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Identification of potential zones on the estimation of direct runoff and soil erosion for an ungauged watershed based on remote sensing and GIS techniques

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Abstract

An investigation of soil and water resources is essential to determine the future scenario of water management and water resources to attain food and water security. The improper management of watersheds results in a huge amount of sediment loss and surface runoff. Therefore, the present study was carried out to estimate the surface runoff and soil erosion using the Soil Conservation Service Curve Number (SCS-CN) method and RUSLE approach, respectively. These have been estimated using geospatial technologies for the ungauged Mandri river watershed from the Kanker district of Chhattisgarh State in India. The runoff potential zones, which are defined by the area's impermeable surfaces for a given quantity of precipitation were identified based on curve numbers at the sub-watershed levels. The land use data were collected from LISS IV images of 2009. The results showed that the average volume of runoff generated throughout the 16 years (2000-2015) was 14.37 million cubic meters (mM^3). While average annual soil loss was found to be 17.23 tons/ha/year. Most of the eroded area was found to be around the major stream in a drainage system of Mandri River and on higher slopes of the terrain in the watershed. This study revealed that surface runoff and soil erosion are primary issues, which adversely affected the soil and water resources in this watershed. Therefore, suitable water harvesting sites and structures can be constructed based on the potential runoff zone and severity of soil erosion to conserve the soil and water in the watershed.

1. Introduction

Natural resource management and its proper utilization are considered a serious issue in the past few decades [1]. Precipitation is a vital source of water for human survival as well as for the basic requirement of flora and fauna, which is partially lost in huge amounts in the form of a direct runoff [2,3]. Runoff is one of the major components of the hydrologic cycle, which has a key role in addressing a wide range of issues interrelated to environment flow and social development [4,5]. The significance of rainfall-runoff modeling has long been intended [6,7]. For the transformation of rainfall into runoff, many previously developed models exist [8,9]. Out of these models, Soil Conservation Service Curve Number (SCS-CN) is used wide spreads for direct runoff estimation because of its acceptability [10]. The SCS-CN method is construed as an infiltration loss model [11-14]. It is essential for the protection and management of water resources mainly in drought-prone areas for watershed management and social development [15]. SCS-CN method can be used to estimate direct runoff from a small and ungauged agricultural watershed [16-19]. The curve number method is also used for water quality modeling and hydrologic simulation, etc. [20-28]. The application of the SCS-CN method has extended into the areas such as water quality modeling, urban hydrology, sediment, drainage, and baseflow, the

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coupling of remote sensing and geographical information system (GIS), in addition to rainfall-runoff modeling [1,29]. The integration of the SCS model and remote sensing has a good possibility to estimate runoff more accurately and faster [30-32]. Ibrahim-Bathis and Ahmed [33] did rainfall-runoff modeling using HEC-HMS and GIS techniques in the Doddahalla watershed in Southern India. He accomplished that the models can be applied in the ungauged watershed and water-scarce regions where the observed data are limited, and runoff estimation is mandatory to endure the water resources. Singh et al., [34] did rainfall-runoff modeling by applying a co-active neuro-fuzzy inference system (CANFIS) and multi-layer perception neural network (MLPNN) in the Naula catchment of river Ramganga in Uttarakhand, India. With the best results of CANFIS model, they suggested that present-day runoff depends on rainfall and runoff of the same and previous 2 days for that particular hilly watershed. Mishra et al. [35] integrated the SCS-CN method with the USLE model for computing the lumped quantity of event sediment load from watersheds. Soil erosion has been accepted as a serious problem arising from agricultural intensification, land degradation, and possibly due to global climatic change [36,37]. The productivity of some lands has declined by 50% due to soil erosion and desertification and degradation [38]. Meshram et al. [22] and Tyagi et al. [39] developed the relationship between curve number and sediment yield (SYI) using four watersheds of the Narmada basin. As per the best statistical outcomes, they proposed to compute SYI for the rest of the watersheds using curve numbers. Rather et al. [40] estimated the soil erosion vulnerability of eight watersheds in Jhelum basin Kashmir by applying a multicriteria analytical (MCA) framework using remote sensing and GIS techniques. The research discovered that three watersheds are highly erosion-prone and require immediate action to minimize the actual problem. The different studies on soil erosion and runoff estimation from gauged and ungauged watersheds have been carried out in different regions of the world [41-45].

The spatial distribution of several erosion-prone locations in the Mandri watershed was determined using the GIS-based RUSLE approach. The results would assist in implementing appropriate erosion control measures in the critically impacted areas. Therefore, the study has been conducted to (i) estimate the surface runoff as well as identify the runoff potential zone, which is the quantity of runoff generated by a specific area for a given amount of precipitation is mostly determined by the area's impermeable surfaces in Mandri watershed of Kanker district at Chhattisgarh, (ii) find out the optimal empirical model irrespective of SCS-CN method and GIS-based model for a generation of runoff in the ungauged agricultural watershed, (iii) estimate the average annual soil loss and potential erosion-prone areas in the watershed using the RUSLE method and suggested the remedial measures to minimize the erosion in higher runoff potential zones. The following outcomes may be used to create better management scenarios and focus on policymakers' choices for controlling soil erosion risks in the watershed's various areas in priority order for remediation.

2. Study area and data used

The study area is a micro-watershed of the Mandri river catchment (Figure 1) under the Chhattisgarh State Watershed Management Agency (CGWMA), the integrated watershed management program under the Government of India (CGWMA, 2014-15). This watershed lies in the Kanker block of district Kanker of Chhattisgarh, India. Its center is located at 20.1990° N latitude and 81.0755° E longitude and has a total geographical area of 6673.77 ha. The region comprises 9 villages and 10 sub-watersheds. It falls in the Middle Mahanadi basin, and Mandri Nadi is the major stream flowing through the area. On average, the region experiences an annual rainfall of around 1326 mm, approximately 90% of which falls from June to September. The majority of the rainfall occurs in the Kharif season, thereby making it a rainy region. The average annual rainfall has fluctuated greatly over the last six years (CGWMA, 2014-15). The topography of the watershed is undulating. The watershed has a maximum elevation of 711 m above mean sea level (a.m.s.l) and a minimum elevation of 330 m a.m.s.l. The climate of the watershed is semi-arid with four seasons. May is generally the hottest month with the mean daily maximum temperature at about 43 °C and December being the coolest with the minimum mean temperature of about 15 °C. The maximum relative humidity is generally around 80% during the monsoon season with a minimum of 35% during the dry season (Chhattisgarh Water Resources Department, CGWRD, 2014-15).

The specification of data used in the research work is presented in Table 1. The Digital elevation model (DEM) (12.5*12.5m) data was provided by the State Level Nodal Agency (SLNA). The land use data were collected from LISS IV images. The soil map was interpreted by the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP). The daily rainfall data (add duration) were collected from the Indian Meteorology Department (IMD).

3. Method

3.1. SCS-CN Method

SCS-CN method developed by the United States Department of Agriculture (USDA) is the widely used approach for runoff computation because of its simplicity, accuracy, and its dependence on important parameter curve numbers (CN) [7,46]. To estimate runoff from storm rainfall, the United States Natural Resources Conservation Service (NRCS) based runoff CN method was used in this study. Determination of CN depends on the watershed's soil and land cover conditions, which the model represents as hydrologic soil group, cover type, treatment, and hydrologic condition [47]. This approach is based on a water balance hypothesis, which is expressed mathematically [48] in Equation 1.

$$\frac{F}{S} = \frac{Q}{P - I} \tag{1}$$

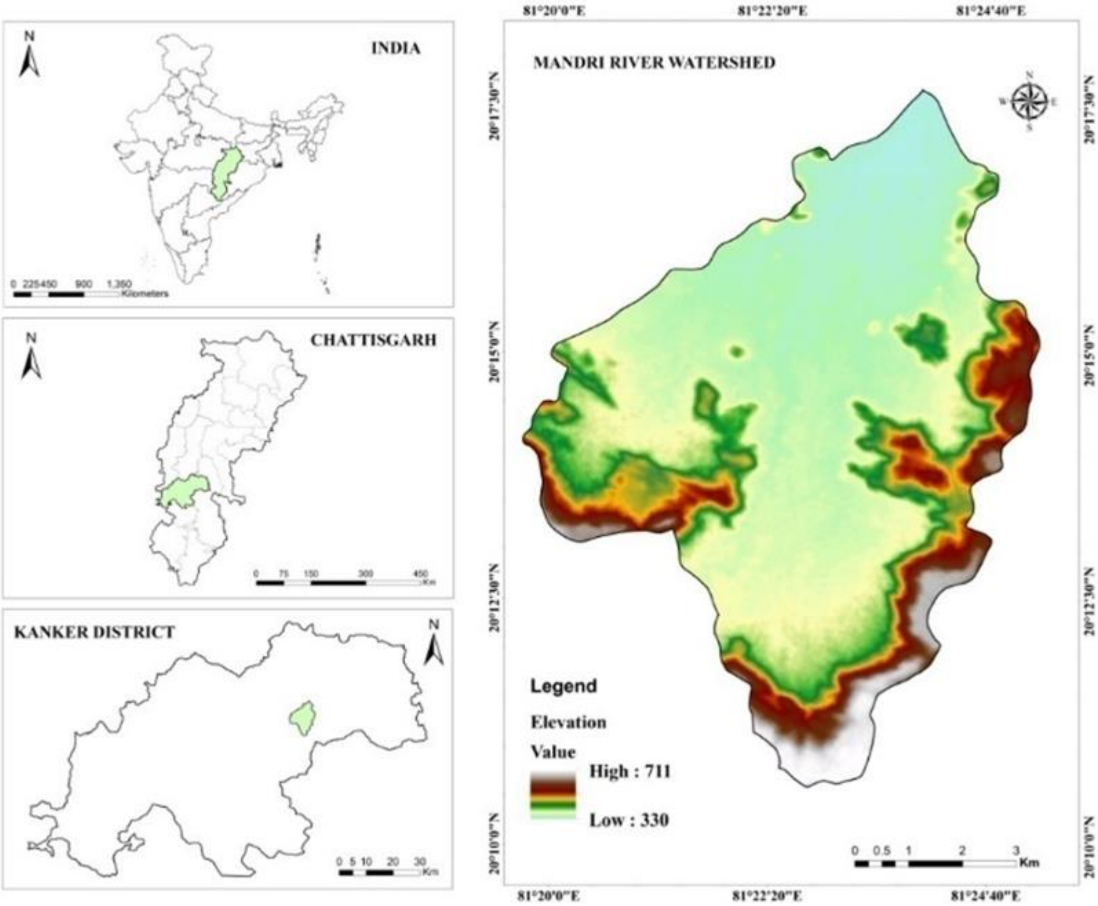


Figure 1. Study area map of Mandri river watershed

Table 1. Data specification and source of data

S.No.	Extracted Parameters	Data Specifications	Sources
1	Soil type	Soil Map Scale- 1:250,000	National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), India
2	Land use	LISS IV images Resolution- 5.8 m Scale- 1:250,000 Year- 2009	National Remote Sensing Centre (NRSC), India
3	Slope and Elevation	ALOS Palsar DEM Resolution- 12.5 m Year- 2018	https://vertex.daac.asf.alaska.edu/
4	Rainfall	Daily Rainfall	Indian Meteorological Department (IMD)

Where, F is the actual amount of retention after runoff incited, mm; S is storage amount in a catchment, mm (S≥F); Q is the actual amount of runoff, mm; P is total precipitation, mm (P≥ Q), I is an initial abstraction in a catchment, mm

The amount of retention can be calculated by the Equation 2.

$$F = (P - I) - Q \qquad (2)$$

In studies of many small agricultural watersheds, I_a was found to be approximated by the following empirical Equation 3:

$$I = 0.2 * S \qquad (3)$$

Substituting Equation 3 from Equation 1 and Equation 2.

$$Q = \frac{(P - 0.2\,S)^2}{(P + 0.8\,S)} (P > Ia) \qquad (4)$$

This equation is used to estimate the direct runoff depth from rainfall. The variable used in this equation has rainfall P and S which is related to curve number CN:

$$S = \frac{25400}{CN} - 254 \qquad (5)$$

Where, CN is a dimensionless runoff indicator and values are in the range of 1 to 100. Higher values of CN indicate higher runoff and lower values of CN indicate lower runoff [49].

CN is an important decisive factor to define the surface runoff in the defined watershed. The major factors that determine CN are the hydrologic soil group (HSG) cover type, treatment, hydrologic condition, and antecedent moisture conditions (AMC) [50]. The detailed description of the methodology to integrate the application of the SCS-CN method with RUSLE is shown in Figure 2.

AMC is mainly based on the following factors like land use, land treatment, hydrologic soil groups, hydrologic and climatic conditions. Direct runoff computation is based on the SCS-CN method due to its simplicity and flexibility. Soil texture is an important feature to classify the soil to its different characteristics like infiltration, soil texture, soil depth, water transmission rate, etc. (Table 2). AMC (Table 3) is a parameter to indicate the availability of soil moisture stored before a rainfall event. It is basically a wetness indicator and has a major effect on runoff generation in a catchment. Perceiving its significance, the soil conservation service (SCS) has prepared a guideline for adjusting the CN based on the total rainfall of the 5-day preceding event. AMC is bifurcated into three levels AMC-I for dry, AMC-II for normal, and AMC-III for wet conditions (Table 3). Based on weighted CN in Equation 6, CN_I and CN_{II} are computed in Equations 7 and 8, respectively. Because a curve number may also be termed AMC-I or CN_I or, dry soil moisture and AMC-II or CN_{II} or, average soil moisture and AMC-III or CN_{III} or, moist condition. The curve number can be adjusted by factors to CN_{II}, where CN_I factors are less than 1 (reduce CN and potential runoff), while CN_{III} factors are greater than 1 (increase CN and potential runoff). Here, the CN values are estimated according to the case of AMC-II [7,48].

$$CN_{II} = \frac{\sum A_i \times CN_i}{\sum_i^n A_i} \quad (6)$$

Where CN_{II} is the weighted CN, i is an index of watersheds subdivisions of uniform land use and soil type, CN_i is the CN for subdivision i, A_i is the drainage area of subdivision i and A is the total catchment area [51].

$$CN_I = \frac{CN_{II}}{(0.281 - 0.0128\, CN_{II})} \quad (7)$$

$$CN_{III} = \frac{CN_{II}}{(0.427 + 0.00573\, CN_{II})} \quad (8)$$

3.2. Soil erosion estimation

The present study uses the Revised Universal Soil Loss Equation (RUSLE), a predictive empirical model, to predict the annual soil loss rate in the Mandri catchment. The RUSLE, developed by the United States Department of Agriculture, is the most widely used erosion model for both agricultural and forest watersheds to predict the average annual soil loss by computing the soil erosion factors [54]. It is a revised version of the original Universal Soil Loss Equation [55] which had been tested and used for many years. RUSLE estimates annual average soil loss in tons per hectare per year using Equation 9:

$$A = R \times K \times LS \times C \times P \quad (9)$$

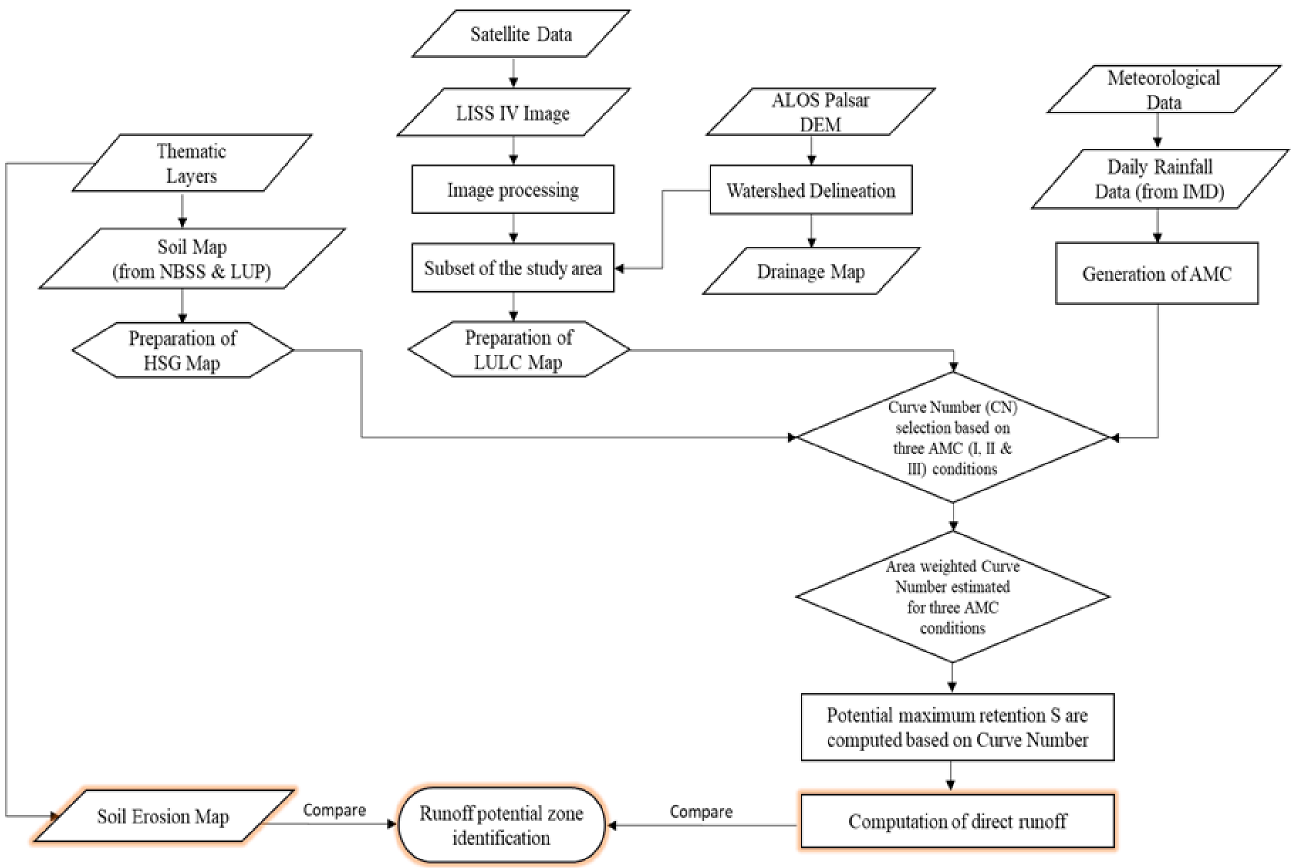


Figure 2. Methodology adopted to estimate runoff by using the SCS-CN method

Table 2. Soil characteristics have been classified into hydrologic soil groups [7,52,53]

Soil Characteristic	HSGs			
	A	B	C	D
Texture	Gravel/sand	Fine to moderate coarse texture	Moderate fine to fine texture	Mainly clay
Infiltration rate	Very high	High to moderate	Slow infiltration	Very slow
Drainage	Well-drained	Moderate to well drainage	Moderate to slow	Very slow
Water transmission rate	Very high	Moderate	Slow	Very slow
Assertion	Low runoff	Moderate runoff	Moderate to high runoff	High runoff

Table 3. Classification of antecedent moisture conditions (AMC) [52]

AMC	Total 5 days antecedent rainfall (mm)	
	Dormant season	Growing season
I	<12.5	<35.6
II	12.5-26	35.6-53.3
III	>26	>53.3

3.2.1. Rainfall-runoff erosivity factor (R)

Rainfall can erode the soil particles, the rainfall-runoff erosivity factor (Table 4) quantifies the effect of rainfall impact and also reflects the amount and rate of runoff likely to be associated with precipitation events it depends on the kinetic energy of the storm and the Intensity of the rainfall [56] Equation 10.

$$R = 81.5 + 0.385 * P_a \quad (10)$$

Where R and P_a represent the average erosion index and mean annual rainfall in mm.

The methodology adopted for soil loss estimation is illustrated in Figure 3.

Table 4. Soil loss factors of RUSLE method

Parameter	**Name**	**Unit**
A	Computed spatial average soil loss over a period selected for R, usually on a yearly basis	[(t/ ha/y)]
R	Rainfall-runoff erosivity factor	[MJ mm/(ha h y^{-1})]
K	Soil erodibility factor	[t ha h/(ha MJ mm)]
LS	Slope length and slope steepness factor	[Dimensionless]
C	Cover and management factor	[Dimensionless]
P	Conservation support practices	[Dimensionless]

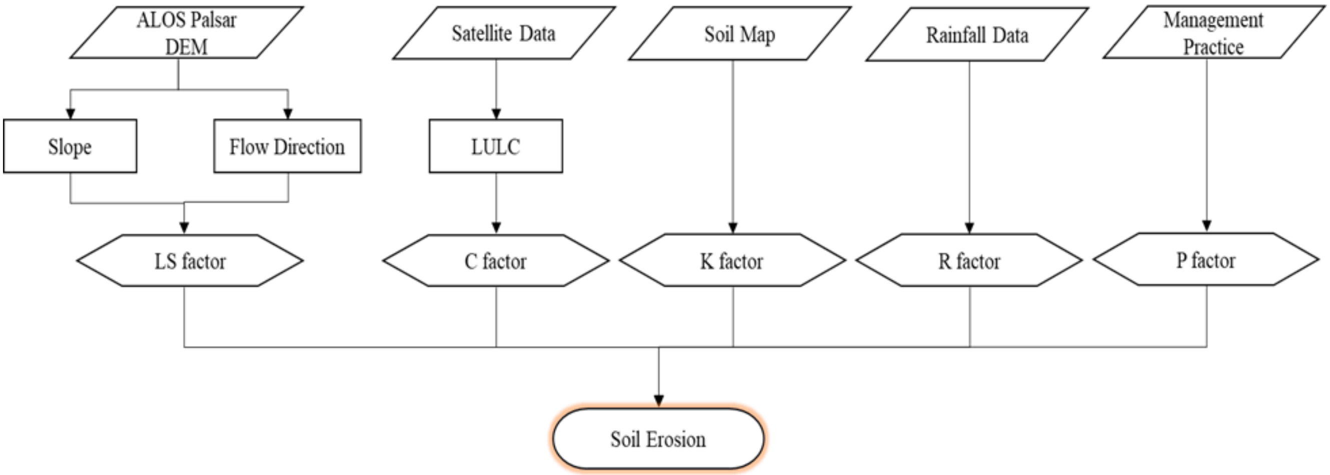


Figure 3. Methodology of soil loss estimation

3.2.2. Soil erodibility factor (K)

Soil erodibility (K) refers to the inherent susceptibility of soils to erosion by rainwater and runoff, and it is a function of a complex interaction of physical and chemical properties of soils affecting detachability, transportability, and infiltration capacity [57]. Clay-rich soils have low K values, ranging from 0.05 to 0.15, due to their resistance to detachment. Because of the low runoff, coarse-textured soils, such as sandy soils, have low K values, ranging from 0.05 to 0.2, despite the fact that these soils are effectively detachable. Medium and coarse soils, such as silt loam soils, possess moderate K values, ranging from 0.25 to 0.4, because they are relatively resistant to separation and generate moderate runoff. And for the higher values of K for high silt content soils tend to be greater than 0.4, because they are easily detached and generate high rates of runoff. In RUSLE, factor K includes the whole soil, but factor Kf (for most soils, Kf = K.) only considers the fine-earth component or material with less than 2.00 mm equivalent diameter [58]. In the present study, the K factor map was prepared from the soil texture map of the NBSS&LUP, Nagpur. Soil texture is a measure of the particle size distribution in soil. Large particles are resistant to transport because of the greater force required to entrain them and fine particles are resistant to detachment because of their cohesiveness [45].

3.2.3. Slope length and slope steepness factor (LS)

The specific effects of topography on soil erosion are estimated by the dimensionless LS factor as the product of slope length (L) and steepness (S). In general, as slope length (L) increases, total soil erosion and soil erosion per unit area also increase due to the progressive accumulation of runoff in the downslope direction [59]. As the slope steepness (S) increases, the velocity and erosivity of runoff increase [60,61] Equation 11.

$$LS = (\text{flow accumulation} \times \text{cell size}/22.13)^{0.4} \times (\sin \text{slope}/0.0896)^{1.3} \quad (11)$$

The computation of the LS factor requires flow accumulation and slope steepness factor which was computed from the Alos Palsar DEM (12.5m resolution).

3.2.4. Cover management factor (C)

Crop or land cover management factor (C) measures the combined effect of all the interrelated vegetative cover and management variables. This is one of the most important factors (after topography) in controlling soil erosion risk. It measures the protection of the soil surface from raindrop impact by vegetative material at some height above the soil surface and protection from raindrop impact and overland flow by the cover in contact with the soil surface, i.e., surface cover [62]. It is defined as the ratio of soil loss from a cropped field under a specific crop to soil loss from a continuous fallow field [63].

3.2.5. Conservation practice factor (P)

The support practice factor (P-factor) reflects the impact of support practices that will reduce the amount and rate of water runoff as well as the amount of soil erosion [64]. It is the ratio of soil loss from given conservation practices to soil loss obtained from up and down the slope. Where, conservation practices are contouring, strip cropping, and terracing [65]. The P-factor identifies differentiation between cropland and rangeland or permanent pasture. Both choices support terracing and contouring, however the cropland option includes a strip-cropping routine while the rangeland option includes an "other technological disruption" routine [58]. In the present study, the slope layer is generated where the slope is calculated in percent, and calculated the P factor layer [64] relates P factor value (Table 5) with the slope of the catchment.

Table 5. Relationship between slope and p factor [64]

Slope (%)	0-2	2-5	5-8	8-12	12-16	16-20	20-25	>25
P factor	0.6	0.5	0.5	0.6	0.7	0.8	0.9	1

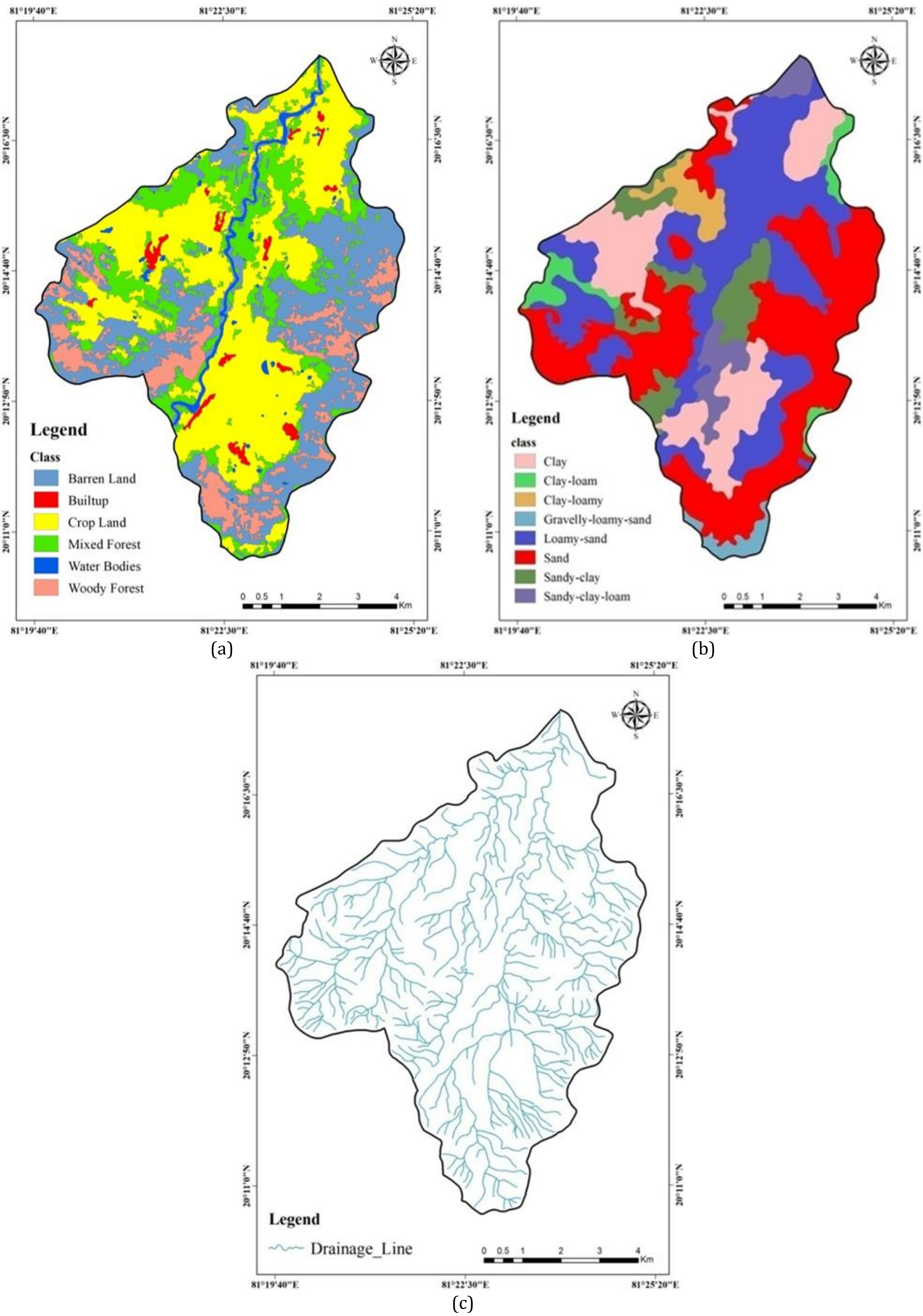
4. Results and Discussion

4.1. LULC, soil, and drainage map

The LULC map shown in Figure 4a gives detailed information about the catchment area that was classified into 6 classes cropland, mixed forest, barren land, woody forest, built up, and water bodies. The majority of land uses are cropland (2545 ha), barren land (1975 ha), and mixed forest (1234 ha) (Figure 4a) (Table 6).

In accordance with various soil properties (like texture, drainage condition, infiltration rate, and depth), Soils are classified into different classes. Major soil classes are sand (2273.78 ha), loamy sand (2029.83 ha), and clay (1087.46 ha) as depicted in Figure 4b and Table 7. With respect to various soil classes hydrologic soil groups (HSG's) A, B, and D are defined (Figure 5). The soil in the region originates from granite, gneiss, sand, and khedar. Most of the area is covered with sand and loamy-sand soil. The other soil types include clay-loamy, clay, sandy clay, and sandy-clay-loam (Figure 4b). The soil is faintly colored in the higher regions of the hilly tract, while in the river valleys; the soil is smooth and fertile.

The overall drainage pattern of the watershed is dendrite. Morphometric analysis showed that it had five order streams. Figure 4c shows the drainage network of the watershed. Drainage characteristic is a key input for watershed management and soil loss estimation [66]. Based on the soil characteristics of the study area, there are three HSG's were found as A, C, and D (Figure 5) in the Kanker district of Chhattisgarh. HSG group A covers 66% area of the whole watershed while C has 4.13% and HSG group D covers 23.81% area (Table 8). Soil group B does not exist in the study area.



(a) (b)

(c)

Figure 4. a) LULC map of the year 2009 **b)** Soil map **c)** Drainage map of the study area

4.2. Model verification

To validate the results of the SCS-CN method, we have used daily rainfall data for 16 years. The study was done on micro-watersheds so observed runoff data were not available. In this case, we used rainfall data as an alternative [18]. The applicability and validity of the SCS-CN method were confirmed by comparing computed runoff and daily runoff peaks [67]. In relation to rainfall and runoff, the runoff coefficient was computed for the monsoon season of 16 years data (2000-2015) (Table 9).

There were six major LULC classes identified in the study area (Table 10). In accordance with that, the curve number values are shown in Figure 6. The potential zone indicates that a higher curve number value requires minimum irrigation water requirement but has more erosion loss [68]. As per the slope ranges the possible remedial measures are suggested to minimize the erosion.

As depicted in Figure 7 and Table 11, the annual rainfall, runoff, annual volume of the area, and annual runoff coefficient were estimated as 1326.98 mm and 215.48 mm with an average runoff coefficient of 0.16. It indicated that 16.23% of average annual rainfall was converted into runoff during 2000-2015. The annual runoff volume was 14373537.6 m^3 that was lost annually from the catchment between 2000 and 2015. In this study, it was concluded that the total annual rainfall of 21231.78 mm generated a runoff of 3447.77 mm, and the annual runoff coefficient was 0.16 (2000-2015).

Table 6. Classes of LULC in the study area

LULC type	Area (ha)	% Area
Barren land	1957.69	29.33
Build up	101.47	1.52
Crop land	2545.26	38.14
Mixed forest	1222.27	18.31
Water bodies	115.06	1.72
Woody forest	732.02	10.97
Total	6673.77	100

Table 7. Classification of soil type class in the study area

Soil type class	Area (ha)	Percentage of Area
Clay	1087.46	16.29
Clay-loam	206.83	3.1
Clay- loamy	192.83	2.89
Gravelly-loamy-sand	104.65	1.57
Loamy-sand	2029.83	30.42
Sand	2273.78	34.07
Sandy-clay	502.94	7.54
Sandy-clay-loam	275.96	4.13
Total	6674.28	100

Table 8. Classification of hydrologic soil groups

Hydrologic Soil Group (HSG)	Area (ha)	Area (%)
Group A	4408.27	66.05
Group C	275.96	4.13
Group D	1989.54	29.81
Total	6673.77	100

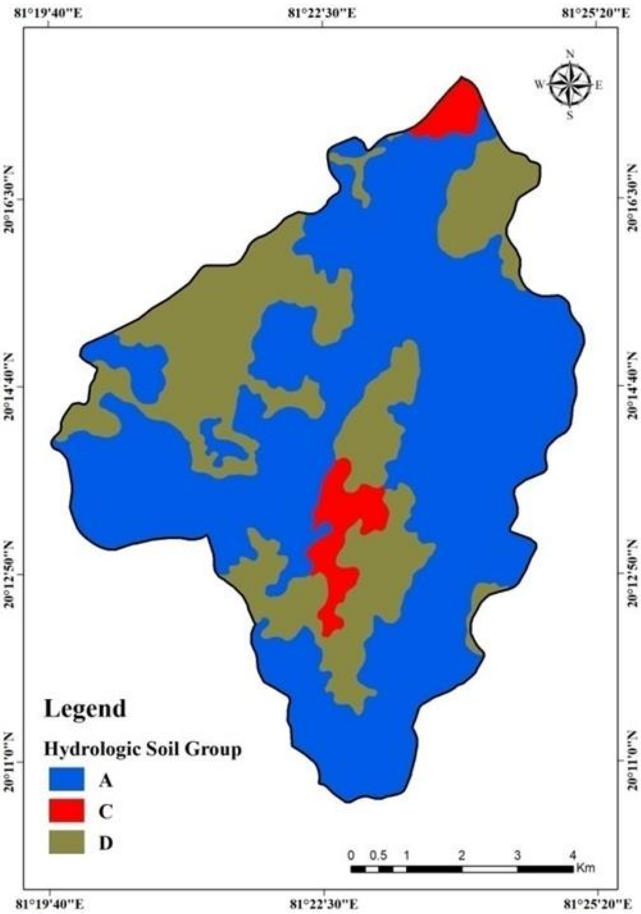


Figure 5. Hydrologic soil group map

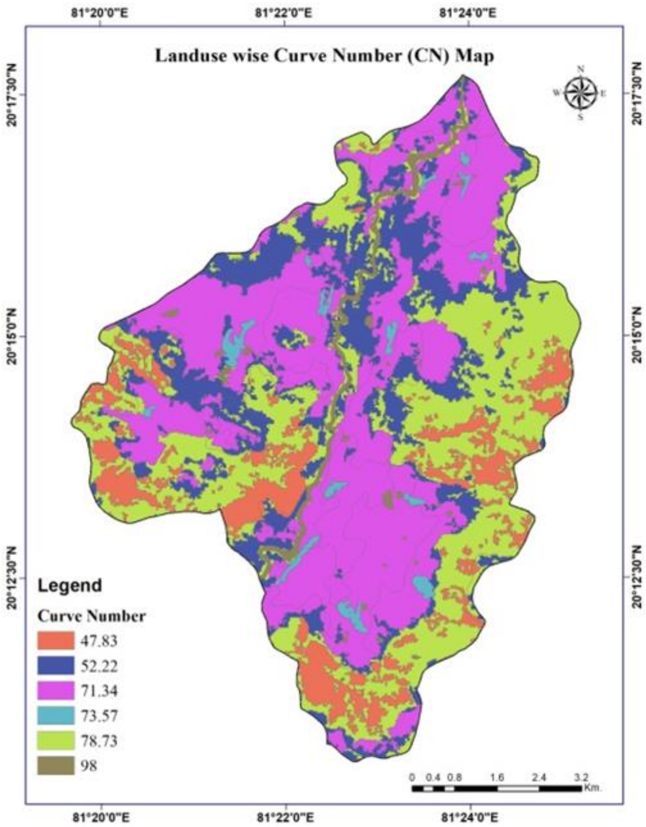


Figure 6. The CN map according to LULC classes

Table 9. Monsoon season rainfall and runoff

		June	July	August	September
2000	R	182.65	348.80	237.80	58.32
	Q	21.22	50.14	19.93	7.05
	CR	0.12	0.14	0.08	0.12
2001	R	526	502.9	672.77	40.05
	Q	93.59	145.87	237.61	0
	CR	0.18	0.29	0.35	0
2002	R	239.7	149.47	431.77	161.02
	Q	33.50	6.72	86.31	7.00
	CR	0.14	0.04	0.20	0.04
2003	R	106.02	377.15	562.42	277.82
	Q	0	50.31	128.80	42.93
	CR	0	0.13	0.23	0.15
2004	R	164.12	269.15	444.65	104.07
	Q	19.52	8.22	92.38	0
	CR	0.12	0.03	0.21	0
2005	R	159.22	322.12	378.70	283.50
	Q	14.65	14.85	55.11	82.23
	CR	0.09	0.05	0.15	0.29
2006	R	88.50	744.25	616.85	251.47
	Q	0	292.88	127.22	25.52
	CR	0	0.39	0.21	0.10
2007	R	518.40	230.37	390.55	270.25
	Q	186.65	14.04	12.40	13.06
	CR	0.36	0.06	0.03	0.05
2008	R	357.50	184.55	356.75	392.37
	Q	64.99	10.04	75.22	66.65
	CR	0.18	0.05	0.21	0.17
2009	R	59.59	487.07	266.42	87.87
	Q	0	110.26	30.95	8.41
	CR	0	0.23	0.12	0.10
2010	R	74.22	417.57	414.40	350.92
	Q	0	46.95	55.34	75.60
	CR	0	0.11	0.13	0.22
2011	R	120.70	285.77	419.27	390.97
	Q	0	16.76	63.14	99.27
	CR	0	0.06	0.15	0.25
2012	R	158.67	393.80	452.27	247.32
	Q	24.91	76.21	85.27	13.90
	CR	0.16	0.19	0.19	0.06
2013	R	289.62	318.24	371.32	125.87
	Q	49.84	26.88	74.87	0
	CR	0.17	0.08	0.20	0
2014	R	47.92	550.50	261.77	276.57
	Q	0	118.79	50.48	69.07
	CR	0	0.22	0.19	0.25
2015	R	271.25	117.65	203.67	270
	Q	56.09	4.09	11.98	85.59
	CR	0.21	0.03	0.06	0.32

*Note: R = Rainfall, mm, Q = Discharge, mm, and CR = Runoff coefficient

Figure 8 represents the variability of season rainfall, runoff, and runoff coefficient. The maximum runoff coefficient observed was 0.39 in July 2006 due to high rainfall were a minimum runoff coefficient of 0 in June 2014 and September 2001 in most of the months. As mentioned in Figure 5 and Table 8 that 66% area is under the HSG A soil group, which has high infiltration as well as a high-water transmission rate so the month of June in most of the years has a runoff coefficient of 0. The average runoff coefficient was found to be 0.16 (Table 9). The rainfall trend in the monsoon season (Jun-Sep) is highly dominated to surface runoff.

In Figure 9, the scenario of rainfall to runoff for each CN condition is plotted. The CNI is CN for dry conditions, CNII is CN for normal conditions and CNIII is CN for wet conditions. Based on the previous 5 days' antecedent moisture condition and season, the runoff is generated for individual CN [53].

4.3. Curve number and soil loss relation

In practice, soil loss from upland areas is generally well correlated with observed runoff [35,69] than with rainfall. Runoff computation by SCS-CN methods is directly proportional to a CN value. With respect to land use, soil, and AMC conditions the CN are defined to each hydrologic response unit (HRU) [70]. Figure 6 and Table 10 show the value of CN for the growing season, which highlights the minimum CN is 36 in the mixed forest whereas the maximum CN is 98 in water bodies and paved surfaces. As per variability of curve number the higher value of CN generates maximum runoff which causes soil erosion risks whereas lowers CN generates minimum runoff [68]. Based on this CN map in Figure 6 runoff potential zone can be identified in the watershed as well as we can suggest the remedial measure to minimize the surface runoff and soil erosion.

The average annual soil loss map was prepared using the R, K, LS, C, P, and RUSLE methods. The soil erosion area is classified into 8 classes, in which very few areas have a high erosion rate (Figure 10b). Table 12 and Figure 10a shows that a few areas of the study area are very high runoff potential zones. The soil erosion classes indicated that around 54% area is under negligible or minimum erosion zone, but the rest of the area has runoff generating land use. Paddy, maize, tomato, gram, chickpea, etc. are the major crops grown in the watershed.

Table 10. LULC wise CN values

S. No	LULC	CN
1	Barren land	78.73
2	Build up	73.57
3	Cropland	77.70
4	Mixed forest	52.22
5	Water bodies	98
6	Woody Forest	47.83
	Average CN	71.3

Table 11. Annual rainfall and runoff depth and volume of the watershed in m^3

Year	Rainfall (mm)	Runoff (mm)	Runoff Coefficient	Volume (mM^3)
2000	866.12	98.35	0.11	6.56
2001	1946.1	484.82	0.25	32.34
2002	1053.55	133.54	0.13	8.91
2003	1541.75	242.52	0.16	16.18
2004	1055.65	120.13	0.11	8.01
2005	1369.1	174.43	0.13	11.64
2006	1864.25	456.2	0.24	30.43
2007	1473.65	226.17	0.15	15.09
2008	1379.9	216.22	0.16	14.42
2009	959.4	149.63	0.16	9.98
2010	1489.3	193.42	0.13	12.90
2011	1280.8	179.18	0.14	11.95
2012	1323.9	200.28	0.15	13.36
2013	1327.82	158.09	0.12	10.55
2014	1249.72	257.03	0.21	17.14
2015	1050.77	157.76	0.15	10.52
Total	21231.78	3447.77	0.16	229.98
Average	1326.98	215.48	0.16	14.37

Remark: The highest annual runoff generation occurs in years of 2006 with a runoff coefficient of 0.24 whereas minimum runoff occurs in the year of 2000 with a runoff coefficient of 0.11
10% of rainfall amount

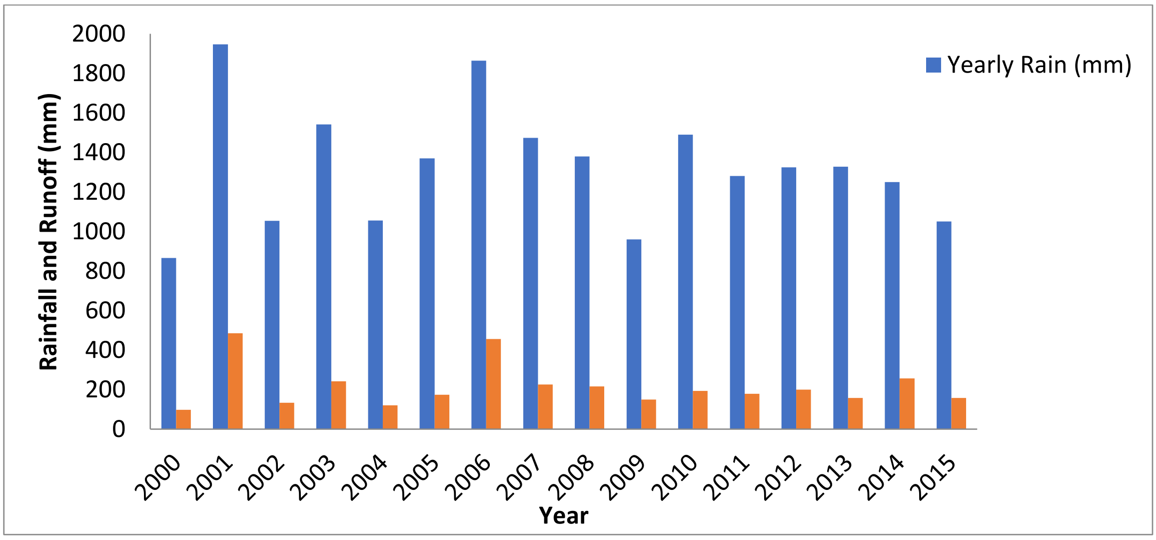


Figure 7. Rainfall-Runoff comparison from 2000-2015

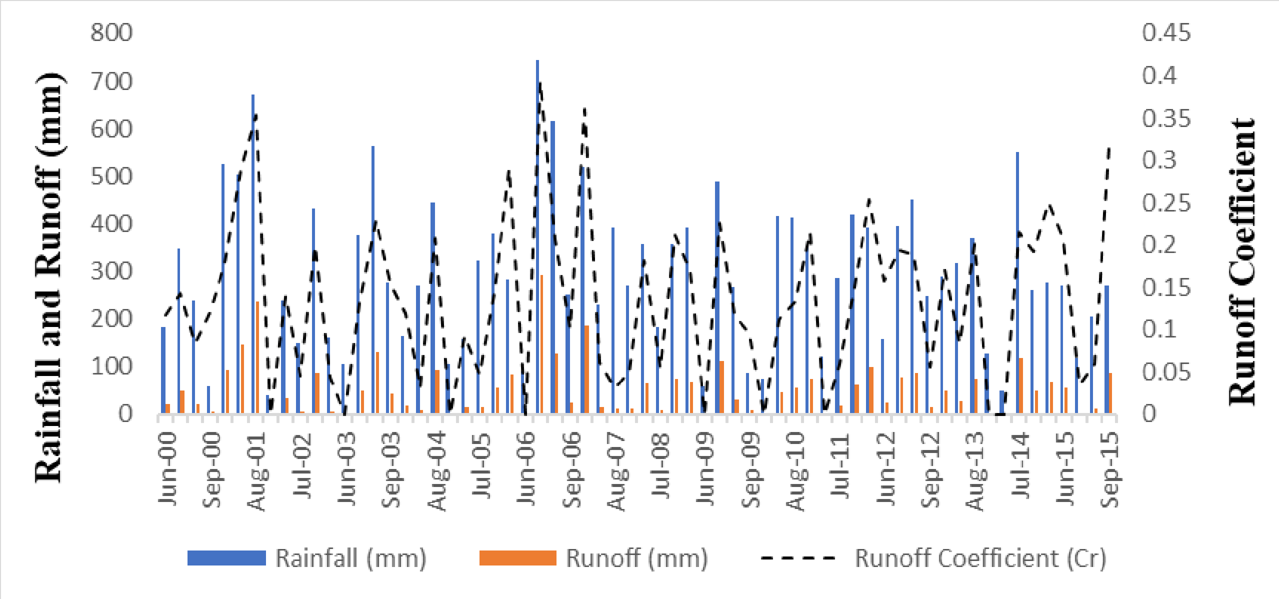


Figure 8. Surface runoff from storm rainfall

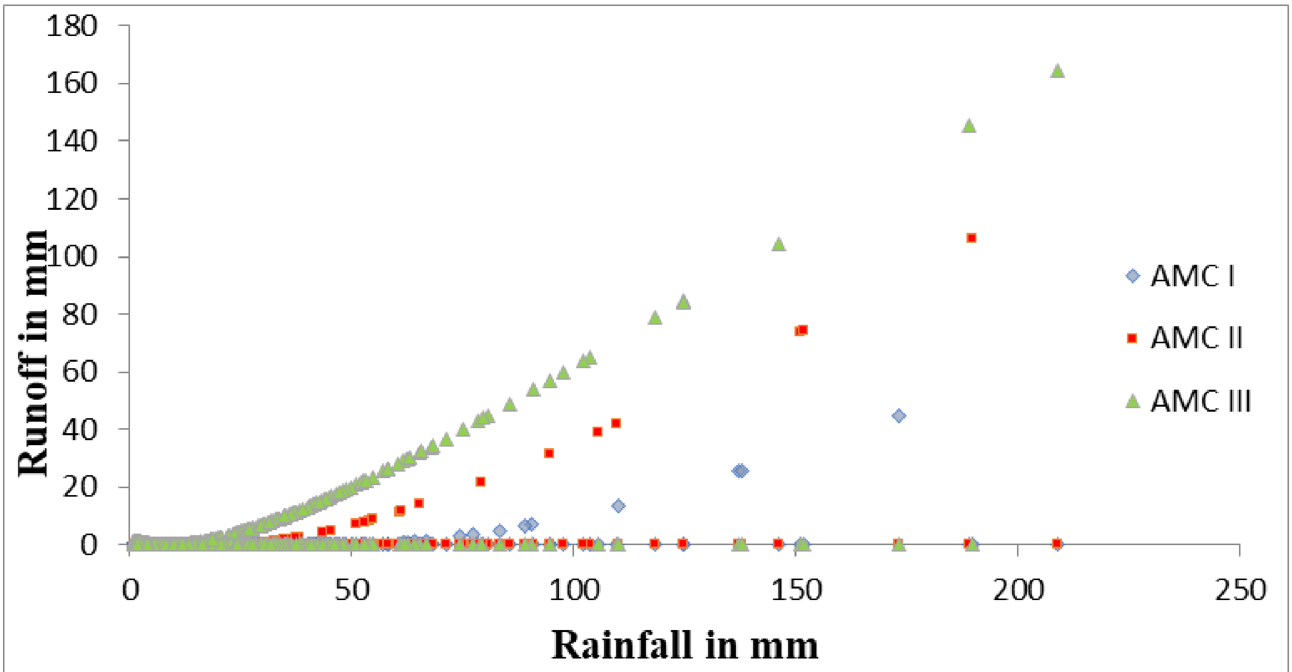


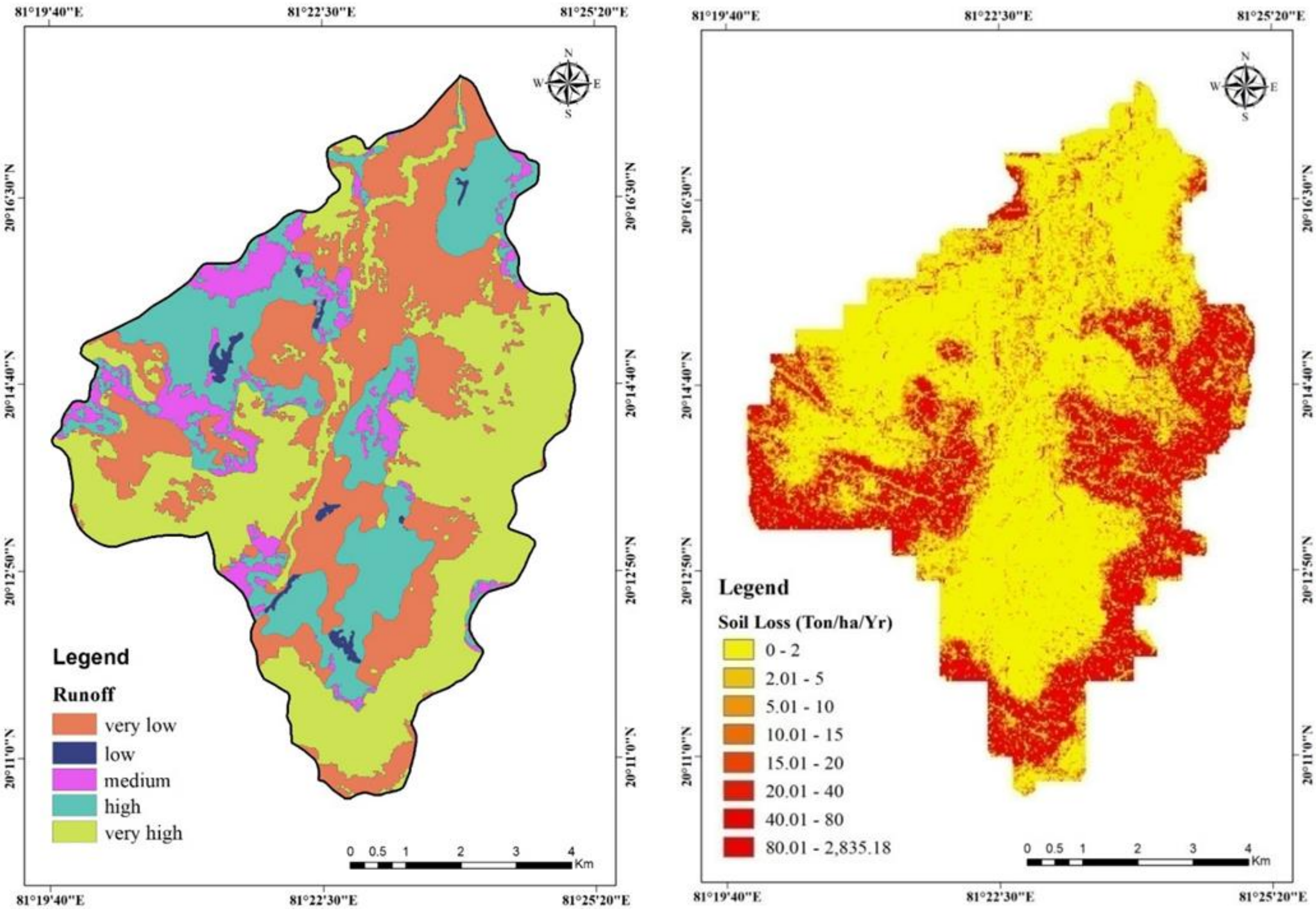
Figure 9. Rainfall-runoff comparison of each AMC conditions

Table 12. The possible remedial measures for erosion control [53]

Class t/ha/yr	Measures
< 2	Negligible
2 to 5	Negligible
5 to 10	Field bunding, Pasture Development
10 to 15	Contour Cultivation, Strip Cropping, Contour strip Cropping, intercropping, vegetative bunding
15 to 20	Intercropping, Contour bunding, Vegetative bunding, Diversion of drainage channels.
20 to 40	Graded bunding, land leveling, Gully Control Structure, Vegetative hedges, Pasture development
40 to 80	Afforestation, Gully Control Structure, Graded bunding, Pasture development

5. Conclusion

The study area is in an undulating agricultural watershed in the Mahanadi basin of Chhattisgarh, India. The area has decent rainfall (the average annual value of 1326 mm) with high intensity and the slope ranges from flat to steep. The watershed falls in a semi-arid region and rainfed agriculture also exists. Due to the climatic and topographic features of the watershed, all four stages of erosion come into account in that particular area. Defining and sorting out the problems of soil and water at a point in agricultural watersheds is a big challenge. In this work, it was concluded that the integration of SCS-CN and RUSLE with the use of GIS and remote sensing (i.e., the CN value, and soil loss rate) highlight the runoff potential zone and erosion-prone areas in the study area. For proper watershed management, the identification and estimation of runoff sources are necessary. Due to inadequate networks of stations, the observed data for hydrologic computation is usually not available at the micro-watershed level. In such cases, remote sensing and GIS are suitable techniques that give a reliable output of runoff and soil erosion. The spatial distribution of extreme average annual soil erosion is found along the stream and high altitudes of the watershed. Erosion is classified in the range from no erosion to extremely severe erosion range concerning that proper management practices are suggested to mitigate the problem. As a study conducted in the ungauged watershed with only the climatic and watershed characteristics, it was suggested that the probable zone for water harvesting structures enhance the water availability in terms of groundwater as well as surface water for crop production. This study emphasizes that proper watershed management could improve the cost-benefit ratio of the farmers as well as the living standard of the community.



(a) (b)

Figure 10. a) Runoff potential map **b)** Soil loss map of the study area

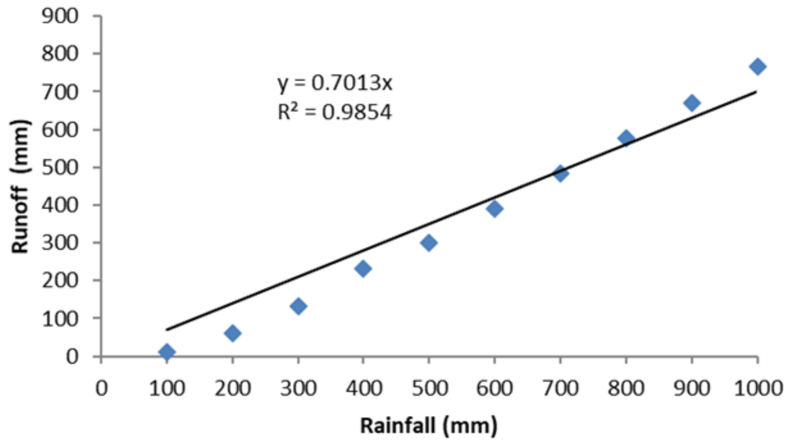


Figure 11. The relationship between rainfall and runoff in the study area

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Author contributions

Manti Patil: Conceptualization, Methodology, Writing-Original draft preparation, Validation **Arnab Saha:** Conceptualization, Data curation, Visualization, Writing-Original draft preparation, Software, Validation **Santosh Murlidhar Pingale:** Methodology, Visualization, Investigation, Writing-Reviewing and Editing, **Validation Devendra Singh Rathore:** Investigation, Writing-Reviewing and Editing **Vikas Chandra Goyal:** Data curation, Investigation, Writing-Reviewing and Editing

Conflicts of interest

The authors declare no conflicts of interest.

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