Run-off and Soil Loss Estimation Using Numerical Approach in Hard Rock Terrain.

Hemant Kumar Pandey
Motilal Nehru National Institute of Technology
Vishal Singh (spaceimage@outlook.com)
Motilal Nehru National Institute of Technology https://orcid.org/0000-0003-2892-7505
Ram Pal Singh
Motilal Nehru National Institute of Technology

Research Article

Keywords: Run-off, Bundelkhand, Curve number(CN), Landuse Landcover, Antecedent moisture condition (AMC).

Posted Date: December 9th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-1045478/v1

Run-off and soil loss estimation using numerical approach in hard rock terrain.

H. K. Pandey[1], Vishal Kumar Singh[2], Ram Pal Singh[3]

*Department of Civil Engineering, Motilal Nehru National Institute of Technology Allahabad, Prayagraj, Uttar Pradesh-211004
[2]spaceimage@outlook.com

Abstract

The present study reveals the potential run-off estimation, soil erosion and scope of groundwater recharge in the Bundelkhand region in the state of U.P. , India. The estimation of run-off and soil erosion have provided a platform to evaluate the realistic potential for water conservation in the study area. The study area is characterized by occurrence of mild to severe drought conditions with significant run-off and poor infiltration. Geomorphological factors such as land use changes, slope, and nature of soil affect the run-off rate and discharge significantly. Soil map and rainfall data for the study area were acquired to evaluate the hydrological soil group (HSG) and antecedent moisture condition (AMC) respectively. Soil Conservation Services and Curve Number (SCS-CN) method has been used to calculate the run-off volume at the point where river/streams join together while soil loss has been calculated using revised universal soil loss equation of RUSLE model with the input of spatial data sets such as soil texture, rainfall, topography etc. The maximum run-off (355mm) has been estimated in watershed-1 during 2016 and minimum (1 mm) in watershed-4 respectively. The estimated run-off varies from 5.5% to 28% of the total rainfall in the study area, while soil loss is maximum (2.1×10^6 ton/ha) in the watershed-1. It is a fact that soil loss is in conformity with run-off. This finding provides the roadmap for the selection of suitable artificial recharge structures to augment the groundwater in the study area. .

Keywords: Run-off; Bundelkhand; Curve number(CN); Landuse Landcover; Antecedent moisture condition (AMC).

Statements and Declarations

The present research work doesn't have any conflict of interest of the researchers who have done the work in this area. The findings of the present research work will provide a road map for making the plan for water management. There is no financial interest related to the work.

Acknowledgment

Authors are thankful to the **Natural Resources Data Management Systems**, **Department of Science and Technology**, Govt. of India for providing the financial support in the mode of R&D project. Thanks are also due to the Director, MNNIT Allahabad, Prayagraj, India for his administrative support. We are thankful to Dr. Sudhir Kumar Singh, K.Benerjee Centre of Atmospheric and Ocean Science, University of Allahabad for his critical comments.

Introduction:

The unfavorable impact of soil erosion on agricultural productivity and environment have long been accepted as severe problems to individuals for sustainable development (Lal 1998). Soil erosion is also one of the challenges for society and government institutions, which can be addressed through proper management of land resources(Tarun et. al. 2019).

Watershed development requires a well planned statement of run-off and geomorphological stability of the land surface. A mathematical model known as rainfall-runoff model that describes the rainfall-runoff relationship of a watershed or of a catchment area. According to Askar (2014) rainfall-runoff model is very useful in calculating the run-off in a watershed. Several methods such as Artificial Neural Network (ANN), Geo-morphological Instantaneous Unit Hydrograph (GIUH), SCS Curve Number model and University of British Columbia Watershed Model (UBCWM) offer run-off estimation, but the SCS-CN curve method gives most accurate result and as well as the simplest method to estimate the run-off (Shwetha et al. 2015). SCS-CN curve method accounts many factors affecting the run-off generation such as land use, land cover, soil type, antecedent moisture condition and ground surface condition with one CN parameter. (Bansode and Patil 2014). This method was first developed by Soil Conservation Service United States in 1972, since then it has been adopted worldwide. (Nayak 2003); (Ashish and Dabral, 2004); (S. Satheesh Kumar 2017); (Shi and Ni 2020); (Walega 2020) have used GIS tools for the estimation of the curve number, they also concluded that Remote Sensing data are very useful for the preparation of several input data required in SCS-CN method. (Dhawale and Arun 2013) have used the SCS-CN model for the estimation of surface run-off depth when adequate hydrological information is not available. Other data pertaining along with soil condition and land use pattern are used to determine Antecedent Moisture Condition (AMC) which influences surface runoff, also a significant factor regulating the initial abstraction of runoff in the SCS-CN method.

In a watershed where no runoff is measured, the curve number method can be used to calculate the total depth of runoff from the incident rainfall. Due to changes in land surface vegetation, and meteorological events, water system changes for a catchment area which can be visualized using run-off modeling. Finally, this method is used to present a single parameter relationship between runoff depth and rainfall.

Wischmeier and Smith of the Department of Agriculture in the United States first developed the Universal Soil Loss Equation (USLE) during 1960s as a field scale model (Prasannakumar et al. 2011, 2012; Dutta et al. 2015; Arekhi et al. 2012). The most commonly used model for soil erosion is USLE (Wischmeier and Smith 1978) as well as its revised version called Revised Universal Soil Loss Equation (RUSLE) (Renard et al. 1997). The RUSLE model requires data pertaining to the nature of terrain, soil texture, ground cover, slope length, climate, aspect and shape (Shinde et al. 2011; Yueqing et al. 2011; Prasannakumar et al. 2011, 2012). Several factors, which directly affect runoff are influenced by soil type and land cover. Infiltration rate is reduced due to undulating terrain and steep slope resulting into vulnerable soil loss in the study area.

With the combination of GIS tools and remote sensing data, SCS-CN method has been used to estimate the run-off while RUSLE model is used to predict annual soil loss precisely. The objective of this study is to estimate the total annual runoff and soil loss in the different watersheds in the hard rock terrain of the Mahoba District, U.P., India.

Study Area

Mahoba district of Bundelkhand region in Uttar Pradesh, India, lies between latitude 25^0 01’30” and 25^0 39’40” North and longitude 79^0 15’00” and 80^0 10’30”East (Fig 1). The total geographical area of the district is 2,884 km^2, it has four administrative blocks. According to the Census 2011,the total population of the district is 875958. Major soil type is sandy deep lomy and average rainfall for the last10 years is 770mm. There is no meteorological observatory located in Mahoba district; however five rain gauge stations have been established by the UP irrigation department. The district experiences a typical subtropical climate punctuated by long and intense summers (Pandey 2002).

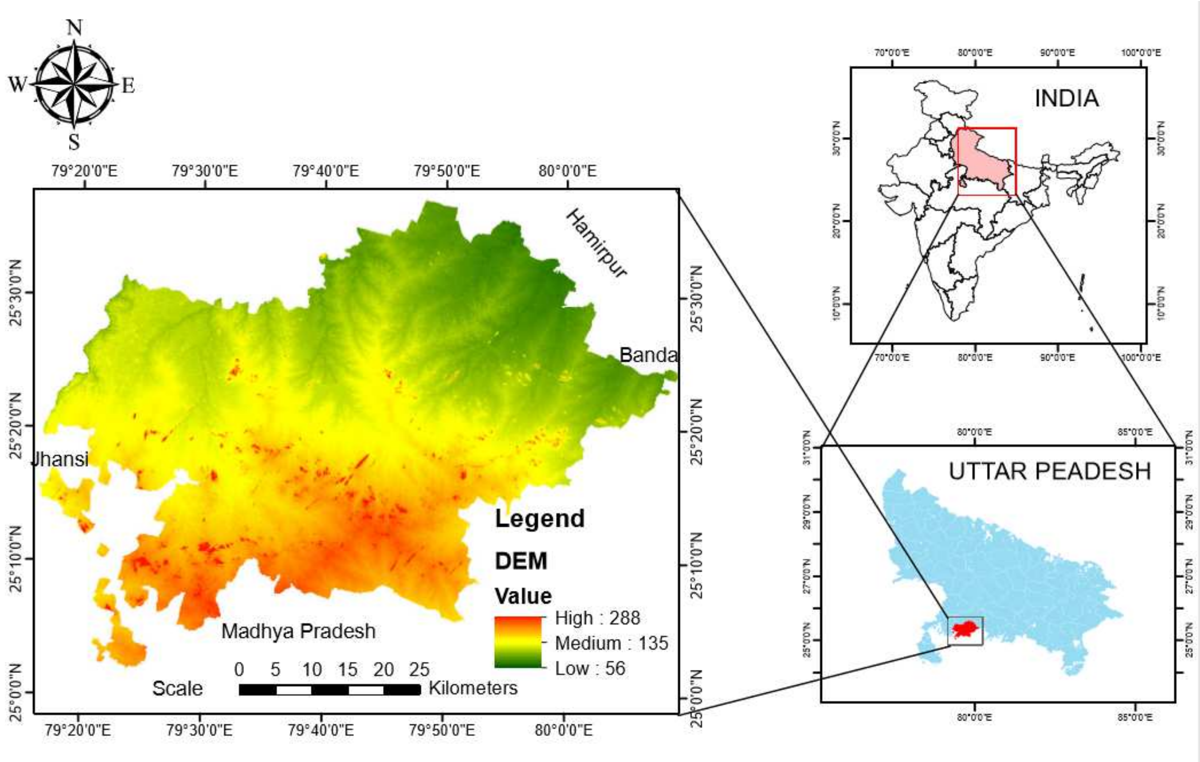

Fig. 1 - Location map of the study area

Moderately heavy rainfall also occurs during the rainy season. The hilly and hard rock terrain cause heavy overland flow and water during the rainy season. As a result, most of the dry period is rather insignificant and whatever base flow takes place in the streams is the contribution of groundwater. The maximum mean monthly atmospheric temperature has been recorded 47.5^0 C during the month of May and minimum 8.3^0 C in January. During the monsoon period (July to September) the relative humidity attains at its highest level ranging between 80 to 85% while it is lowest around 30% during peak summer (May)(Pandey 2002).
Agriculture is the main source of livelihood for the people of Mahoba district . Both surface water and groundwater are used for irrigation. Most of the agricultural land depends upon the precipitation for irrigation. **Swami Bramha Nand** Dam and **Arjun Sagar Reservoir** are the collection points of the rainwater through run-off. Dhasan, Urmil, Bima and Arjun rivers flow across the district. These rivers and streams constitute the natural drainage lines in the district and separate many administrative boundaries. Watersheds where geographical area as estimated from DEM data are tabulated below (Table 1). All other watersheds are named as micro-watersheds covering less than 10% of the total area.

Table 1: Administrative division of Watersheds of the study area

Sl No.	Watershed	Area(Km^2)	Block name
1	Watershed-1	712.3156	Panwari, Jaitpur
2	Watershed-2	458.829	Charkhari, Kabrai
3	Watershed-3	299.241	Charkhari, Kabrai
4	Watershed-4	196.539	Charkhari

5	Watershed-5	170.93	Kabrai

Data and Methodology

Satellite Sentinel 2.0 data, which have spatial resolution of 10m for blue, green, red and infrared bands, were used for preparation of landuse/landcover, NDVI and other maps of the different watersheds. The data pertaining to the study area were downloaded from the European Space Agency website. The flow chart of methodology adopted is as below(Fig 2);

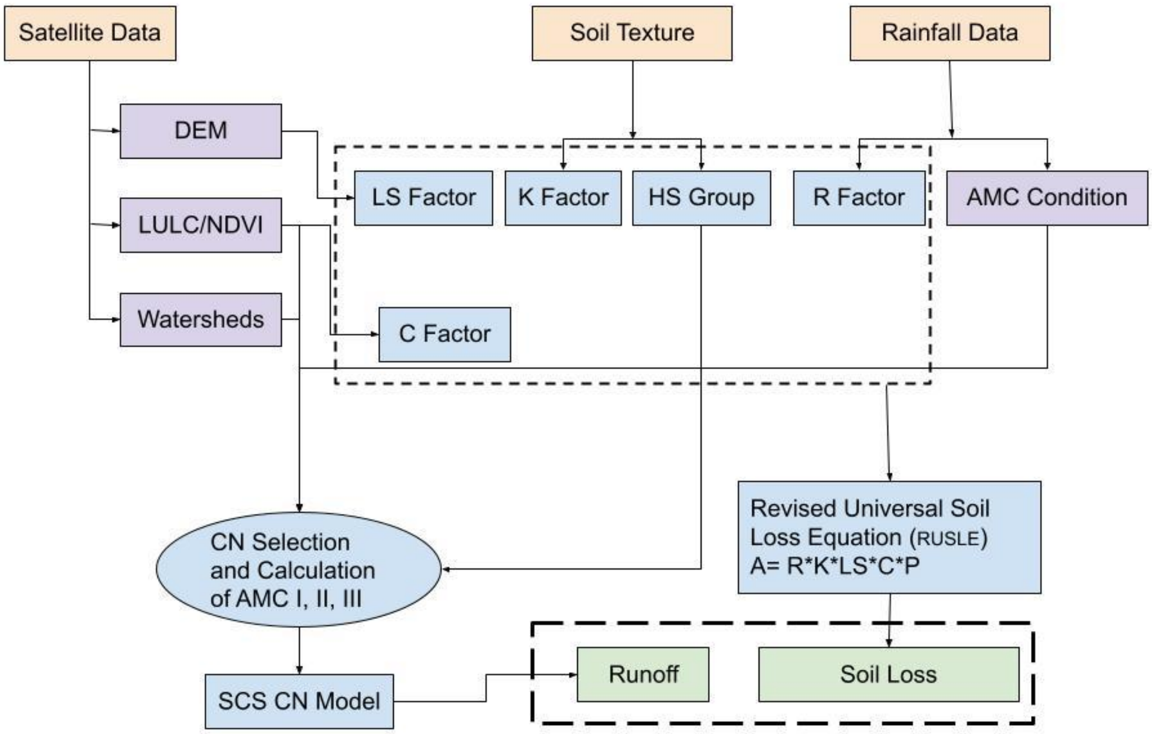

Fig. 2 Flow chart of methodology

Carto Dem data were used for generating Digital Elevation Model(DEM) having 30m of resolution. To obtain the Hydrologic soil group and K-factor soil texture was used. The data pertaining to the soil were downloaded from NBSS and LUP Regional center, Delhi (http://www.nicra-icar.in/nicrarevised/images/statewiseplans/Uttar%20Pradesh/UP50-Mahoba-26.07.14.pdf). The soil type of the selected watersheds was found to be deep, loamy with very gentle slope (<3% and 3-5%). To calculate the accumulated annual rainfall occurrence in the study area, IMDLIB python tool was used. Basically thematic layers of R-factor and antecedent moisture condition (AMC) were generated by analyzing rainfall data for the past 10 years (2010-20). The SCS-CN model requires AMC, Hydrologic soil group and LULC for selection of curve number to estimate surface runoff. On the other hand, Revised Universal Soil Loss Equation (RUSLE) is applied for the estimation of annual soil loss.

Land use Land cover

LULC map (Fig. 3-a) provides the forest cover, built up, impervious surfaces, agriculture, and other land and water bodies. The given pie chart(Fig. 3-b) illustrates land cover in the Mahoba district. Agriculture accounts for 62% of the total land. whereas commercial activities like mines account for less than 1%. Approximately 16% of the land is covered by wetland followed by the barren land (9.4%.) Water Bodies in the district is less than one percentage of the total land cover. Since, the study area is densely populated the built up area accounts for more than vegetation and water bodies covering 7.1% area. The landuse landcover has been used in finding out the SCS-CN Curve. The land use pattern of the study area as follows;

- Agriculture land: 1,825 sq.km
- Wetland: 490 sq.km
- Barren land :276 sq.km
- Builtup area- 209 sq.km
- Vegetation/Forest-103 sq.km
- Water bodies-25 sq.km
- Mines- 16 sq.km

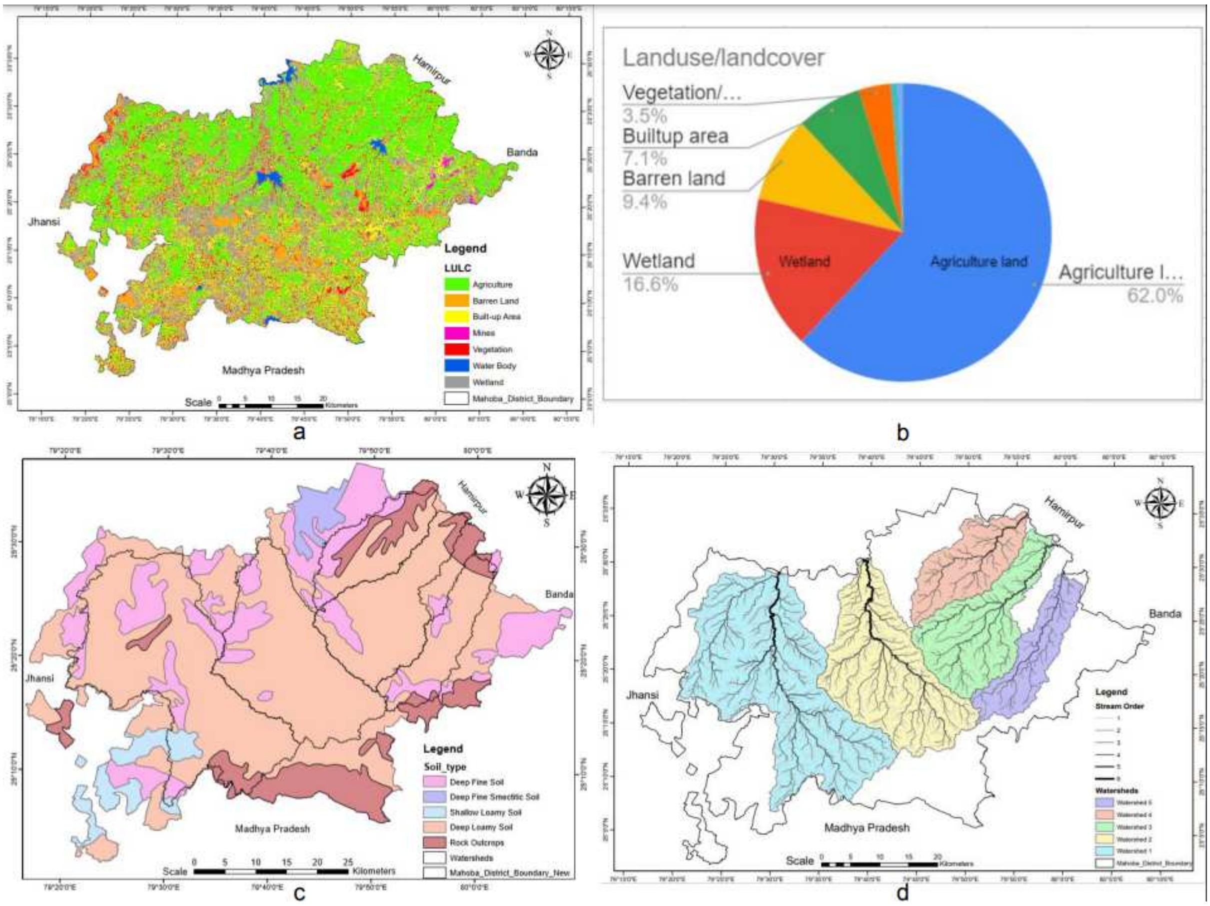

Fig. 3 a) Landuse/Landcover; b) Pie-chart showing percentage of land cover; c) Soil map; d) Watersheds and Drainages order.

Hydrologic Soil Groups

The amount of run-off is influenced by the soil properties i.e. a hydrological parameter after prolonged wetting known as soil group. The least rate of infiltration obtained for bare soil is used to represent these properties. Soil's surface condition also influences the infiltration rate, transmission rate and soil erosion. The variable which shows the soil run-off capacity is the qualitative baseline for grouping all soil types into four categories (Satheesh Kumar et al. 2017). These soil groups have been named as **Group A**, (Soil having high infiltration rate, for example: gravels or drained sands, deep soil), **Group B** (Soils with average infiltration rate such as: deep to moderately deep, moderately well drained soil, moderately coarse texture or file soils), **Group C** (Soil with low infiltration rates, for example: soils of moderately fine to fine texture or soil with characteristics to prevent downward movement of water.) and **Group D** (Soils with very low infiltration rates, for example: clay soil with in perpetuity deep water table, shallow soils over impervious material, clay soils with a high swelling potential). The soils of India have also been classified according to their infiltration rate and run-off potential characteristics (Nagarajan and Poongotha 2012). Soil types of the study area are characterized by deep loamy soil with variant slope condition and texture (Fig 3-c). The soil of the study area falls under **GroupB**(Table 2). Soil has different slopes and textures in the study area. Loamy soil is formed with the mixture of sand, silt and clay. It is further classified as sandy or clay loamy depending on their predominant compositions. Different watersheds of the study area are shown in Fig-3-d.

Table 2: Soil Groups for watersheds in the study area

Watershed	Drain_Density	Area	Drainage_frequency	Soil_Type	Soil Group
Watershed 1	0.414354556	712.3	0.307454724	Deep, Loamy Soil	Group B
Watershed 2	0.425442278	458.8	0.255013078	Deep, Loamy Soil	Group B
Watershed 3	0.428640381	299.2	0.190508021	Deep, Loamy Soil, Slope 3 to 5 %	Group B
Watershed 4	0.36646283	196.5	0.218829517	Deep, Loamy Soil	Group B
Watershed 5	0.441514991	170.9	0.362785255	Deep, Loamy Soil	Group B

Precipitation

Precipitation is the source of run-off in a watershed, high precipitation indicates high run-off in steeper terrain because distribution of the rainfall along with the gradient of the slope affects soil erosion and infiltration rate immensely. Indian meteorological department(IMD) data were used to analyse rainfall conditions in the study area. On an average, the highest rainfall occurs in the southern part (Fig 4-a) which accounts for 837 to 925 mm and the lowest in the northern part of the study area. The rainfall distribution has direct implications on run-off and the selection of groundwater recharge structures.

Slope

The study area is characterised by undulating terrain which indicates poor infiltration rate and significant run-off. The slope map(Fig 4-b) was prepared using CartoDEM data of spatial resolution 30m, it was downloaded from National Remote Sensing Center's website (https://bhuvan.nrsc.gov.in/) and processed in ArcGIS software. The slope varies from 1.26^0 to 32^0 in the entire study area. Hill slopes constitute slopes varying from 10^0-32^0, indicating high run-off potential and soil erosion. The average slope varies between 0-1.26 ^{0} in most of the study area.

Drainage density

Drainage density is a very important geomorphological feature. Physical properties of a drainage basin is described by drainage density, which is influenced by numerous factors such as vegetation cover, infiltration rate, soil erosion, runoff intensity, climatic conditions and surface roughness (Langbein 1947; Verstappen 1983). Drainage density map (Fig 4-c) indicates highest drainage density as 0.44 km channels per Km^2 in watershed-5 and lowest as 0.36 km channels per Km^2 in watershed-4 of the study area. Higher drainage density represents high run-off and increased soil erosion.

Antecedent Moisture Condition(AMC)

The soil moisture condition in a watershed before the occurrence of run-off is an influencing factor for the final CN value. Sindhu et al. (2013); Amutha and Porchelvan (2009) explained that AMC usually depends upon the soil characteristics and five days antecedent rainfall. The moisture condition of the soil is classified into the following three Antecedent Moisture Conditions (AMC): AMC I, AMC II and AMC III from the reference of National Engineering Handbook Section 4 (NEH-4) tables (SCS 1972). As per USDA (1986), the AMC classes are shown below (Table 3);

Table 3 AMC Classes (for soil)

Seasonal rainfall limits for AMC classes			
5-day antecedent rainfall (mm)			
Antecedent Moisture Condition Class	Dormant season (mm)	Growing season (mm)	Average (mm)
I	< 13	< 36	< 23
II	13 - 28	36 - 53	23 - 40
III	> 28	> 53	> 40

AMC I: The soils in the watershed are practically dry (wilting point).
AMC II: Average condition, depending on the 5 days precipitation amount an the median CN value represents the AMC II condition
AMC III: The soils in the watershed are saturated from antecedent rainfalls (High water content).

For AMC-I and AMC-III the following equations are used (Chow et al. 2002):

$$CN(I) = \frac{CN(II)}{2.281 - 0.0128\, CN(II)} \quad (1)$$

$$CN(III) = \frac{CN(II)}{0.427 + 0.00573\, CN(II)} \quad (2)$$

where, CN(II) is the curve number for normal conditions, CN(I) is the weighted curve number for dry conditions, and CN(III) is the weighted curve number for wet conditions. Weighted CN(II) is the sum of multiplication of area of land cover multiple of CN(II) divided by the total area of the watershed. Mathematically it can be expressed as follows:

$$CNw = \sum CNi * Ai/A \quad (3)$$

Where CN_i is the curve number from 1 to any number *N;* 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.

SCS-CN Curve

The SCS-CN curve method was first developed by Soil Conservation Service United States in 1972, since then it is widely used all over the world for the calculation of run-off. Generally, the curve number method depends on two incidents, abstraction and retention (Jun et al. 2015). Before the starting point of run-off the initial accumulation of rainfall appears for interception, depression storage, and infiltration, this is called initial abstraction. It is calculated according to the initial possible water retention from the day of infiltration(Geetha et al. 2007). Due to infiltration some of the added rainfall is lost, this phenomenon is called actual retention that increases to a maximum value with increase in the rainfall. SCS curve number is the ratio of actual run-off to potential maximum run-off that will be equal to the ratio of actual retention to potential maximum retention. It is also considered as rainfall minus initial abstraction. Mathematically it can be expressed as follows (USDA

1972):-

$$\frac{F}{S} = \frac{Q}{P-Ia} \tag{4}$$

$$F=P-I_a-Q \tag{5}$$

Substituting Eqs(4) in Eqs (5)

$$Q = \frac{(P-Ia)2}{(P-Ia)+S} \tag{6}$$

where

F = actual retention (mm)
S = potential maximum retention (mm)
Q = accumulated run-off depth (mm)
P = accumulated rainfall depth (mm)
I_a *= initial abstraction (mm)*

I_a represents total losses before the rainfall began which is given by

$$I_a = 0.2S \tag{7}$$

Substituting Eqs(7) in Eqs(6), Eqs 7 become (USDA 1972)

$$Q = \frac{(P-0.2S)2}{(P-0.8S)+S} \quad \textit{For } P>Ia\ (0.2S) \tag{8}$$

S = the potential infiltration after the run-off begins, it can be expressed by the following equation.

$$S = \frac{25400}{CN}\text{-}254 \tag{9}$$

CN values(Fig 4-d) obtained from NEH-4 tables which depend upon the characteristics of a watershed such as hydrological conditions, slope, LULC, soil type and AMC are also applicable to both ungauged and gauged catchment areas (Shwetha et al. 2015).It is a dimensionless number ranging from 0 to 100 (USDA 1972) (Dhvani and Narendra 2016). The curve number (CN) derived from the graph is plotted between rainfall vs run-off for each year in the watershed (Silveira et al. 2009).

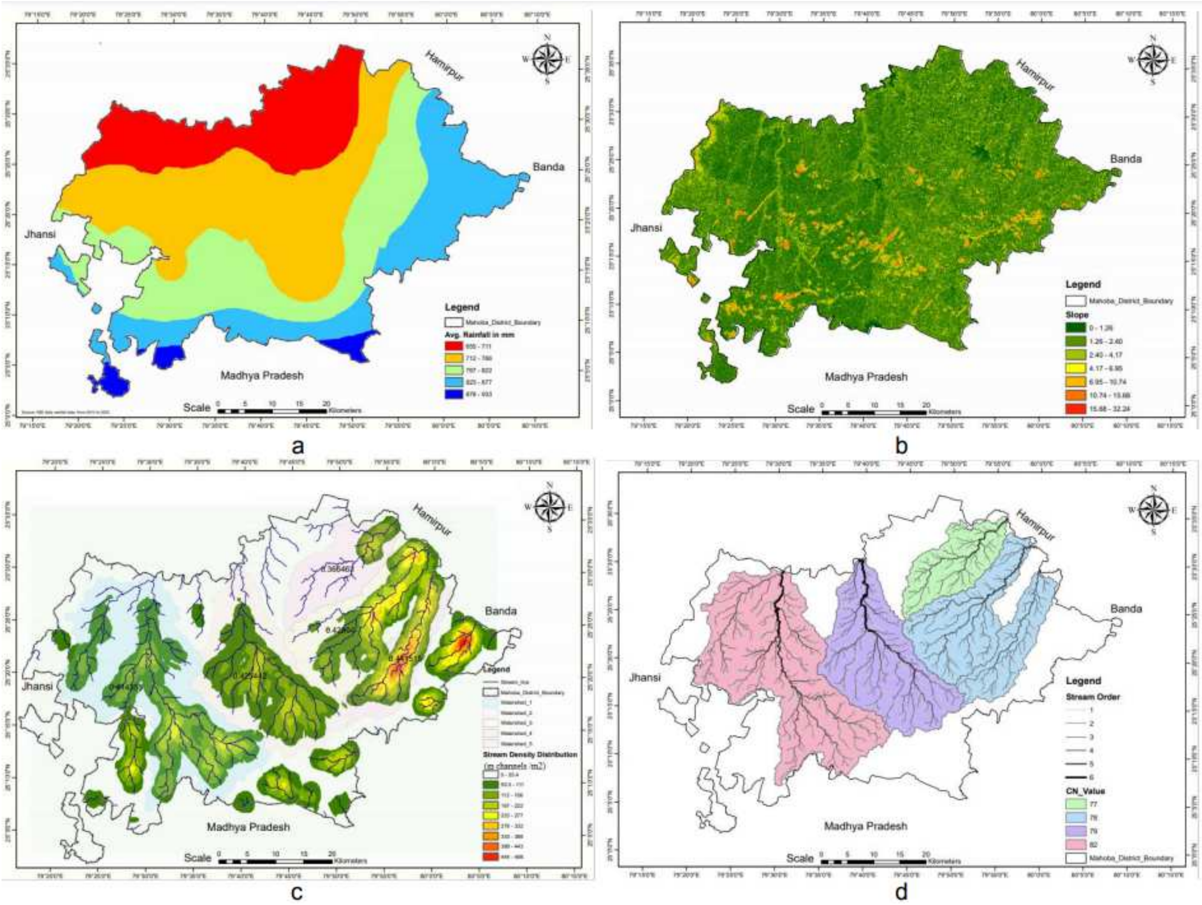

Fig 4: a) Average rainfall; b) Slope map; c) Drainage density; d) CN values and steam order for different watersheds

Crop management factor-C

According to Ayalew et al. (2020), factor C is expressed as the soil loss rate (SLR) from a given watershed covered with a particular vegetation to a basin prepared for the bare seedbed plowed up and down the slope**.** It directly affects the density and crop cover. The amount of erosion is inversely proportional to the density of vegetation. The C-factor values (Fig 5-a) vary from 0.003 to 1 for protected soil with dense vegetation and bare soil respectively (Tarun et. al. 2019). It has been calculated using the following equation:

$$C = exp\left|-\ \alpha.\frac{NDVI}{(\beta - NDVI)}\right| \quad (10)$$

where α and β are empirical constants.

Soil Erodibility Factor (K)

Soil erodibility is also known as K-factor, which is an inherent property of soil, it is defined as the ability of water to detach and transport the soil particles. According to Wischmeier et al. (1971) and Renard et al. (1997) soil texture, soil structure, soil organic matter and basic permeability of the soil profile are used for the calculation of soil erodibility factor. Its values vary from 0 (poorly permeable rock) to 1 (highly permeable soil). Value of the K-factor has been adopted from different studies (Table-4). Denudational hills, pediment and pediplain erosional landforms are observed in the study area. K factor varies from 0.03 to 0.34(Table-4 and Fig 5-b) in the study area which corroborates the type of soil as observed in the study area.

Table 4: Soil erodibility (K- Factor)

Soil Type	K-factor	Reference
Rock Outcrop	0.03	Pacific Northweste National Laboratory https://mepas.pnnl.gov/mepas/formulations/source_term/5_0/5_32/5_32.html
Deep Loamy Soil	0.34	
Deep Fine Smectitic Soil	0.24	
Shallow Loamy Soil	0.30	
Deep Fine Soil	0.20	

Topographic factor (LS)

The topographic factor is influenced by slope length (L) and steepness (S). The amount of soil erosion increases as the slope increases (Wischmeier and Smith 1978). The values of L and S were calculated using the Digital Elevation Model (CartoDEM 1 arc second). L and S factors are directly proportional to the amount of soil erosion, it has been computed using the following equation:

$$LS = (m + 1)[a.\,Cell\,Size \div a_0]^m \times [(sinS \div S_0)]^n \quad (11)$$

where ($m = 0.6$ and $n = 1.3$) m and n are empirical exponents(Moore and Wilson 1992), S = slope in degrees, a = surface of contribution at the upstream, $a_0 = 22.13$ m, and $S_0 = 0.4$, cell size is the size of digital elevation model(DEM) grid cell value. The L and S factor has been shown in Fig 5-c.

Rainfall erosivity factor (R)

According to Hudson (1971); Wischmeier and Smith (1978) the physical characteristics of the rainfall such as kinetic energy, drop size, terminal velocity and distribution pattern causes soil erosion and its magnitude. In general the R-factor is the product of erosivity of rainfall and maximum kinetic energy. The following equation (Eq. 12) has been used for calculating the R factor.

$$R = \sum_{1}^{12} 1.735 * 10^{(1.5 \log_{10}{}^{Pi/P}) - 0.08188)} \qquad (12)$$

Where P is annual precipitation in *mm* and R is annual rainfall erosivity (*MJ.mm. ha*$^{-1}$ *h*$^{-1}$ *year*$^{-1}$)

Revised Universal Soil Loss Equation (RUSLE)

According to Wischmeier and Smith (1978) RUSLE model is used for the estimation of annual and average soil loss. The RUSLE model retains the general framework of the USLE model but refines the calculations for each of the five erosion factors through greater temporal and spatial precision (Renard et al. 1997). The method is based on the detachment and transportation of the soil particle by runoff. This method enables us to estimate the soil erosion due to monthly, seasonal and individual storms rainfall in a watershed. The amount of soil erosion has been estimated using the following equation:

$$A = R \times K \times LS \times C \times P \qquad (13)$$

where *K* is the soil erodibility factor (*ton ha h ha*$^{-1}$ *MJ*$^{-1}$ *mm*$^{-1}$); *A* is the soil loss in ton ha^{-1}year^{-1}; *LS* is the slope steepness and slope length factor; *R* is the rainfall erosivity factor in *MJ mm ha*$^{-1}$ *h*$^{-1}$ *year*$^{-1}$; *P* is the conservation practices factor equals to one when no protection measures taken; *C* is the crop management factor.

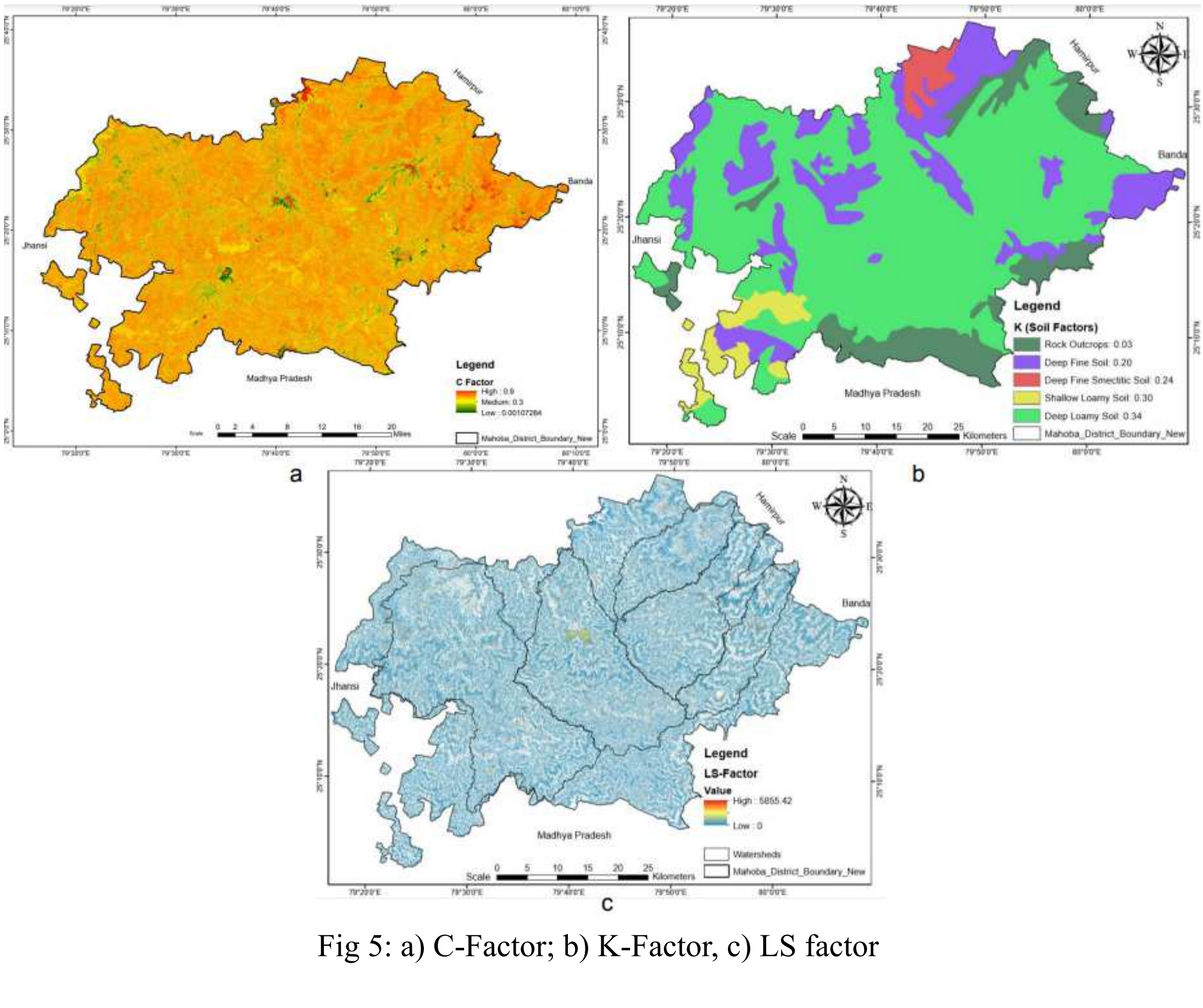

Fig 5: a) C-Factor; b) K-Factor, c) LS factor

Results and Discussion

The run-off and soil loss have been calculated for five watersheds, and the findings have been discussed for each watersheds respectively as below:

Watershed-I

Watershed-I has an area of 712 Km^2, it has drainage density of 0.41km per square kilometers of area, and frequency of drainage is 0.30 streams per Km^2. The watershed consists of 58 percent of agriculture lands, followed by 20% of wetland; it has only 3.8 percent of forest cover, while built-up area accounts for 7.5 percent. The soil of this watershed is deep loamy, consisting of clay and silty sand. The hydraulic soil group is considered to be in Group B. The weighted CN value obtained according to AMC is 82.41 (Table 5). The weighted CN of the watershed has been applied to estimate run-off. The maximum 1190 mm rainfall occurred in the year 2013 whereas the minimum(518mm) in the year 2015(Fig 6-a). Run-off volume is maximum 354mm and minimum 12mm respectively while estimated average soil loss is 2.1×10^6 ton/ha (Table-5).

Table 5: LU/LC, CN II, run-off and average soil loss for watershed-I

Watershed-1							
Land use/Land Cover	**Area in Sq. Km**	**% Area**	**CN (II)**	**Area*CN (II)**	Weighted CN II	Maximum run-off	Average Soil Loss
Water Body	0.948	0.133	100	94.8	82.41928662	354mm	2125867 ton/ha
Mines	1.7924	0.2519	82	146.9768			
Vegetation/Forest	27.2992	3.832	72	1965.5424			
Built-up Area	54.0304	7.585	82	4430.4928			
Barren Land	64.9856	9.129	81	5263.8336			
Wet Land	149.386	20.971	100	14938.6			
Agriculture	413.874	58.102	77	31868.298			
Total	712.3156			58708.5436			

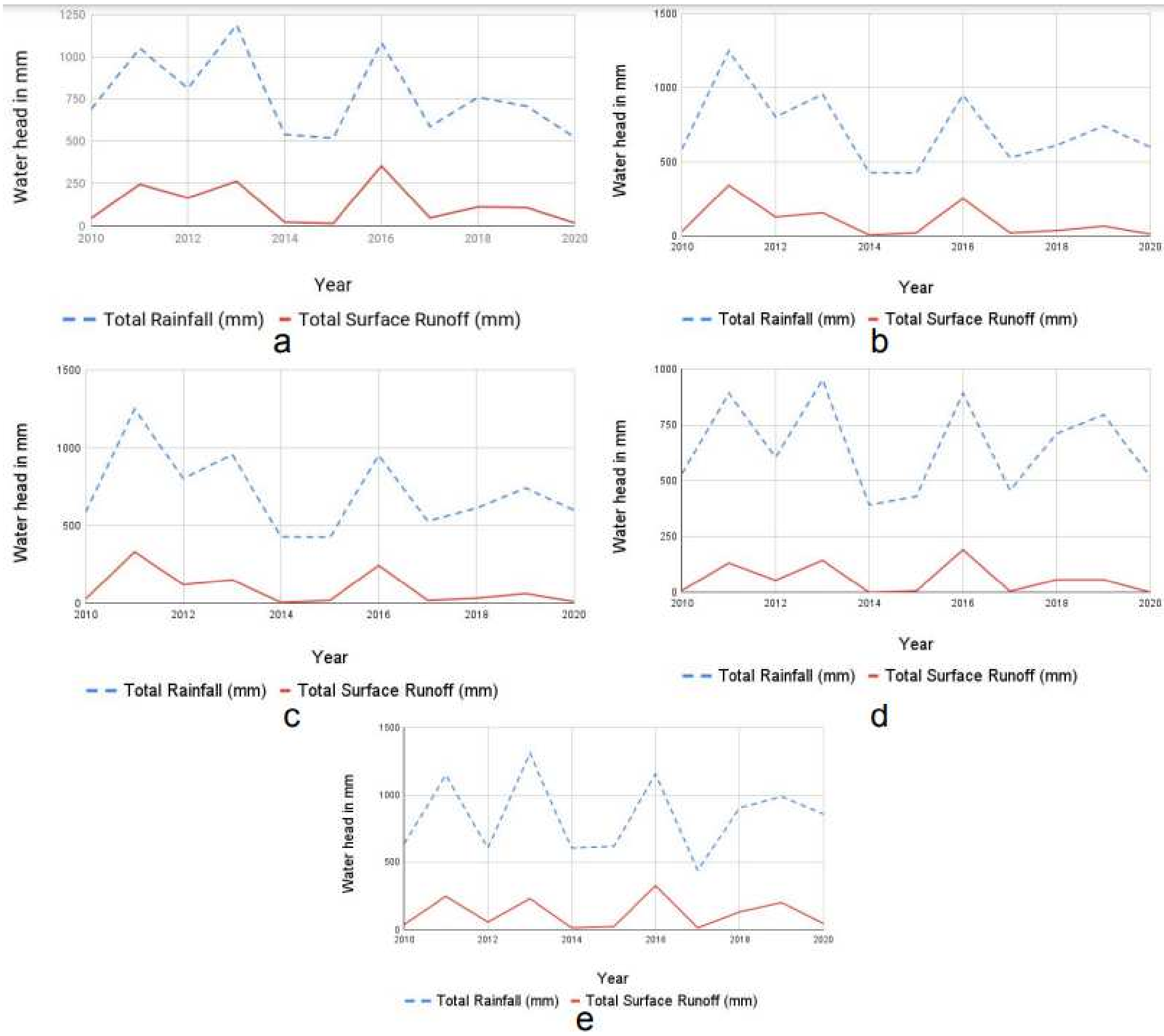

Fig. 6: a) Accumulated rainfall and run-off for the watershed-I; b) Accumulated rainfall and run-off for the watershed-II; c) Accumulated rainfall and run-off for the watershed-III; d) Accumulated rainfall and run-off for the watershed-IV; e) Accumulated rainfall and run-off for the watershed-V

Watershed-II

Watershed II has an area of 458 Km^2, the drainage density of this watershed is calculated as 0.42 Km per Km^2 and frequency of drainages is 0.25 streams per Km^2. LULC indicates that the water body of this basin consists of 1.8 percent of the total area while built-up area is 5.7 percent. Agricultural land accounts for the highest land cover 56 percent followed by the wetland 22 percent (Table 6). Soil type of this watershed is deep loamy and moderately eroded. The hydraulic soil group is considered as in Group B. According to AMC conditions, the weighted CN value for this watershed is 78.91, which is further used to estimate the run-off. The maximum rainfall 1251 mm for this region occurred in the year 2011 and maximum run-off 345mm in the same year, least rainfall 427 mm occurred in the year 2015 and minimum run-off 8 mm in the year 2014 (Fig 6-b). Estimated average soil loss is 1.3×10^6 ton/ha (Table 6).

Table 6: LU/LC, CN II, run-off and average soil loss for the watershed-II

Watershed-2

Land use/Land Cover	Area in Sq. Km	% Area	CN (II)	Area*CN(II)	Weighted CN II	Maximum run-runoff	Average Soil Loss
Water Body	8.53	1.859	100	853	78.91	345mm	1388901 ton/ha
Mines	1.308	0.285	82	107.256			
Vegetation/Forest	12.946	2.821	72	932.112			
Built-up Area	26.453	5.765	82	2169.1952			
Barren Land	55.394	12.072	81	4486.9464			
Wet Land	96.515	21.035	81	7817.7636			
Agriculture	257.682	56.160	77	19841.514			
Total	458.829			36207.7872			

Watershed III

This watershed has an area of 299 Km^2, which is located in the Charkhari, Kabrai administrative block of Mahoba district. The major soil type is deep loamy with very gentle slope, the hydraulic soil group for the selection of curve number is defined as Group B. The watershed consists of 6 orders of streams with drainage density 0.42Km per Km^2 and drainage frequency of 0.19 streams per Km^2. As per LULC analysis agriculture accounts for 69% of the total area followed by wetland 10%, water body accounts for 1.6 percent of the total land cover, and mines at 0.3 percent at lowest, forest cover is 5 percent while barren land is 7.6 percent (Table 7). Weighted CN value for this is 78.13, which is applied to estimate the run-off. The maximum rainfall 1250mm occurred in the year 2011 and minimum 427 mm in the year 2015 (Fig 6-c), average rainfall for this region is 717mm. The maximum run-off 333 mm and minimum 7 mm found respectively, while the estimated average soil loss is 7.3x10^5 ton/ha (Table 7).

Table 7: LU/LC, CN II, run-off, average soil loss for the watershed-III

Watershed-3							
Land use/Land Cover	Area in Sq. Km	% Area	CN (II)	Area*CN(II)	Weighted CN II	Maximum run-off	Average Soil Loss
Water Body	5.0076	1.673	100	500.76	78.13	333 mm	734508 ton/ha
Mines	0.9084	0.303	82	74.488			
Vegetation/Forest	15.1552	5.064	72	1091.174			
Built-up Area	14.7516	4.929	82	1209.632			
Barren Land	22.868	7.6411	81	1852.308			
Wet Land	32.9	10.994	81	2664.9			
Agriculture	207.650	69.392	77	15989.080			

Total	299.241			23382.343			

Watershed IV

This watershed has an area of 196 km^2, it is located in Charkhari administrative block. Soil properties for this region is deep loam with a very gentle slope, The hydraulic soil group is considered as Group B. It has the lowest drainage density of 0.36 km per Km^2 and drainage frequency of 0.21 streams per Km^2, the watershed streams are in 6 orders. According to LULC agriculture has the highest percentage (85%) land cover followed by wetland 3.9 percent while the built-up area accounts for 4.6 percent, mines and forest cover account for 0.19 and 2.15 percent respectively (Table 8). According to the AMC condition, weighted CN value is 77.44, it is applied to estimate the run-off. The maximum rainfall of 952 mm occurred in the year 2013, and minimum 392 mm in the year 2014(Fig 6-d). Maximum surface run-off 192 mm occurred in the year 2016, and in 2014 it was minimum 1 mm, which is the lowest surface run-off in the study area. On an average annual soil loss is estimated as $3.5x10^5$ ton/ha (Table 8).

Table 8: LU/LC, CN II, run-off and average soil loss for the watershed-IV

Watershed-4					Weighted CN II	Maximum run-off	Average soil loss
Land use/Land Cover	Area in Sq. Km	% Area	CN (II)	Area*CN(II)	77.44	192 mm	356129 ton/ha
Water Body	0.138	0.0704	100	13.84			
Mines	0.384	0.195	82	31.520			
Vegetation/Forest	4.242	2.158	72	305.424			
Built-up Area	9.159	4.660	82	751.054			
Barren Land	6.452	3.283	81	522.644			
Wet Land	7.798	3.968	81	631.7028			
Agriculture	168.364	85.664	77	12964.028			
Total	196.539			15220.214			

Watershed V

This watershed has an area of 170 Km^2, it is located in Kabrai Administrative Block. Soil properties for this region are deep loamy, moderately eroded associated with fine smectitic soils and slightly eroded with slope varying from 3 to 9 percent. The hydraulic soil group for the selection of initial CN is considered as Group B. As per LULC (Table 9), 65 percent of total land is covered by agricultural land while the water body accounts for only 0.23 percent, built-up area (13.6%) in this region is more than barren (5.9%) and wetland (9.7%). According to AMC conditions, weighted CN value is 78.32, which is applied to estimate the run-off. The maximum rainfall 1311 mm occured in 2013 whereas minimum 441mm in the year 2017 (Fig 6-e). The run-off for this region is the highest 327 mm and lowest 5 mm respectively while the estimated average soil loss is $3.4x10^5$ ton/ha(Table 9).

Table 9: LU/LC, CN II, run-off and average soil loss for the watershed-V

Watershed 5					Weighted CN II	Maximum run-off	Average Soil Loss
Land use/Land Cover	Area in Sq. Km	% Area	CN (II)	Area*CN(II)	78.326	327 mm	340655 ton/ha
Water Body	0.396	0.231	100	39.68			
MInes	3.954	2.313	82	324.228			
Vegetation/Forest	5.238	3.064	72	377.136			
Built-up Area	23.324	13.645	82	1912.633			
Barren Land	10.143	5.933	81	821.599			
Wet Land	16.591	9.706	81	1343.919			
Agriculture	111.28	65.104	77	8569.145			
Total	170.93			13388.34			

Groundwater Recharge

The findings of runoff and soil erosion in different watersheds have provided a road map to manage groundwater recharge on one hand and arrestation of soil loss on the other hand. The watershed wise groundwater recharge structures have been discussed below;

Construction of artificial recharge structures is another phase of the watershed planning which includes tapping drainages which are responsible for channelizing water to a common point. Check dams and drainage line treatment are the two important structures, which are useful under watershed development in the study area.

The objectives of the drainage line treatment is to check soil erosion in the channel bed, control volume and velocity of run-off, which in-turn the recharge ground water. Loose boulders are also used for the treatment of watershed. Under this, small barriers of rocks, clay and sand bags are placed across a constructed drainage. These are also known as loose boulder check dams. These structures reduce the velocity of the throwing water allowing sediment to settle and direct the run-off to a tank/reservoir.

Topographical characteristics and drainage discharge are the basis for the selection of these artificial recharge structures. Quantitative description of the drainage system provided by the morphometric analysis is an important characterization of watersheds (Strahler 1964). According to Horton (1945) the first step of quantitative analysis pertaining to the ordering of watershed streams. Later this was supported by Strahler (1952) with certain modifications. For the first order streams maximum frequency has been noticed, which is inversely proportional to the stream order. The performance of a watershed always depends upon correct positioning of the recharge structures. The present study suggests the following positions of recharge structures in view of the drainage system which is discussed below;

a.) 1st and 2nd order streams: Drainages with the first and second order streams are usually the smaller streams in watersheds and these streams contain several small tributaries, these streams feed larger streams and don't have any water flowing into them (Fig 7). They are also known as 'strater' streams (Anil and Ankit

2015). They are located in the northern part of study area. Only they flow during monsoon so called as seasonal streams. They flow quickly because of the steep slope and meet the next order streams. Because of the limited discharge, it is advisable to construct loose boulders dams.

b) 3rd order stream: Generally, two 2nd order streams come together to form 3rd order streams and discharge gets doubled that of 2nd order streams. This stream has a high flow rate, therefore construction of trenches in the drainage line can ensure the maximum infiltration of the stream water through soil or bedrock.

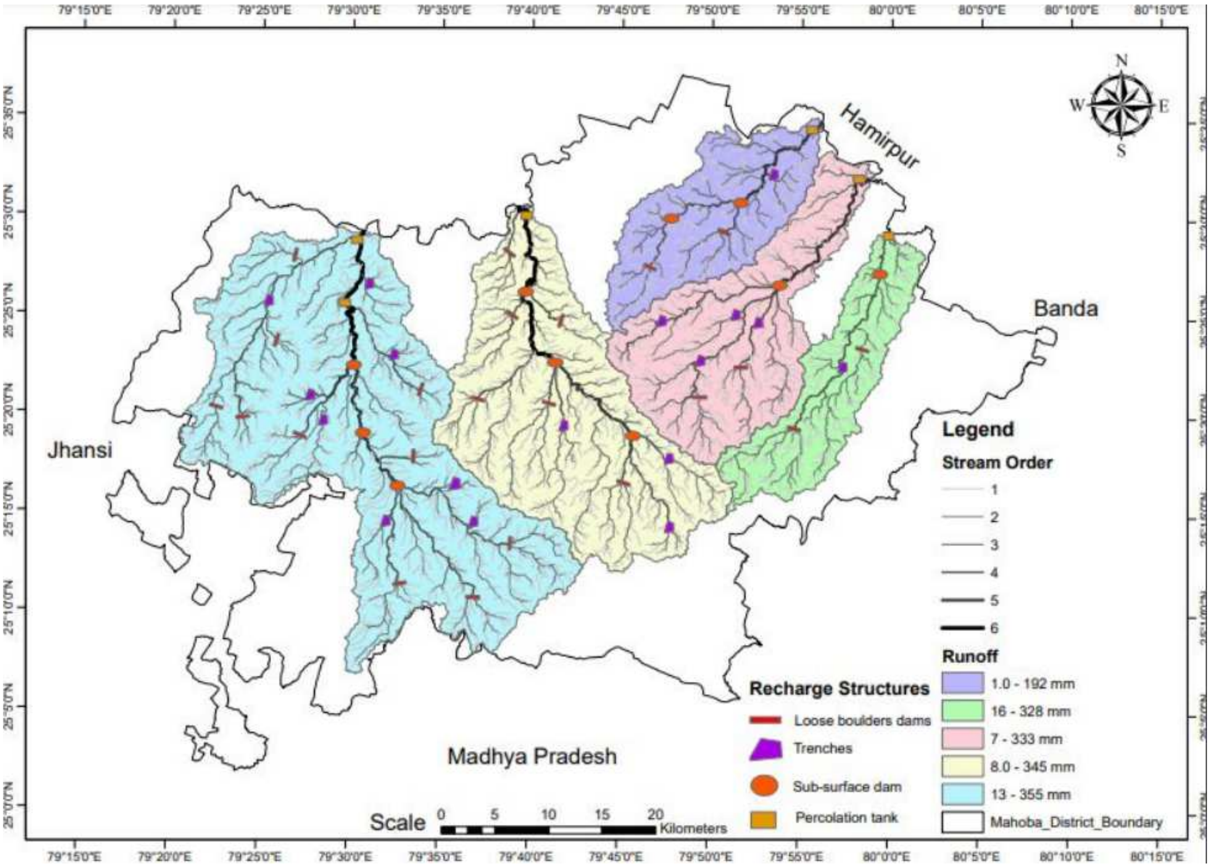

Fig 7: Groundwater recharge structures

c) 4th order stream: This stream is the result of two 3rd order streams joins together, this has high flow rate and high discharge, therefore, the construction of percolation tanks can ensure the utmost infiltration of the stream water. These are located in the central region of the study area.

d) 5th order stream: These streams constitute approximately 50 to 70% of waterways in the study area, they usually flow slower and are less steep, as they collect water from smaller waterways following into them, they have large volume of run-off, therefore construction of percolation tanks, check dams and subsurface dams can ensure high infiltration rate and accelerate the groundwater recharge.

e) 6th order streams:These streams are known as headwater streams, they constitute approximately 75 to 80 % of the world's waterways (Anil and Ankit 2015), they tend to have large volume of water. Usually they drain off water into reservoirs/lakes etc, they are located in the central region of the study area.

Conclusion:

The study area consists of five watersheds in the Mahoba district of Bundelkhand region of Uttar Pradesh, covering 2,884 km^2 area. Drainage density varies between 0.44 km per Km^2 to 0.36 km per Km^2. The maximum frequency of the drainages is estimated as 0.36 in the watershed 5. The initial CN value varies from 72 to 100 as per LULC and hydraulic soil Group. The study shows weighted CN values for AMC I, II and III vary from 60 to 91. The average run-off as estimated during 11 years (2010-2020) varies from 60mm to 126mm. The

maximum run-off (355mm) occurred in watershed-1 during year 2016 and minimum (1 mm) in watershed-4 during 2014. The run-off as estimated varies from 5.5% to 28% of the total rainfall in the study area.
The maximum soil erosion occurred in watershed-1 while it is minimum in watershed-4. Average soil loss for the watershed-1 was 2.1×10^6 ton/ha annually.
The run-off accumulated in different watersheds provides the opportunity to conserve and augment the groundwater. Since, the realistic run-off and soil loss have been estimated using SCS-CN and RUSLE method respectively, the types of water conservation and their locations have been identified. The present finding does not only reveal about the quantum of run-off and soil loss but also have implications for selection of water conservation structures. The suitable recharge structure like check-dem, sub-surface dam, percolation tank and tranches have been identified as feasible groundwater recharge structures, which will arrest run-off as well as soil loss. This would be quite beneficial to planners as well as researchers.

References:

Amutha R, Porchelvan P (2009) Estimation of surface run-off in Malattar sub-watershed using SCS-CN method. J Soc Remote Sens 37(2):291–304

Anil Kumar Misra, Ankit (2015)watershed Management Structures and Decision Making Frameworks, ISSN 0920-4741

Arekhi S, Niazi Y, Kalteh AM. 2012. Soil erosion and sediment yield modeling using RS and GIS techniques: a case study, Iran. Arabian J Geosci. 5(2):285-296

Ashish Pandey and Dabral. P.P. (2004), “Estimation of run-off for Hilly Catchment Using Satellite Data”, Journal of Indian Society of Remote Sensing, Vol. 32, No. 2, pp. 236-240.

Ayalew, D.A.; Deumlich, D.; Šarapatka, B.; Doktor, D. Quantifying the Sensitivity of NDVI-Based C Factor Estimation and Potential Soil Erosion Prediction using Spaceborne Earth Observation Data. *Remote Sens.* **2020**, *12*, 1136. https://doi.org/10.3390/rs12071136

Bansode A, Patil KA (2014) Estimation of run-off by using SCS curve number method and arc GIS. Int J Sci Eng Res 5(7):1283–1287

Chow VT, Maidment DK, Mays LW (2002) Applied Hydrology, McGraw-Hill Book Company, New York, USA

Dhawale, Arun W., (2013). run-off Estimation for Darewadi Watershed using RS and GIS, International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-1, Issue-6, 46-50.

Dhvani Tailor and Narendra J. Shrimali (2016), Surface Run-off Estimation By Scs Curve Number Method Using Gis For Rupen-khan Watershed, Mehsana District, Gujarat, J. Indian Water Resour. Soc., Vol 36, No. 4, Oct, 2016

Dutta D, Das S, Kundu A, Taj A. 2015. Soil erosion risk assessment in Sanjal Watershed, Jharkhand (India) using geo-informatics, RUSLE model and TRMM data. Model Earth Syst Environ. 1(4):1–9. http://dx.doi.org/10.1007/s40808-015-0034-1

H. K. Pandey, Report on District Ground Water Management Studies Mahoba District, U.P. CGWB-2002

H. Verstappen, The Applied Geomorphology, Geomorphological surveys for environmental developments, Elsevier Amsterdam(1983), p. 437p

Horton RE (1945) Erosional development of streams and their drainage basins. Bull Geol Soc Am 56:275–370.

Hudson NW. 1971. Soil conservation. Great Britain: Batsford Ltd.; p. 179–194.

Jun LI, Changming LIU, Zhonggen WANG, Kang L, (2015), Two universal run-off yield models: SCS versus LCM. J Geogr Sci 25(3):311–318. doi:10.1007/s11442-015-1170-2

K. Geetha, S. K. Mishra, T. I. Eldho, A. K. Rastogi, and R. P. Pandey; Modifications to SCS-CN Method for Long-Term Hydrologic Simulation; J. Irrig. Drain Eng., 2007, 133(5): 475-486

Lal R (1998) Soil erosion impact on agronomic productivity and environment quality: critical reviews. Plant Sci 17:319–464

M. Kh. Askar, Rainfall-runoff model using the SCS-CN method and geographic information systems: a case study of Gomal River watershed, WIT Transactions on Ecology and The Environment, Vol 178, © 2014 WIT Press, www.witpress.com, ISSN 1743-3541 (on-line), doi:10.2495/ 13WS 0141.

N. Nagarajan and S. Poongotha, Spatial Mapping of run-off from a Watershed Using SCS-CN Method with Remote Sensing and GIS, J. Hydrol. Eng., 2012, 17(11): 1268-1277

Nayak, T.R. and R.K. Jaiswal, “Rainfall-runoff modelling using satellite data and GIS for Bebas river in Madhya Pradesh”, IE (I) Journal 84, pp. 47- 50, 2003 Pacific

Northwest National Laboratory, https://mepas.pnnl.gov/mepas/formulations/source_term/5_0/5_32/5_32.html

Prasannakumar VHV, Abinod S, Geetha N. 2012. Estimation of soil erosion risk within a small mountainous sub-watershed in Kerala, India, using revised universal soil loss equation (RUSLE) and geoinformation technology. Geosci Front. 3(2):209–215

Prasannakumar VRS, Geetha N, Vijith H. 2011. Spatial prediction of soil erosion risk by remote sensing, GIS and RUSLE approach: a case study of Siruvani River watershed in Attapady Valley, Kerala, India. Environ Earth Sci. 64:965–972

Renard K, Foster G, Weesies G, McDool D, Yoder D. 1997. Predicting soil erosion by water: a guide to conservation planning with the revised universal soil loss equation (RUSLE). USDA Agricultural Handbook 703, USDA-ARS

Satheesh kumar, 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. Environ.* 3, 24 (2017). https://doi.org/10.1007/s40808-017-0301-4

Shwetha G, B. Maheshwara Babu, B. S. Polisgowdar, G. V. Srinivas Reddy & U. K. Shanwad, Estimation Of Surface Runoff In Timmapur Watershed Using Scs-cn Method, International Journal Of Agricultural Science And Research (Ijasr) Issn(P): 2250-0057; Issn(E): 2321-0087 Vol. 5, Issue 6, Dec 2015, 1-8.

Silveira L, Charbonnier F. And Genta J. L. (2000). “The Antecedent Soil Moisture Condition of the Curve Number Procedure.” Journal of hydrological sciences , 2000,45(1), pp 3-12, DOI: 10.1080/02626660009492302

Sindhu, D., Shivakumar, B.L., Ravikumar, A.S., 2013. Estimation of surface run-off in nallur amanikere watershed using SCN-CN method - International Journal of Research in Engineering and Technology, nov-2013, eISSN: 2319-1163 | pISSN: 2321-7308, 404- 409.

Strahler AN (1952) Dynamic basis of geomorphology. Bull Geol Soc Am 63:923–938.

Strahler AN (1964) Quantitative geomorphology of drainage basin and channel network. Handbook Appl Hydrol 39–76

Shinde V, Sharma A, Tiwari KN, Singh M. 2011. Quantitative determination of soil erosion and prioritization of micro-watersheds using remote sensing and GIS. J Indian Soc Remote Sens. 39(2):181–192

Tarun Kumar, D. C. Jhariya & H. K. Pandey (2019): Comparative study of different models for soil erosion and sediment yield in Pairi watershed, Chhattisgarh, India, Geocarto International, DOI: 10.1080/10106049.2019.1576779

USDA (1972) Soil Conservation Service, National Engineering Handbook. Hydrology Section 4. Chapters 4-10. Washington, D.C: USDA

USDA (1986) Urban hydrology for small Watersheds, TR-55, United States Department of Agriculture, 210-VI-TR-55, 2nd edn June 1986

W. B Langbein, Topographic Characteristics of Drainage Basins, U.S. Geol. Surv. Water-Supply Paper, 986(C) (1947), pp. 157-159

Walega, A.; Amatya, D.M.; Caldwell, P.; Marion, D.; Panda, S. Assessment of storm direct runoff and peak flow rates using improved SCS-CN models for selected forested watersheds in the Southeastern United States. J. Hydrol. Reg. Stud. 2020, 27, 100645.

Wenhai Shi and Ni Wang, An Improved SCS-CN Method Incorporating Slope, Soil Moisture, and Storm Duration Factors for Runoff Prediction, Water 2020, 12, 1335; doi:10.3390/w12051335

Wischmeier WH, Smith DD. 1978. Predicting rainfall erosion losses. (Agriculture Handbook No. 537). Washington D.C., USA: Agricultural Research Service, U.S. Department of Agriculture

Yueqing XU, Ding LUO, Jian P. 2011. Land use change and soil erosion in the Maotiao River watershed of Guizhou Province. J Geogr Sci. 21(41171088):1138–1152