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ANALYSIS OF THE RUNOFF FOR HOSKOTE SUB-WATERSHED USING SCS-CN METHOD AND GEOGRAPHIC INFORMATION SYSTEMS

Mooganayakanakote Veeranna Ramaswamy[1], Shivkumar J Nyamathi[2], Navyashree M L[3], Shruti Halli[4]

[1]Department of Civil Engineering, University of Visvesvaraya College of Engineering, Bengaluru, India

[2]Professor, Department of Civil Engineering, University of Visvesvaraya College of Engineering, Bengaluru, India

[3]Research Scholar, Masters in Water Resource Engineering, University of Visvesvaraya College of Engineering, Bengaluru, India

[4]Research Scholar, Masters in Water Resource Engineering, University of Visvesvaraya College of Engineering, Bengaluru, India

ABSTRACT

Reliable estimation of surface runoff is vital for effective watershed management, especially in regions characterized by variable rainfall patterns. This study investigates the Hoskote Sub-Watershed using the Natural Resources Conservation Service- Curve Number (NRCS-CN) method, integrated with Geographic Information Systems (GIS) and Remote Sensing (RS) techniques, to model the rainfall-runoff relationship. Curve Number (CN) values were derived by overlaying land use/land cover data with hydrologic soil group classifications. Historical rainfall data from 1985 to 2015, sourced from the Indian Meteorological Department, along with satellite-derived thematic layers, served as essential inputs. The findings indicate that the average annual runoff in the sub-watershed is approximately 170.08 mm, constituting about 5% of the mean annual rainfall of 837.70 mm. A strong positive correlation (R = 0.85) *between annual rainfall and runoff was observed, with the highest runoff recorded in 2022. The study demonstrates that the NRCS-CN method, when complemented by GIS and RS technologies, provides a reliable and efficient approach for runoff estimation in ungauged catchments.*

Keywords: Remote sensing, Geographical information systems, Sub-Watershed, NRCS-CN, Rainfall-runoff modelling, AMC

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Introduction

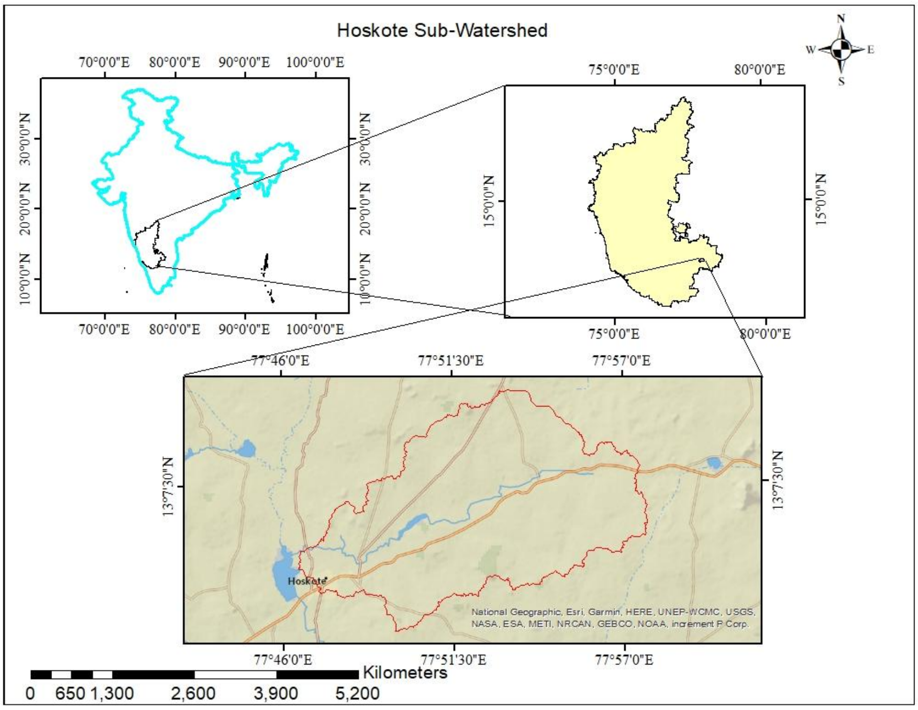
Runoff is the most basic and important data needed when planning water control strategies/ practices, such as, waterways, storage facilities or erosion control structures. (Arun W. Dhawale, 2013). Runoff is the process which takes place after satisfying the abstraction losses the excess water that goes down without being used for any purpose, due to steep slope and stones in the soil causing soil erosion and converted into degraded land. Accurately predicting the quantity and speed at which runoff flows from the land surface into streams and rivers is a challenging and time-consuming task, particularly for ungauged watersheds. Nonetheless, this information is crucial for addressing various issues related to watershed development and management. Traditional models used to forecast river discharge rely heavily on extensive hydrological and meteorological data, which can be costly, time-consuming, and logistically demanding to collect.

Remote sensing technology offers significant advancements in rainfall-runoff studies compared to conventional methods. Its role in runoff calculation primarily involves providing input data and aiding in estimating equation coefficients and model parameters. Through satellite data interpretation, thematic information related to land use, soil, vegetation, drainage, and more can be derived. When combined with conventionally measured climatic parameters (such as precipitation and temperature) and topographic parameters (including height, contour, and slope), these inputs are essential for rainfall-runoff models. The extracted information from remote sensing and other sources can be stored as georeferenced data in a geographical information system (GIS). This system provides efficient tools for data input, retrieval of specific data items for further processing, and software modules that analyze and manipulate the retrieved data to generate the desired information in a specific format.

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. (Ashish Bansode, 2014). The U.S. Soil Conservation Service [SCS, now called the Natural Resources Conservation Service (NRCS)] [U.S. Department of Agriculture (USDA) 1985] developed a method for computing runoff amount from rainfall amount for individual storm events. The SCS method is widely used for estimating runoff volume and peak discharge for ungauged watersheds in rural and urban areas. Although originally developed primarily for the design of soil conservation works, the SCS method has evolved well beyond its original intent and has been adopted for urbanized and forested watersheds (USDA 1986)(Bofu Yu,2012). Among the available methodologies, the SCS-CN (Soil Conservation Service Curve Number) method stands out as a well-established and widely accepted approach, particularly in the United States and other countries. It offers easily understandable and reasonably well-documented environmental inputs. However, the SCS-CN method does have some notable weaknesses. Firstly, it does not account for the impact of rainfall intensity and its temporal distribution. Additionally, it does not adequately address the effects of spatial scale, making it less suitable for large-scale applications. Furthermore, the SCS-CN method exhibits high sensitivity to changes in the values of its sole parameter.

Study Area Description

Hoskote Taluk is part of Bangalore Rural district 25 km away from Bangalore city. It is located in eastern portion of Bangalore Rural district, Karnataka state covering an area of 548 Sq. Km and is a part of South Pennar river basin located at North latitude 12°51’49” to 13°15’ 17” and east longitude of 77°45’38” to 77°57’59”. It is surrounded by Sidlaghatta Taluk of Chikkaballapur district in the north, Devanahalli Taluk of Bangalore Rural district, Devanahalli and Anekal Taluk of Bangalore Urban district in the west, towards south by Tamil Nadu and in east it is surrounded by Kolar and Malur Taluks of Kolar district. Hoskote Taluk is occupied by Banded Gneisses called as Peninsular Gneissic Complex and a small patch of laterite occurs north of Hoskote. The most conspicuous areas of very high and very low area of the GP lies at 955 m and 859 m of contour lines above the mean sea level respectively with an elevation difference of 96 m and the general slope is from west to east.



Map 1 Location Map

Methods and Data Collection

The adopted methodology of the present study is shown in this Fig. 2 which shown the flowchart for the model development of runoff. The various steps are involved in the

following manner as follows. The land use and land cover map are obtained from Esri Global land use and land cover data 2020. Soil types (Sandy Clay Loam,) Texture, structure, from FAO, Global soil, Digital Elevation model (DEM) derived from USGS Website and Rainfall Data collected 1985-2015 from IMD.

The process begins by delineating the watershed and catchment area boundaries. Soil types within these areas are classified into Hydrologic Soil Groups (A, B, C, or D) based on their infiltration capacities. By overlaying Land Use/Land Cover (LULC) data with soil group information, a set of polygons is generated. Each unique polygon is then assigned a specific curve number (CN) corresponding to its LULC and hydrologic soil group combination, using CN lookup tables.

Natural Resources Conservation Service (NRCS) curve number (CN) Model

The curve number method (Soil Conservation Services, NRCS, 1972), also known as the hydrologic soil cover complex method, is a versatile and widely used procedure for runoff estimation. This method includes several important properties of the watershed namely soil permeability, land use and antecedent soil water conditions which are taken into consideration.

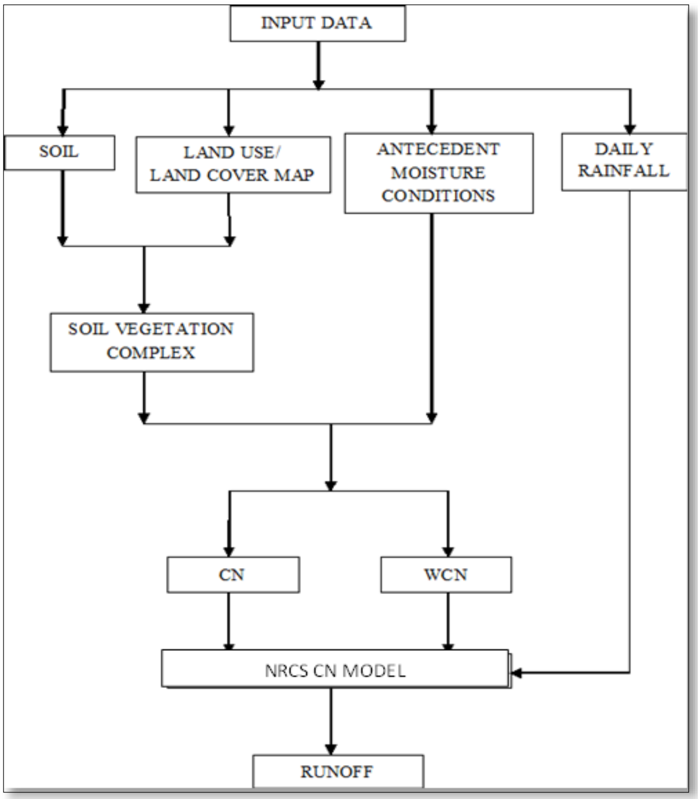


Fig 1 Methodology to find runoff

Runoff Volume

The NRCS curve number method is based on the water balance equation and two fundamental hypotheses. Ratio of the actual direct runoff to the potential runoff is equal to the ratio of the actual infiltration to the potential infiltration.

Ratio of the actual direct runoff to the potential runoff is equal to the ratio of the actual infiltration to the potential infiltration.

$$\frac{Q}{P - I_a} = \frac{F}{S} \qquad (1.1)$$

where,

Q = actual runoff in mm P = rainfall.

F = actual infiltration (difference between the potential and accumulated runoff).

Ia = initial abstraction, which represents all the losses before the runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, and initial infiltration. This is highly variable but generally is correlated with soil and cover parameters;

S = the potential infiltration after the runoff begins (S ≥F).

The amount of initial abstraction is some fraction of the potential infiltration.

$$F = (P - Ia) - Q \tag{1.2}$$

Substituting eq. (1.2) in eq. (1.1)

((P - Ia)-Q)/(S)=Q/((P - Ia)) 1.3

Q=(P - Ia)2/((P - Ia)+S) 1.4

The retention S is constant for a particular storm because it is the maximum that can occur under existing conditions if the storm continues without limit. The retention F varies because it is the difference between (P-Ia) and Q at any point on the mass curve.

The units of P, Q, Ia and F are the factors in equation 1.4 are best understood by the use of a mass curve which shows the relation of Q versus P. The volume of rainfall is separated into initial abstraction, retention, storage and runoff. The initial abstraction consists of interception, infiltration and surface storage, all of which occur before the runoff begins. An empirical analysis was performed for development of NRCS rainfall-runoff relation and the following formulas were arrived for estimating Ia.

Determination of Curve Number (CN)

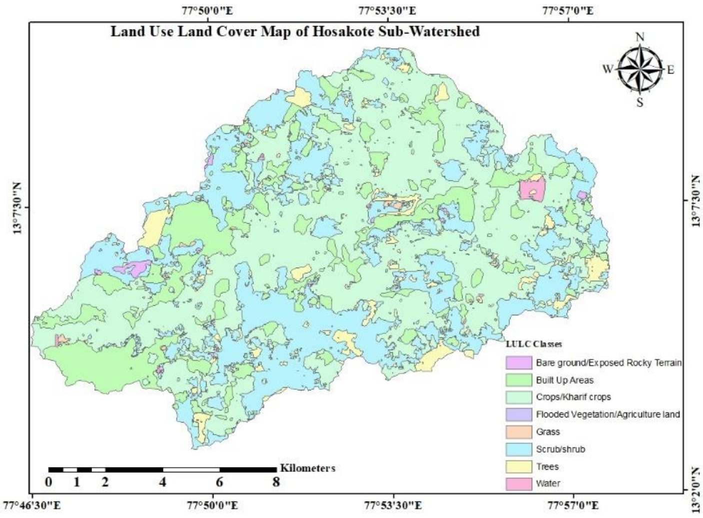
The curve number is an index that represents the combination of a hydrologic soil group and antecedent moisture conditions. The CN value is determined from hydrological soil group and antecedent moisture conditions of the watershed. For curve number determination the land use/land cover and hydrological soil group map were overlaid and based on their combinations the curve numbers were selected from the available source. Table 1 shows the curve number (AMC II) available in the literature to estimate runoff.

Table 1 Curve number for different land use / land cover classes

Sl. No	Type of land use/land cover	Hydrological Soil Group			
		A	B	C	D
1	Agriculture Plantation	45	53	67	72
2	Barren Rocky	45	66	77	83
3	Cropped in two seasons	62	71	78	81
4	Deciduous (Dry/Moist/Thorn)	45	66	77	83
5	Evergreen/Semi Evergreen	25	55	70	77
6	Fallow Land	77	77	86	94

7	Forest Plantation	25	55	70	77
8	Gullied/Ravenous land	72	82	87	89
9	Lake/Pond	100	100	100	100
10	Reservoir/Tank	100	100	100	100
11	River	97	97	97	97
12	Rural	59	74	82	86
13	Salt affected land	40	62	71	82
14	Scrub Forest	55	72	81	86
15	Scrub land	55	66	80	87
16	Temperate/Sub Tropical	50	62	78	84
17	Tree clad area	70	70	81	89
18	Urban	89	92	94	95

Source: (Source: Ven Te Chow, 1984)



Map 2 Land use Land Cover Map

Hydrological Soil Group Classification

NRCS developed a soil classification system that consists of four groups, which are identified as A, B, C, and D according their minimum infiltration rate. The identification of the particular NRCS 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 2 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

Antecedent Moisture condition (AMC)

Antecedent Moisture Condition (AMC) refers to the water content present in the soil at a given time. It is determined by total rainfall in 5-day period preceding a storm. The AMC value is intended to reflect the effect of infiltration on both the volume and rate of runoff according to the infiltration curve. An increase in index means an increase in the runoff potential. The NRCS developed three antecedent soil-moisture conditions and labeled them as I, II, III. These AMCs correspond to the following soil conditions.

AMC I: Soils are dry but not to the wilting point; satisfactory cultivation has taken place.

AMC II: Average conditions.

AMC III: Heavy rainfall or light rainfall and low temperatures have occurred within last 5 days; Saturated soils. Table 3 shows the seasonal rainfall units for the AMC classification and for CN.

Table 3 Classification of Antecedent Moisture Condition (AMC)

AMC Class	Total five-day 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

(Source: Ven Te Chow, 1984)

The curve numbers for average antecedent moisture condition (AMC II) were taken by overlaying the land use/land cover and hydrological soil groups of the watershed. The unique combination for the land use/land cover and hydrological soil groups for which curve number was picked from Table 3 From the AMC II condition, the values of curve numbers for AMC I and III were obtained either from the following equations (Chow et. al, 1988).

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

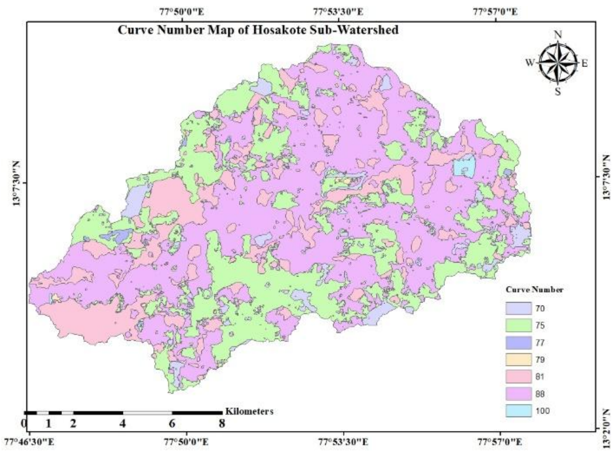
$$CN_3 = \frac{CN_2}{0.427+0.00573CN_2}$$

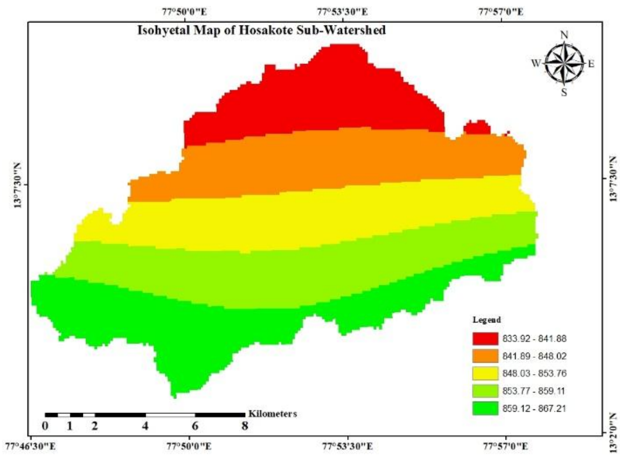
All the three AMC conditions were considered for the estimation of runoff from the catchment. The curve number map prepared by integrating land use / land cover and hydrological soil group map through ArcGIS software. The runoff is estimated (RO) from each Sub-Watershed.

A weighted runoff was estimated for the watershed as

$$Weighted\ Q = \frac{(A_1 \times q_1 + A_2 \times q_2 + \cdots\cdots\cdots + A_n \times q_n)}{(A_1 + A_2 + \cdots\cdots\cdots + A_n)}$$

where A1, A2…An are the areas of the watersheds having runoff q1, q2….qn respectively. The runoff approach was again extended to quantify the total amount of runoff for the entire catchment.

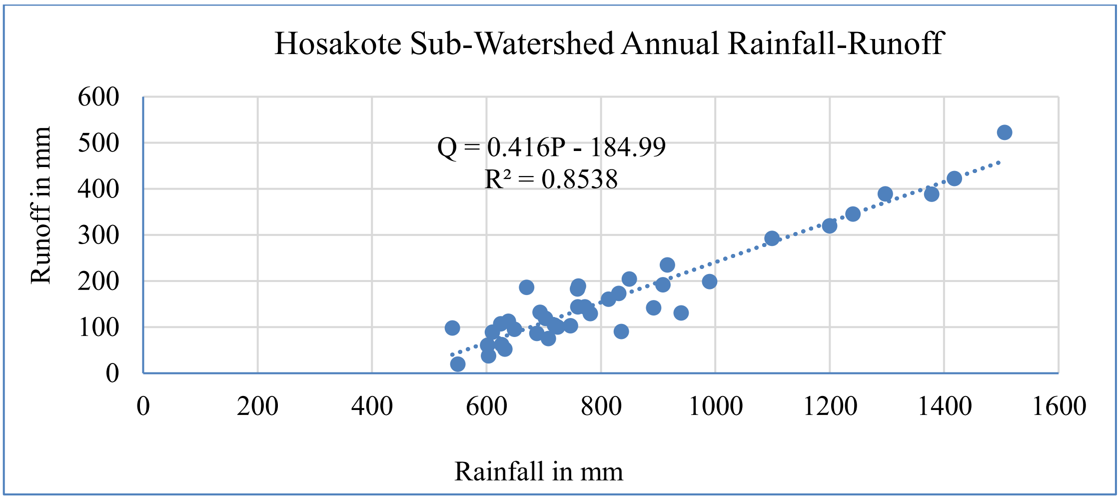


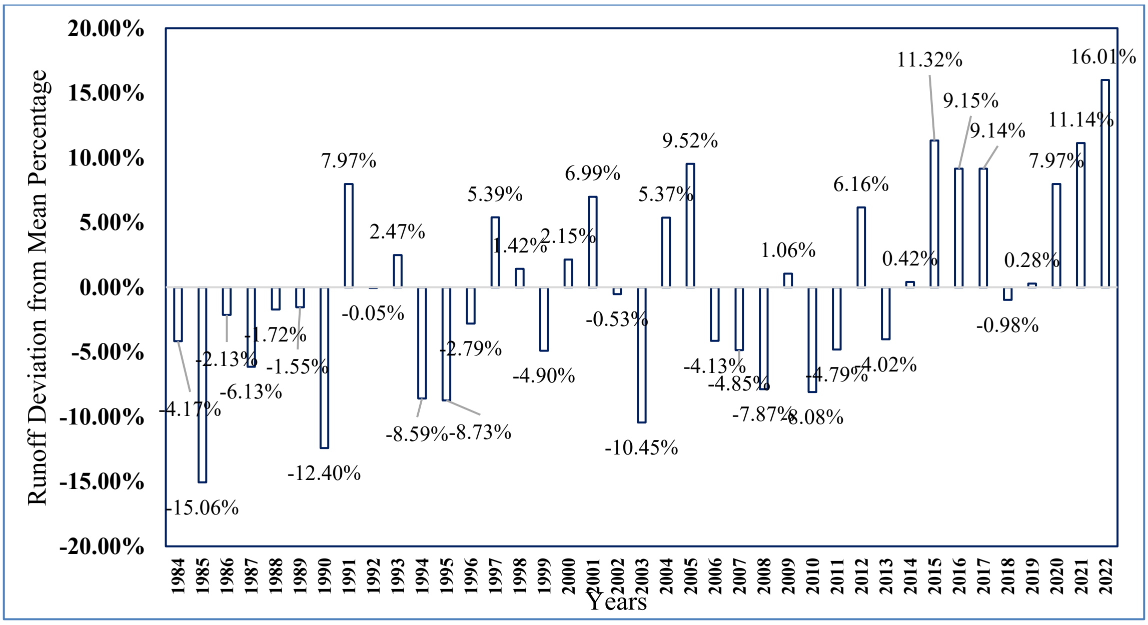


Results and Discussions

The findings from the study are summarized in the table below. Based on the calculations, the average annual surface runoff in the Hoskote Sub-Watershed was found to be [170.08 mm], which represents approximately 5% of the total average annual rainfall (837.70 mm). The annual rainfall and corresponding runoff data for the period 1984–2021 in the study area are presented in the table. The below and graphs above illustrate the rainfall-runoff relationship for the Hoskote Sub-Watershed from 1984 to 2022. According to the data, the Sub-Watershed experienced its highest rainfall of 1505.50 mm and maximum runoff of 522.07 mm in 2022. The correlation between rainfall and runoff is approximately 0.85. The lowest recorded rainfall and runoff were 540.20 mm and 19.80 mm in 2002, and 1985 mm respectively. The deviation of runoff from the annual average is 18.67%, with negative percentages indicating a deficit and positive percentages indicating a surplus. 1985 Hoskote experienced a significant deficit in runoff, while in 2022, it saw a surplus compared to other years.

Year	**Rainfall in mm**	**Runoff in mm**	**Year**	**Rainfall in mm**	**Runoff in mm**
1984	718.86	104.23	2004	849.29	204.12
1985	549.59	19.8	2005	1378.02	388.47
1986	781.48	129.26	2006	610.41	88.73
1987	687.92	86.27	2007	724.22	100.07
1988	702.78	119.08	2008	835.3	90.17
1989	624.76	106.97	2009	813.14	160.4
1990	603.26	37.78	2010	707.77	74.93
1991	1098.73	292.71	2011	940.16	130.43
1992	771.99	143.71	2012	760.35	188.8
1993	908.18	192	2013	648.88	95.05
1994	601.58	60.63	2014	693.37	132.33
1995	626.52	62.23	2015	1296.65	388.82
1996	891.84	141.58	2016	670.04	186.4
1997	758.71	182.53	2017	1240.48	344.98
1998	990.08	198.91	2018	637.99	112.87
1999	746.77	102.82	2019	759.47	143.89
2000	831.04	172.97	2020	1199.72	319.58
2001	915.94	234.96	2021	1417.38	422.48
2002	540.2	97.95	**2022**	**1505.5**	**522.07**
2003	632.1	51.96			
			Average	837.70	170.08





Conclusions

The Sub-Watersheds under study experience high levels of rainfall, though the pattern tends to be irregular and erratic. In the context of the water balance equation, surface runoff plays a critical role alongside rainfall and infiltration, the latter contributing to soil moisture and groundwater recharge. Accurate estimation of surface runoff is essential for effective water resource planning and management. The NRCS Curve Number (CN) method offers a practical and reliable approach to estimate runoff. This study aimed to assess the efficiency of the NRCS-CN method by utilizing land cover data derived from remote sensing. The highest recorded annual rainfall for these areas occurred in 1378.03 mm in 2005 for Hoskote. The estimated average annual runoff for these sub-watersheds was 170.08 mm for Hoskote, the correlation coefficient between annual rainfall and runoff across all four Sub-Watersheds was found to be 0.867, indicating a strong positive relationship. Overall, the runoff estimation using the NRCS-

CN method proves to be a valuable tool for understanding watershed yield and supports better planning and management of river basins.

References

[1] Aghil and Rajashekhar S.L (2018), “Estimation of Runoff using SCS-CN Method for Yelahanka Region”, International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 7 pp. 229-233.

[2] Arun W. Dhawale (2013), “Runoff Estimation for Darewadi Watershed using RS and GIS”, International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-1, Issue-6

[3] Ashish Bansode, K. A. Patil, “Estimation of Runoff by using SCS Curve Number Method and Arc GIS”, International Journal of Scientific & Engineering Research, Volume 5, Issue 7,

[4] Chow, V. T., D. R. Maidment and L. W. Mays. 1988. Appl. Hydrology. New York, N.Y.: McGraw-Hill

[5] Jaimin Patel, N. P. Singh , Indra Prakash and Khalid Mehmood “Surface Runoff Estimation Using SCS-CN method- A Case Study on Bhadar Watershed, Gujarat”, India Imperial Journal of Interdisciplinary Research (IJIR) Vol-3, Issue-5, ISSN: 2454-1362.

[6] Mamata Singh and D.PSatapathy (2017) “Rainfall-Runoff Estimation Using SCS-CN and GIS Approach in the Kuakhai Watershed of the Mahanadi Basin of Bhubaneswar Odisha”, International Journal of Emerging Research inManagement and Technology ISSN: 2278-9359(Volume-6, Issue-12).

[7] Mishra S.K. (2017). “A revisit of NRCS-CN inspired models coupled with RS and GIS for Runoff Estimation.” Hydrological Science Journal, Vol. 62, No. 12, 1891–1930.

[8] United States Department of Agriculture Natural Resources Conservation Service Conservation Engineering Division Technical Release 55 June 1986.

[9] Verma S.(2018). "Efficacy of Slope-adjusted Curve Number Models with Varying Initial Abstraction Coefficient for Runoff Estimation", International Journal of Hydrology Science and Technology,8(4),317-338.

[10] Yadupathi M.R. (2009). "Curve-Number-Based Watershed Model Incorporating Quick Subsurface Runoff, with Applications in the Western Ghats, South India." Journal of Hydrologic Engineering 14:876-881.

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