Indian Journal of Ecology (2022) 49(5): 1843-1847
DOI: https://doi.org/10.55362/IJE/2022/3745

Manuscript Number: 3745
NAAS Rating: 5.79

# Estimation of Runoff Potential using Curve Number Method

Rajashekhar D. Barker and G. Chandrakantha[1]

*Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga -577 204, India*
*[1]Kuvempu University, Shankaraghatta, Shivamogga -577 451, India*
*Email: rdbarker11@ gmail.com*

***Abstract***: Runoff estimation is important for hydrological structure design. The SCS curve number (SCS-CN) approach is a popular technique for assessing rainfall-induced direct runoff. In this study, the runoff depth was calculated for the Hebburu micro-watershed in Tarikere Taluk, Chikkamagaluru district, Karnataka, using the Soil Conservation Service-Curve Number (SCS-CN) method. The Hebbur Micro-Watershed, which spans an area of 1038 ha, is situated between latitudes of 13º 46' 14.81" N to 13º 44' 23.95" N and longitudes of 75º 58' 24.38" E to 76º 0' 41.14" E. For the analysis, many parameters including information on the soil, rainfall, and land use were taken into account. Daily runoff was estimated between 2009-2018. Highest runoff was observed during 2014 (520 mm) followed by 2010 and 2009. During 2016 lowest runoff was generated in the watershed due to low rainfall in the year. Correlation coefficient between rainfall and runoff was found 97 per cent between 2009-2018. The results showed that the curve number approach, when combined with remote sensing and GIS technologies, can be effectively be used to estimate the runoff in an ungauged watershed.

***Keywords***: Curve number, Runoff potential, Watershed, Remote sensing, Soil conservation service

A watershed is a region that drains to a single outlet. For proper watershed management, such as flood control and its management, irrigation and drainage network design, hydropower generation, etc., accurate runoff depth and volume estimation is an essential responsibility. Rainfall-generated runoff is influenced by many factors, including soil type, vegetation, and types of land use, in addition to the intensity, length, and distribution of rainfall. The current study uses the Natural Resource Conservation Service Curve Number (NRCS-CN) method to calculate the runoff depth (Rajbanshi 2016). There are various methods for modelling rainfall and runoff, including the Artificial Neural Network (ANN), the SCS Curve number model, the hydrograph, and others. (Askar 2014). SCS–CN technique is one of the simplest methods for rainfall runoff modelling. The curve number is based on the area's of hydrologic soil group, land use, treatment and hydrological conditions (Askar 2014). 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 (Sahoo and Patra 2014). The Soil Conservation Service Curve Number (SCS-CN) method is widely used for predicting direct runoff volume for a given rainfall event (Soulis and Valiantzas 2012). The objective of the study was to estimate the runoff potential using curve number method. Estimation of the same is carried out to determine and forecast its effects. Estimation of direct rainfall-runoff is always efficient (Bansode et al 2014).

## MATERIAL AND METHODS

**Study area:** The Hebbur micro-watershed of Ajjampura sub-watershed, Tarikere taluk, Chikkamagalore district has been selected for analysis of runoff using SCS-CN Method. Hebbur Micro-Watershed is located between 13º 46' 14.81" N to 13º 44' 23.95" N Latitude and 75º 58' 24.38" E to 76º 0' 41.14" E Longitude, covering an area of 1038 ha (Fig. 1). Area falls under semi-arid region with average annual rainfall of 874 mm. Apart from rainfall, tanks and bore wells are the source of water resources. Watershed area is covered mostly of black soils however it also contains smaller portion of red and sandy textured soil. The major crops grown in study area are maize, ragi, onion, ginger, potato and chilly during *Kharif,* whereas chick pea, jawar, safflower, wheat and horsegram during *Rabi* season. Major horticulture crops grown are arecanut, coconut, banana, mango and pomegranate.

**Method:** Topographic data from Survey of India (SOI) toposheet (57 C/2) of scale 1:50,000 was used to identify the study area. Daily rainfall data (2009-2018) from Ajjampura rain gauge station was collected from KSNDMC, Bangalore. The Indian Remote Sensing satellite with Linear Imaging Self Scanning sensors (IRS – LISS III) data of scale 1:50000 were collected from KSRSAC, Bengaluru to use land use/ land cover of the study area (Fig. 2).

The methodology adopted in assessing the runoff potential of the study area is explained in the following steps.

The first step is to determine the hydrologic soil group (HSG) of the particular soil. Soil data was obtained from Land

Use Inventory information under KWDP-II, Sujal-III Watershed Development project, for making appropriate hydrological soil classification A, B, C & D (Fig. 3). All soils are classified in one of four different categories-ranked A-D on the basis of their runoff potential (Sahoo and Patra 2014).

**Class A** soils mostly having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have high rate of water transmission. [Ex-deep sand, deep loess and aggregated silt]

**Class B** soils have moderately fine to moderately coarse textures and are considered to have moderate infiltration rates when completely wet [Ex– shallow loess, sandy loam, red loamy soil, red sandy loam and red sandy soil]

**Class C** soils have moderately fine to fine textures with slow infiltration rates.[Ex- clayey loam, shallow sandy loam, soils usually high in clay, mixed red and black soils]

**Class D** soils are primarily clay soils or soils with clay pan that have slow infiltration rates.[Ex-heavy plastic clays certain saline soils and deep black soils]

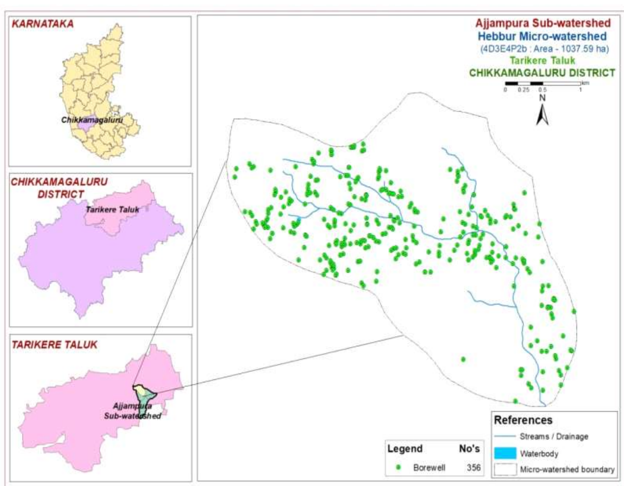


**Fig. 1.** Location map of the watershed

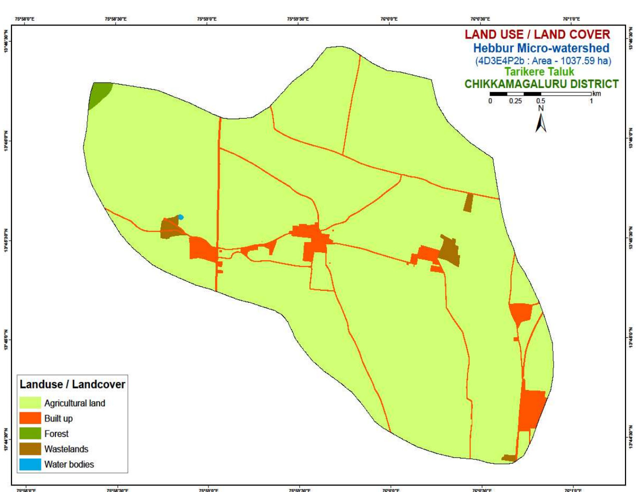


**Fig. 2.** Land use or land cover of the study area

Next step is to determine the five-day antecedent moisture condition of the particular soil from the daily precipitation record. It is an index for basin wetness. AMC (Antecedent Moisture Conditions) indicates the moisture content of soil at the beginning of the rainfall event under consideration. Three levels of AMC were documented by SCS are AMC I, AMC II and AMC III. The limits of these three AMC classes are based on rainfall magnitude of previous five days and season (dormant season and growing season). The values of curve number are determined based on the antecedent moisture conditions (Table 1).

The third step is to decide-on the basis of the land cover, the cultivation treatment, the hydrologic condition of the soil, and the hydrologic soil group of the particular soil-the actual runoff curve number to use in determining daily runoff from precipitation (SCS, 1972). SCS runoff CN for hydrologic soil cover complex under AMC II condition for the study area is given in Table 2. CN for AMC I and CN for AMC III were determined using equation (1) and (2).

CN for AMC I is calculated as: $CN_I = CN_{II}/(2.281 – 0.01281\ CN_{II})$...... (1)

CN for AMC III is calculated as: $CN_{III} = CN_{II}/(0.427 – 0.00573\ CN_{II})$...... (2)

Area weighted composite curve number for various conditions of land use and hydrologic soil conditions are computed as follows

$CN = (CN_1 \times A_1) + (CN_2 \times A_2) + ...\ .... + (CN_n \times A_n)/A$ ...... (3)

Where A1, A2, A3, …., An represent land use areas of having CN values CN1, CN2, CN3,….., CNn respectively and A is the total area of the watershed.

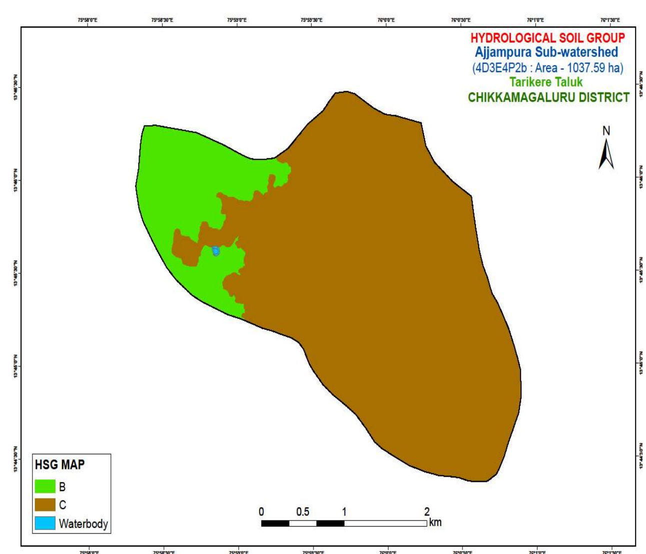


**Fig. 3.** HSG map of study area

**Table 1.** Antecedent moisture conditions for determining the value of CN

| AMC type | Total rain in previous five days | |
|---|---|---|
| | Dormant season | Growing season |
| AMC-I: Soils are dry but not to wilting point. Satisfactory cultivation has taken place. | <13 mm | <36 mm |
| AMC-II: Average conditions | 13-28 mm | 36-53 mm |
| AMC-III: Sufficient rainfall has occurred within the immediate past 5 days. Saturated soil conditions prevail | >28 mm | >53 mm |

**Table 2.** Curve number for HSG under AMC II conditions (Ahmad et al 2015)

| Land use | Hydrological soil group | | | |
|---|---|---|---|---|
| | A | B | C | D |
| Agricultural land | 76 | 86 | 90 | 93 |
| Built up | 49 | 69 | 79 | 84 |
| Forest | 26 | 40 | 58 | 61 |
| Wastelands | 71 | 80 | 85 | 88 |
| Water bodies | 97 | 97 | 97 | 97 |

**Table 3.** Sample of daily rainfall runoff computation of study area

| Date | Rainfall (mm) | 5 days cumulative rainfall (mm) | AMC condition | CN | S | Runoff (mm) |
|---|---|---|---|---|---|---|
| 01-07-2009 | 0 | 11.5 | 1 | 78 | 71 | 0 |
| 02-07-2009 | 4 | 5 | 1 | 78 | 71 | 0 |
| 03-07-2009 | 9.5 | 14.5 | 2 | 89 | 31 | 0 |
| 04-07-2009 | 10.5 | 24 | 2 | 89 | 31 | 0 |
| 05-07-2009 | 4.5 | 28.5 | 3 | 95 | 13 | 0 |
| 06-07-2009 | 10.5 | 39 | 3 | 95 | 13 | 2 |
| 07-07-2009 | 2 | 37 | 3 | 95 | 13 | 0 |
| 08-07-2009 | 0.5 | 28 | 3 | 95 | 13 | 0 |
| 09-07-2009 | 3 | 20.5 | 2 | 89 | 31 | 0 |
| 10-07-2009 | 12.5 | 28.5 | 3 | 95 | 13 | 3 |
| 11-07-2009 | 0.5 | 18.5 | 2 | 89 | 31 | 0 |
| 12-07-2009 | 3.5 | 20 | 2 | 89 | 31 | 0 |
| 13-07-2009 | 3.5 | 23 | 2 | 89 | 31 | 0 |
| 14-07-2009 | 6.5 | 26.5 | 2 | 89 | 31 | 0 |
| 15-07-2009 | 32.5 | 46.5 | 3 | 95 | 13 | 19 |
| 16-07-2009 | 36.5 | 82.5 | 3 | 95 | 13 | 23 |
| 17-07-2009 | 19.5 | 98.5 | 3 | 95 | 13 | 8 |
| 18-07-2009 | 7.5 | 102.5 | 3 | 95 | 13 | 1 |
| 19-07-2009 | 7.5 | 103.5 | 3 | 95 | 13 | 1 |
| 20-07-2009 | 1 | 72 | 3 | 95 | 13 | 0 |
| 21-07-2009 | 1 | 36.5 | 3 | 95 | 13 | 0 |
| 22-07-2009 | 1 | 18 | 2 | 89 | 31 | 0 |
| 23-07-2009 | 1 | 11.5 | 1 | 78 | 71 | 0 |
| 24-07-2009 | 0 | 4 | 1 | 78 | 71 | 0 |
| 25-07-2009 | 0 | 3 | 1 | 78 | 71 | 0 |
| 26-07-2009 | 0 | 2 | 1 | 78 | 71 | 0 |
| 27-07-2009 | 1.5 | 2.5 | 1 | 78 | 71 | 0 |
| 28-07-2009 | 1 | 2.5 | 1 | 78 | 71 | 0 |
| 29-07-2009 | 2.5 | 5 | 1 | 78 | 71 | 0 |
| 30-07-2009 | 3.5 | 8.5 | 1 | 78 | 71 | 0 |
| 31-07-2009 | 0 | 8.5 | 1 | 78 | 71 | 0 |

Potential maximum retention is calculated using equation (4).

$$S = \left(\frac{24500}{CN}\right) - 254 \qquad (4)$$

Runoff is estimated using equation (5).

$$Q = \left(\frac{(P - \lambda S)^2}{(P - (1 - \lambda)S)}\right) \qquad (5)$$

For Indian conditions $\lambda = 0.3$

## RESULTS AND DISCUSSION

The daily rainfall values were used as inputs to compute daily runoff. Using CN for AMC-II conditions, CN for AMC-I and AMC-III were calculated using equations (1)-(2). Using equation (3) weighted CN was calculated. Using equation (5) the daily runoff depth were computed. First daily rainfall runoff computation is shown in Table 4.

From the daily runoff, monthly and annual values can be derived. The annual runoff depths are computed for each rainfall event for the years 2009 - 2018 is shown in Table 5 and the relationship between rainfall-runoff is shown in Figure 4. Highest runoff was observed during 2014 which was about 42 percent of the annual rainfall followed by 2009 (39%) and 2010 (37%). Lowest was observed during 2016 due to low rainfall. Increase in runoff was observed with increase in rainfall in the year. Coefficient of determination for rainfall runoff was 0.94 for the watershed (Fig. 4).

**Table 4.** Runoff values (2009-2018)

| Year | Rainfall (mm) | Runoff (mm) |
|---|---|---|
| 2009 | 1051 | 404.74 |
| 2010 | 1167 | 440.08 |
| 2011 | 808 | 224.38 |
| 2012 | 513 | 152.60 |
| 2013 | 969 | 312.92 |
| 2014 | 1239 | 520.14 |
| 2015 | 1087 | 378.89 |
| 2016 | 542 | 107.08 |
| 2017 | 663 | 212.30 |
| 2018 | 1011 | 328.02 |

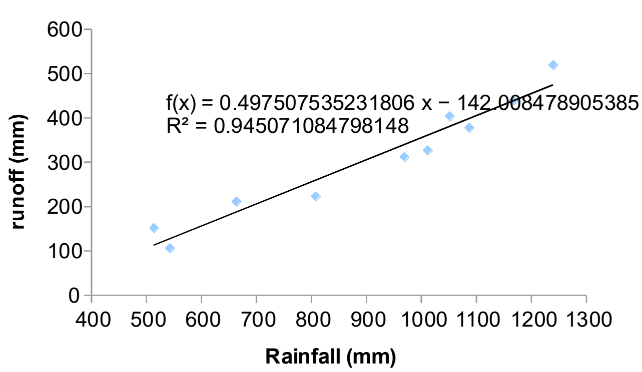


**Fig. 4.** Rainfall-runoff relationship

## CONCLUSION

Daily runoff was estimated between 2009-2018. Highest runoff was observed during 2014 (520 mm) followed by 2010 and 2009. During 2016 lowest runoff was generated in the watershed due to low rainfall in the year. Correlation coefficient between rainfall and runoff was found 97 per cent between 2009-2018. This estimated runoff will be helpful for planning of the soil and water conservation structures in the watershed.

## ACKNOWLEDGEMENT

Authors are thankful to World Bank for funding this project under KWDP-II, SUJALA-III, WDD, Gok Karnataka, Bengaluru Authors are also thankful to University of Agricultural and Horticultural Sciences, Shivamogga, 577 204, Karnataka.

## REFERENCES

Ahmad I, Vivek V and Mukesh KV 2015. *2nd International Conference on Geological and Civil Engineering*. IPCBEE 80 (2015).

Askar MKh. 2014. Rainfall-runoff model using the SCS-CN method and geographic information systems: A case study of Gomal River watershed. *WIT Transactions on Ecology and The Environment* **41**(3):178.

Athira Raj 2017. Estimation of runoff using curve number method and its modifications. *Journal of Structural and Transportation Studies* **2**(1): 1-9.

Bansode, Ashish K and Patil A 2014. Estimation of runoff by using SCS curve number method and Arc GIS. *International Journal of Scientific & Engineering Research* **5**(7): 1283-1287.

Dhvani Tailor and Narendra J Shrimali 2016. Surface Runoff Estimation by SCS Curve Number Method using GIS for Rupen-khan Watershed, Mehsana district, Gujarat**.** *Journal of Indian Water Resource Society* **36**(4): 1-5

Gabale S and Deshpande ARM 2020. Geospatial technique for runoff estimation based on SCS-CN method in Sudha river basin of Indrayani River, *International Journal of Multidisciplinary Research and Development* **7**: 172-177.

Kimeli N and Okumu BM 2017. Application of GIS for estimation of water runoff volume in water collection sites case study: Northern Collector water tunnel, *American Journal of Geographic Information System* **6**(5): 169-177.

Nayak, Tejram, Verma MK and Hema Bindu 2012. SCS curve number method in Narmada basin. *International Journal of Geomatics and Geosciences* **3**(1): 219-228.

Aanil Kumar P and Viswanadh GK 2017. Estimation of runoff by using SCS curve number method integrated with GIS. *International Advanced Research Journal in Science, Engineering and Technology* **4**(7): 34-38.

Rajbanshi J 2016. Estimation of runoff depth and volume using NRCSCN Method in Konar catchment (Jharkhand, India). *Journal of Civil Environment Engineering* **6**: 236.

Kale SS et al 2022. Estimation of runoff of Kudavale Micro watershed using SCS curve number method and gis approach. *International Journal of Novel Research and Development* **7**(5): 296-304.

Sahoo B and Kanhu CP 2014. *Civil Engineering Systems and Sustainable Innovations*. ISBN: 978-93-83083-78-7 83.

Satheeshkumar S, Venkateswaran S and Kannan R 2017. Rainfall–runoff estimation using SCS–CN and GIS approach in the Pappiredipatti watershed of the Vaniyar sub basin, South India.

Shadeed, Sameer and Mohammad Almasri 2010. Application of GIS-based SCS-CN method in west bank catchments, Palestine, *Water Science and Engineering* **3**(1): 1-13.

Shimelis Sishah 2021. Rainfall runoff estimation using GIS and SCS-CN method for Awash River Basin, Ethiopia. *International Journal of Hydrology* **5**(1): 33-37.

Soulis KX and Valiantzas JD 2012. SCS-CN parameter determination using rainfall-runoff data in heterogeneous watersheds-the two-CN system approach. *Hydrology and Earth System Sciences* **16**: 1001-1015.

Zeenat Ara and Mohammad Zakwan 2018. Estimating runoff using SCS curve number method. *International Journal of Emerging Technology and Advanced Engineering* **8**(5): 195-200.

*Received 11 June, 2022; Accepted 15 September, 2022*