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Estimation of Yield by Soil Conservation Service Curve Number Model for Gulakamale watershed

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ABSTRACT
Accurate estimation of runoff and sediment yield amount is not only an important task in physiographic characteristics but also important for proper watershed management. Watershed is an ideal unit for planning and management of land and water resources. 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 (CN) method (soil conservation service CN [SCS-CN]) is the most popular. The CN depends on soil and land use characteristics. This study was conducted in the Gulakamale watershed using remote sensing and geographic information system (GIS). The soil map and land use were created in the GIS environment because the CN method is used here as a distributed model. The major advantage of employing GIS in rainfall-runoff modeling is that more accurate sizing and catchment characterization can be achieved. Furthermore, the analysis can be performed much faster, especially when there is a complex mix of land use classes and different soil types. The results showed that the surface runoff ranged from 7.63 mm to 361.73 mm in the study area when rainfall rates were received from 438.40 mm to 1604 mm. To find the relationship between rainfall and runoff rates, the straight-line equation was used. That was found that there was a strong correlation between runoff and precipitation rates. The value correlation coefficient between them was 82%.

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I. INTRODUCTION

Runoff means the drainage of flowing off of precipitation from a catchment area through a surface channel. Thus, it represents the output from the catchment in a given unit of time. To determine the quantity of surface runoff that takes place in any river basin, understanding of complex rainfall and runoff processes which depends upon many geomorphologic and climatic factors are necessary. Estimation of surface runoff is essential for the assessment of water yield potential of the watershed, planning of water conservation measures, recharging the ground water zones and reducing the sedimentation and flooding hazards downstream. Also it is an important and essential prerequisite of Integrated Watershed Management (IWM). Runoff is one of the most important hydrologic variables used in most of the water resources applications. Reliable prediction of quantity and rate of runoff from land surface into streams and rivers is difficult and time consuming to obtain for ungauged watersheds, however, this information is needed in dealing with many watershed development and management problems. Conventional methods for prediction of river discharge require hydrological and metrological data. Experience has shown that SOI topo maps data can be interpreted to derive thematic informations on land use/land cover, soil, vegetation, drainage, etc. which combined with conventionally measured climatic parameters (precipitation, temperature etc) and topographic parameters such as height, contour, slope provide the necessary inputs to the rainfall-runoff models.

II. MATERIALS AND METHODS

Study Area

The study area chosen is Gulakamale watershed which lies in Bangalore district. The culvert with its longitude of 77^0 31’ 50.07” E and latitude of 12^0 47’ 50.07” N is situated over the two-lane district highway road near Kaggalipura village. The nearest national highway passing through to the watershed is NH 209. The location map shown in Figure. 1, indicates some of the salient features in the vicinity of Gulakamale watershed.

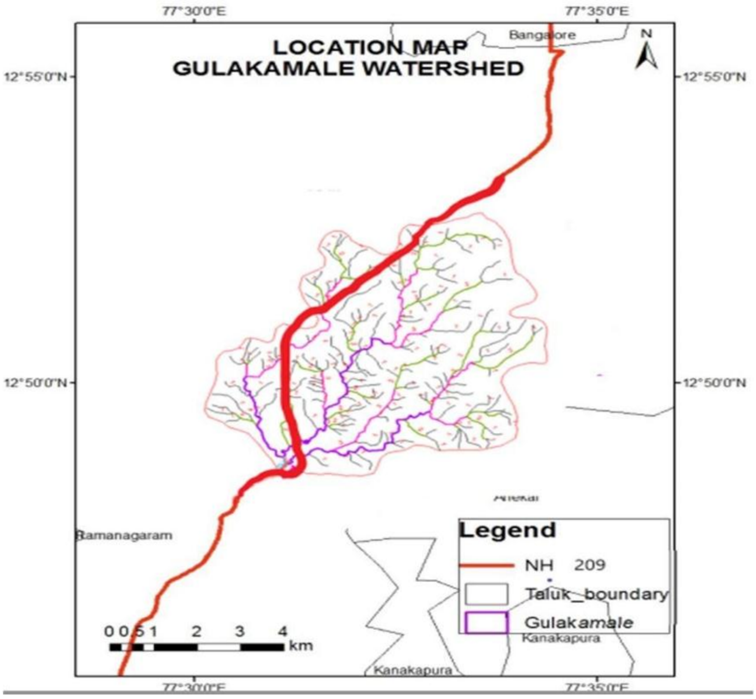

Figure 1: Location of Gulakamale watershed

III. METHODOLOGY

In this model, runoff will be determined as a function of current soil moisture content, static soil conditions, and management practices. Runoff is deduced from the water available to enter the soil prior to infiltration. Figure.2 shows the methodology adopted for runoff estimation using SCS curve number method. The SCS curve number method is developed from many years of stream flow records for agricultural watersheds in several parts of the United States. The method is also called hydrologic soil cover complex number method. It is based on the recharge capacity of a watershed. The recharge capacity can be determined by the antecedent moisture contents and by the physical characteristics of the watershed. Basically the curve number is an index that represents the combination of hydrologic soil group and antecedent moisture conditions. The SCS prepared an index, which is called as the runoff Curve Number to represent the combined hydrologic effect of soil, land use and land cover, agriculture class, hydrologic conditions and antecedent soil moisture conditions. These factors can be accessed from soil survey and the site investigations and land use maps, while using the hydrologic model for the design. The specifications of antecedent moisture conditions is often a policy decision that suggest the average watershed conditions rather than recognitions of a hydrologic conditions at a particular time and places.

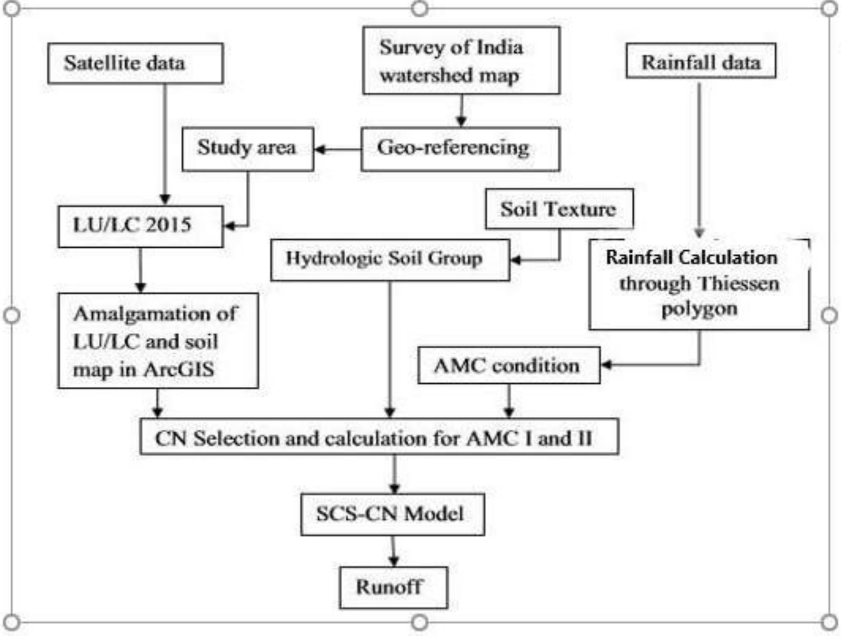

Figure 2: Methodology to estimate rainfall-runoff by SCS-CN method

Expressed mathematically as given,

$$Q = \frac{(P-Ia)^2}{(P-Ia)+S}$$

Where Q is the runoff, P is the precipitation and F is the infiltrations and it is the difference between the potential and accumulated runoff. Ia is beginning abstraction, which represents all the losses before the runoff begins. It include water retained in surface depressions, water intercepted by vegetation, and initial infiltrations. This is variable but generally is correlated with soil and land cover parameter; S is the potential infiltrations after the runoff begins. Thus, a runoff curve numbers is defined to relate the unknown S as a spatially distributed variable are,

$$S = \frac{25400}{CN} - 254$$

Determination of Curve Number (CN)

The SCS cover complex classification consists of three factors: land use, treatment of practice and hydrologic condition. There are approximately eight different land use classes that are identified in the tables for estimating curve number. Cultivated land uses are often subdivided by treatment or practices such as contoured or straight row. This separation reflects the different hydrologic runoff potential that is associated with variation in land treatment. The hydrologic condition reflects the level of land management; it is separated with three classes as poor, fair and good. Not all of the land use classes are separated by treatment or condition. CN values for different land uses, treatment and hydrologic conditions were assigned based on the curve number table. Runoff Curve Numbers for (AMC II) hydrologic soil cover complex is shown in Table 1.

Table 1 Runoff Curve Numbers for (AMC II) hydrologic soil cover complex

Sl No	Land use	Hydrologic Soil Group			
		A	B	C	D
1	Agricultural land without conservation (Kharif)	72	81	88	91
2	Double crop	62	71	88	91
3	Agriculture Plantation	45	53	67	72

4	Land with scrub	36	60	73	79
5	Land without scrub (Stony waste)	45	66	77	83
6	Forest (degraded)	45	66	77	83
7	Forest Plantation	25	55	70	77
8	Grass land/pasture	39	61	74	80
9	Settlement	57	72	81	86
10	Road/railway line	98	98	98	98
11	River/Stream	97	97	97	97
12	Tanks without water	96	96	96	96
13	Tank with water	100	100	100	100

Land use map developed using Topo maps on 1:50,000 scale bearing numbers 57 H/5 and 57 H/9, of Gulakamale watershed, which was collected from Survey of India department shows that there are 15 different types of land use in the study area (Figure 3, Table 2).

Hydrological soil group classification

SCS developed a soil classification system that consists of four groups (Table 4), which are identified as A, B, C, and D according to their minimum infiltration rate. The identification of the particular SCS soil group at a site can be done by one of the following three ways: (i) Soil characteristics, (ii) county soil surveys, and (iii) minimum infiltration rates. Table 2 shows the minimum infiltration rates associated with each soil group. Table 3 shows the spatial distribution of soil textures in the study area. Figure 4 shows the soiltexture map of Gulakamale watershed and there are 9 types of soil texture available in the studyarea.

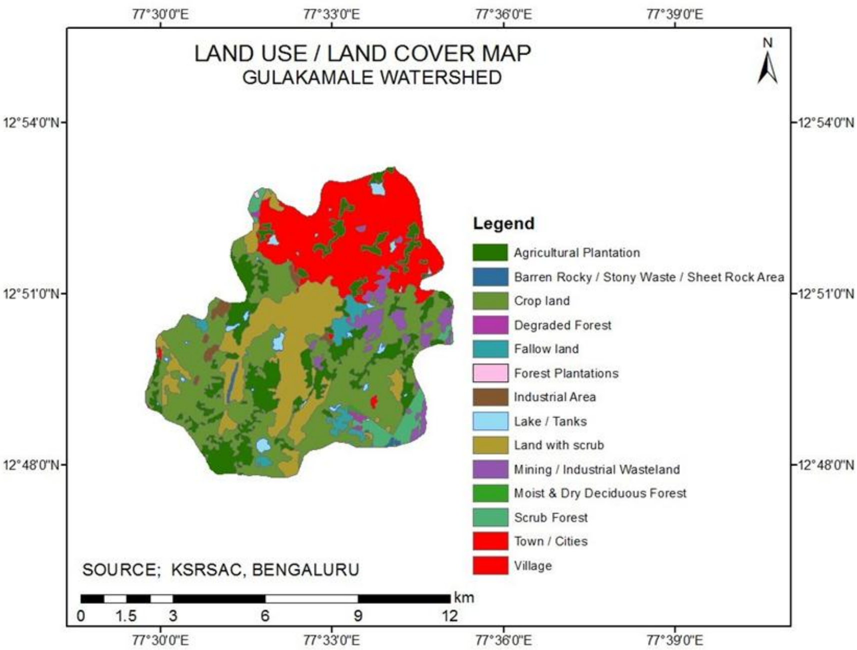

Figure 3: Land use land cover map of the Gulakamale watershed

Table 2: Land use and Land cover description

Sl. No.	Particulars of land use and land cover	Area (sq.km)	% Area
1	Agricultural Plantation	11.025	16.38
2	Barren rocky/stony	0.216	0.32
3	Degraded forest	0.185	0.27
4	Fallow land	1.561	2.32

5	Forest plantations	0.030	0.044
6	Industrial area	0.669	0.990
7	Kharif + Rabi (Double crop)	2.241	3.33
8	Kharif crop	19.352	28.75
9	Lake/Tanks	1.028	1.53
10	Land with scrub	10.885	16.17
11	Mining industrial waste land	3.130	4.65
12	Moist-dry deciduous open forest	0.079	0.12
13	Scrub forest	2.474	3.68
14	Town/cities	14.159	21.03
15	Village	0.220	0.33

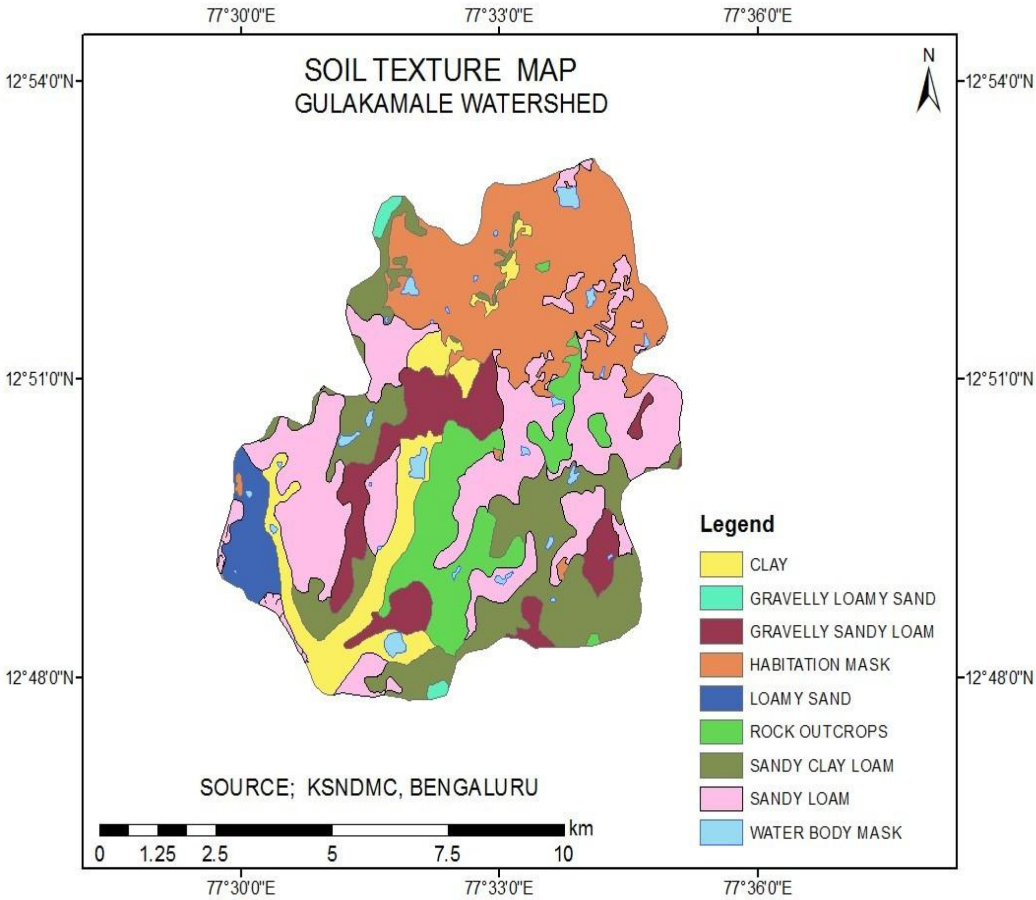

Figure 4: Soil texture map of the Gulakamale watershed

Table 3: Soil texture map of Gulakamale watershed

Sl No.	Soil Texture	Area (sq.km)	Area (%)
1	Clay	5.153	7.66
2	Gravelly loamy sand	0.356	0.53
3	Gravelly sandy loam	6.100	9.06
4	Habitation mask	14.43	21.44
5	Loamy sand	2.053	3.05

6	Rock outcrops	6.184	9.19
7	Sandy clay loam	14.800	21.98
8	Sandy loam	17.201	25.55
9	Waterbody mask	1.028	1.53
Total		**67.313**	**100%**

AMCs

AMC refers to the water content present in the soil at a given time. The AMC value is intended to reflect the effect of infiltration on both the volume and rate of runoff according to the infiltration curve. The SCS developed three antecedent soil moisture conditions and labeled them as I, II, and III. The value of CN is shown for AMC II (Table 5) and for a variety of land uses, soil treatment, or farming practices. The hydrologic condition refers to the state of the vegetation growth. The curve number map of study area is shown in Figure 5. The CN values for AMC-I and AMC-III can be obtained from AMC-II by the method of conservation. The empirical CN1 and CN3 equations for conservation methods are as follows.

$$CN_1 = \frac{CN_2}{2.281 - 0.01281 CN_2}$$

$$CN_3 = \frac{CN_2}{0.427 + 0.00573 CN_2}$$

Table 4 Minimum infiltration rates associated with each soil group

Soil Group	Minimum Infiltration Rate (mm/hr)
A	7.62 - 11.43
B	3.81 - 7.62
C	1.27 - 3.81
D	0 - 1.27

Table 5 Antecedent Moisture Condition (AMCs)

AMC_S	FIVE DAYS ANTECEDENT RAINFALL (mm)	
	Dormant season	Growing season
I	< 12.7 mm	<35.56 mm
II	12.7-27.94 mm	35.56-53.34 mm
III	> 27.94 mm	53.34 mm

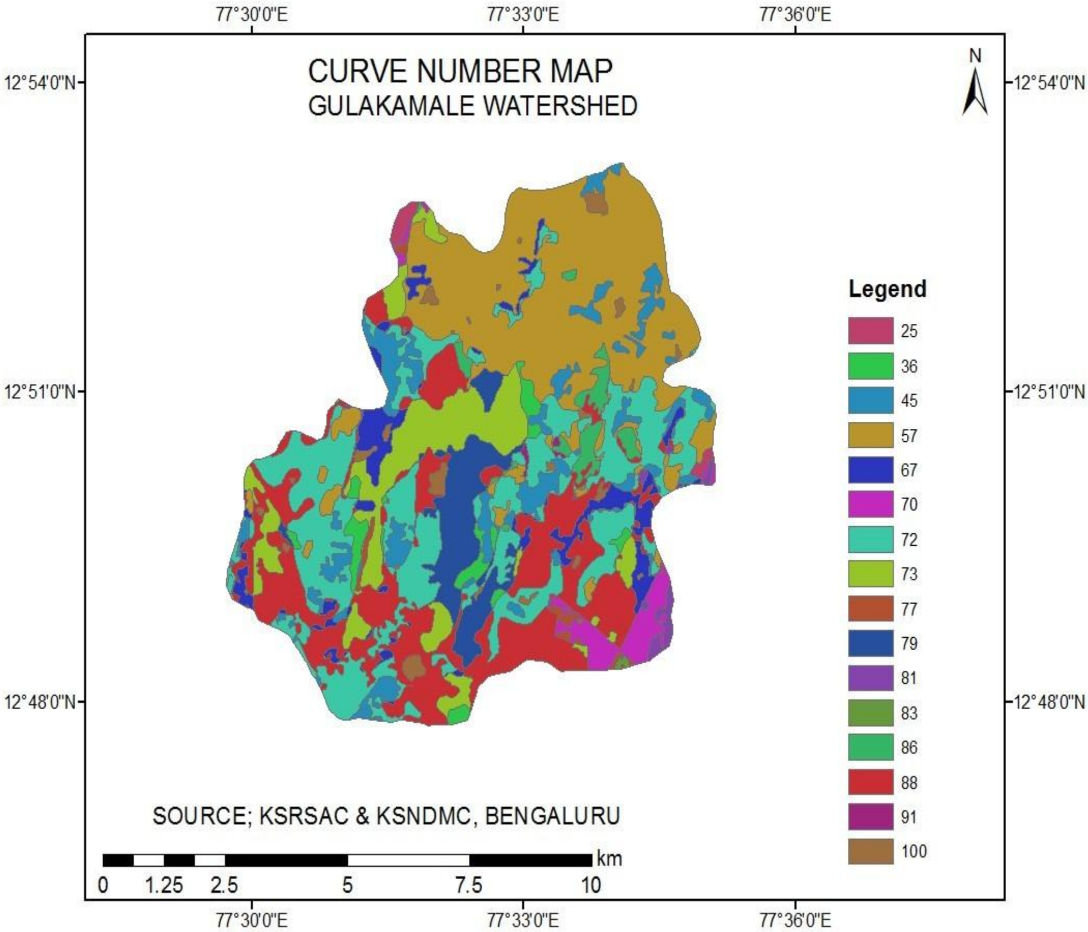

Figure 5: CN map of Gulakamale watershed.

Table 6: Annual Rainfall- Runoff

Period in Years	Rainfall (in mm)	Runoff (in mm)
1980	923.50	194.00
1981	859.70	80.08
1982	595.30	60.93
1983	761.90	30.82
1984	622.50	110.53
1985	524.20	9.12
1986	500.50	67.13
1987	863.90	42.73
1988	1103.30	181.72
1989	738.60	74.79
1990	438.40	7.63
1991	926.60	124.14
1992	508.20	30.49
1993	774.20	54.25
1994	452.60	14.79
1995	548.80	44.15

1996	649.90	85.46
1997	579.00	28.84
1998	951.00	159.22
1999	778.60	62.59
2000	1137.10	199.53
2001	1059.00	186.35
2002	764.00	114.38
2003	727.00	88.43
2004	1145.00	209.82
2005	1604.00	361.73
2006	681.00	69.71
2007	1251.00	229.24
2008	1291.00	238.21
2009	1061.00	249.67
2010	1039.00	137.28
2011	1178.90	172.41
2012	392.70	21.22
2013	681.40	20.48
2014	645.75	44.99
2015	1165.70	126.16

Table 6 shows the calculated runoff values from the NRCS-CN method for a period of 35 years.The maximum annual runoff of 361.73mm occurs in the year 2005 for an annual rainfall of 1604.00 mm and a minimum annual runoff of 7.63 mm occurs in the year 1990 for an annual rainfall of 438.4 mm.

Figure 6 shows how runoff maintains linearity with the rainfall. The value of coefficient of correlation is 0.8224 which shows there is a fairly strong linear dependence between the annualrainfall and runoff. Here we can see in the figure though the rainfall in the year 1983 and 2002 almost same but we get less runoff in 1983 than the 2002 because of the spatial and temporal variability of rainfall, thevariability of antecedent moisture and the associate soil moisture content and the intensity of rainfall also takes main role in the runoff.

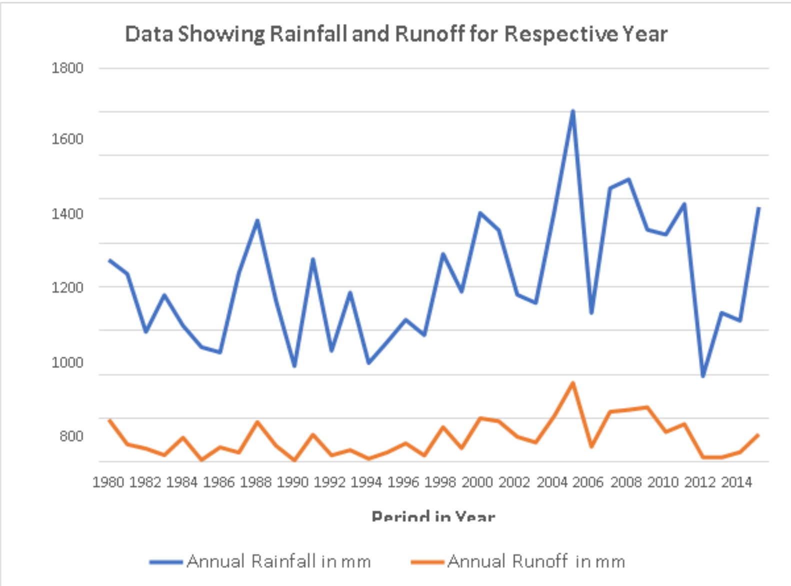

Figure 6: Rainfall verses Runoff Variation

Closure

Surface runoff, the important parameter in the water balance equation, other than rainwater and infiltration (recharging factor to the soil as soil moisture) is necessary for efficient planning and management of the available water. The SCS curve number method uses, minimum data as input, and gives reliable output by using remote sensing and GIS techniques in most efficient way. The purpose of this study was to evaluate the performance of the procedure using land cover database from remotely sensed data. From the Table 6 it is observed that during the year 2005 maximum runoff of 361.73 mm has occurred. It was also observed that the minimum runoff of 7.63 mm has occurred in the year 1990. The values of correlation coefficients are very high as 0.822. Hence, it can be said that there is a strong positive linear dependence between the annual rainfall and annual runoff and it can be observed that in the regression equation as the values of slope increases the runoff generated also increases. The runoff estimation carried out by using SCS curve number method will help in proper planning and management of catchment yield for better planning of river basin as well as for the design of hydraulic structures.

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