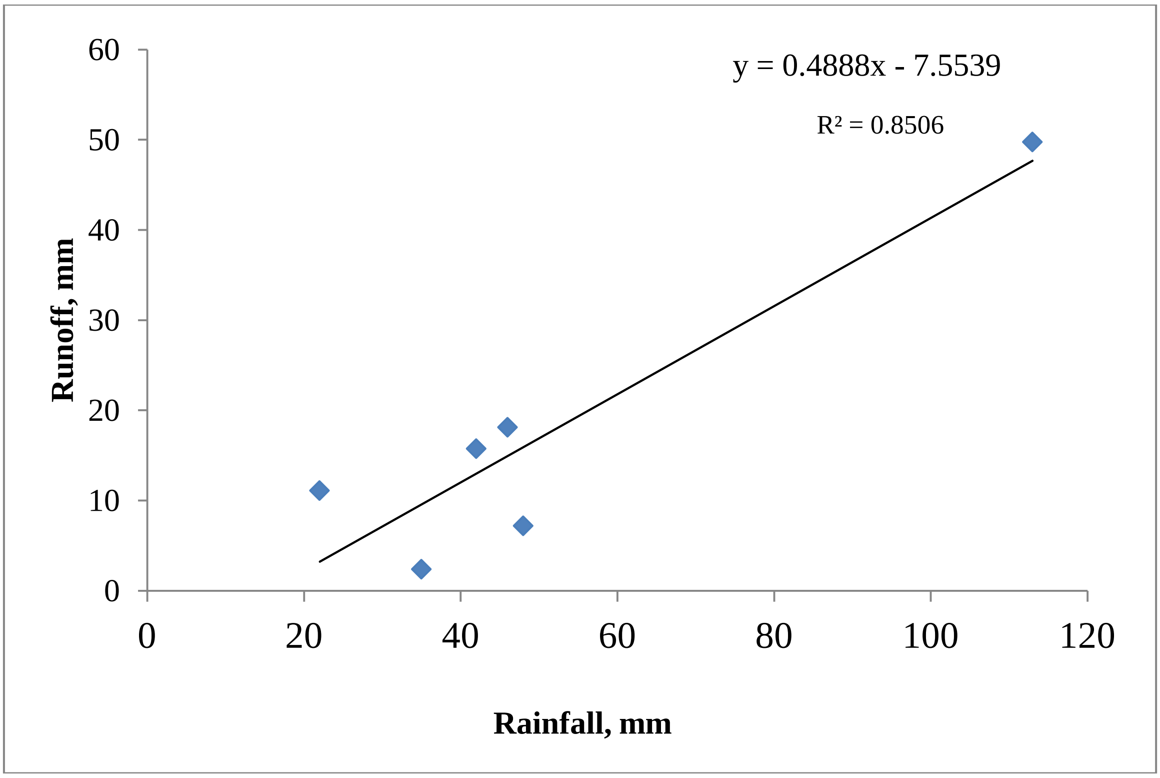

Fig. 12. Scatter plot of measured runoff and rainfall during study period

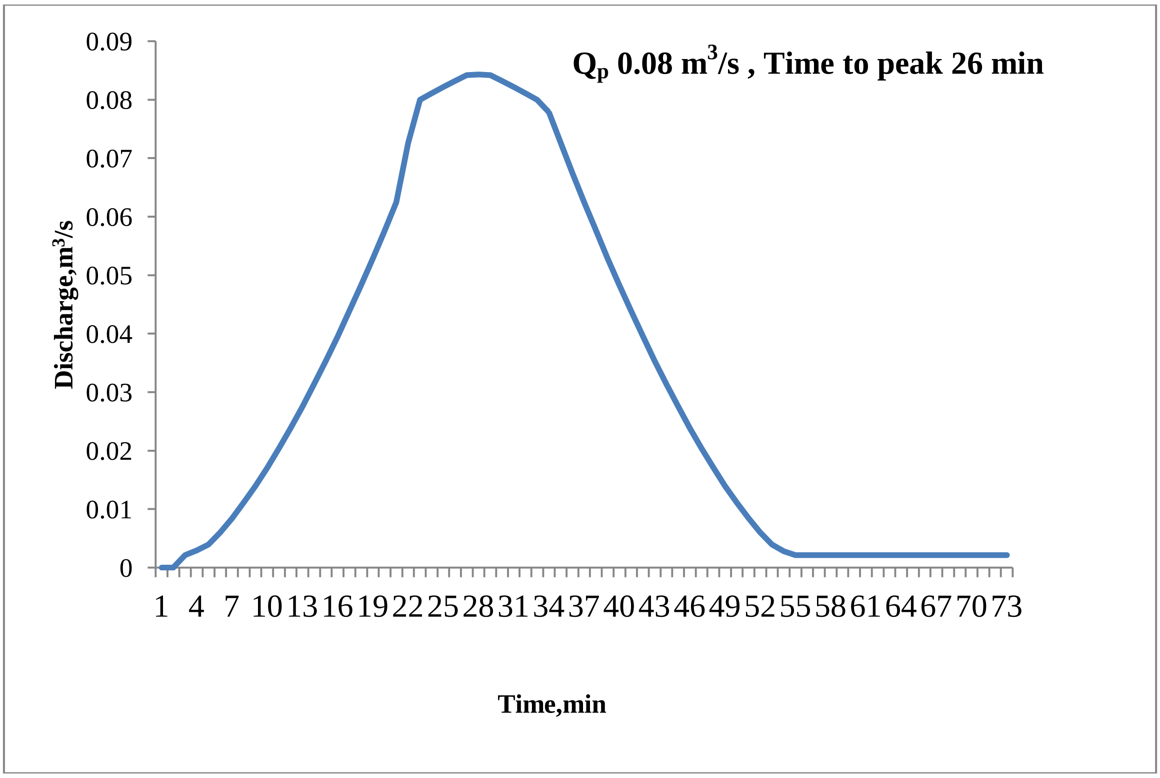

Fig. 13a. Measured runoff hydrograph generated on 18/07/2019

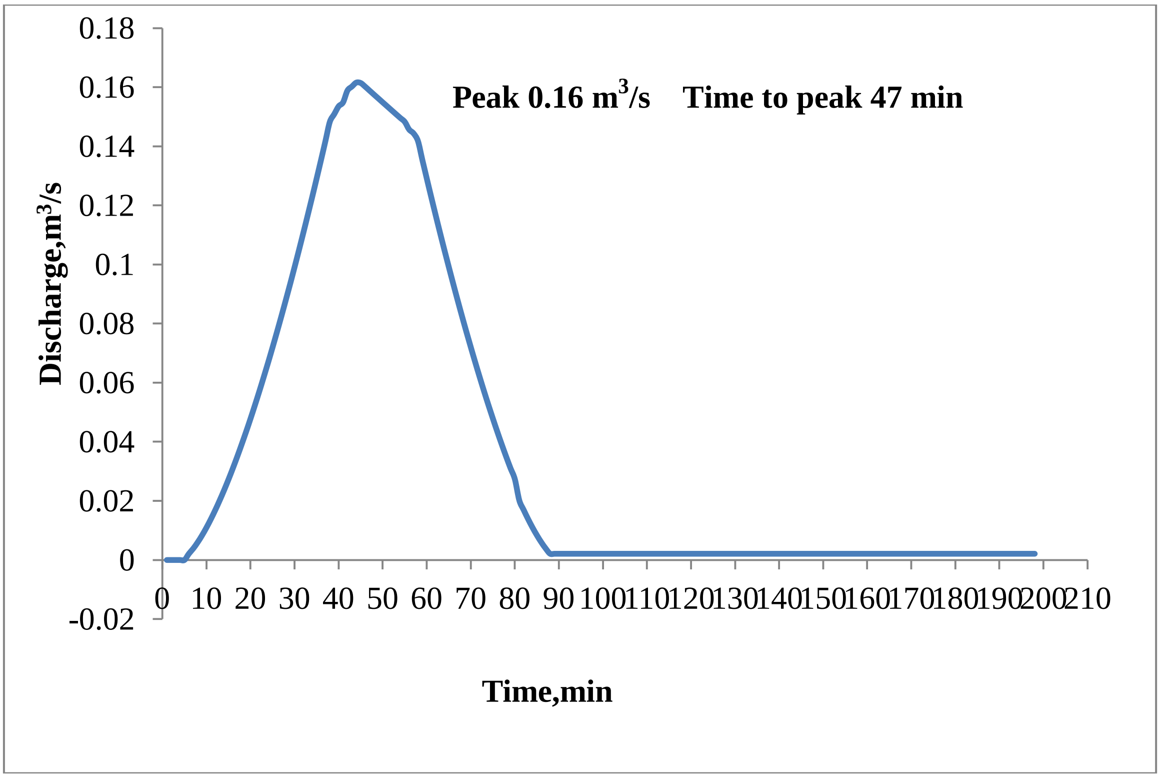

Fig. 13b. Measured runoff hydrograph generated on 18/09/2019

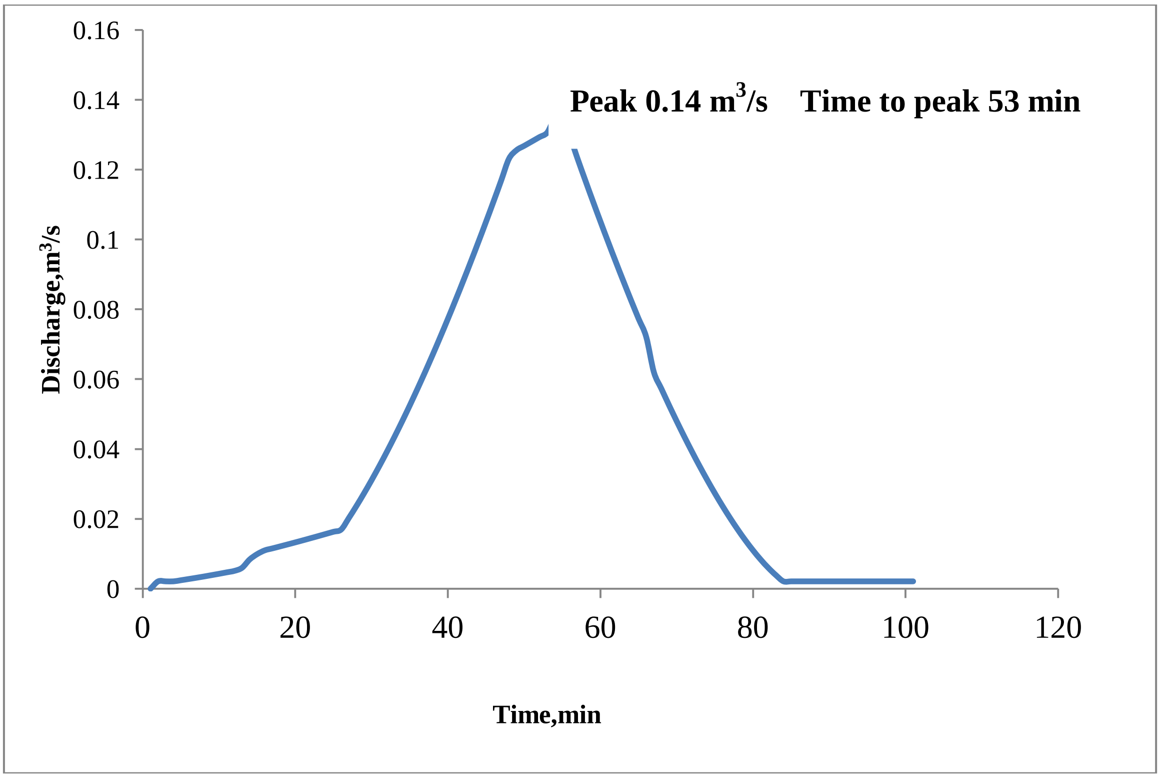

Fig. 13c. Measured runoff hydrograph generated on 19/09/2019

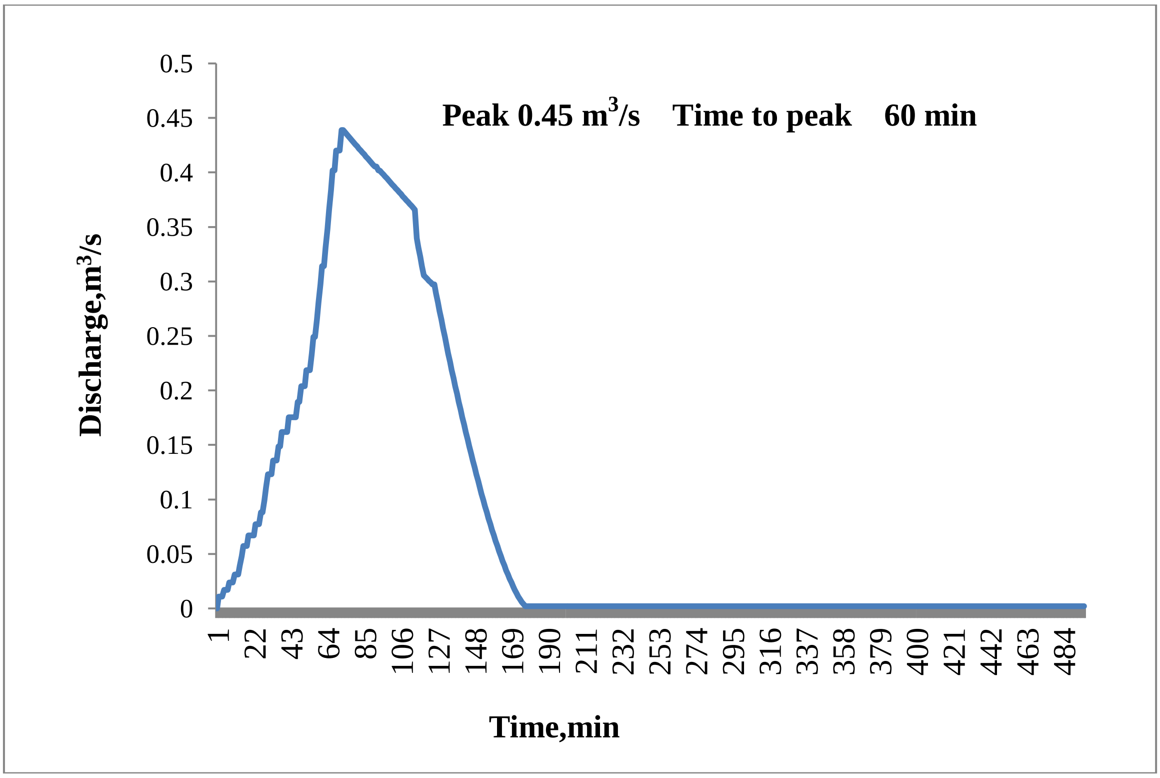

Fig. 13d. Measured runoff hydrograph generated on 25/09/2019

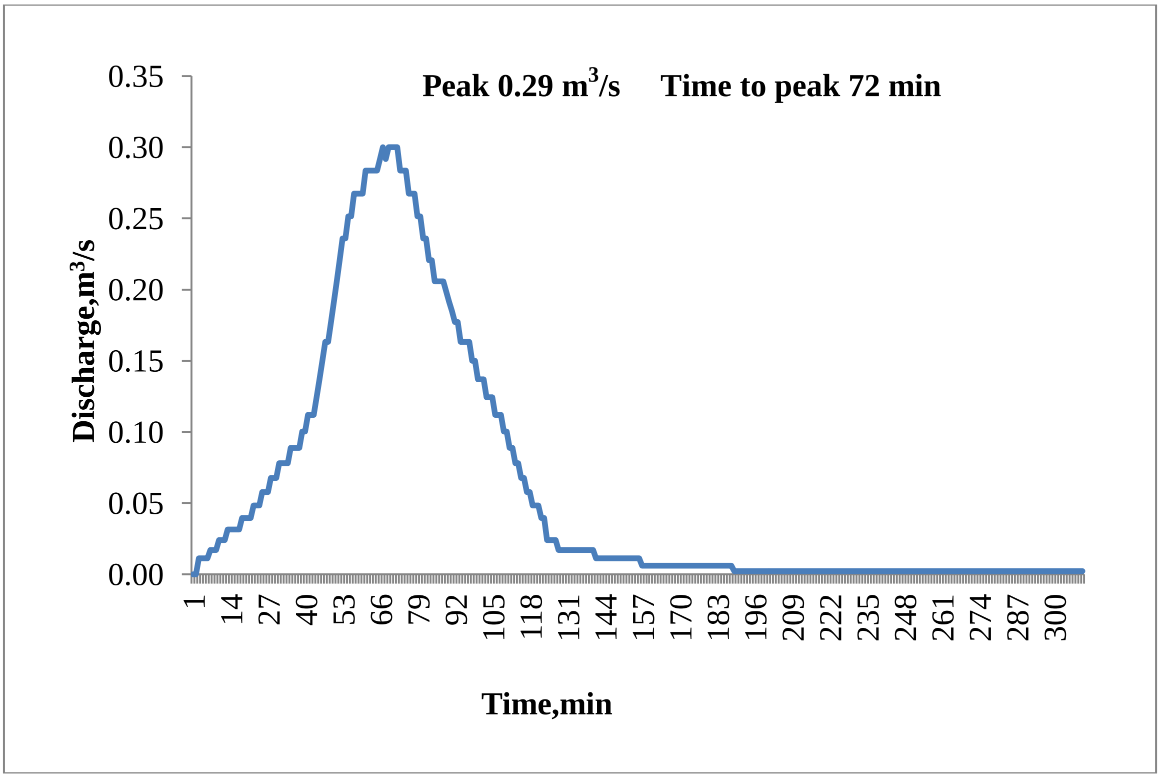

Fig. 13e. Measured runoff hydrograph generated on 04/10/2019

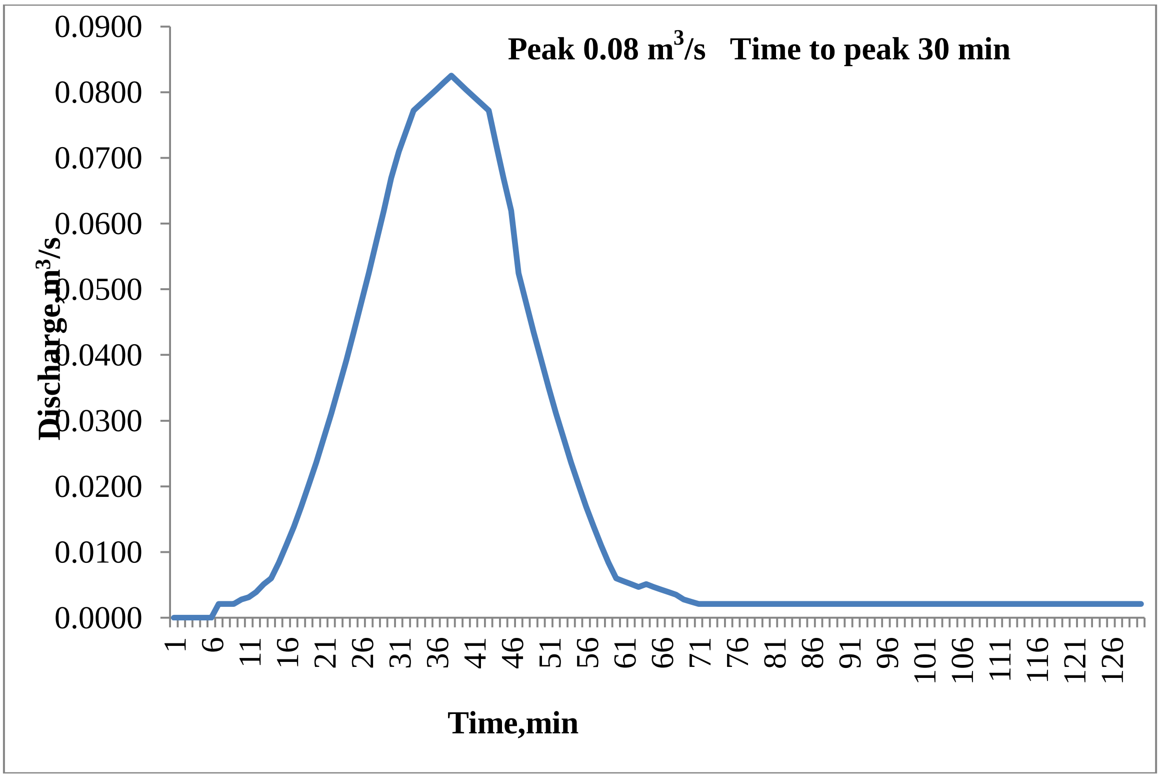

Fig. 13f. Measured runoff hydrograph generated on 25/10/2019

During the present investigation, low amount of runoff was occurred in the month of July because during these periods the soil moisture in the soil profile is not full, the early season runoff is low and most of the runoff occurs during the months of September and October when the soil profile is adequately full.

The contribution of a few big runoff events to annual runoff recorded from study area are quite high. A close examination of the individual runoff events during 2019 reveals that, 1-2 big runoff events which were occurred in the month of September and October accounts for more than 65 per cent of the annual runoff.

3.3.2 Rainfall intensity-runoff relationship of the study area during study period

The intensity of rainfall for each event was obtained using self-recording rain gauge. The rain gauge charts were analysed and calculated the intensity of rainfall. The rainfall mass curve has been divided into sub events within a storm event based on continuous duration of rainfall and its intermittent change in intensity is shown in the Table 7. The rainfall intensity was monitored from 1-09-2019 to 28-10-2019 and there have been total 17 numbers of events with varying rainfall intensities. Out of which only six runoff causing events were occurred and selected for interpretation of rainfall runoff relationship. The minimum average intensity of rainfall 18.73 mm/hr was observed on 25-10-2019 and maximum average intensity was 21.63 mm/hr was noticed on 18-09-2019. Similarly, maximum intensity of rainfall ranged from 19.70 mm/hr to 41.10 mm/hr which were reordered on 4-10-2019 to 25-09-2019 respectively.

The relationship between maximum intensity of rainfall and runoff was shown by scatter plot in the Fig. 14. The maximum intensity of rainfall and runoff during six events were showed statistically insignificant relationship with R^2 value of 0.370. There is no correlation between intensity of rainfall and runoff.

Investigations of the rainfall events with higher weighted mean rainfall intensities indicated that these big runoff events were not necessarily those with highest rainfall intensities, but those with large amounts of total rainfall, particularly when received while the soils were saturated from the previous rainfalls. This suggests that proper management of big effectively controlling the runoff on semi-arid tropics soil types.

Similar results obtained by Camacho et al. 2015 here observed events 1 and 4 had the largest contributions of direct runoff among the four events, accounting 29 per cent runoff in the case of event 1 and up to 36 per cent for event 4. Event 2 and 3 had lower direct runoff generation ranging from 5 to 13 per cent event 2 and 2 to 12 per cent for event 3. However, for Raichur region it was observed that event 1 and 2 had low runoff generation 6.79 per cent (2.37 mm) and 14.95 per cent (7.18 mm) respectively. Event 4 had high runoff generation 44 .03 per cent (49.75 mm).

Strongly affected by variation in runoff volume which in turn due to rainfall intensity. The crop cover management practices in the study area also affected the sediment yield as it varied from month to month and year to year. In the present study the red gram crop was grown and it had affected the sediment yield especially during September and October months.

Similar results were found by Premanand [15], it revealed that there are about 15 runoff events occurred during calibration period (2012-2014) and 7 runoff events during validation period (2015-2016). During calibration period sediment yield varied from 0.023 to 0.554 t/ha with a corresponding runoff volume of 28185.79 m^3 and 199492.50 m^3 respectively, conducted at Patapur micro-watershed. However, during validation

Table 7. Event wise rainfall intensities and runoff generated during 2019-20

Sl. No.	Date of event	Rainfall (mm)	Average rainfall intensity (mm/hr)	Max rainfall intensity (mm/hr)	Runoff (mm)	Remarks
1	18-07-2019	35	19.93	28.00	2.37	Medium intensity
2	18-09-2019	48	21.63	26.00	7.18	Medium intensity
3	19-09-2019	42	20.00	20.00	15.73	High intensity
4	25-09-2019	113	18.73	41.10	49.75	Medium intensity
5	04-10-2019	46	19.70	19.70	18.11	Medium intensity
6	25-10-2019	22	19.00	33.10	11.09	Low intensity

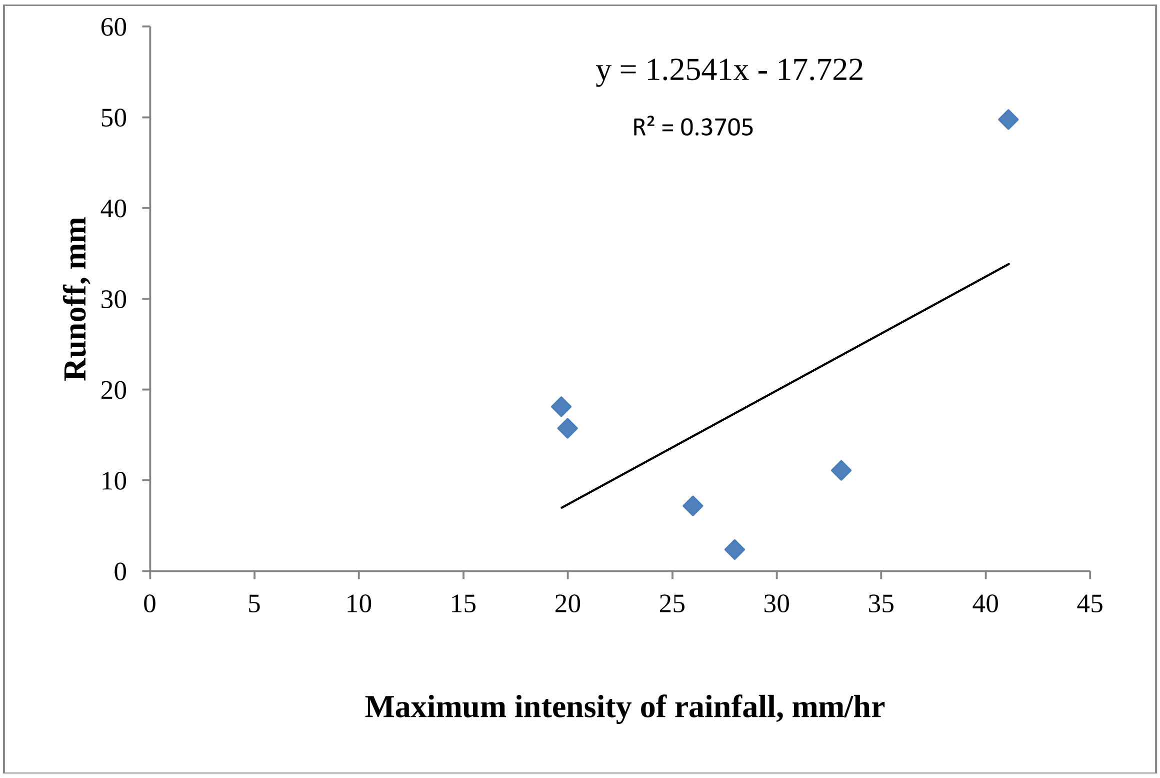

Fig. 14. Scatter plot of maximum intensity of rainfall and measured runoff during 2019

period the day wise sediment yield varied from 0.054 to 0.878 t/ha against runoff volume of 37767.55 m^3 and 41350.65 m^3, respectively and Pathak et al. [16] who found that mean annual rainfall, runoff for Alfisols were 890 mm, 199.70 mm and 0.21m^3 s^{-1} ha^{-1} and 4.76 t/ha, respectively at the ICRISAT centre, Patancheru, AP, India. Where as in the present study sediment yield varied from 0.096 to 0.056 t/ha with a corresponding runoff volume of 142.66 to 665.62 m^3 [17-19].

4. CONCLUSION

The study well developed to characterize soil, topography, rainfall characteristic and also storm wise runoff behaviour in the catchment area. Rainwater harvesting either runoff collection from a catchment area upslope or through conservation of rainfall where it falls in the cropped area or pasture has received growing attention in rainfed systems. The storm wise high runoff percent was due to the fact that high intensity of rainfall followed by high AMC in the soil. The maximum intensity of rainfall and runoff during six events were revealed statistically insignificant relationship with R2 value of 0.370. There is no relationship between intensity of rainfall and runoff.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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