Estimation of Surface Runoff Volume in Chamarajanagara District Using SCS-CN Method

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***Abstract*: The amount of rainfall in excess of the infiltrated quantity, which flows over the ground surface, is termed to be "Surface Runoff". In this study we are considering SCS-CN method along with Geographic Information Technique for calculating surface runoff volume. It is the most common method to estimate the runoff which was developed by United States Department of Agriculture (USDA) Soil Conservation Service (SCS, 1985). The Soil Conservation Service (SCS) Curve Number (CN) is the widely used method in applied hydrology in order to find the runoff. It's a conceptual model. SCS-CN method depends on soil type, land use and land cover, surface Antecedent Moisture Conditions (AMC). By this study we get the average surface runoff volume from the year 2009 to 2017 of the study area. The analysis in the study area is carried out watershed wise. There are 17 subwatersheds and surface runoff volume for each subwatershed for the specified years has been calculated. The total surface runoff volume for the study area obtained is 31.64 TMC and peak discharge is 512 m^3/sec.**

***Keywords:* Chamarajanagara District, Subwatersheds, Soil Conservation Service (SCS) Curve Number (CN), surface runoff, rainfall, actual infiltration, potential maximum retention and Peak discharge.**

I. INTRODUCTION

Surface runoff is one of the important hydrological variables used in hydrology. Its occurrence and quantity mainly depends on rainfall events, i.e., its intensity, duration and its distribution. Surface runoff also depends on topological feature, slope, vegetation and depressions in this area. The Soil Conservation Service (SCS) Curve Number (CN) is the widely used method in applied hydrology in order to find the runoff. This method was developed by United States Department of Agriculture (USDA) Soil Conservation Service (SCS, 1985) [1]. It's a conceptual model The SCS-CN method depends on soil type, land use and land cover, surface Antecedent Moisture Conditions (AMC). The CN for each subwatershed has been calculated by overlaying the LULC and hydrological soil layers in Arc GIS 10.2 software. The assigned CN for each watershed which depends on the hydrological soil type and LULC. SCS-CN is the only methodology that features the environmental inputs and it is a well known method, used in United States and other parts of the countries. On the other hand the weak points of this method is that it does not consider the intensity of rainfall and its temporal distribution and it does not indicate the effect of adjacent moisture condition [2].

II. DESCRIPTION OF STUDY AREA

Chamarajanagara district which is located in the southern tip of Karnataka. The district has a territory of 5,648 square kilometers and undulating and mountainous with north south trending hill ranges of both Eastern and Western Ghats. The district is located 185 kms away from Bangalore state capital and lies between the North latitude 11º 40` 58`` and 12º 06` 32`` and East longitude 76º 24` 14`` and 77º 46` 55`` with an altitude of 1816m above mean sea level. The location map of the study area is as shown in Figure 1. The district has been segregated into 4 Taluks namely Chamarajanagara Taluk, Gundlupet Taluk, Kollegal and Yalandur Taluks. The district falls under semi-Arid Monsoon climatic zone. The district records as whole 764 mm of annual average precipitation with 47 rainy days. Chamarajanagara district soils are derived from Granitic gneisses and Charnockite rocks. Large area of the district is covered by Medium deep, red gravelly clay soils, mostly seen in the upland areas. Chamarajanagara district falls in Cauvery river basin. There are no major rivers flowing in the district, however Cauvery the perennial river flows along the border of Kollegal taluk of Chamarajanagara district with its tributaries like Suvarnavathy and Chikkahole.

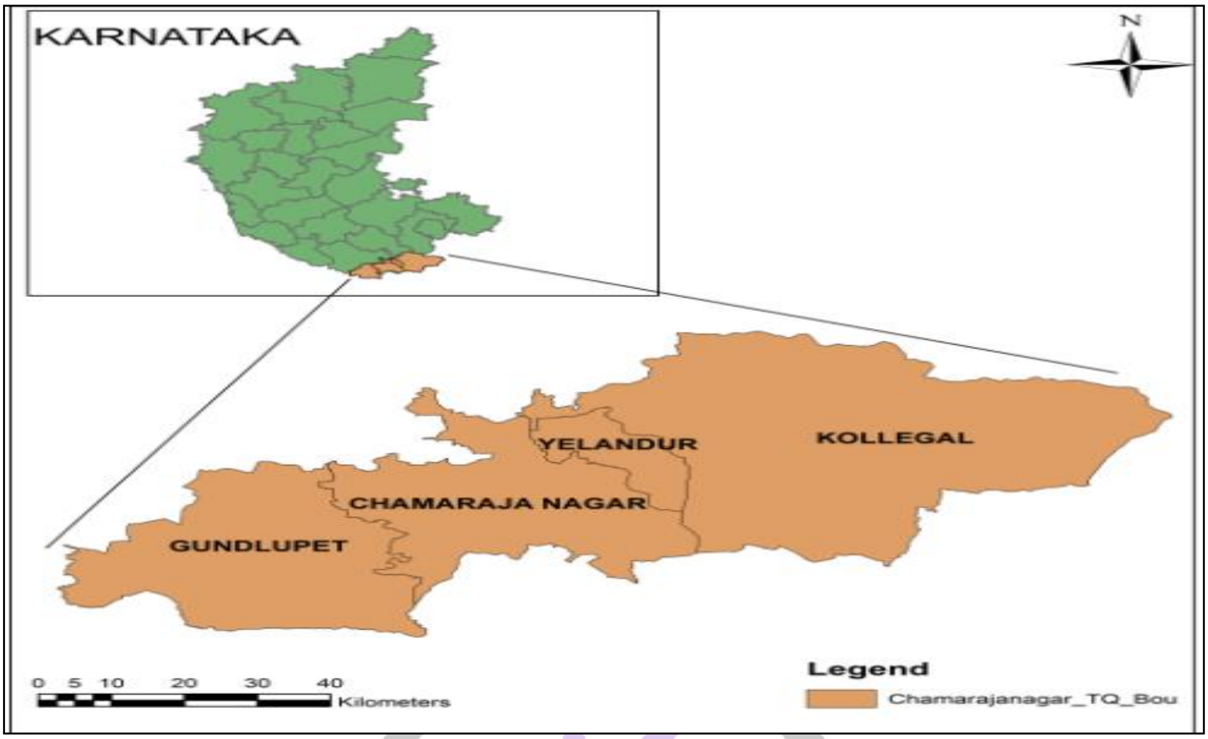

Fig-1: Location map of Chamarajanagara District

III. METHODOLOGY

The SCS-CN method is established by the water balance equation. The SCS-CN method is based on two fundamental hypotheses. First hypotheses is that the ratio of the amount of direct surface runoff "RO" to the total rainfall "RF" is equal to the ratio of actual infiltration "I" and amount of potential maximum retention "S" [3]. The second hypotheses relates to the initial abstraction "Ia". Thus, the method has the following equation:

$$\frac{RO}{RF - Ia} = \frac{I}{S} \qquad (1)$$

However, the actual infiltration corresponding to any rainfall event is equal to $(RF - Ia - RO)$. Hence on simplification, the above equation can be written as mentioned below,

$$RO = \frac{(RF - Ia)^2}{S - RF - Ia} \qquad (2)$$

Here, Ia is the initial losses, and it also depends on S, hence Ia is considered to be a fraction of S and hence Ia = 0.2S or 0.3S depending upon the catchment condition. Here in this study area, for all the watersheds, Ia = 0.2S.Hence for the study area the equation is simplified as below,

$$RO = \frac{(RF - 0.2)^2}{RF + 0.8S} \qquad (3)$$

The potential maximum retention, "S" depends on the physical conditions of the catchment, i.e., soil type, land use and land cover and AMC and is related to CN. The CN is dimensionless and it varies from 0 to 100. The relation between S and CN is as given below,

$$S = \left(\frac{25{,}400}{CN}\right) - 254 \qquad (4)$$

The watershed of study area is as shown in Figure 2. Weighted average rainfall for all the subwatersheds has been calculated by Thieseen Polygon method using Arc GIS 10.2.The Curve Number for each subwatershed has been assigned by overlying the LULC and hydrological soil layers in Arc GIS 10.2 software. By this we will obtain the required CN of each subwatershed and hence we can calculate potential maximum retention, S. After which we can calculate the surface runoff of each subwatershed by using S and weighted average rainfall. By which we can obtain the required surface runoff volume in TMC of each subwatershed. Peak discharge for the study area has to be calculated from the year 2009 to 2017. The peak discharge should be calculated in order to define a base for any structural mitigation to be taken.

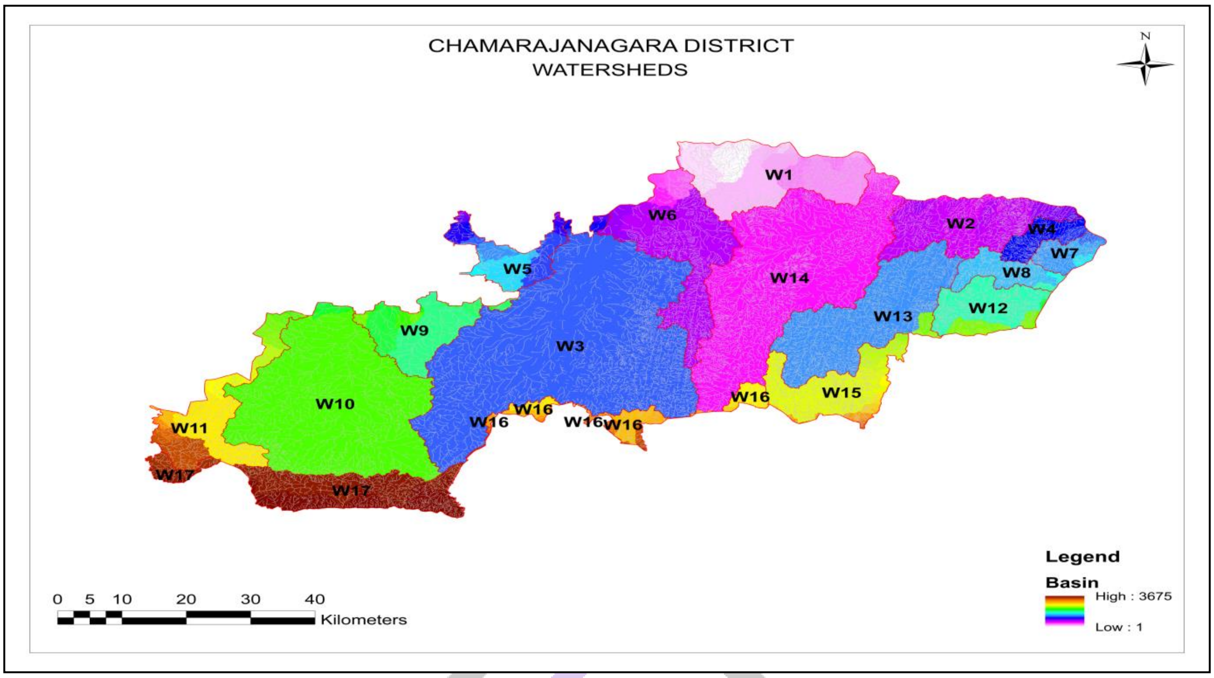

Fig-2: Subwatersheds along with stream lines in Chamarajanagara district

IV. RESULT AND DISCUSSION

For calculating surface runoff we primarily need the CN, which is calculated by overlaying hydrological soil map and LULC map in Arc GIS 10.2 software as shown in Figure 3. The Table 1 shows the CN and also the area of each subwatershed. Next the weighted average rainfall of the subwatershed is calculated using Thiessen Polygon Method in Arc GIS 10.2 software as shown in Figure 4. By calculating the weighted average rainfall and potential maximum retention, we can calculate the surface runoff for each subwatershed from the year 2009 to 2017. Next the surface runoff co-efficient is found out, which is the ratio of the surface runoff to the respective rainfall. The values of average surface runoff co-efficient are as shown in Table 2. Now, the calculated average rainfall volume and average runoff volume of each subwatershed from the year 2009 to 2017 is as shown in Table 3. Peak discharge of the 17 subwatersheds has been found out in order to know the maximum possible discharge in the watersheds over the years (2009 - 2017). The average peak discharge for each subwatershed has been given in Table 4.

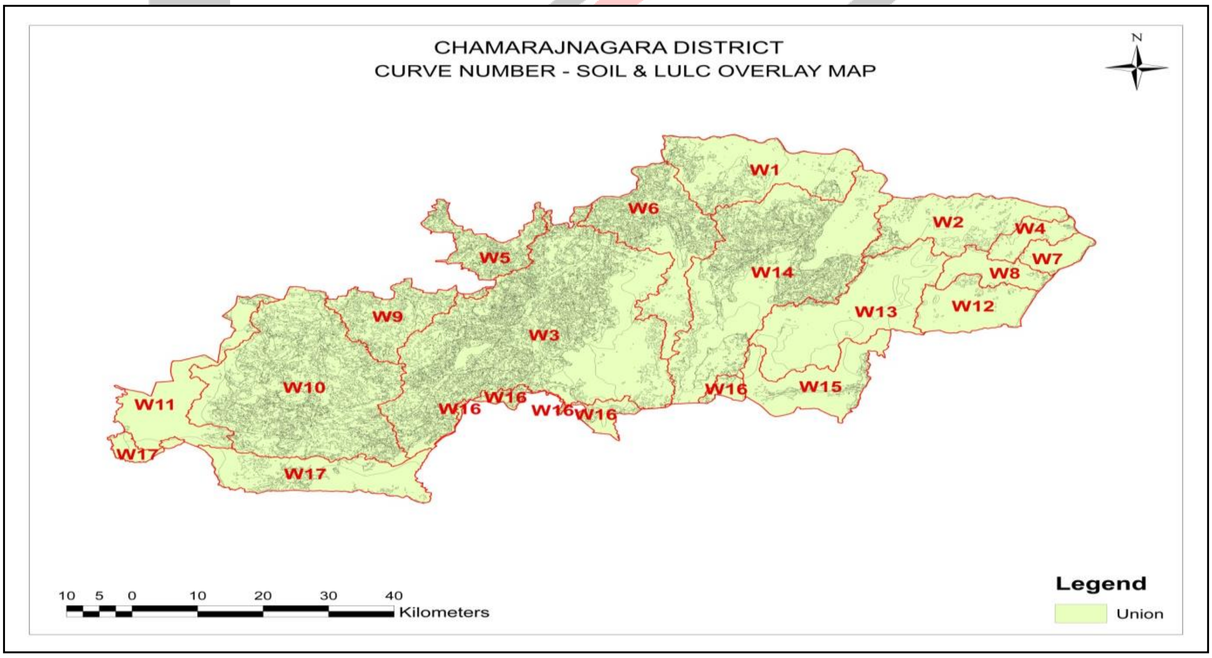

Fig-3: Overlay map of Soil and LULC- Curve Number

Table-1: Showing Area and CN of subwatersheds

Watershed	Area (Sq meter)	CN
W1	325708007	59
W2	253116873	49
W3	1220242575	60
W4	65223431	43
W5	133586753	61
W6	339561641	59
W7	60232345	55
W8	87019546	42
W9	186377838	59
W10	806017328	60
W11	229219284	50
W12	163373024	37
W13	400669360	48
W14	796247059	56
W15	207023848	52
W16	99629197	54
W17	275229117	47

Table-2: Showing Surface Runoff Co-efficient of each subwatershed

Watersheds	Surface RO-Coefficient
W1	0.21
W2	0.20
W3	0.22
W4	0.18
W5	0.25
W6	0.22
W7	0.23
W8	0.18
W9	0.22
W10	0.22
W11	0.18
W12	0.19
W13	0.19
W14	0.21
W15	0.21
W16	0.18
W17	0.17

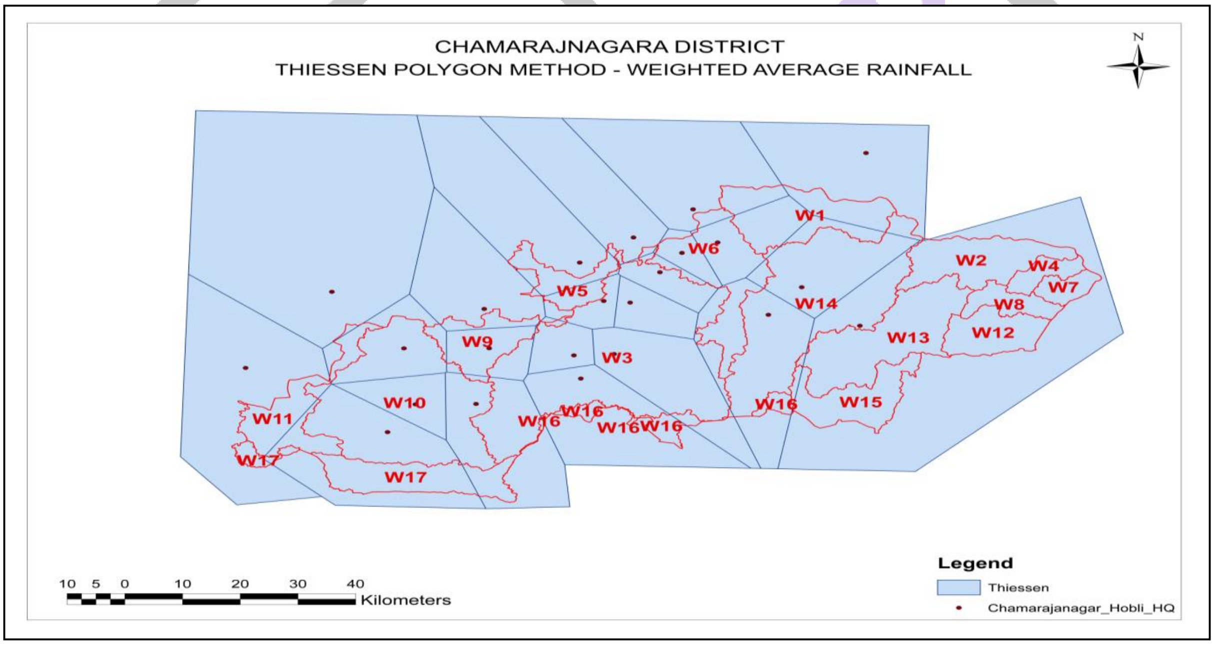

Fig-4: Thiessen Polygon method for finding weighted average rainfall

Table-3: Showing RF & RO in each watershed

Watershed	RF (TMC)	RO (TMC)
W1	7.31	1.61
W2	7.05	1.42
W3	30.71	7.15
W4	1.82	0.32
W5	2.87	0.73
W6	8.75	2.07
W7	1.68	0.41
W8	2.42	0.43
W9	4.36	0.95
W10	20.78	4.82
W11	6.51	1.15
W12	4.55	0.81
W13	11.15	2.21
W14	19.97	4.39
W15	5.75	1.26
W16	2.47	0.47
W17	7.96	1.45

Table-4: Showing Average Peak Discharge in each subwatershed

Watersheds	Peak Discharge (m3/sec)
W1	51.4
W2	41.79
W3	94.09
W4	5.49
W5	20.36
W6	49.52
W7	16.23
W8	6.85
W9	12.65
W10	46.63
W11	7.61
W12	13.74
W13	31.33
W14	83.95
W15	24.78
W16	1.46
W17	4.16

V. CONCLUSION

Based on the studies carried out for the study area, following conclusions are made

- By the analysis we got to know that W3, which acquires an area of 1220 sq.km, is having high surface runoff volume (7.15 TMC) and W4 with an area of 65 sq.km, is having the minimum surface runoff (0.32 TMC).
- The total surface runoff volume of the study area is 31.64 TMC.
- The runoff co-efficient is high in W5 (0.25) and minimum in W17 (0.17), which indicates that higher the co-efficient higher the runoff.
- Peak discharge of the subwatersheds has been found out in order to know the maximum possible discharge in the subwatersheds over the years, and the result shows that maximum discharge is found in W3 (94.09 m3/sec) and minimum is found in W16 (1.46 m3/sec).

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