Comparative Evaluation of Morphometric Parameters on Runoff Estimation of Savitri Watershed, India

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Abstract. A Morphometric assessment has emerged as an effective tool to recognize and analyze the neotectonic signatures governing a particular drainage basin. Studies on Morphometric properties involving the linear, areal and relief aspects are vital as it aids in evaluating the hydrological response and prioritization of watersheds. This would further help in understanding the simulation of the rainfall-runoff process as it forms an inherent component of the hydrological environment at the watershed scale. The present research attempts to investigate and compare the morphometric parameters of the Savitri watershed considering two datasets (toposheet and DEM) over two time periods. The Savitri is designated as a seventh-order basin with a dendritic pattern covering a total area of 1966.34 km^2. Additionally, after the enumeration of the parameters, the runoff estimation is determined using the Natural Resources Conservation Service-Curve Number (NRCS-CN) method that incorporates soil types, land use, and land cover, slope, rainfall of the region along with antecedent moisture conditions. The scatter plot computed between rainfall and runoff signifies that the correlation coefficient (r) is 1 representing a perfectly positive correlation between the two variables. Thus, the results reveal that the runoff of the region has been substantially reduced from high to moderate flow accompanied by a decrease in rainfall amount from 1990 to 2020.

Keywords: Morphometric analysis · NRCS-CN · Runoff Estimation

J. An et al. (Eds.): GeoChina 2021, SUCI, pp. 58–79, 2021.
https://doi.org/10.1007/978-3-030-79641-9_5

1 Introduction

Being an integral part of the fluvial landscape, watersheds form geohydrological units draining to a common point by a system of streams (Sakthivel et al. 2019). To understand the underlying structural components, hydrological and geomorphological features, (Mahala 2020) it is necessary to investigate and quantify the Morphometric properties of each drainage basin. Morphometric analysis refers to the quantitative or numerical measurement of landforms (Clarke 1966) in respect to linear, areal, and relief aspects of any basin that aids in assessing the hydrologic response (Abdulkareem et al. 2018) and prioritization of watersheds. With time, owing to both natural and human-induced factors, watersheds across the globe are facing rapid deterioration in terms of water quality and aquatic ecosystems (Agidew and Singh 2018) that needs to be addressed.

The quantitative assessment provides insight upon the form and processes governing a drainage basin and its related information is vital (Prabhakaran and Raj 2018) for sustainable planning and managing the existing resources available within a watershed. Initially, the Morphometric study propounded by Horton (1932, 1945) and later on many scholars such as Stahler (1952, 1964) further carried forward the works (Asfaw and Workineh 2019). Furthermore, geomorphological investigation reflects the hydrological characteristics which are vital to understand the simulation of the rainfall-runoff process and also to predict any flood peaks in the future (Abdulkareem et al. 2018). This rainfall-runoff response constitutes an extremely complex event (Pathare and Pathare. 2020) forming intrinsic components of the hydrological environment at the watershed scale.

Rainfall and runoff comprise the major sources of water for replenishing groundwater in a particular watershed. The magnitude and rate of runoff are influenced by geomorphological variables, especially the land-use dynamics, soil, precipitation data, etc. (Kumar et. al. 2017). To estimate and predict the runoff volume for a given rainfall event, the most widely used method developed by the United States Department of Agriculture (USDA) is Natural Resource Conservation Service Curve Number (NRCS-CN) model (Rao 2020, Soulis and Valiantzas 2012, Saravanan and Manjula 2015).

With the advent of geospatial tools involving Remote Sensing (RS) and Geographical Information System (GIS), computation of various morphological and hydrological parameters has become convenient and time-effective. The evaluation of various Morphometric variables and runoff estimation of the present research has been assessed and processed in a GIS environment (Agidew and Singh 2018, Pathare and Pathare 2020, Agarwal et al. 2013). The work also involves a comparative analysis of Morphometric variables extracted from the Survey of India (SoI) topographical sheet (1:50,0000) for the year 1967 and AlosPalsar DEM (30 m) for 2020 to examine the changes developed over the Spatio-temporal dimension in the study area. In contrast, for the assessment of runoff, the NRCS-CN model is integrated with geospatial tools wherein the Curve Number (CN) parameter values are selected from the NRCS standard table (Soulis and Valiantzas 2012, Amutha and Porchelvan 2009). Keeping this view in the backdrop, the present study aims to perform the Morphometric parameters and runoff estimation using geospatial tools to assess the hydrological behavior sustaining in the Savitri watershed.

2 Study Area

Administratively, the study area as shown in Fig. 1 is situated in the Raigad District of Maharashtra State. The district is spread over 134 km in the north-south direction and an average east-west extent is 52 km. The topography of the district is dissected by basins of westward flowing rivers namely Patalganga, Amba, Kundalika, Kal, and Savitri. The study area falls within the Western Ghat region wherein the maximum elevation is 520 m and the width of the coastal belt in this region is about 50 km. The Mahad region is part

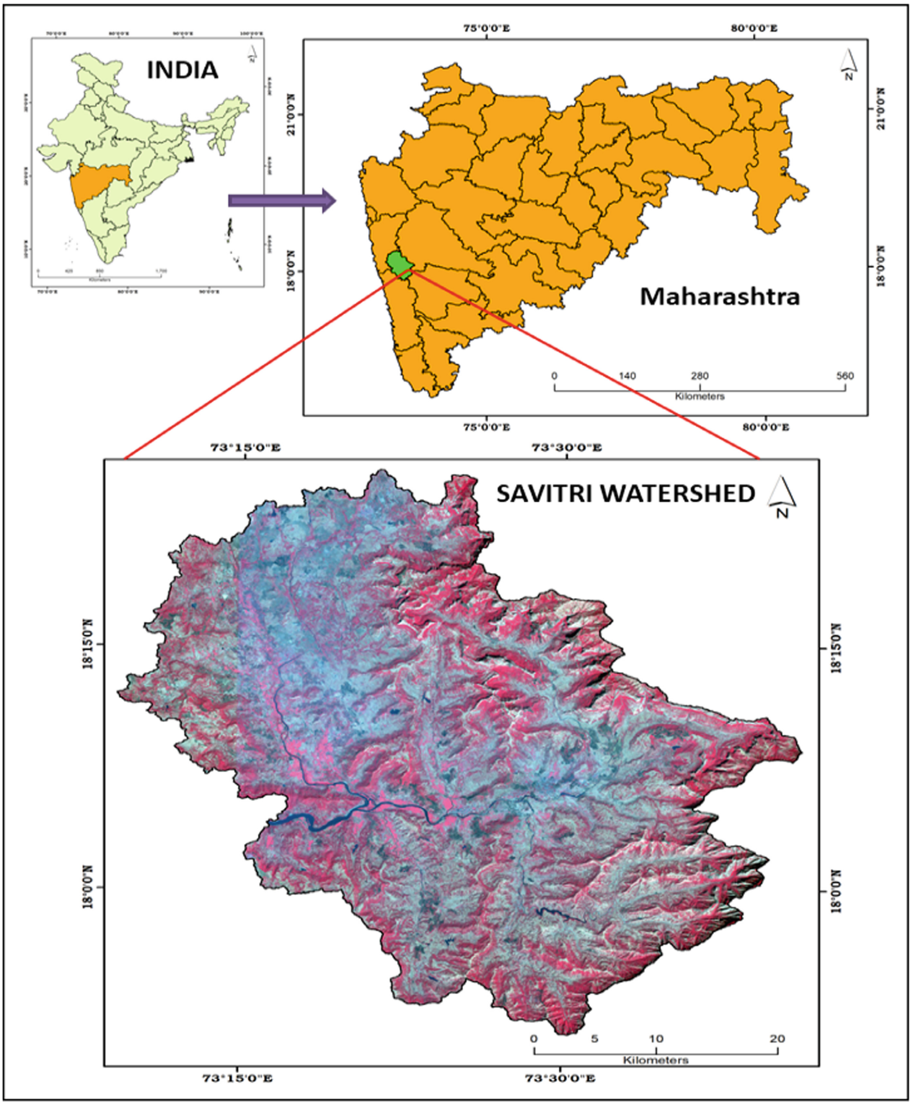


Fig. 1. Location map of Savitri watershed

of the Konkan Coastal Belt from the Raigad district of Maharashtra. This region is traversed by westerly flowing Savitri River and its tributaries. The major tributaries of Savitri are Kal River, Gandari River, Ghodnala, Kalnadi, Negeshrinadi. The study area is bounded between 17° 51′5″ North to 18° 25′ 56″ North Latitude and 73° 9′ 18″ East to 73° 41′3″ East Longitude and includes about 1966.34 sq. km. The area is covered by Survey of India topographic maps numbers of 47F/3, 47F/4, 47F/7, 47F/8, 47F/11, 47F/12, 47G/5, 47G/9 of 1:50,000 scale. In the study area, most of the drainages were controlled by structural features and originated from the plateau top and make it highly dissected in nature. Different geomorphic features like a dissected plateau, debris slope, pediment, and Pedi plain complexes, and younger alluvial plain are found in the area. The study region receives an average annual rainfall of 3413 mm per year. The study region was affected by landslides due to heavy rainfall particularly during southwest monsoon (June to September); for example in 1992 (20th August), 1994 (24th August), 2005 (25th and 26th July), 2018 (5th July) caused huge damages to properties, injuries and death of people.

3 Morphometric Analysis

The flow chart of the adopted methodology is presented in Fig. 2. Initially, the base map of the Savitri watershed is delineated using a set of geo-referenced Survey of India (SoI) topographical maps viz. 47F/3, 47F/4, 47F/7, 47F/8, 47F/11, 47F/12, 47G/5, 47G/9 (R.F 1:50,000) and later verified with ALOS PALSAR data of resolution 30 m in GIS platform. The main objective of the present research is to prepare a comparative study of morphometric parameters extracted from two datasets separately - a) Topographical maps (1:50,000 scale) for 1967 and b) ALOS-Phased Array type L-band Synthetic Aperture Radar (PALSAR) digital elevation model (DEM) (30 m) for 2020 (Rajasekhar et al. 2018). The comparative assessment is undertaken to understand the hydrological characteristics of the basin over different time scales. Thus, the derived information of the basin properties will enhance to estimate of the rainfall-runoff relationship that would further predict the occurrences of flood peak in a basin (Harsha et al. 2020; Abdulkareem et al. 2017).

Extraction of Morphometric attributes from topographical sheets is traditional as it is manually computed but recently, it has been overcome by the use of digital datasets having more global coverage with better resolution (Fenta et al. 2017; Kanday and Javed 2017). For the present work, the parameters calculated using topographical maps are considered as the base for comparing with that derived from ALOS PALSAR DEM and is validated with Google earth imageries/country points. Within the framework for assessing Morphometric variables, three aspects such as linear, areal, and relief involving the variables such as stream order, stream number, stream length, form factor, elongation ratio, circularity ratio, drainage density, stream frequency, relative relief, absolute relief, etc. are selected for the study. The description of numerous Morphometric properties (Table 1) and their comparative assessment is represented in (Table 2). The comparative study is conducted to see the variation between the two datasets as well as to detect the changes undergoing by the basin over the period. (Dikpal et al. 2017; Soni 2017; Chandrashekar et al. 2015; Vincy et al. 2012, Malik et al. 2019; Balasubramanian et al. 2017).

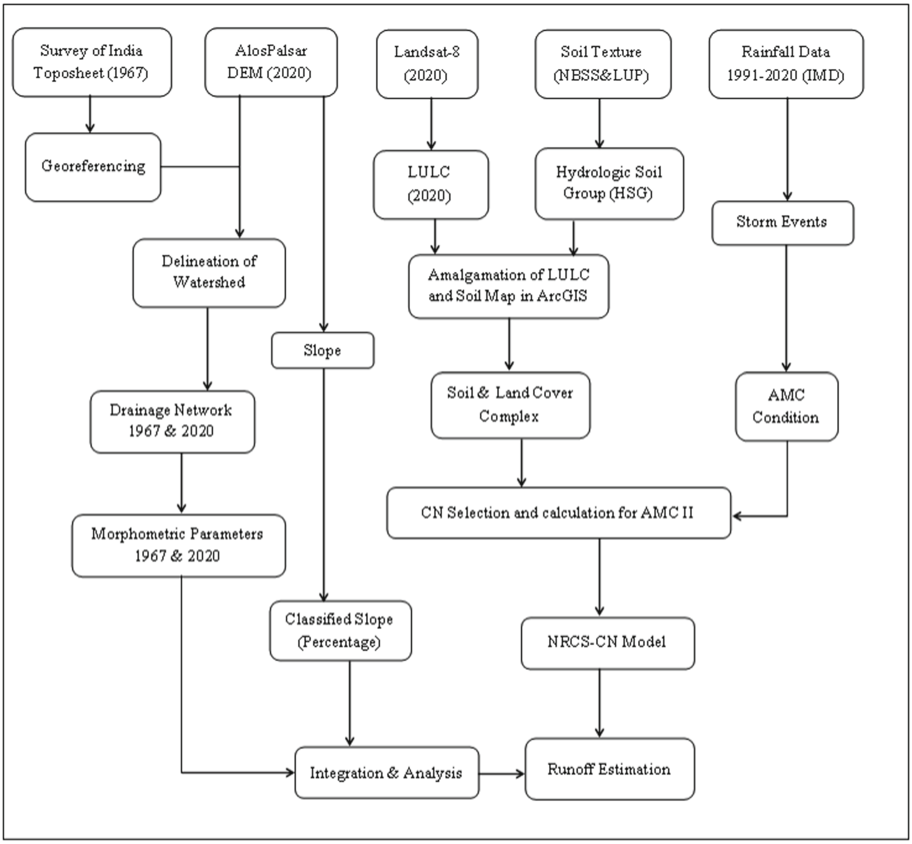


Fig. 2. Methodology flow chart for runoff estimation

Table 1. Standard methods of morphometric attributes

Sr. No.	Morphometric attributes	Methods
Drainage network		
1	Stream order (u)	Hierarchical rank
2	Stream numbers (Nu)	Nu = N1 + N2 + N3 + …Nn
3	Stream length (Lu)	Lu = L1 + L2…Ln
4	Bifurcation ratio	Rb = Nu/Nu + 1
5	Main channel length (MC)	GIS analysis
6	Sinuosity (Si)	Si = VL/LB
Basin geometry		

(*continued*)

Table 1. (*continued*)

Sr. No.	Morphometric attributes	Methods
7	Watershed area (A)	GIS analysis
8	Basin length (LB)	GIS analysis
9	Basin perimeter (Pr)	GIS analysis
10	Basin width (W)	W = A/LB (km)
11	Circularity ratio (Rc)	$Rc = 4\pi A/P^2$
12	Elongation ratio (Re)	Re = d/(Lb)
13	Texture ratio (Rt)	$Rt = \sum Nu/Pr$
14	Form factor ratio (FFR)	A/LB^2
15	Basin shape index (Ish)	$Ish = 1.27A/LB^2$
Drainage texture		
16	Stream frequency (Fs)	N/A, N is the total stream number
17	Drainage density (Dd)	L/A, L is total stream length
18	Drainage intensity (Di)	Di = Fs/Dd
19	Length of overland flow (Lo)	1/2D
20	Infiltration number (FN)	FN = Ds * Fs
Relief properties		
21	Maximum elevation (H)	GIS analysis
22	Minimum elevation (h)	GIS analysis
23	Relief (Rf)	Rf = H−h
24	Relief ratio (Rr)	Rr = (Rf/LB) * 100
25	Ruggedness number (Rn)	Rn = Rf.D
26	Mean Elevation (Hm)	GIS analysis

Table 2. Morphometric attributes of Savitri watershed derived from toposheet and DEM

Morphometric attributes	Computed value	
	Toposheet (1967)	DEM (2020)
Drainage network		
Stream orders	7	7
Stream numbers	10132	6753
Stream length (km)	6490.89	5655.86
Mean Bifurcation ratio	3.83	3.8
Main channel length (km)	73.69	68.13

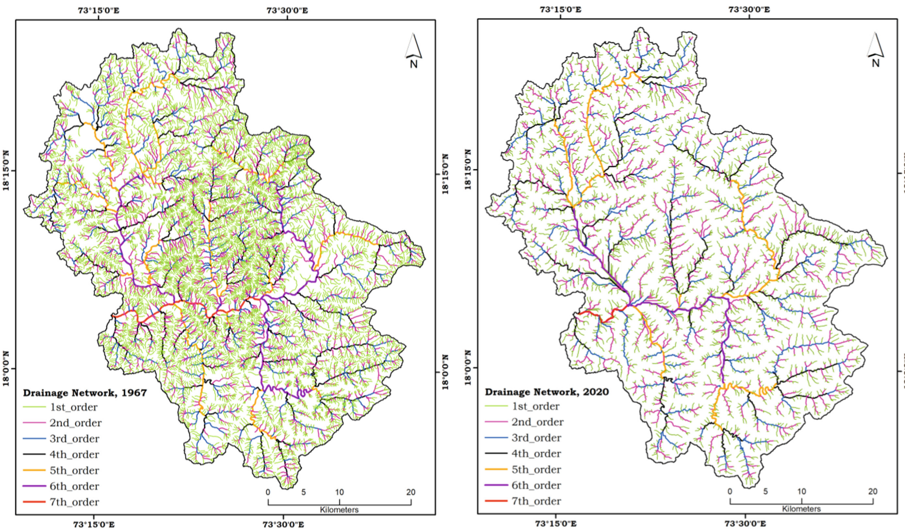
(*continued*)

Table 2. (*continued*)

Morphometric attributes	Computed value	
	Toposheet (1967)	DEM (2020)
Sinuosity	1.45	1.39
Basin geometry		
Watershed area (Sq. Km)	1966.34	1966.34
Basin length (km)	40.9	40.06
Basin perimeter (km)	361	361
Basin width (km)	48.07	49.08
Circularity ratio	0.2	0.2
Elongation ratio	0.8	0.8
Texture ratio	28.06	13.16
Form factor ratio	0.47	0.47
Basin shape index	1.52	1.55
Stream frequency (sq.km)	5.15	3.43
Drainage density (sq.km)	3.3	2.87
Drainage intensity	1.56	1.19
Length of overland flow (km)	1.65	0.8
Infiltration number	17	9.87
Relief characteristics		
Maximum elevation (m)	1100	1401
Minimum elevation (m)	20	2
Relief	1080	1399
Relief ratio		
Ruggedness number	3.56	4.01
Mean elevation	332	701

4 Comparative Assessment of Morphometric Parameters Extracted from Different Datasets

The Morphometric parameters undertaken for the present study are presented in Table 1. Based on the selected indicators, a comparative analysis is prepared using manual and digital extraction procedures for the years 1967 and 2020 in the GIS platform shown in Fig. 3. This comparison analysis would help in synthesizing the changes in hydrological behavior of a particular river basin affecting the runoff flow in the different periods. It is noteworthy that the map scale and DEM resolution are vital in the extraction of various quantitative factors.



(a) **(b)**

Fig. 3. (a) Drainage network, 1967 and (b) Drainage network, 2020

Stream order (u) happens to be the foremost step in any quantitative study (Rai. et al. 2019) wherein Strahler's stream ordering is widely followed based on the hierarchical ranking of streams. The stream ordering of the Savitri watershed is classified as a seventh-order basin with a dendritic drainage pattern. While extracting from topographical maps, the total number of streams (Nu) calculated was 10132 having a stream length (Lu) of 6490.89 km and the stream orders extracted from DEM are 4753 with a total length of 3151.08 km respectively. The stream length is an important variable as it provides information about run-off characteristics. Moreover, the bifurcation ratio (R_b) indicates the degree of integration prevailing among the stream orders within a basin (Rai. et al. 2014). The mean bifurcation ratio of the watershed derived from both the sources are similar i.e. 3.8 that describes lesser influence by the underlying structure on drainage network. The main channel is considered as a stream segment that is joined to constitute the next hierarchical order (Kaliraj et al. 2014) and the calculated channel length (L) found varies from 73.69 km to 68.13 km from 1967 to 2020. Moreover, the sinuosity of the basin ranges from 1.45 (toposheet) to 1.39 (DEM) indicating the straight-sinuous channel of the Savitri river.

The basin geometry refers to the varied shape of a watershed that controls the rate at which water is provided to the main channel (Fenta et al. 2017). The total area of the Savitri watershed extracted from both topographical maps and DEM is 1966.34 km^2 and the basin perimeter i.e., the outer boundary of the watershed found is 361 km. However, the circularity ratio of the basin is 0.2 representing a lesser circular shape while the elongation ratio is 0.8 which indicates that the region is covered by high relief with gentle to steep ground slopes (Schumn 1956). Another striking parameter is the form factor which specifies that the lesser the form factor value, the more the basin will be elongated and vice-versa. The calculated form factor of the present watershed is 0.47

indicating elongation shapes that define the flatter peak of low flow for a longer time. Drainage density (Dd) refers to the closeness of spacing between channels and it is calculated as the total length of stream segments to the basin area (Meshram and Sharma 2015). The computed value of Dd extracted from toposheet is 3.3 km/km^2 and DEM is 2.87 km/km^2 which specifies that the region had fewer infiltration rates and more runoff but in later years the Dd value decreased that indicates more infiltration rate and moderate runoff. In contrast, the stream frequency (f) derived is 5.15 streams/km^2 (toposheet) and 3.43 streams/km^2 exhibiting a positive correlation to drainage density.

The relief aspects represent three-dimensional characteristics primarily depending upon the maximum and minimum height of the basin (Venkatesh and Anshumali 2019) mainly affecting the runoff and sediment transport. The basin relief as derived from the topographical map (20 m contour interval) was 1080 m while the relief from DEM is 1399 m. The resultant values are responsible for the presence of some steep slopes and high relief governing the watershed.

Relief ratio forms an effective measure to gradient aspects of the watershed. The Rr value of 26.40 km (toposheet) and 34.92 (DEM) denotes the presence of hilly terrain with low permeability (Prakash et al. 2017). Ruggedness number implies the structural complexity of the terrain and the computed Rn value for the present watershed varies from 3.56 (toposheet) to 4.01 (DEM) indicating that the region is highly erosion-prone operating along the slopes.

5 Runoff Estimation Using NRCS-CN

Now, the enumerated Morphometric variables were matched with both the datasets for the Savitri basin to evaluate its effect on runoff potential. The basin properties have exerted a strong influence on hydrologic variables and therefore the estimation and prediction of runoff amount are further determined with the help of the Natural Resources Conservation Service-Curve Number (NRCS-CN) method described in this chapter.

After the enumeration of the selected quantitative attributes necessary to understand the hydrological characteristics, it is significant to estimate the runoff flow governing in a certain watershed (Savita et al. 2017).To achieve this, NRCSCN is applied along with the parameters viz. rainfall, land use and land cover, slope, and soil texture maps that will provide a combined hydrologic effect (Abdulkareem et al. 2017. For the preparation of the rainfall map, the average annual rainfall data is collected from 1991–2020 for 30 years from the Indian Meteorological Department (IMD). The land use and landcover map is generated from LANDSAT 8 imagery of 2020 using a supervised classification approach. In contrast, the soil texture map is prepared based on the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), and the resultant map is converted into hydrologic soil groups viz. A, B, C, and D depending on their soil infiltration capacity (Adham et al. 2014; Satheeshkumar et al. 2017). The produced LULC map is overlaid upon the hydrologic soil group and on this basis; a Curve Number (CN) is allotted for preparation of soil cover complex map. Further, this process is accompanied by integrating the obtained soil cover complex map and Antecedent Moisture Condition (AMC), allotting actual curve number (CN) values thereby calculating maximum retention (S) and initial abstraction (*Ia*) that finally leads to runoff estimation (Satheeshkumar et al. 2017, Rawat and Singh 2017; Ajmal et al. 2014).

6 NRCS-CN Model

The United States Department of Agriculture (USDA) and Soil Conservation Services (SCS) have developed the most popular and common method to determine runoff within a watershed in the 1950s. The model was formerly known as the SCS-CN model and later renamed Natural Resources Conservation Service (NRCS) (Pancholi et al. 2015). This method is also known as Curve Number (CN) that was evolved primarily for small agricultural watersheds (Rawat and Singh 2017). This technique incorporates several influencing factors for runoff generation viz. rainfall, soil, land cover, slope, and antecedent moisture conditions (AMCs) in a single CN parameter (Kumar et al. 2017). Thus, the CN method is based on the assumption of proportionality between retention and runoff (Bansode and Patil 2014) that is derived by the following expression

$$Q = \frac{(P - Ia)^2}{P - Ia + S} \tag{1}$$

Where, Q = runoff (mm),

P = rainfall depth (mm),

S = potential maximum retention after runoff begins (mm),

Ia = initial abstraction (mm).

Initial abstraction (*Ia*) is determined based on antecedent moisture conditions. It involves surface storage, interception, evaporation, and infiltration before the runoff in the watershed (Kumar et al. 2017). *Ia*has been taken as $0.3S$ for Indian condition (Ahmad et al. 2015) and hence, the empirical relationship can be represented as,

$$Ia = 0.3S \tag{2}$$

Substituting Eq. (2) in Eq. (1); we get,

$$Q = \frac{(P - 0.3S)^2}{P + 0.7S} \tag{3}$$

Moreover, parameter S indicates the potential infiltration after runoff begins derived by the following equation.

$$S = \left(\frac{25400}{CN}\right) - 254 \tag{4}$$

Where, CN stands for curve number, the values of which can be obtained from the SCS Handbook of Hydrology (NEH-4), (USDA 1972) depending on land cover, HSG, and AMC. It is noteworthy that the NRCS-CN method is revised for runoff assessment in big watersheds by weighing curve numbers concerning basin land cover area. The equation for calculating the weighted curve number is as

$$CN_w = \sum \text{CNi} \times \frac{\text{Ai}}{A} \tag{5}$$

Where, CN_w is the weighted curve number;

CN_i is the curve number from 1 to any number N;

A_i is the area with curve number CN_i; and

A is the total area of the watershed.

7 Antecedent Moisture Condition (AMC)

Antecedent Moisture Condition refers to the availability of moisture content in the soil before a storm event. It is determined by total rainfall in 5 day period preceding a day of analysis (Askar 2013; Vinithra and Yeshodha 2013). Few properties of the basin viz. LULC and soil types of the basin, AMC, and recharge capacity of the basin are significant for computing the curve number method (Jasrotia et al. 2002). The Natural Resource Conservation Service (NRCS) had developed three antecedent soil moisture conditions namely AMC-I, AMC-II, and AMC-III representing dry, normal, and wet conditions, respectively (Askar 2013; Amutha and Porchelvan 2009; Pandey and Stuti 2017) for dormant and growing seasons as shown in Table 3. In the current research, average condition i.e. AMC II is chosen to obtain the CN value for this purpose.

Table 3. AMC classes for computation of CN values **(Ref.:** Amutha and Porchelvan 2009

AMC group	Soil characteristics	Five-day antecedent rainfall in mm	
		Dormant season	Growing season
I	Soils are dry but not to the wilting point; satisfactory cultivation has taken place	Less than 13	Less than 36
II	Average Condition	13–28	36–53
III	Heavy rainfalls or light rainfall and low temperatures have occurred within the last 5 days; stared soil	Over 28	Over 53

8 Hydrologic Soil Group (HSG)

Soil types are fundamental in the generation of runoff as varied soil types exhibit different infiltration rates. The infiltration rates of soils vary depending upon the nature of subsurface permeability. For the estimation of runoff, curve number (CN) values for individual soil types are necessary.

As per National Engineering Handbook (NEH) developed by the USDA, soils are categorized into four groups viz., A, B, C, and D according to the soil's infiltration rate, texture, depth, drainage condition, and water transmission (Rawat and Singh 2017) (Table 4). The present watershed is mainly dominated by the C soil group indicating clay loam and shallow sandy loam soil with slow infiltration capacity.

Table 4. Soil Conservation Service classification (USDA 1974)

Hydrologic soil groups (HSGs)	Soil textures	Water transmission	Runoff potential	Final infiltration
A	Deep, well-drained to excessively drained sand or gravel	Rapid rate	Low	>7.5
B	Moderately deep to deep, moderately well-drained to well-drained soils of moderately fine to moderately coarse texture	Moderate rate	Moderate	3.8–7.5
C	Clay loams, shallow sandy loam, soils with moderately fine to fine textures	Slow rate	Moderate	1.3–3.8
D	Clay soils that swell significantly when wet, heavy plastic, and soils with a permanent high water table	Very slow rate	High	<1.3

9 Area Weighted Curve Number

The distinct layers of HSGs, LULC, and AMC are overlaid and a new polygon attribute table (PAT) is achieved using ArcGIS. The result obtained from the new PAT is used to determine the total area-weighted curve number (WCN) of the watershed. The computed weighted curve number (WCN) of the watershed is 81.14 as presented in Table 5.

Table 5. Weighted curve number for Savitri watershed

LULC	HSG	CN	Area (km^2)		% Area	% Area*CN	Weighted curve number (WCN)
Barren land	C	83	2.08	7.89	0.11	8.77	**81.14**
	D	87	5.82		0.30	25.75	

(*continued*)

Table 5. (*continued*)

LULC	HSG	CN	Area (km^2)		% Area	% Area*CN	Weighted curve number (WCN)
Built-up (urban and rural)	C	90	0.12	7.05	0.01	0.55	
	D	95	6.93		0.35	33.50	
Crop land	A	67	1.88	750.54	0.10	6.42	
	B	78	0.09		0.00	0.37	
	C	85	243.10		12.37	1051.67	
	D	89	505.47		25.73	2289.63	
Deciduous broad leaf forest	A	42	0.15	197.82	0.01	0.33	
	C	79	83.76		4.26	336.77	
	D	85	113.91		5.80	492.78	
Evergreen broad leaf forest	C	71	124.14	142.80	6.32	448.59	
	D	77	18.66		0.95	73.13	
Fallow land	C	88	33.16	56.70	1.69	148.50	
	D	90	23.54		1.20	107.83	
Mangrove forest	C	98	0.12	0.12	0.01	0.60	
Mixed forest	A	38	8.91	262.70	0.45	17.22	
	C	75	137.76		7.01	525.86	
	D	81	116.03		5.91	478.33	
Permanent wetland	D	78	7.85	7.85	0.40	31.16	
Plantation	B	53	0.60	80.26	0.03	1.63	
	C	67	57.30		2.92	195.41	
	D	72	22.35		1.14	81.90	
Shrub land	A	36	2.86	416.10	0.15	5.24	
	C	73	267.82		13.63	995.06	
	D	79	145.42		7.40	584.69	
Water bodies	A	97	0.75	34.98	0.04	3.72	
	C	97	21.11		1.07	104.23	
	D	97	13.11		0.67	64.75	

10 Runoff Estimation Through NRCS Model

To run the NRCS-CN model in the Savitri watershed, a set of variables such as rainfall, soil types, LULC, slope, and AMC have been taken into account to estimate runoff flow within the basin. The land use and land cover (LULC) map (Fig. 4) of the study area have been prepared using satellite imagery for the year 2020 in the GIS platform. Based on LULC classification, the Savitri watershed has been classified into twelve classes viz. barren land, fallow land, cropland, deciduous broadleaf forest, evergreen broadleaf forest, mangrove forest, mixed forest, built-up (urban and rural), permanent wetland, plantation, shrubland, and water bodies. On one hand, the dominant class is cropland covering an area of 750.54 km^2 followed by shrubland and forest while mangrove forest occupies a negligible area of 0.12 km^2.

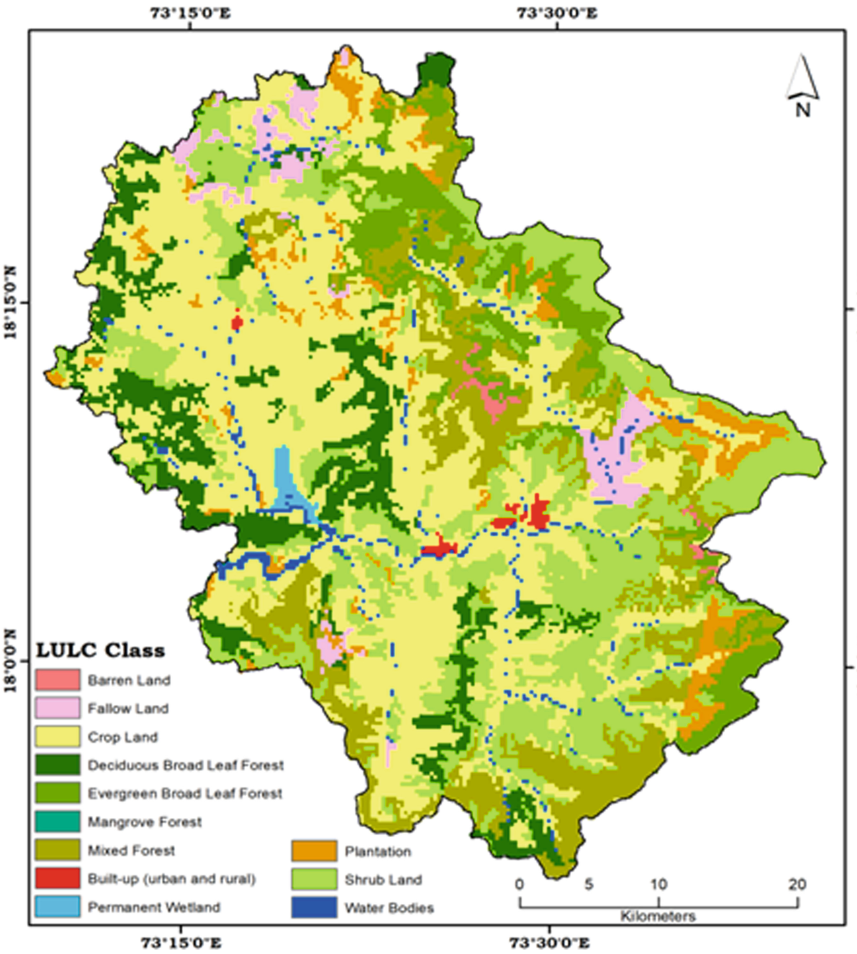


Fig. 4. LULC map

The average annual rainfall of the region for 30 years is taken under consideration wherein rainfall ranges from 30.51 mm to 257.95 mm from 1991 to 2020. However, another parameter i.e. slope of a region plays a pivotal role in determining the runoff characteristics as the steep slope will fasten the runoff rate with the least water holding capacity and the gentle slope will slow the rate with maximum water retention capacity. The slope map (Fig. 5) of the Savitri watershed represents four classes viz. nearly level, gentle, moderate, and steep. About 1639.47 km^2 (83.44%) falls under the nearly level and gentle category while 325.34 (16.55%) km^2 comes under moderate to the steep category that indicates that the area has more water retention capacity causing lesser runoff amount.

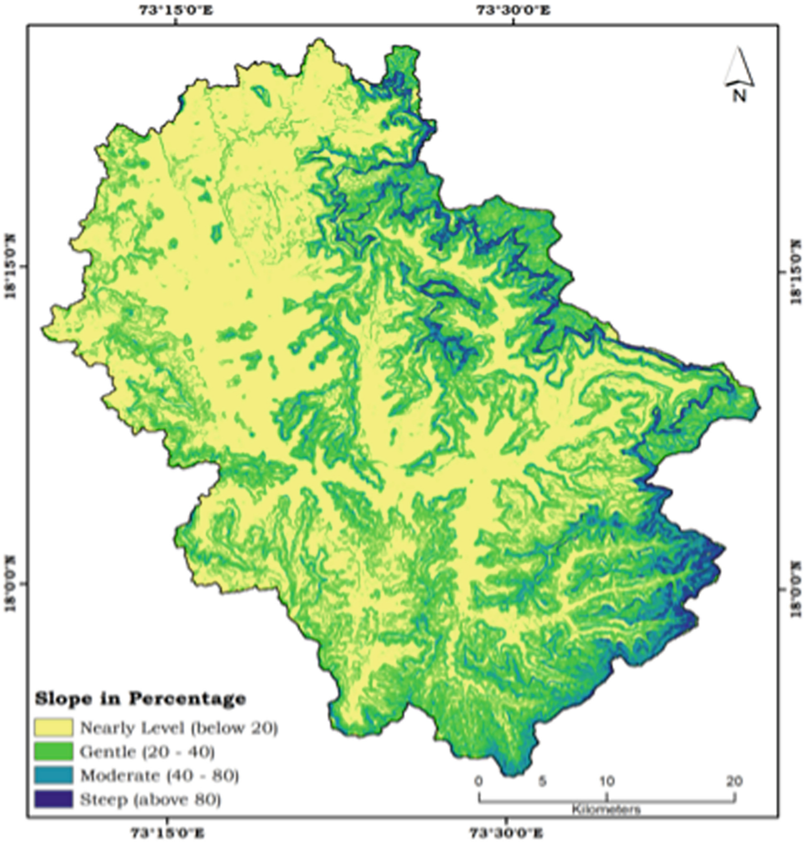
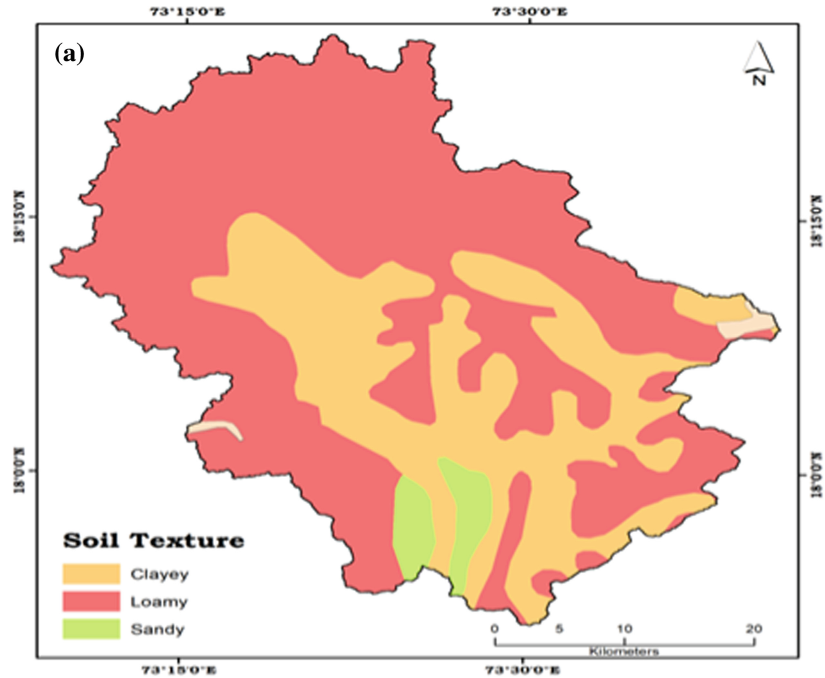


Fig. 5. Slope map

The soil texture map (Fig. 6: (a)) speculates that most of the region is covered by loamy soil (1294.71 km^2) followed by clayey (598.45 km^2) and sandy soil (60.77 km^2). Moreover, the Hydrological Soil Group (HSG) map (Fig. 6:(b)) depicts that the maximum area of the Savitri watershed falls under Group C composing of clayey loam with moderate water transmission rate. Thus, these parameters coupled with distinct CN values (Fig. 6: (c)) and AMC conditions are requisite for the application of the NRCS model in the watershed to determine the runoff amount from 1991–2020.



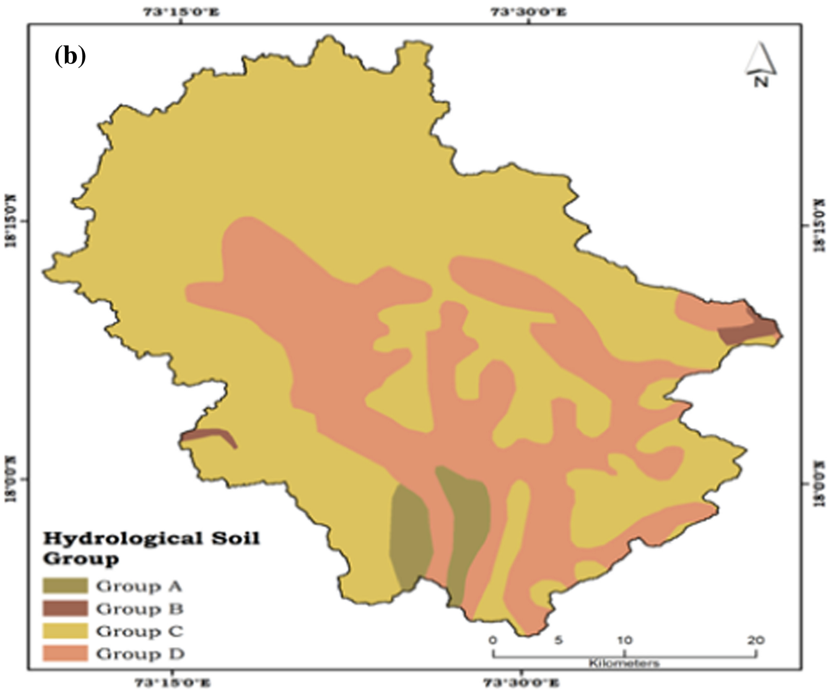


Fig. 6. (a) Soil texture map, (b) Hydrological soil group map, (c) CN-II Map

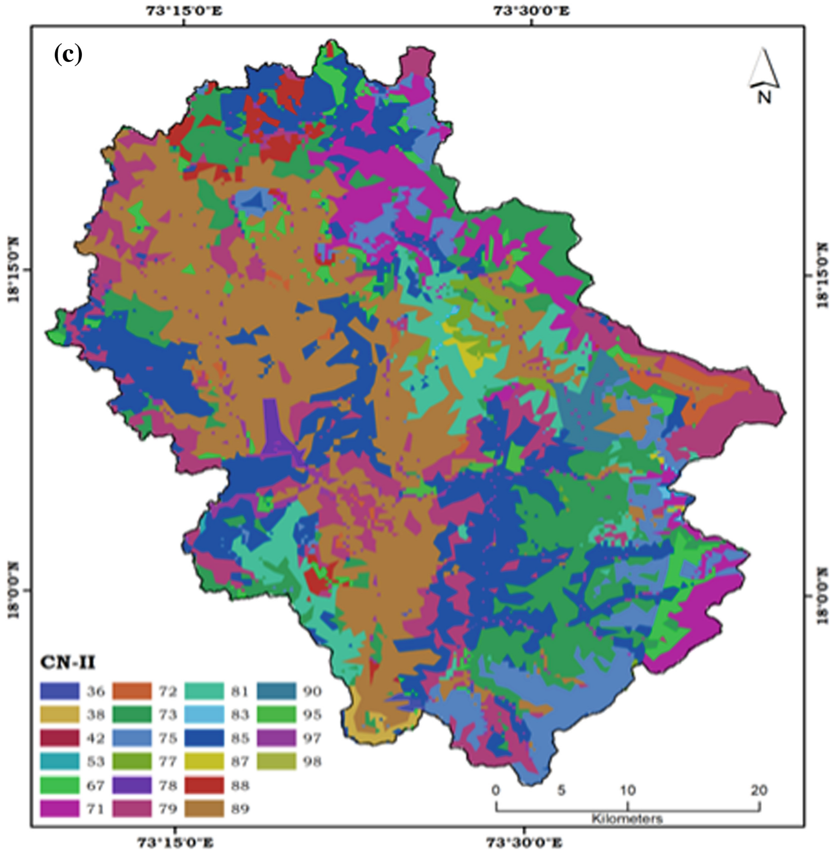


Fig. 6. (*continued*)

11 Rainfall-Runoff Estimation

To assess the flood condition of a certain area, it's vital to understand and predict the rainfall-runoff relationship (Kumar et. al. 2017) governing in a basin so that planning and management of water resources could be analyzed systematically. The average annual rainfall and runoff of the basin during 1991 and 2020 are calculated as 303.51 mm and 236.87 mm while in 2020 are 257.95 mm and 192.85 mm respectively (Fig. 7). The runoff volume (product of runoff and a total area of the watershed) is another significant indicator (Adham et.al. 2014) wherein it extends from 465396.43 m^3 in 1991 to 378903.53 m^3 in 2020 (Table 6). Similarly, the average runoff and runoff volume for 30 years are computed as 233.65 mm and 459075.58 m^3. Also, the scatter plot (Fig. 8) depicts the relationship between rainfall and runoff wherein the correlation coefficient (r) value is 1 that signifies a perfectly positive correlation between the variables.

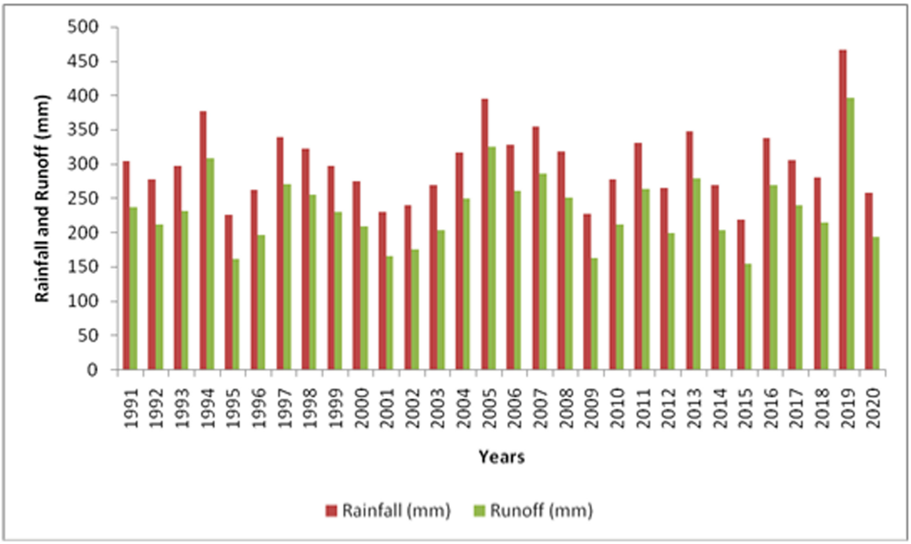


Fig. 7. Annual rainfall and runoff of Savitri Watershed

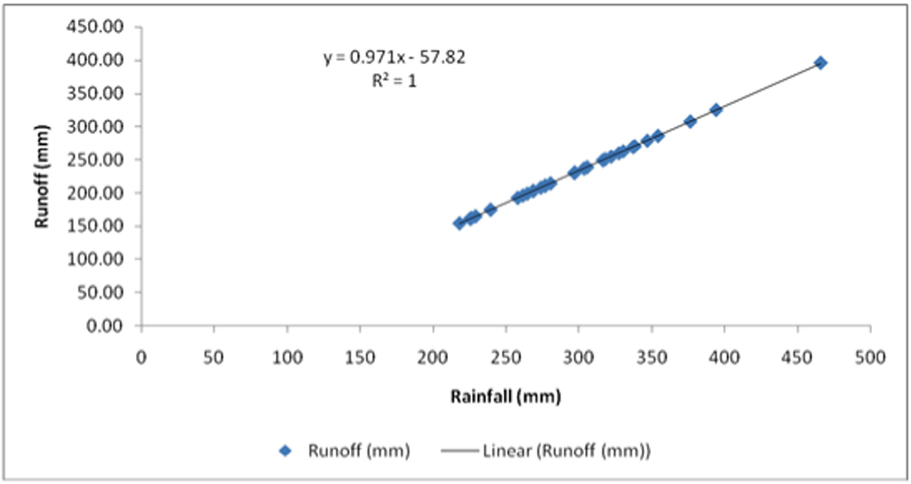


Fig. 8. Co-relationship between annual average SCS-CN runoff (mm) and annual rainfall (mm)

Table 6. Computation of runoff and volume (1991–2020)

Years	Rainfall (mm)	Runoff (mm)	Volume (m^3) = Runoff × Area
1991	303.51	236.87	465396.43
1992	276.87	211.07	414716.89

(*continued*)

Table 6. (*continued*)

Years	Rainfall (mm)	Runoff (mm)	Volume (m^3) = Runoff × Area
1993	297.32	230.86	453597.34
1994	376.49	308.08	605318.55
1995	225.23	161.56	317424.25
1996	261.56	196.32	385723.72
1997	338.35	270.78	532027.64
1998	322.12	254.96	500944.43
1999	296.79	230.35	452587.69
2000	273.82	208.13	408932.55
2001	229.02	165.16	324510.66
2002	239.33	175.00	343837.16
2003	268.59	203.09	399023.37
2004	316.43	249.42	490064.42
2005	394.26	325.51	639564.36
2006	327.41	260.11	511067.89
2007	354.29	286.35	562619.79
2008	318.08	251.03	493218.45
2009	226.26	162.54	319349.11
2010	276.81	211.02	414603.06
2011	330.39	263.02	516774.11
2012	264.59	199.23	391453.11
2013	346.96	279.19	548544.61
2014	268.65	203.14	399136.98
2015	218.01	154.70	303953.68
2016	337.04	269.50	529516.21
2017	305.64	238.94	469459.53
2018	280.53	214.61	421663.31
2019	466.02	396.14	778334.58
2020	257.95	192.85	378903.53
Average	**299.94**	**233.65**	**459075.58**

12 Conclusions

The present research explains the significance of quantitative assessment to understand the geohydrological processes operating in the basin. Investigation of Morphometric properties plays an important role in evaluating the response of a basin to climate change, drainage, and flood risk vividly. Thus, there exists a relationship between the quantitative attributes and flood potential necessary for flood forecasting in a basin. The comparison of Morphometric indices for Savitri watershed based on traditional and digital datasets for two time periods have evolved contrasting results. Within the framework of Morphometric variables, the values of stream number, stream length, main channel length, drainage density, frequency, intensity, length of overland flow, infiltration number, etc. have decreased substantially over time attributed to physical and human-induced factors. The comparisons have been incorporated to examine the variability in the rainfall-runoff relationship that can be accessed from the basin properties. Due to the unavailability of rainfall data before the 1990s, a total of 30 years have been taken into account from 1991–2020. The maximum average annual rainfall and runoff was observed in 2019 as 466.02 mm and 396.14 mm. The NRCS model is employed in the Savitri watershed indicating that previously the region experienced high rainfall and runoff while now the region encounters moderate runoff conditions due to a decrease in rainfall and other parameters. Furthermore, the curve numbers were derived for different hydrologic soil groups and it was found that the study area mostly falls under group C soil category which infers lower infiltration rate and moderate runoff flow. Therefore, this study might be a base for planning and managing water resources required for hydrological modeling to harness the potentialities sustainably within a watershed.

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