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RAINFALL–RUNOFF MODELLING USING SCS–CN AND GIS APPROACH IN THE TAWA CATCHMENT OF MADHYA PRADESH, INDIA

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ABSTRACT

A rainfall-runoff model is a mathematical model that shows how a catchment area, drainage basin, or watershed's rainfall-runoff relationship works. The rainfall-runoff relationship is used in hydrology science and research, such as hydraulic structure design, drainage morphology, and irrigation planning, as well as flood forecasting. The same is estimated in order to identify and forecast its impact on the Tawa River. With the use of remote sensing and GIS technologies, the Soil Conservation System (SCS) CN technique is utilised in this research for runoff estimation, which analyses parameters such as slope, vegetation cover, and watershed area. The use of remote sensing and geographic information systems (GIS) can help solve problems with traditional runoff estimation approaches.

Keywords:

INTRODUCTION

A rainfall-runoff model is a mathematical representation of the rainfall-runoff connection in a catchment region, drainage basin, or watershed. When it comes to calculating outflow from the basin, a rainfall runoff model comes in handy. The rainfall-runoff relationship is used in hydrological science and research, such as hydraulic structure design, drainage and irrigation planning, and flood predictions. Runoff has a considerable impact on the use of water resources. The intensity, duration, and dispersion of rainfall events determine the occurrence and quantity of runoff. The most essential hydrologic variable in most water resources applications is runoff. The most significant component to consider in watershed management is runoff, which is assessed by the watershed's physiographic characteristics. Estimating runoff in a watershed is critical for efficient management of precious water resources. The Soil Conservation Services (SCS) Curve Number methodology is the most extensively used method for estimating direct runoff for watersheds.

Obtaining runoff from the land surface into streams and rivers in ungauged watersheds is challenging and time intensive. Predicting river discharge necessitates a large amount of hydrological and meteorological data, which is an expensive and time-consuming operation (Kumar et al., 2010). The most typical challenge faced in hydrological research is estimating runoff from a watershed for which there are records of precipitation but no records of observed runoff.

This type of problem can be solved by comparing runoff characteristics to watershed characteristics. Soil type and cover, which includes land use, are important watershed factors when determining the volume of runoff that will arise from a given quantity of rainfall (Jabari et al. 2009).

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As Tawa catchment is ungauged it's become imperative to assess the runoff through available techniques. Therefore SCS–CN model is used for estimation of runoff.

In drainage basins where no runoff has been recorded, the curve number approach, SCS-CN, can be used to forecast the depth of direct runoff from rainfall depth, given an index characterising runoff response characteristics. The Curve Number Method was designed for conditions in the United States by the Soil Conservation Service (Soil Conservation Service 1964; 1972). It has been adapted to situations in other regions of the world since then. The method is represented by representing a single parameter relationship between rainfall depth and runoff depth with curve numbers. S is the single parameter relation, while CN is the transform of S. (Clapper [6]). To calculate direct surface runoff, the SCS-CN approach is extensively employed. It emerged from (I) Sherman's (1949) proposal to plot direct runoff versus storm rainfall; Andrews' (1982) graphical procedure for estimating runoff from rainfall for a combination of soil texture and type, amount of vegetation cover, and conservation measures, also known as soil vegetation land use, and Mockus' (1949) work on estimating surface runoff for ungauged stations using soil information, rainfall, storm duration, and average annual temperature (SVL).Thus the empirical runoff relation of Mockus and SVL complex of Andrews founded SCS-CN method. Extensive work has been done to estimate discharge in rivers and are as follows: Chanu et al (2015); Manjunath and Suresh (2013); Topno *et al*. (2015); Aghil and Rajashekhar S.L (2018); These studies focuses on estimating direct runoff using Soil Conservation Service Curve Number (SCS-CN) method based on all the three antecedent moisture conditions (AMC I, AMC II and AMC III). The Runoff curve maps were obtained by combining these empirical and SCS-CN table. Singh *et al.* (2011) Estimation of daily flood discharge for small ungauged watersheds has been carried out using SCS-CN. The catchment area of Varekhadi is about 442 km^2 and is a part of Lower Tapi basin in Western India. The model required parameters such as hydrological soil group, land use and incidence soil moisture were prepared in GIS and remote sensing software. In this case study, the runoff estimation from the SCS–CN model adjusted for India conditions was employed in the Tawa watershed utilising a conventional database and GIS.

STUDY AREA

Tawa River, a left bank tributary originates from Mhadeo hills in Chindwara district, flows through Betul and drains a part of Hoshangabad district and finally merges in to Narmada River in Hoshangabad. It is the longest tributary of Narmada (172 Km) on the left bank (Chatterjee, Undated). At Tawa, Denva River joins Tawa River 823m upstream of Tawa dam site. This reservoir is located near Ranipur village, 35 Km from Itarsi railway Junction. The dam is positioned at latitude of 22º 30’40’’ N and a longitude of 77º 56’30’’ E. The study area falls in survey of India (SOI) Toposheet Nos. 55 F/12, 55 F/13 between latitude 22º30' 00" to 22º50' 00" N and longitude 77º 45' 00" to 78º 00' 00"E.The catchment area of the reservoir is 5836.6 Km^2.

Drainage map have been prepared with the help of Digital Elevation Model and verified by toposheets and field checks. Drainage map shows the water bodies and tributaries in the Tawa catchment. Drainage network is divided up to fourth order streams. The total length of channel in Tawa catchment is 1787.85 Km and total basin area is 5836.6 Sq.Km. Drainage density of basin is calculated Drainage Density of Basin = Total Channel Length (km) / Total Basin Area (km^2).DEM of Tawa Catchment shows lowest elevation of 300 m and highest elevation of 1,333 m.

MATERIAL AND METHODS

SCS (Soil Conservation Services) is a simple, predictable, and stable conceptual framework for estimating runoff depth that was developed in 1969.It is a well-established strategy that is commonly used in the United States and other countries. The hydrologic soil group, land use, treatment, and hydrologic condition all influence the curve number. The distributed SCS-CN model in a GIS platform is used to estimate runoff in the Tawa river basin in this study.

Fig. 4 depicts the research approach used in this study. The LISS III satellite image was used to create the land use and land cover map. The data for Soil types (clayey and fine) and texture have been collected from National Bureau of

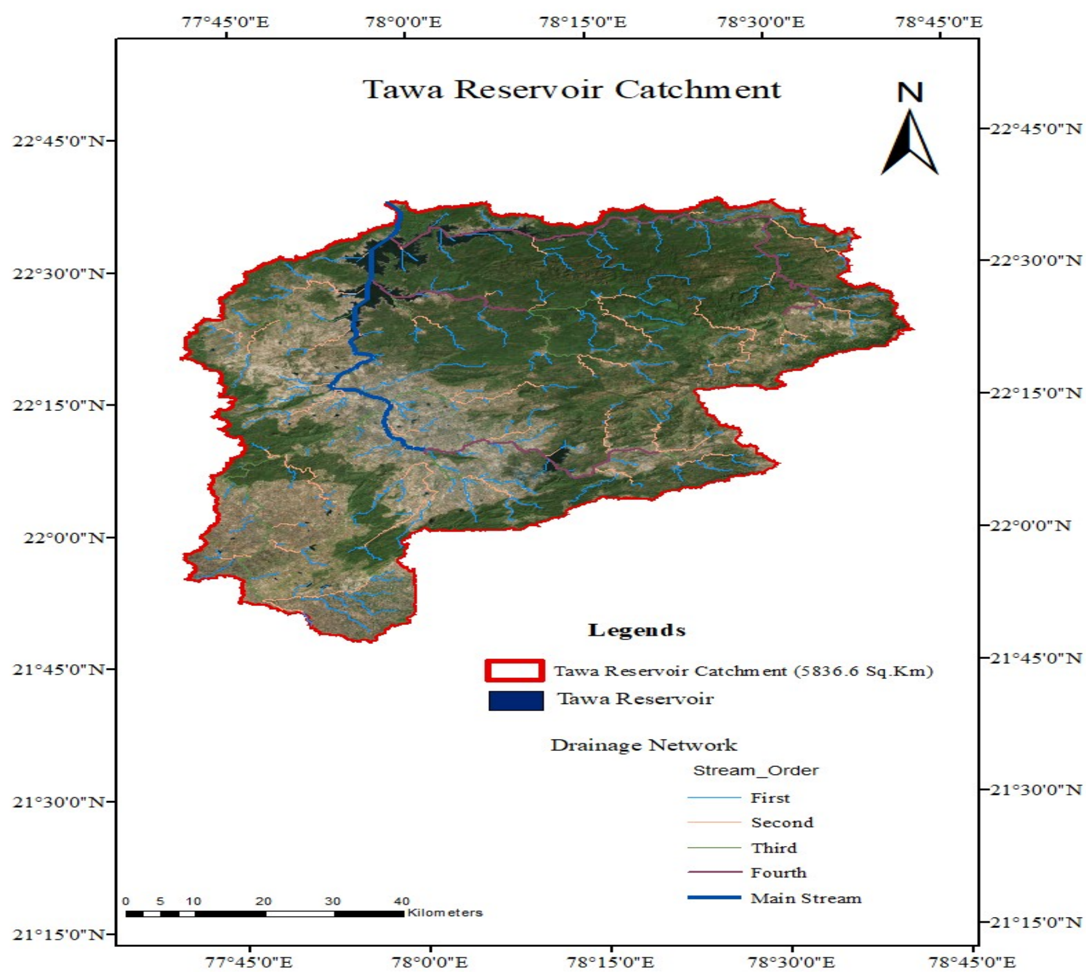

Fig.1: Study Area of Tawa Catchment

Soil Survey and Land Use Planning. (NBSS&LUP, India). ASTER DEM was downloaded from USGS earth explorer. The daily rainfall data is collected from 1996 up to 2017 from State Water Data Centre (SWDC), M.P, India. The surface runoff is estimated using a combination of GIS and the Soil Conservation Service's Curve Number Method. The Soil Conservation Service Curve Number (SCS-CN) approach is commonly used in long-term (continuous) hydrologic simulation models to determine surface run-off. Using ArcGIS' overlaying tool, for the study area, the appropriate area-weighted curve number is computed. The algorithm is then updated to include the daily rainfall database in order to estimate direct runoff. The linear regression model is also established for rainfall – runoff correlation. The results obtained from SCS - CN model and a linear regression model are compared with inflow calculated by Tawa dam authority at the Tawa reservoir site as Tawa is an ungauged river basin.

Surface runoff through SCS - CN model

The Soil Conservation Services (SCS-CN) is one such equation that takes factors such as rainfall, initial abstraction loss, potential maximum retention, soil, and land use/land cover into consideration while assessing runoff. To calculate the direct runoff within the Tawa catchment, the SCS-CN was coupled with ArcGIS 10.4. Each land use soil group with polygon is delineated from the type of soil in the study area and overlaid on LULC to determine the CN based on HSG and LULC using the ArcGIS 10.4 superimposition method, resulting in each land use soil group with polygon. Finally, the area of each polygon is determined and a curve number is assigned to each unique polygon based on standard SCS curve number. The SCS-CN computations were carried out using the mathematical formula listed below. This combination computes the simulated runoff potential for the entire watershed and areas of high runoff potential were identified.

SCS-CN Model

In the early 1950s, the United States Department of Agriculture's Natural Resources Conservation Service (NRCS) (previously known as the Soil Conservation Service (SCS)) developed a method for predicting runoff from rainfall. It's based on the Water Balance formula.

Mathematical description of the SCS-CN model is based on three equations (water balance and two concepts).The water balance equation equates the total rainfall (P) to sum of initial abstraction (I_a), actual infiltration (F) and direct runoff (Q).

The SCS-CN method, expressed as equation (1.1) below.

$$Q = (P-Ia)^2/P-Ia+S \quad \text{............. (1.1)}$$

where, Q = Accumulated storm runoff, m; P = Accumulated storm rainfall, mm, S = Potential maximum retention of water by the soil, Ia = Initial quantity of interception, depression and infiltration and empirical relation was developed for the term Ia and it is given by,

The empirical relationship is,

Ia = 0.2S

In the SCS method it is assumed that the value of λ coefficient equals 0.2, although for Indian context pertaining to the black soil region the values are taken as follows (NIH, 98).

For black soil region (Antecedent Moisture Condition I) and for all other regions:

$$I_a = 0.3S \quad \text{.......... (1.2)}$$

For black soil region (Antecedent Moisture Condition II & III):

$$I_a = 0.1S \quad \text{.......... (1.3)}$$

The form S in the potential maximum retention for Indian conditions is given by,

$$S = \frac{25400}{CN} - 254 \quad \text{............. (1.4)}$$

The potential maximum retention by the soil is given by relating it to a dimensionless parameter known as the curve number (CN) that depends upon the hydrologic soil groups, antecedent moisture conditions as well as land use land cover factors in the catchment area. Where CN is the curve number, which can be found in section 4 of the SCS handbook of Hydrology (NEH-4) (USDA 1972). The equation may now be rewritten as follows:

$$Q = (P - 0.2S)^2/P + 0.8S \quad \text{for } P>0.2S \quad \text{............... (1.5)}$$

Significant the value of CN, the runoff from the watershed was calculated from equation 1.4 and 1.5.

Thus the value of Q that is the net runoff depth depends on the factors like precipitation depth, and the Curve Number chosen for the specific catchment. The criteria for hydrologic soil group classification and CN values for selected land uses for various soil groups have been provided shown in Table 1 and Table 2 respectively. Soils are classified into four hydrologic soil types based on the rate of runoff probable and final infiltration, according to the US Soil Conservation Service (SCS).

Table 1: Hydrologic Soil Groups and Infiltration Rates ***(Source: TR-55)***

Hydrological Soil Group	Minimum Infiltration Rate (in/hr)	Soil Texture
A	0.30-0.45	Sand, Loamy Sand or sandy loam
B	0.15-0.30	Silt loam or loam
C	0.05-0.15	Sandy Clay Loam
D	0-0.05	Clay Loam, Silty Clay Loam, Sandy Clay, Silty Clay or Clay

Table 2: Curve Number for Standard Land Uses and Hydrologic Soil Groups *(Source: SCS or NRCS 1986)*

Land use class	Hydrologic Condition	Hydrologic Soil Group			
		A	B	C	D
Woods And Forest	Poor	45	65	76	82
	Fair	36	60	73	79
	Good	30	55	70	77
Pasture, grassland or range-continuous forage for grazing	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Scrub with Cultivation		45	66	77	83
Agricultural Land (row crops)	Poor	72	81	88	91
	Good	67	78	85	89
(Fallow)	Poor	76	85	90	93
	Good	74	83	88	90
Built Up (Rural) area		46	66	78	83
Water bodies - (River/Stream/ Lakes/ponds)		100	100	100	100

Antecedent Moisture Conditions (AMC)

The antecedent moisture condition (AMC) is the index of the soil condition with respect to runoff potential before the storm. The antecedent moisture conditions are based on the season and 5-days antecedent precipitation (SCS, 1985). AMC II in a watershed is simply an average moisture state for modelling purposes. The following Eqs. 1.6 and 1.7 can be used to calculate equivalent curve numbers (CN) from LU/LC and soil type for the average condition (AMC II), dry conditions (AMC I), or wet conditions (AMC III). In the case of AMC-II, the Curve Number values are acknowledged (USDA 1985) Tables 3, ***(Source: Subramanya K. (1994) "Engineering Hydrology)***

Table 3: Group of Antecedent soil moisture classes (AMC)

AMC Type	**Total Rain in Previous 5 days**	
	Dormant Season	**Growing Season**
I	Less than 13 mm	Less than 36 mm
II	13 to 28 mm	36 to 53 mm
III	More than 28 mm	More than 53 mm

Table 4: Calculations of the watershed's hydrology

AMC Type	CN	**S**	**Ia=0.2S**	**Ia=0.8S**
I	51	248	49.6	77.4
II	70	108	21.6	32.4
III	85	46	9.2	13.8

In the cases of AMC-I and AMC-III (Chow et al. 2002), the following equations are used: For finding out CN value AMC- I and AMC -III used formula.

$$\text{AMC-I } CN(I) = \frac{CN(II)}{2.281 - 0.0128\,CN(II)} \qquad \text{...........1.6}$$

$$\text{AMC-III} CN(III) = \frac{CN(II)}{0.427 + 0.00573\,CN(II)} \qquad \text{...........1.7}$$

Computation of Average Curve Number

To calculate the area weighted average curve number for a watershed, following steps were adopted: The land use map was superimposed on the soil map in ArcGIS platform to get polygons with unique land use class and hydrologic soil group. Appropriate CN value for AMC-II was assigned to each polygon. The geographical area and CN value was multiplied w.r.t. each polygon finally, sum of the product was divided by the catchment area to get area weighted average CN value for the watershed for AMC-II conditions. Where, CN is a dimensionless parameter. It is determined based on hydrological soil group, land use, land treatment and hydrologic conditions.CN=$\sum$ (CNi x Ai) / A

Where,

CN = Weighted curve number

CNi = Curve number from 1 to any number N Ai = Area with curve number CNi

A = Total area of the watershed

Hydrologic Soil Group

Soil attributes such as effective depth of soil, average clay content, infiltration characteristics, and permeability are used to categorize soils hydrologically as shown in Table 2 (Source*: SCS or NRCS 1986),* hydrological soil group is determined for Tawa catchment which basically fall under HSG of B and D(Table 4 and Figure 2). Group B soils had a moderate infiltration rate and were fairly well drained to well drained, whereas group D soils had a sluggish infiltration rate and possible high runoff (Figure 2).

Average Rainfall Assessment by Thiesson Polygon Method

A.H. Thiesson (1911) suggested this method in which weighing effect of area in the area in the form of polygon closest to the station has been considered. Thus it tries to nullify the error due to non-uniform distribution of rain-gauges. 8 Raingauge stations are found in Tawa catchment which is installed in Hoshangabad, Betul and Chinndwara district. Figure 3 depicts the spatial and temporal distribution of rainfall at sub-basin level using Thiessen Polygon method.

The average precipitation of the area is given by $P = (P1A1 + P2A2 + \cdots + PnAn)/\ (A1 + A2 + ... + An)$, Where, A1, A2…., An =Areas of the Thiesson polygon representing the stations 1, 2… n. P1, P2, Pn= Precipitations of corresponding stations.

Using Remote Sensing and GIS techniques, Soil Conservation Service Curve Number (SCS-CN) model was performed to estimate direct runoff. The SCS curve number method requires the parameters such as watershed area, soil, land use/land cover, initial abstraction, and potential maximum retention for estimation of curve number and runoff.

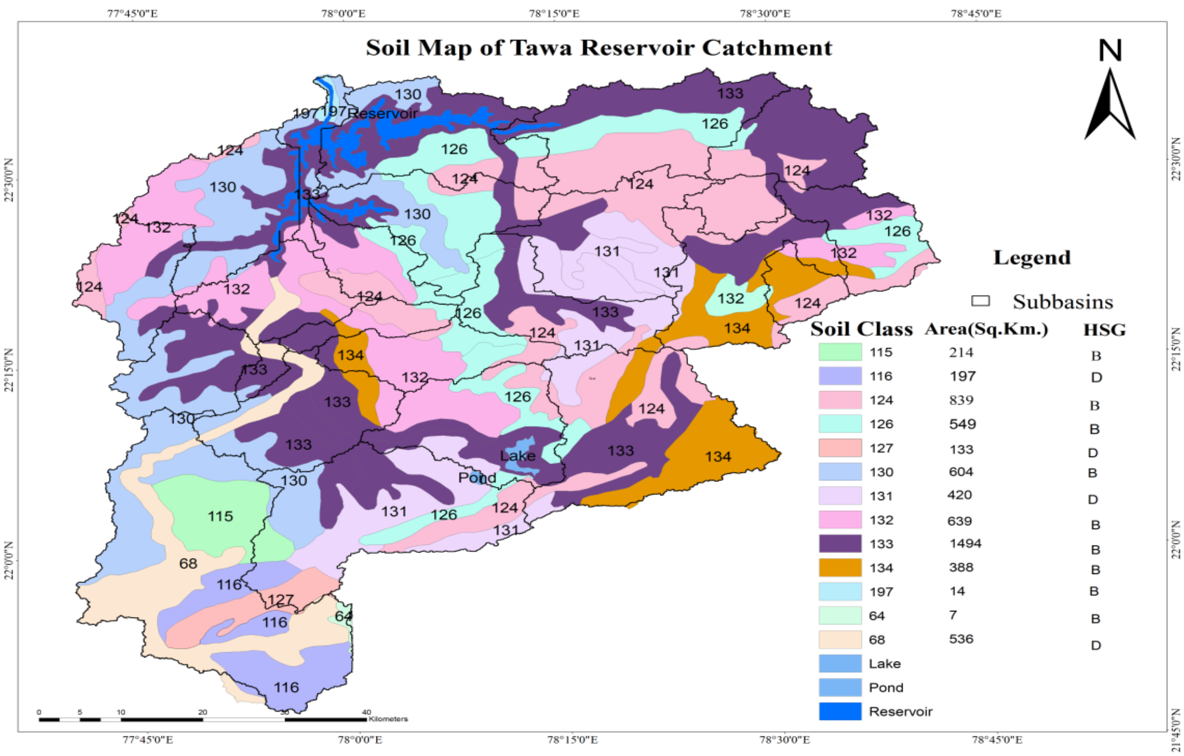

Fig. 2: Soil Map and Hydrological Soil Group of Tawa Catchment

Table 5 : Soil Classification of Tawa Catchment (NBSS)

Soil Class	Description
127	Clayey Soil (Moderately Deep, well drained, Sloping Pediments with Moderate Erosion)
68	Clayey Soil (Deep, Moderately well drained, Gently Sloping with Moderate Erosion)
64	Loamy Soil (Very Shallow, Excessively drained, Severe Erosion)
197	Loamy Soil (Deep, well drained, Moderate Erosion)
116	Clayey Soil(Moderately Deep, well drained, Moderate Erosion)
115	Loamy Soil (Shallow, well drained, Moderate Erosion)
134	Loamy- Skeletal Soil(Extremely Shallow, Excessively drained, Severe Erosion)
131	Clayey Soil (Moderately Deep, well drained, Moderate Erosion, Gently Sloping with Moderate Erosion)
130	Loamy Soil (Shallow, well drained, Severe Erosion)
132	Loamy Soil (Deep, well drained, Gently Sloping with Moderate Erosion)
133	Loamy Soil (Deep, well drained, Moderately Sloping with Moderate Erosion)
126	Loamy Soil(Moderately Deep, well drained, Moderate Erosion)
124	Loamy Soil (Very Shallow, excessively Drained, Moderately Steep Sloping with Severe Erosion.

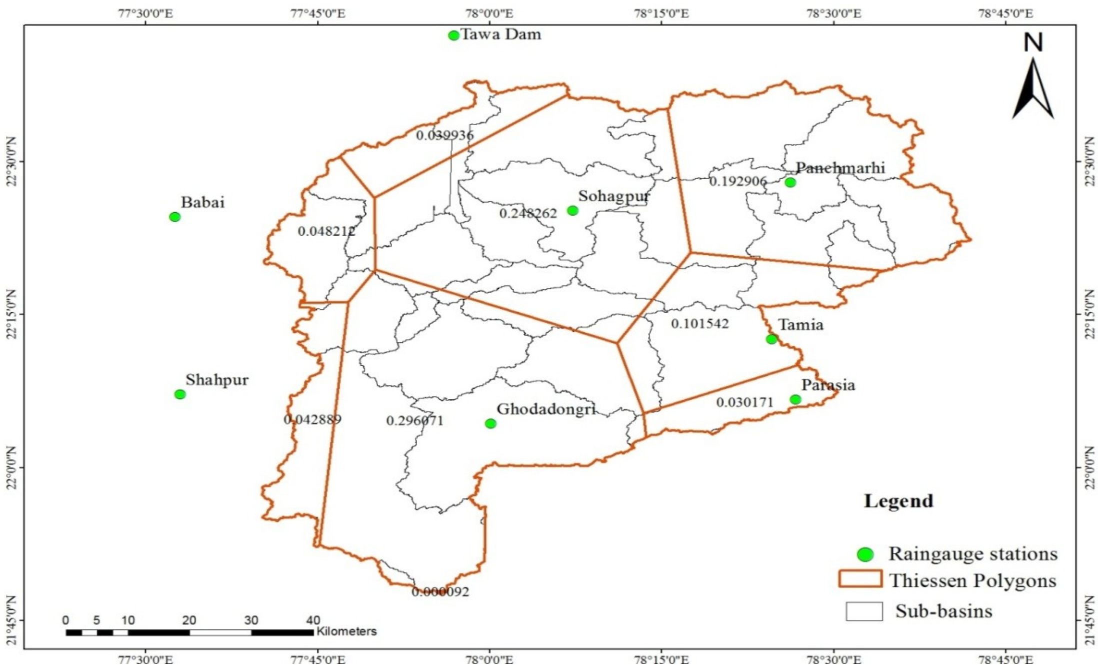

Fig. 3: Spatial distribution of Rainfall at sub-basin scale for Tawa Catchment.

A= Total area of the catchment.

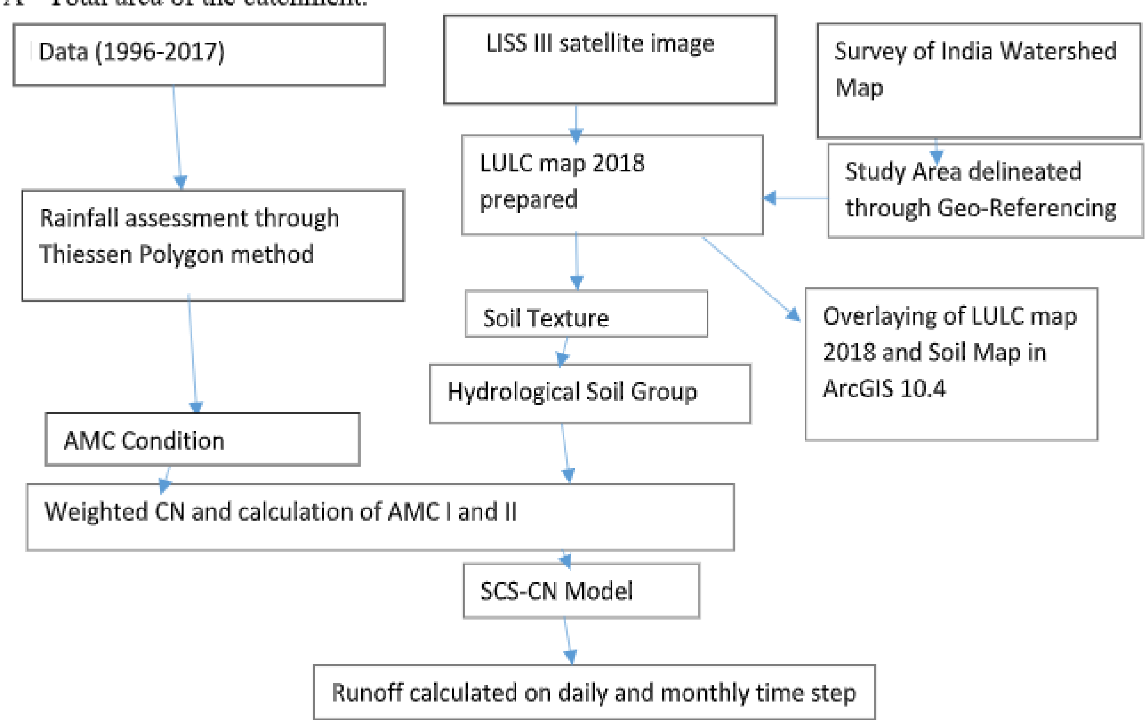

Fig. 4: Flow Diagram methodology for the estimation of direct runoff using the SCS-CN Method

Table 6: SCS-CN model parameter for the year 2017

Moisture	AMC I	AMC II	AMC III
Condition	**Dry**	**Normal**	**Wet**
CN	51	70	85
S	248	108	46
Ia=0.2S	49.6	21.6	9.2
Ia=0.8S	77.4	32.4	13.8

Table 1: Development of weighted CN using Union of LULC and Soil map.

Class	Land Use Classes	HSG	Curve Number	Area(Sq.Km)	Area (%)	Area(%)*CN
1	Settlement	B	72	3.65	0.0626	4.5072
		D	86	9.16	0.1568	13.4848
2	Forest	B	55	2928.4	50	2750
		D	86	641.3	10.99	945.14
3	Water	B	100	177.1	3.03532	303.532
		D	100	37.5763	0.644	64.4
			100	117.98	2.0167	201.67
4	Agriculture or Crop Land	B	81	1187.67	20.36	1648.77
		D	95	286.12	4.9	465.5
5	Scrub Land	B	60	304.02	5.21	312.6
		D	85	140.576	2.4	204
	Sum			5836.4	100	6913.599044
6913.59/100= 70 Weighted CN= 70						

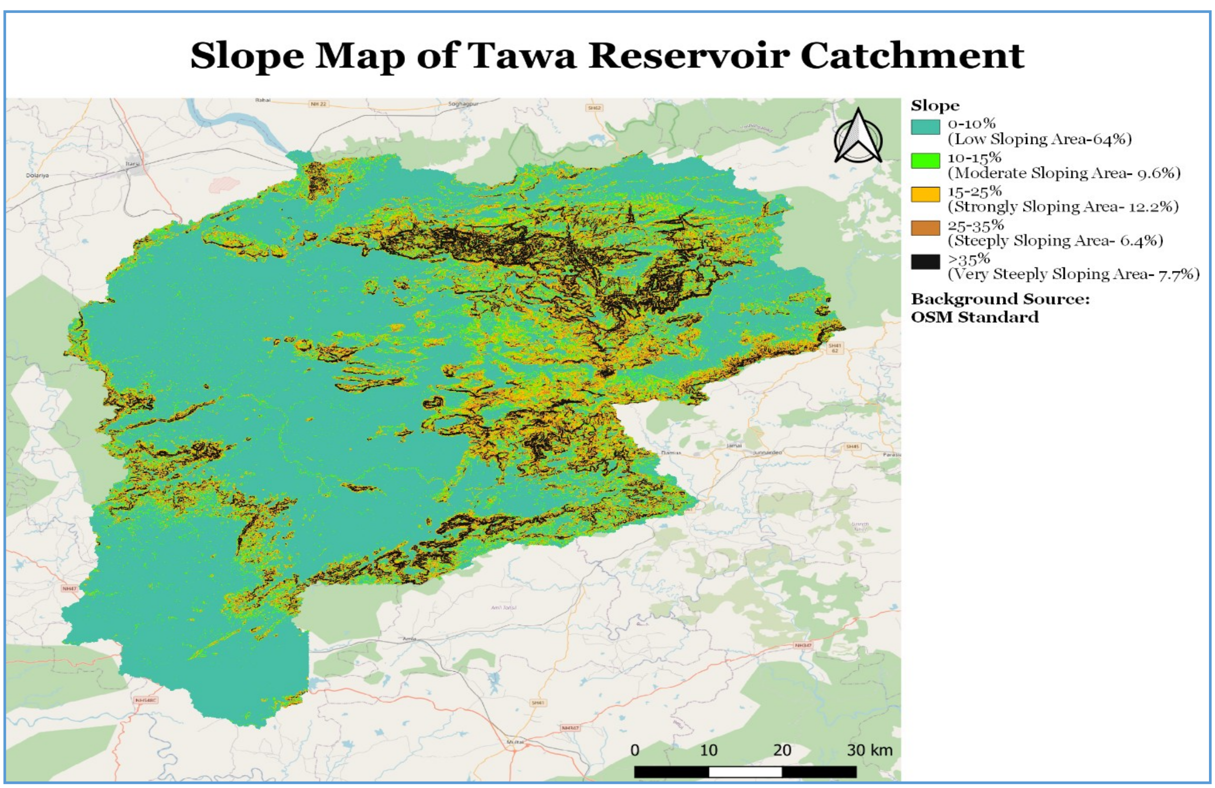

Fig. 5: Spatial distribution of slope map

In the study area, GIS techniques to spatial and temporal distribution of rainfall at sub-basin size have proven to be quite effective (Fig.5). Most area of Tawa Catchment falls under low to moderate sloping class representative of water holding capacity for longer duration (Pawar et al. 2008 and Sateeshkumar et al. 2017) in turn increasing the chances of infiltration and recharge in the study area. Along with drainage, this is an excellent location for check dams and percolation tanks, both large and small. The average annual surface runoff depth in the Tawa watershed for the last twenty-four years has been calculated using the SCS method and found to be approximately equal to 5820.469 mm, which when multiplied by the watershed's area (5982.9Sq.Km or 5,983,000,000m^2) yields a total average runoff volume of (1450994580 m^3), accounting for 22.00 percent of total annual rainfall. Table 8 shows the annual rainfall and runoff in the study region from 1995 to 2018.

RESULTS AND DISCUSSION

In this study, an attempt is made to estimate the amount of runoff from Tawa Reservoir Catchment in Hoshangabad district of Madhya Pradesh. The Curve Number method of the Soil Conservation Service (SCS) is a simple, frequently used, and effective method for calculating the quantity of runoff following a rainfall event in a specific area. The approach was used to estimate the runoff from the Tawa Catchment in this study. The following are the study's primary conclusions:

In Table 7, the computed curve numbers for normal, wet, and dry circumstances are 70, 85, and 51, respectively. As illustrated in Table 8, the runoff fluctuates between 59 and 653.50 mm from 1995 to 2018. As indicated in Fig.8, rainfall in the watershed ranges from 607 to 1797 mm. The computed average annual runoff is 234.55 mm, and the

Table 8: Annual average runoff depth and volume

Years	Rainfall in mm	Runoff in mm	Volume(m^3)=Runoff*Area
1995	789.08625	89.60	536071408.4
1996	856.39875	149.69	895633204.1
1997	1030.5	201.79	1207350500
1998	1178.452	318.13	1903359968
1999	1536.784	390	2333370000
2000	768.706	59.10	353632173.8
2001	949.764	129.21	773082099.8
2002	1169.836	270.63	1619198890
2003	1196.888	170.90	1022551609
2004	1028.124	162.52	972339283.5
2005	1211.306	257.65	1541554283
2006	1313.084	250.95	1501419326
2007	1146.552	330.41	1976870996
2008	909.82	82.71	494857402.5
2009	1263.196	256.44	1534297323
2010	984.596	113.55	679398017.6
2011	817.0116667	74.40	445139052.6
2012	1626.975	628.48	3760222271
2013	1797.225	653.50	3909893829
2014	1105.825	300.61	1798556434
2015	1061.7	233.46	1396767640
2016	1270.8625	438.05	2620880828
2017	827.725	104.01	622330766.6
2018	607.625	81.74	489040202.7
Average	1102.00 mm	242.51mm	1450994580 m^3

average runoff volume for the past twenty-four years is 1433077496 m^3. The rainfall runoff relationship for the Tawa watershed is shown in Fig. 8. Rainfall and runoff are strongly correlated, with a correlation coefficient (r) of 0.84.

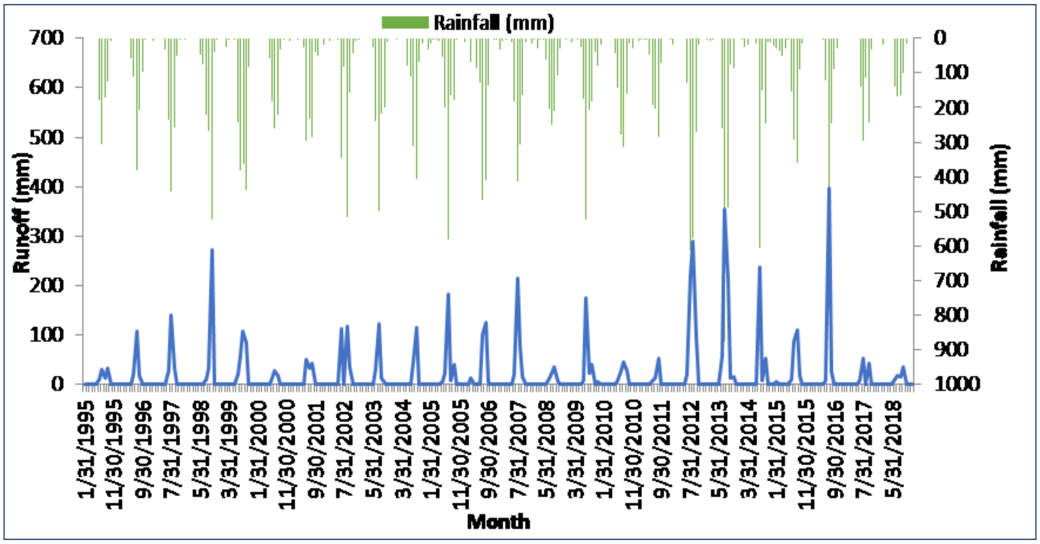

Figure 6: Monthly Runoff Simulation from SCS-CN (1995-2018)

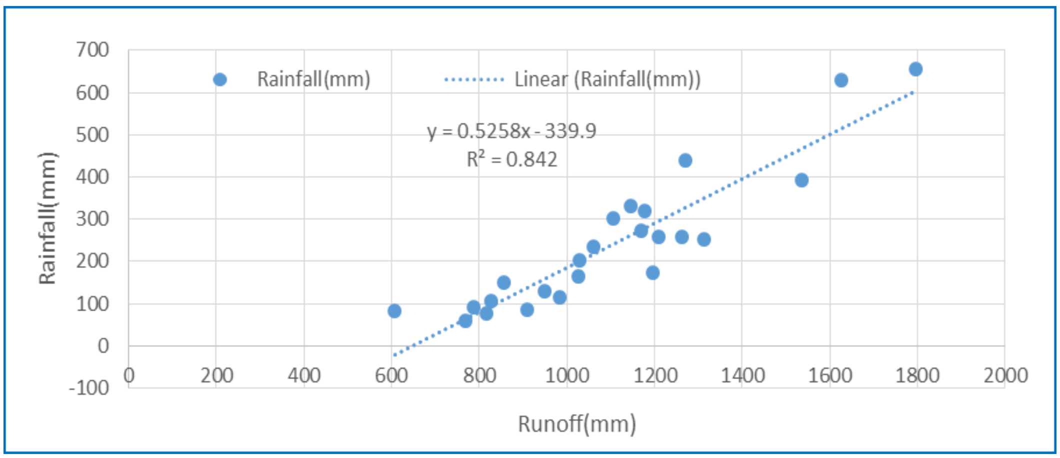

Fig. 7: Scatter plot between the yearly rainfall and simulated runoff(SCS-CN model)

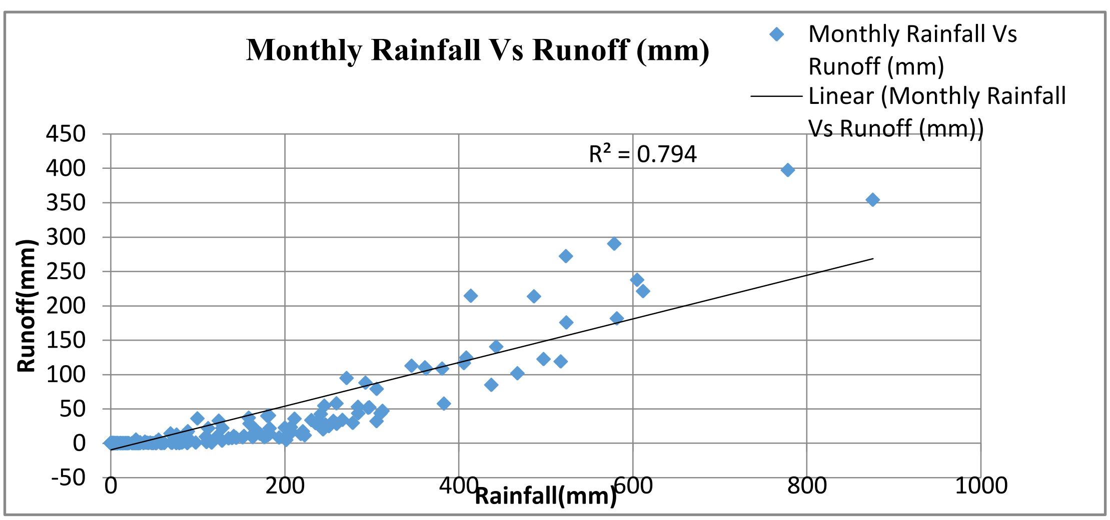

Fig. 9: Scatter plot between the monthly rainfall and simulated runoff (SCS-CN model).

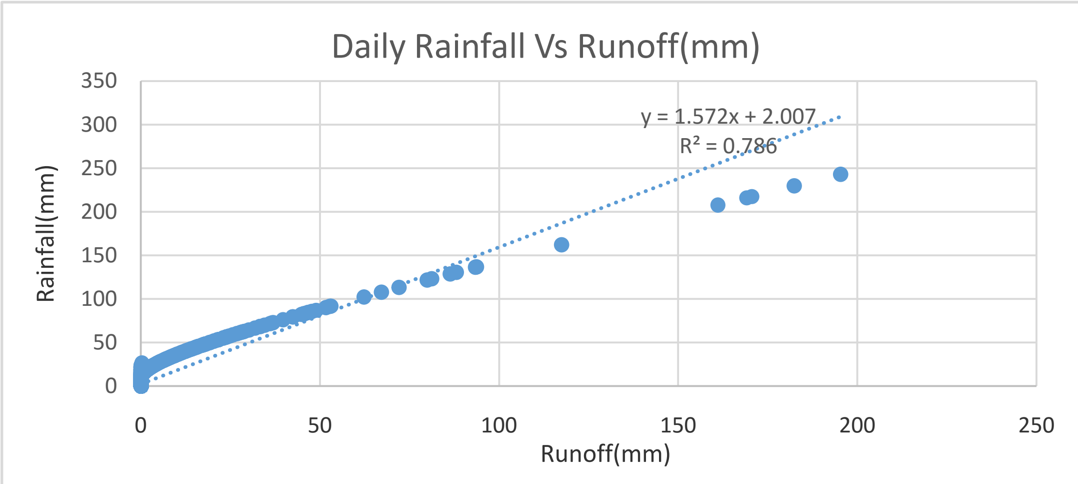

Fig. 10: Scatter plot between the daily rainfall and simulated runoff (SCS-CN model).

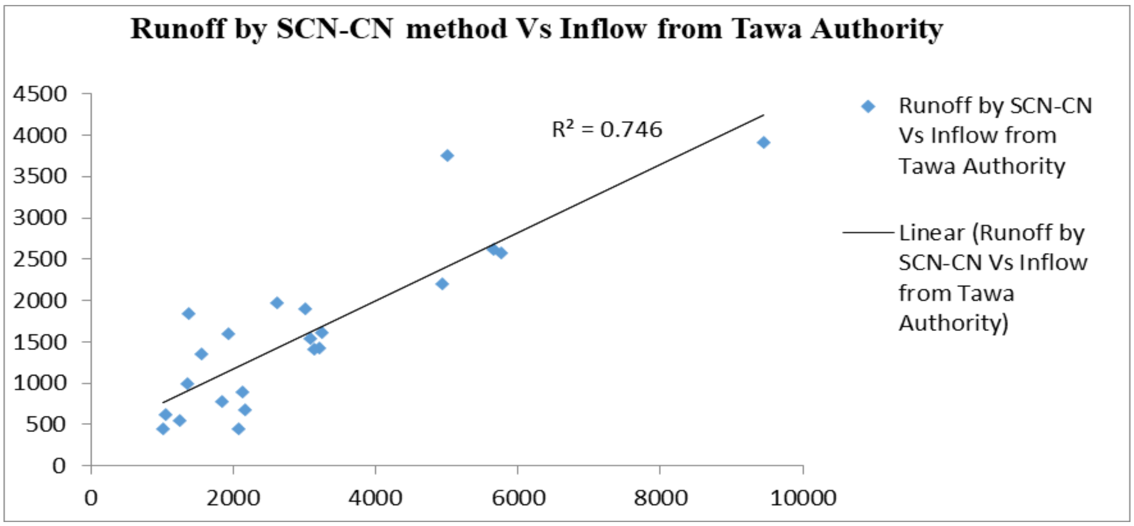

Fig. 11: Correlation Coefficient between Simulated Inflow(SCS-CN model) and Inflow data (Tawa dam control authority)

1. The daily rainfall trend in the catchment region is examined during a 23-year period, from 1995 to 2018. On July 7, 2007, the highest daily rainfall of 229.66 mm was recorded. The highest monthly rainfall was 875.78 mm in July 2013, while the maximum annual rainfall was 1797.22 mm. July and August were the months with maximum rainfall over the previous 23 years. Over a period of 23 years, precipitation has shown to be highly varied.

2. The runoff for the Tawa catchment is calculated using SCS-CN method for a period of 23 years i.e 1995-2018. The calculated yearly runoff in mm for the last 11 years from 2008-2018 is 82.71, 251.44, 113.55, 74.40, 628.48, 653.50, 300.61, 233.45, 438.05, 104.01 and 81.74 mm respectively.

3. For the years 1995 to 2018, the SCS-CN approach was used to compute monthly and annual runoff. In the year 2000, the minimum runoff was recorded, and in the year 2013, the maximum runoff was recorded.

4. The correlation coefficient shows good correlation (R^2 =0.75) between observed inflows (Tawa dam control authority) and computed runoff (SCS-CN method) shown in Figure 11 and is useful in validating the observed inflow series.

CONCLUSION

In this study, the soil conservation service and the Curve Number model were used to model the hydrology of the Tawa Catchment utilising land use and land cover maps and soil maps developed in ArcGIS as input. Stakeholders can use this strategy to protect water resources and water quality in a watershed. The runoff calculation in this study was based on an average yearly precipitation of 1102 mm from 1995 to 2018. The precipitation caused a runoff of 243 mm. As most of the Tawa catchment falls under the low to moderate sloping class (74%) representative of water holding capacity for longer duration, This data indicates that 78 percent of rainfall infiltrates into the ground, while the remaining 22 percent is transformed to runoff, enhancing infiltration and recharge opportunities in the studied region. Good soil and water conservation measures must be established and implemented in the watershed to reduce runoff and soil erosion. For controlling runoff and soil erosion, good soil and water conservation measures must be established and executed in the watershed region, which is classed as very steeply sloping followed by strongly sloping (26 percent). The CN number changes depending on the soil, and this is taken into account when determining runoff depth, therefore the soil's prior moisture state is crucial. The CN number in the Tawa catchment is calculated to be 51 for AMC-I, 70 for AMC-II, and 85 for AMC-III (Table 6). To summarise, the Soil Conversations Service –Curve Number approach has been successfully proven as a method that helps in validating the observed inflow series at the Tawa dam site (R^2 =0.75) in Fig.11, as well as consuming less time and facility to handle large data sets and a wider environmental area to identify site selection of artificial recharge structures.

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Declarations

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Conflict of Interest: no conflict of interest

Availability of Data and material: The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval-complied with ethical standards.

Consent to participate- Consent given by all authors

Consent for publication-The authors has not submitted this paper elsewhere and give their consent for publication in this reputed journal.

REFERENCES:

1. Andrews' (1982) “Bank stability and channel width adjustment, East Fork River, Wyoming” Water Resource Research, Vol18 Issue 4, pp 1184-1192.
2. Aghil and Rajashekhar S.L (2018); “Estimation of Runoff using SCS-CN method for Yelahanka region”, International Journal of Applied Engineering Research (IJAER) Volume 13, Number 07(2018) Special Issues, pp. 229-233.
3. Chanu S.N, Thomas Alex, Kumar Pravendra (2015); “Estimation of Curve Number and runoff of a micro-watershed using Soil Conservation Service Curve Number method”, Journal of Soil & Water Conservation 14(4): 317-325.
4. Clapper, P. E., “Antecedent moisture considerations in the SCS Curve Number rainfall-runoff model”: unpubl. MSc thesis, Dept. Civil Engineering, Colorado State Univ., Fort Collins, CO, 104~,1980.
5. Manjunatha,S.B, Gowda Y.P, Satyareddi Sunil & Yogesh C; (2013). Study on Water Requirement of Maize (Zea mays L.) using CROPWAT Model in Northern Transitional Zone of Karnataka. Journal of Environmental Science, Computer Science and Engineering & Technology. 2. 105-113.
6. Mockus, V. 1949. Estimation of total (peak rates of) surface runoff for individual storms, Exhibit A of Appendix B, Interim Survey Report Grand (Neosho) River Watershed, USDA.
7. Pawar NJ, Pawar JB, Kumar S, Supekar A (2008) Geochemical eccentricity of ground water allied to weathering of basalt from the Deccan volcanic province, India: insinuation on CO2 consumption. Aqua Geochem 14:41–71.
8. Sateeshkumar.S, Venkateswaran .S, Kannan.R; Rainfall–runoff estimation using SCS-CN and GIS approach in the Pappiredipatti watershed of the Vaniyar sub-basin, South India. Model.Earth Syst. Environment. (2017) 3:24
9. SCS, 1985 Soil Conservation Service_ 1985. National engineering handbook. Section 4- Hydrology. Washington, DC
10. *SCS or NRCS 1986* SCS. Urban Hydrology for Small Watersheds, Technical Release No. 55 (TR-55); United States Department of Agriculture, Soil Conservation Service, US Government Printing Office: Washington, DC, USA, 1986; pp. 2–6.
11. Sherman, L. K. (1949). “The unit hydrograph method.” Hydrology, pt. 9 of Physics of the earth, O. E. Menizer, ed., Dover Pub., New York, 514.
12. Subramanya K. (1994) Engineering Hydrology Tata McGraw-Hill Education, 01-Jan-1994 - Hydrology - 392 pages
13. Thiessen, A. H. (1911). Precipitation average for large areas. Monthly Weather Review, 39: 1082- 1084.
14. Topno. A, Singh A.K, Vaishya, R.C. (2015); SCS-CN Runoff estimation for Vindhyachal region using remote sensing and GIS. Int. J. Adv. Remote Sens. GIS 2015, 4, 1214–1223.
15. USDA (1985), Soil Conservation Service, "National Engineering Handbook", USA.
16. USDA (1986) Urban hydrology for small Watersheds, TR-55, United States Department of Agriculture, 210-VI-TR-55, 2nd edn June 1986.