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ESTIMATING RAINFALL – RUNOFF RELATIONSHIP BY USING SCS CURVE NUMBER METHOD OF RAINFED REWA DISTRICT

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ABSTRACT
Rainfall is an important factor influencing the environment of society, forest and optimum growth of agriculture and vegetation. Rainfall and runoff are important components contributing significantly to the hydrological cycle, design of hydrological structures and morphology of the drainage system. Estimation of the same is carried out to determine and forecast its effects. Direct runoff in a catchment depends on soil type, land cover and rainfall. Of the many methods available for estimating runoff from rainfall, the curve number method (SCS-CN) is the most popular. The curve number depends upon soil and land use characteristics. Understanding the basic relationships between rainfall, runoff and soil loss are studied for effective management and utilization of water resources and soil conservation planning. Curve Number (CN) method is also a widely used method for estimating infiltration characteristics of the watershed, based on the land use property and soil property. This study was carried out in Khuthulia farm located in Rewa district of Madhya Pradesh. Curve numbers are assigned for different land cover and soil types. In present study 10 years period, July (364.7 mm) and August (291.7 mm) months recorded maximum rainfall and the runoff varies from 61.38 mm to 791.34 mm of the study area. The correlation coefficients for daily, monthly and yearly runoff are 0.862, 0.973 and 0.952 respectively.

KEYWORDS: Rainfall, Runoff, Curve number.

INTRODUCTION

Rainfall is a common term for the precipitation, which has been defined as “the depositing of water from the atmosphere on to the surface. This deposit may be in the form of solid or liquids” (Wiesner, 1970) , The liquid water is characterizing drops having more than 0.5mm diameter with a intensity of 1.25mm.. According to Navarra (1979), the rainfall is usually related with “the amount of precipitation of any type usually taken as that amount which is measured by means of a rain gauge thus a small varying amount of direct condensation is included”. Sharma and Sharma (1996) have considered the precipitation as the total supply of water derived from the atmosphere in the form of rain, snow, mist, frost, hail, sleet and others, which is of particular concern to man and agriculture. The amount of rain that reaches to earth surface is expressed in millimeter (mm), centimeter (cm), or inch depth of water over an area. The daily rainfall pertains to the rainfall from 08.30 hrs of previous day to 08.30 hrs IST of date. Rainfall differs from; place to place and year to year. Variation in rainfall is due to the difference in seasonal temperatures (Raghunath, 2007). Rainfall is highly correlated with air, temperature and atmospheric humidity, and is closely affected by temperature through the process of evaporation. If the evaporation is higher than the annual rainfall is also very high. The rainfall amount and frequency depend upon the time period and space (Singh, 2010). Runoff is one of the most important hydrologic variables used in most of the water resources applications. Its occur-rence and quantity are dependent on the characteristics of rainfall event, *i.e*. the intensity, duration and distribution. Apart from these rainfall characteristics, there are number of catchment specific factors, which have a direct effect on the occurrence and volume of runoff. This includes soil type, vegetation cover, slope and catchment type. SCS-CN provides an empirical relationship for estimating initial abstraction and runoff as a function of soil type and land-use. Curve Number (CN) is an index developed by the Natural Resource Conservation Service (NRCS), to represent the potential for storm water runoff within a drainage area. The CN for a drainage basin is estimated using a combination of land use, soil, and antecedent soil moisture condition (AMC). There are four hydrologic soil groups: A, B, C and D. Group A have high in-filtration rates and group D have low infiltration rates. The Soil Conservation Service Curve Number (SCS-CN) method is widely used for predicting direct runoff volume for a given rainfall event. This method was originally developed by the US Department of Agriculture, Soil Conservation Service and documented in detail in the National Engineering Handbook, Sect. 4: Hydrology (NEH-4) SCS, 1956, 1964, 1971, 1985, 1993). Due to its simplicity, it soon became one of the most popular techniques among the engineers and the practitioners, mainly for small catchment hydrology. The main reasons for its success is that it accounts for many of the factors affecting runoff generation including soil type, land use and treatment,

surface condition, and antecedent moisture condition, incorporating them in a single CN parameter. Furthermore, it is the only methodology that features readily grasped and reasonably well documented environmental inputs and it is a well-established method, widely accepted for use in the United States and other countries.

On the other hand, the SCS-CN main weak points are the following: it does not consider the impact of rainfall intensity and its temporal distribution, it does not address the effects of spatial scale, it is highly sensitive to changes in values of its sole parameter; and it does not address clearly the effect of adjacent moisture condition.

Study Area

Rewa is the city and division of India 's Madhya Pradesh province. It is a major town located 131km south of Allahabad city. This city produces a part of the Vindhya plateau of Madhya Pradesh province and is tones, bihad, irrigated by river Beecha and its help rivers. Uttar Pradesh state in its north, Satna in the west and Sidhi district in east and south. Its area is 2,509 square miles. It was a big principality earlier. The inhabitants of the Gond and Cole people also live in the mountainous areas. In the district there is excess of forests, from which millions, wood and wild animals are received. White tiger breeds have been found in Rewa forests only. The main produce of the district is paddy. The historic fort of Bandhgarh is in the jungle called Tala in the district.

The former Rewa kingdom was established in about 1400 AD by Baghel Rajputs. After the demolition of Bandhavgarh by Mughal Emperor Akbar, Rewa became important and in 1597 AD, it was elected as the capital of the former Rewa kingdom. In 1812 AD, the local ruler here conferred with British authority and handed over his sovereignty to the British. The city was also the capital of the British Baghelkhand Agency.

METHODOLOGY

The Soil Conservation Service (SCS) curve number method developed by United States Department of Agriculture (USDA) computes direct runoff through an empirical equation that requires the rainfall and a watershed coefficient as inputs. The watershed coefficient is called as the curve number (CN), which represents the runoff potential of the land cover soil complex. This involves relationship between land cover, hydrologic soil class and curve number. The method is based on an assumption of proportionality between retention and runoff in the form. Normally the SCS CN method computes direct runoff with the help of following relationship (Hand book of Hy-drology, 1972)

$$S = (24500/CN) - 254 \quad \text{---------- (1)}$$

$$Q = ((P - 0.3S)^2)/(P + 0.7S) \quad \text{---------- --- (2)}$$

$$\text{Where, } CN = (\Sigma (Ci * Ai))/A \quad \text{---------- (3)}$$

Where,

CN = weighted curve number.

CNi = curve number from 1 to any no. N.

Ai = area with curve number CNi

where CN is the runoff curve number of hydrologic soil cover complex, which is a function of soil type (In this case silty clay loam soil and hydrologic soil group is D), land cover and antecedent moisture condition (AMC); Q, actual direct runoff, mm; P, total storm rainfall, mm; and S, the potential maximum re-tention of water by the soil, mm.

TABLE 1. Runoff Curve Numbers for (AMC II) for the Indian Conditions

Sl No.	Landuse	Treatment/practice	Hydrologic condition	Hydrologic soil group			
				A	B	C	D
1	Cultivated	Straight row	------	76	80	90	93
		Contoured	Poor	70	79	84	88
			Good	65	75	82	86
		Contoured and terraced	Poor	66	74	80	82
			Good	62	71	77	81
		Bunded	Poor	67	75	81	83
			Good	59	69	76	79
		Paddy (rice)	------	95	95	95	95
2	Orchards	With under stony cover	------	39	53	67	71
		Without under stony cover	------	41	55	69	73
3	Forest	Dense	------	26	40	58	61
		Open		28	44	60	64
		Shurbs		33	47	64	67
4	Pasture		Poor	68	79	86	89
			Fair	49	69	79	84
			Good	39	61	74	80
5	Waste Land	-------	------	71	80	85	88
6	Hard Surface	-------	------	77	86	91	93

Curve Number: The USDA curve number Table No 1 (Tripathi, 1999) modified for Indian conditions was used for the determination of the curve number for individual sub watersheds based on the hydrological soil groups and land use classes of respective areas. The weighted CN_2 (AMCII) values for Row crops and straight row good type is 89. Equivalent curve numbers (CN) can be computed by using the following Eqs. 4 and 5.

AMC Group	Soil Characteristics	Five day antecedent rainfall	
		Dormant season	Growing Season
I	Wet condition	Less than 13	Less than 36
II	Average condition	13-28	36-53
III	Heavy rainfall	Over 28	Over 53

2). The following equations are used in the cases of AMC-I and AMC- III (Chow *et al.* 2002):

$$CN(I) = \frac{CN(II)}{2.281 - 0.0128\,CN\,(II)} \quad (4)$$

$$CN(III) = \frac{CN(II)}{0.427 + 0.00573\,CN\,(II)} \quad (5)$$

where, *(II) CN* is the curve number for normal condition, (I) *CN* is the curve number.

For dry condition, and (III) *CN* is the curve number for wet conditions.

Estimation of runoff using Curve Number technique

The Soil Conservation Service (SCS) Curve Number method is used for estimating the runoff from the recorded rainfall data of the area. The values of curve number were determined from the standard table 1 for AMC-II as 89 for straight raw crop. By using this curve number, weighted curve numbers were calculated as AMC-I 78.07 and AMC-III 94.34. Using the value of curve number (CN), the maximum potential retention (S) was calculated. By considering antecedent moisture condition of previous five days rainfall, maximum potential retention and rainfall data, the one day runoff was calculated using one day rainfall data.

Rainfall and runoff relationship

Relationship was developed by plotting the rainfall (P) and corresponding calculated or observed runoff (R) data and drawing best fit curve. More authentic method is drawing the best fit "linear regression line" between runoff and rainfall, which gives accurate estimate when correlation coefficient between them is 1.0. The form of linear regression equation between R and P is given as,

R = a P + b (6)

Where, a and b are the regression coefficients.

The value of correlation coefficient (r) lying between 0.6 < r < 1.0 indicates a good correlation between the variables.

RESULTS AND DISCUSSION

Runoff was estimated by using SCS-CN Method and was analyzed further on daily, monthly and yearly basis. The same was inserted in tabular form and histograms of it were prepared for interpretation. Further graphs were prepared showing linear variation of rainfall-runoff, based on this correlation coefficients were obtained. (Figure 1, 2, 4 & 6).

In the figure shown below on X axis it represents 10 years rainfall data starting from 2008 to 2017 of Rewa district under which the respective Kuthulia catchment falls and on Y axis is the respective rainfall-runoff in mm and same as in June month of respective 10 years (Figure 3 & 5).

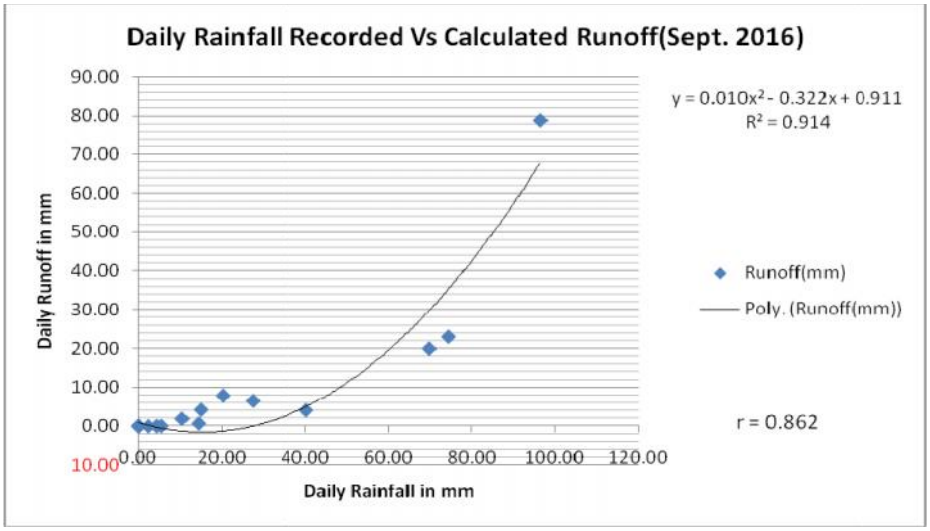

FIGURE 1: Correlation coefficient for Daily Rainfall-Runoff series

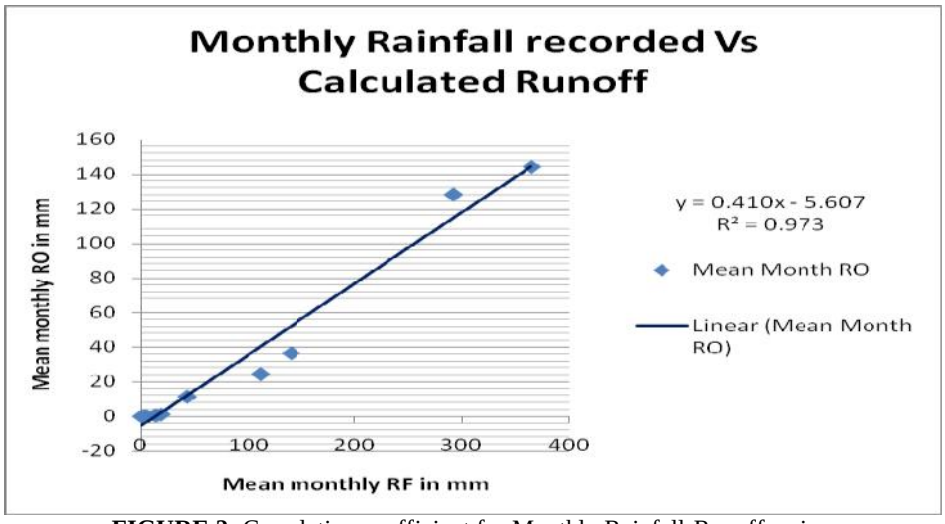

FIGURE 2: Correlation coefficient for Monthly Rainfall-Runoff series

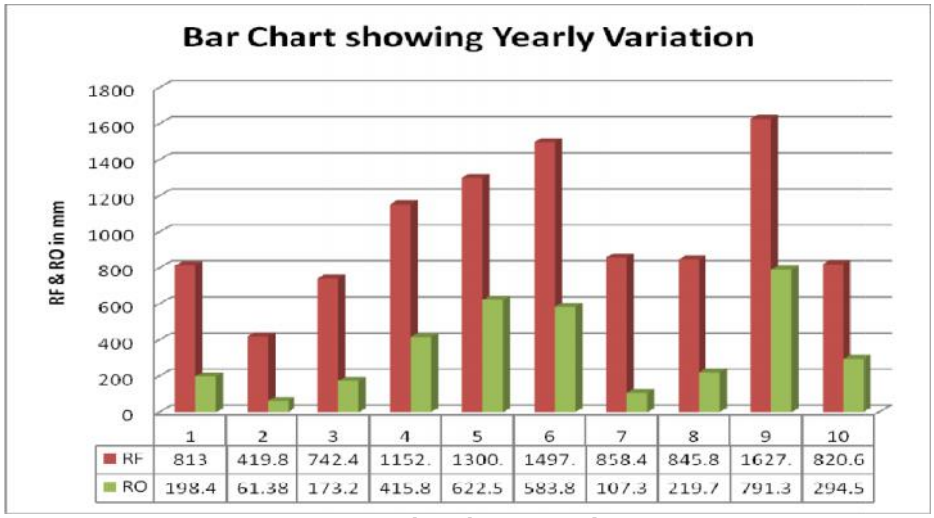

FIGURE 3: Bar Chart showing yearly variation

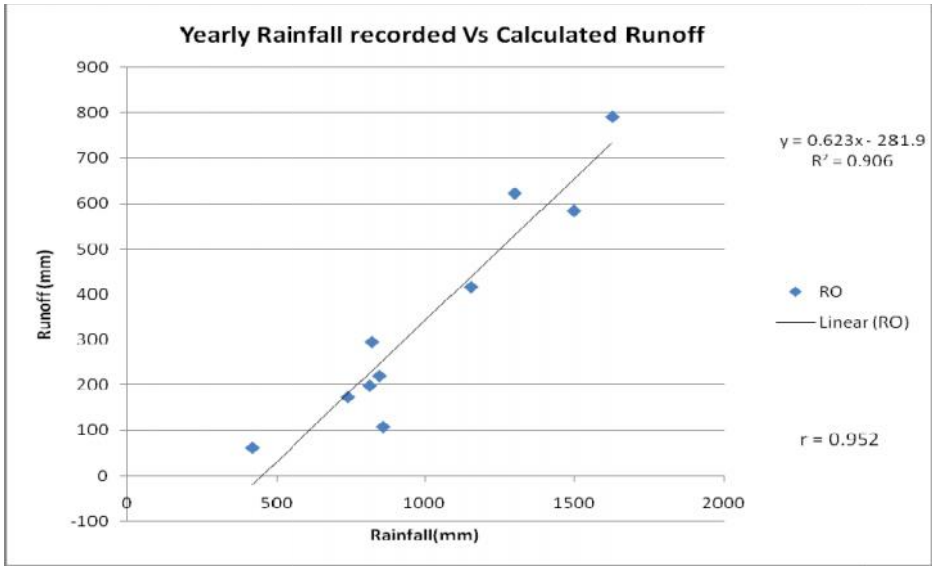

FIGURE 4: Correlation coefficient for yearly rainfall-runoff series

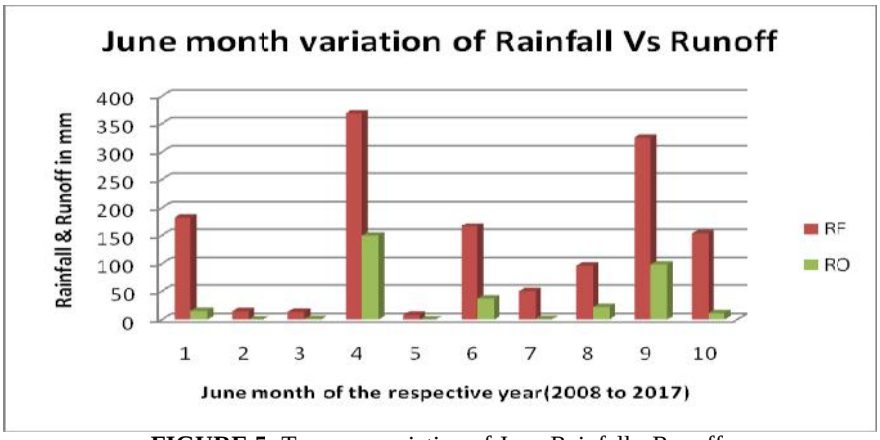

FIGURE 5: Ten year variation of June Rainfall - Runoff

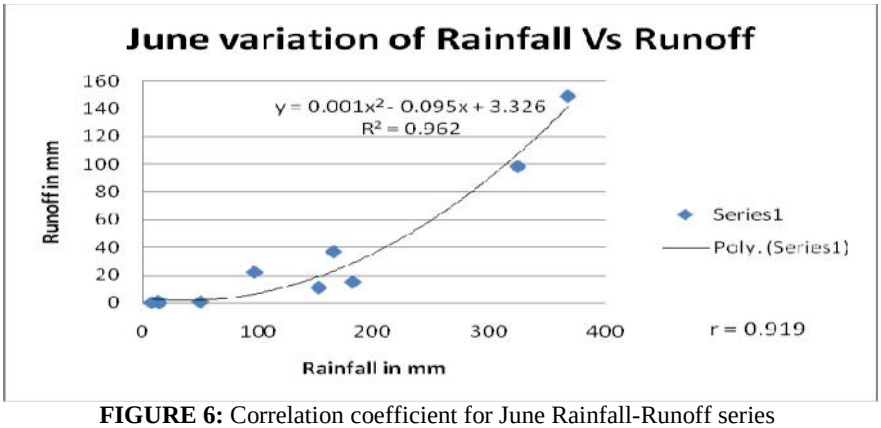

FIGURE 6: Correlation coefficient for June Rainfall-Runoff series

CONCLUSION

Based on the studies carried out for, Khuthulia catchment, Rewa District, The following conclusions are made.

1. The trend of daily rainfall in the catchment area is studied for a period of 10 years *i.e.*, from 2008 to 2017. The highest monthly rainfall recorded was 752.60 mm in the month of August 2016 and the highest yearly rainfall recorded was 1627.4 mm in the year 2016. In the above 10 years period, July (364.7 mm) and August (291.7 mm) months recorded maximum rainfall. The rainfall shows fluctuating nature during the ten years.
2. The runoff for the study area is calculated using SCS-method for a period of 10 years *i.e.*, 2008-2017. The calculated yearly runoff in mm for the years from 2008 to 2017 is 198.42, 61.38, 173.27, 415.84, 622.56, 583.84, 107.32, 219.71, 791.34 and 294.57 mm respectively.
3. The monthly runoff and yearly runoff is calculated for the period of 10 years using SCS-CN method. Mini-mum runoff 61.38 mm was observed in the year 2009 and maximum runoff was791.34 observed in the year 2016 by using SCS-CN method.
4. The correlation coefficients for daily, monthly and yearly runoff are 0.862, 0.973 and 0.952 respectively. The graph for the yearly runoff is best fitted than daily and monthly runoff.

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