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ESTIMATION OF DIRECT RUNOFF FOR PURNA RIVER SUB-BASIN, USING SCS-CN METHOD, DANGS DISTRICT, GUJARAT

Anjali Mistry[1], P.P.Lodha[2], Indra Prakash[3], Khalid Mehmood[4]

[1]Student, L. E. College, Morbi
[2]Professor, L. E. College, Morbi
[3]Faculty, BISAG
[4]Project Manager, BISAG

Abstract *—In this paper, direct surface runoff for Purna river sub-basin in the Dangs district of Gujarat, was estimated by using Soil-Conservation Service-Curve Number (SCS-CN) method. Daily rainfall data of four rain gauge stations of study area was analyzed. Average rainfall of sub-basin was estimated by Thiessen polygon method. Thematic maps such as Soil, land use, geology, topography have been prepared from Liss-III and Google earth images Weighted curve number and Antecedent Moisture Conditions have been determined using thematic maps and rainfall data in GIS environment. Runoff depth of study area was determined by SCS-CN method.*

Keywords: *SCS-CN, ArcGIS, Hydrologic Soil Group, Antecedent Moisture Condition.*

I. INTRODUCTION

Dangs district of Gujarat is a hilly area in South Gujarat traversed by two main rivers Ambica and Purna. There is scope of construction of water harvesting structures in this district considering its topography and drainage basin characteristics. In the present study Purna River sub basin has been selected for the estimation of direct run off. Meteorological data has been collected from the State Water Data Centre (SWDC), Gandhinagar, Gujarat and remote sensing data and thematic maps from the state and central government agencies.

There are number of methods available to calculate direct runoff such as Peak discharge method, Tabular Method, Unit Hydrograph Method and SCS-CN Method. In the present study SCS-CN method which is a simple, predictable and stable conceptual method (Subraminya 2016) has been selected for study. The modified SCS-CN method has been widely used in Indian condition. The Soil Conservation Service (SCS) runoff model is useful for estimating runoff depths for different antecedent moisture conditions (AMC).

II. STUDY AREA

The study area is located in part of the Purna River sub basin in Dangs district, southeastern part of Gujarat state and lies between 20°33’50” to 21°04’52” North latitudes and 73°27’58” to 73°56’38” East longitudes. The Purna River emanate from Sahyadri hills in the state of Maharashtra and its major tributaries from Mohpada on Saputara hill, Dangs district of Gujarat state. This river finally drains its water in the Arabian Sea near Navsari. The length of Purna River in Gujarat is 180km.

The study area (Purna river sub-basin) covers 784.079sq.km. The annual mean maximum and minimum temperature recorded at Ahwa is 45°C and 10°C respectively.

The entire Dangs district is characterized by rugged topography, conical hills, small plateaus and steep valleys. Ridges and valleys mainly extend in NW-SE direction. The entire district is covered by flood basalt flows (Rocks). Drainage pattern of Purna River sub-basin is *dendritic type***.**

Major part of the area is covered by loamy soil. The Dangs district gets rainfall of around 2400 mm per year. Though the district receives maximum rainfall in the state, yet there is an acute shortage of water.

The entire district falls under moderate seismic zone –III.

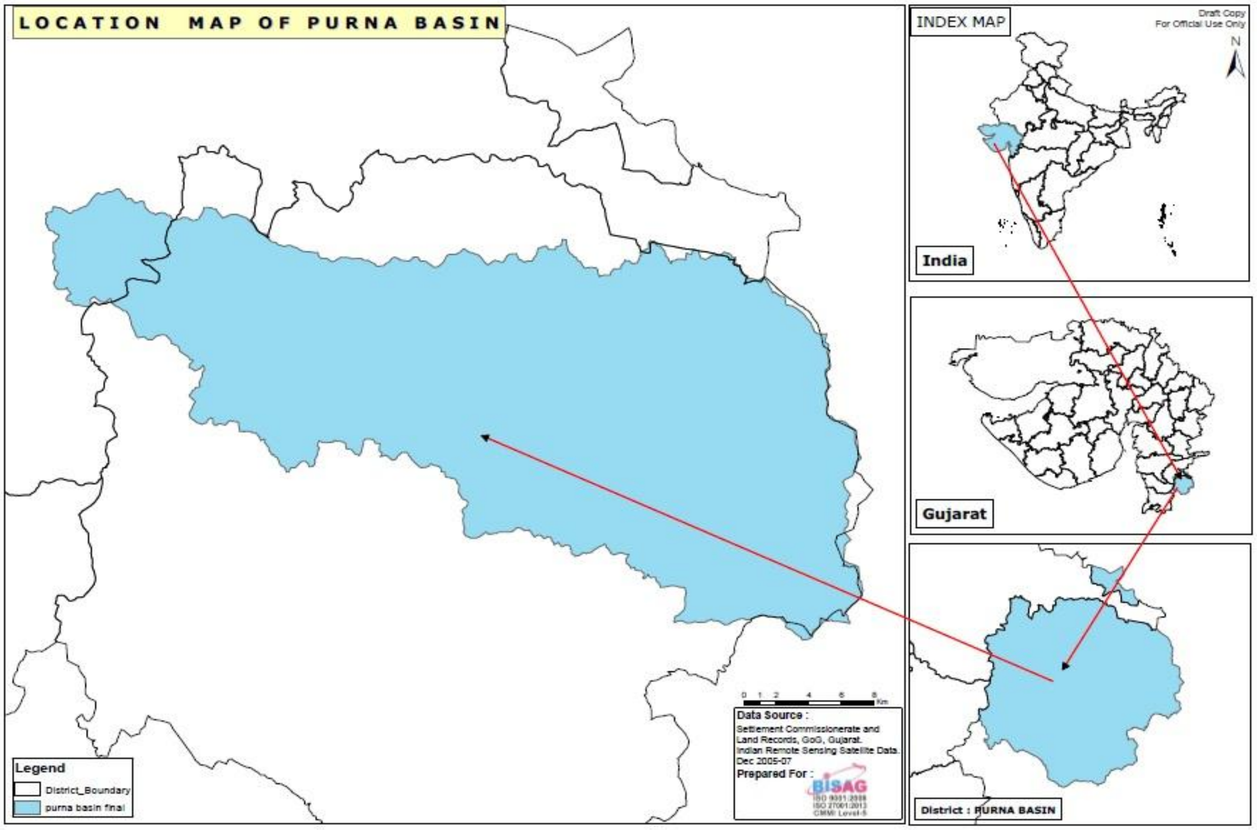

Fig. 1: Location Map of Study Area

III. THEMATIC MAPS USED

Thematic maps such as soil (Fig.2) and land use (Fig.3) have been used in the determination of curve number in the SCS-CN method in conjunction with the hydrological data. Soil in the area is loamy, loamy skeleton, fine and clayey. Landuse pattern in the area is mainly agriculture, scrub forest, dense forest, deciduous forest, built up area.

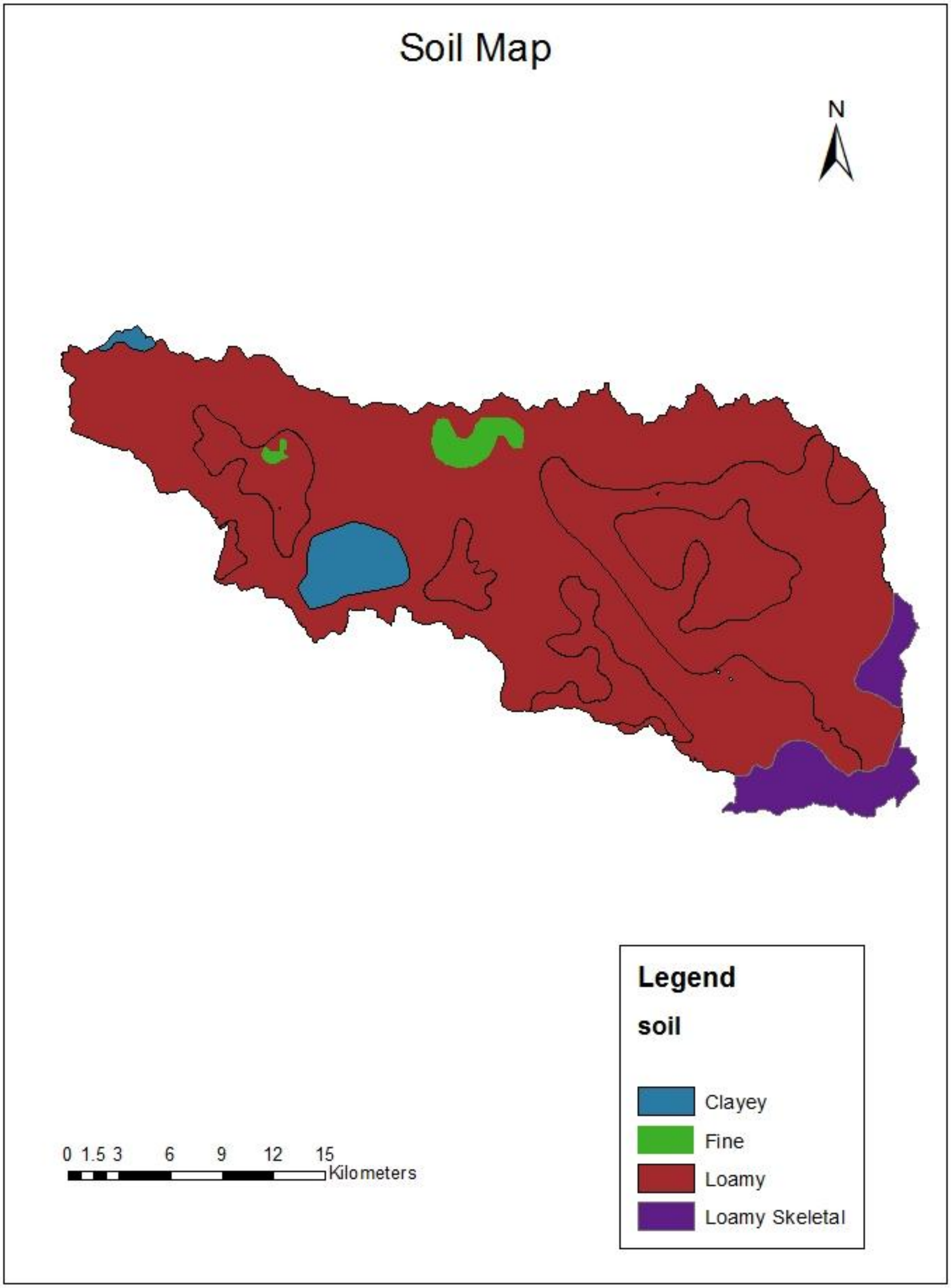

Fig. 2: Soil Map of the study area

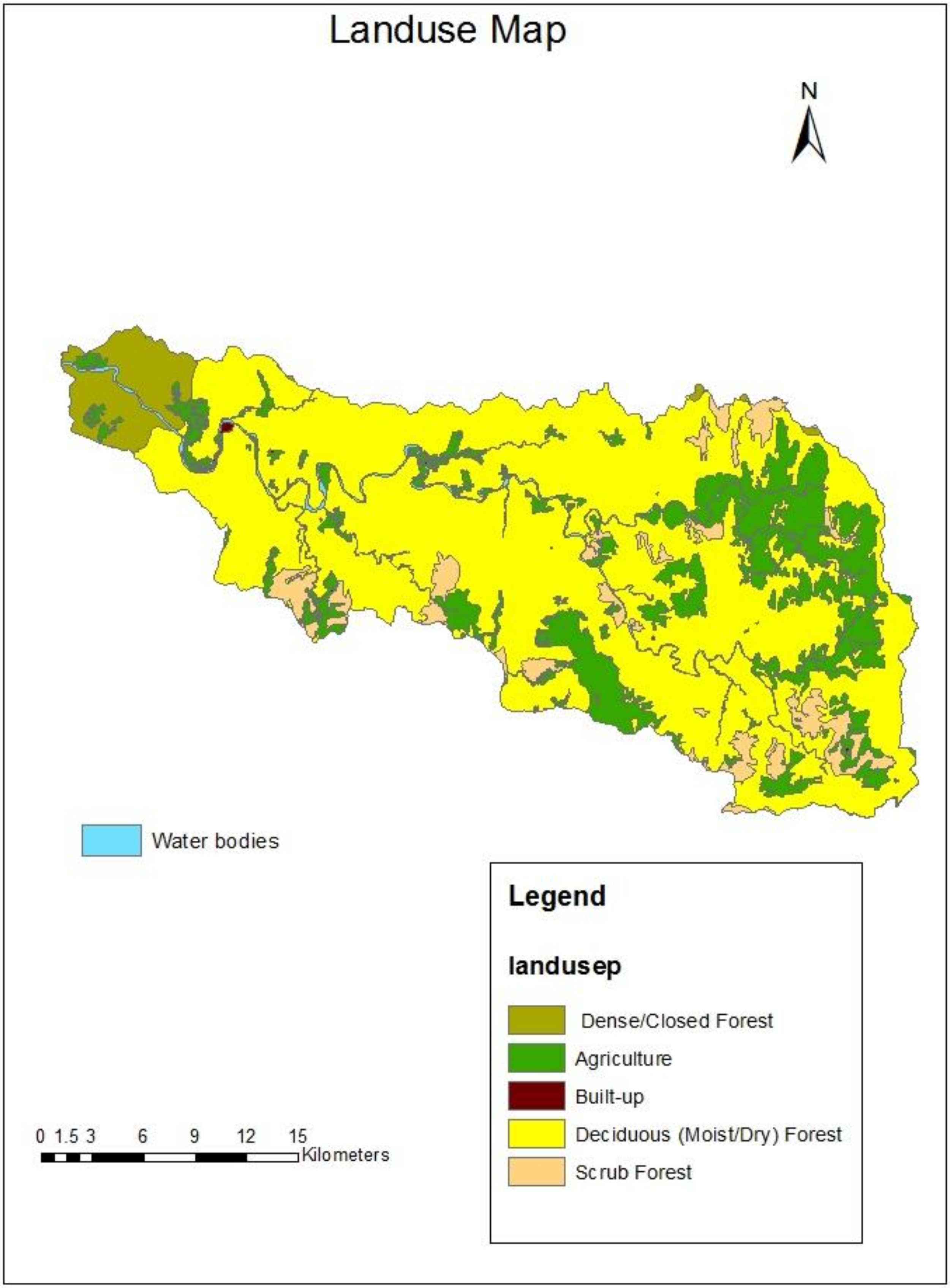

Fig. 3: Landuse map of the study area

IV. METHODOLOGY

Methodology adopted in the present study for the estimation of runoff is given in Fig.4.

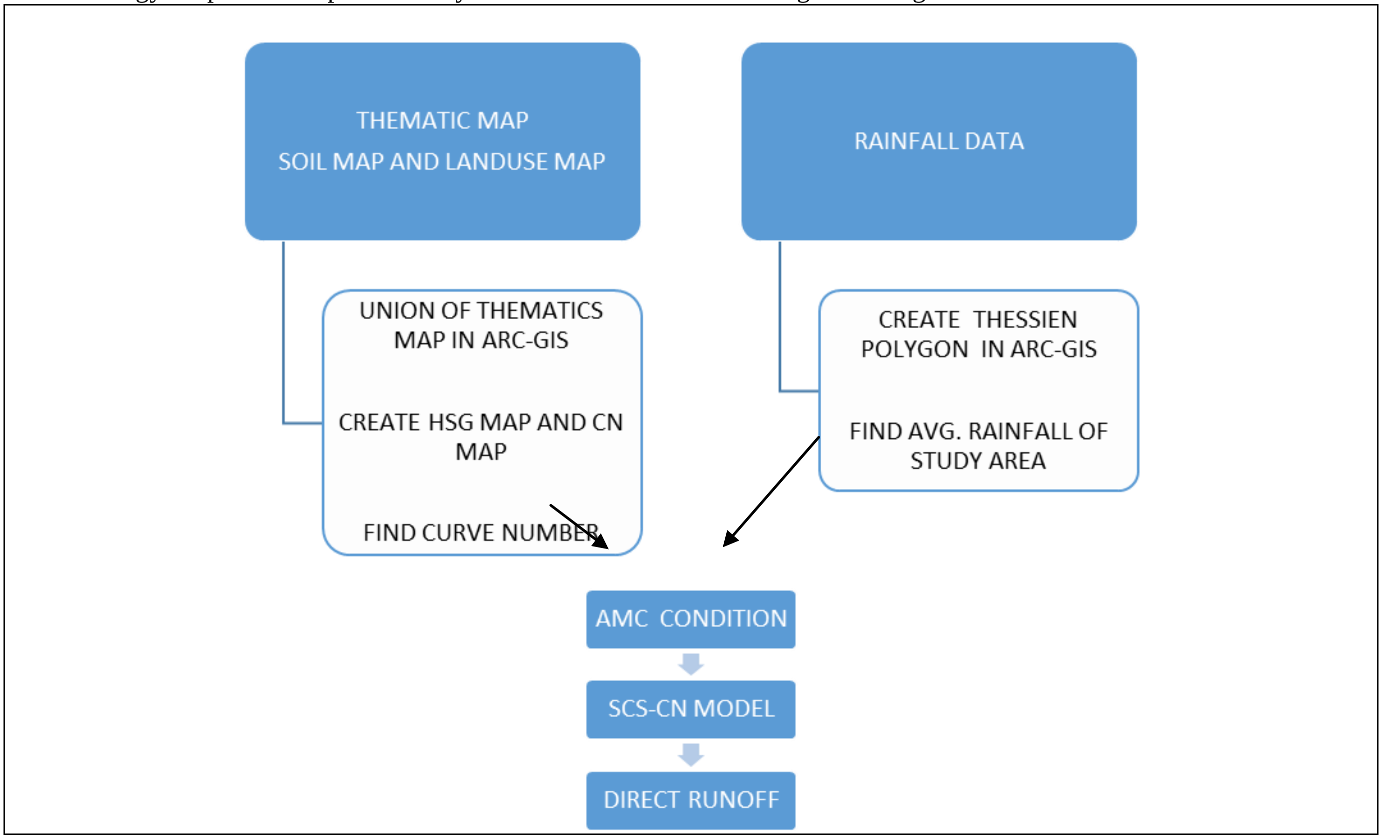

Fig. 4: Methodology for Direct Runoff Estimation

IV.1 SCS CURVE NUMBER METHOD

The Soil Conservation Service (SCS) CN method developed bySoil Conservation services (scs) of USA in 1969 for estimation of direct runoff depth based on storm rainfall depth. The general equation for the SCS curve number method is as follows:

$$\frac{Q}{P-\mathrm{Ia}} = \frac{F}{S} \qquad (1)$$

Where,
F = actual retention (mm),
S = potential maximum retention (mm),
Q = actual direct runoff (mm),
P = total rainfall (mm),
I = initial abstractions (mm).

From the continuity principle,

$$P = \mathrm{Ia} + \mathrm{F} + \mathrm{Q} \qquad (2)$$

As per Handbook of Hydrology as follows, the value of the initial abstraction Ia to be approximately equal to 30% of the watershed storage S.

$$\mathrm{Ia} = 0.3 \times \mathrm{S} \qquad (3)$$

Solving equation 1 and 2 simultaneously,

$$Q = \frac{(P-0.3S)^2}{(P+0.7S)} \qquad \text{For } P>0.3S \qquad (4)$$

The watershed storage S and Curve Number CN related by,

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

$$CNw = \frac{\sum(CNi * Ai)}{A} \quad (6)$$

Where,
CNw = the weighted curve number,
CNi = the curve number from 1 to any number N,
Ai = the area with curve number CNi,
A = the total area of the watershed.

The parameter Curve Number, having a range of values between 0 and 100 is called the curve number. In SCS CN method, a curve number (CN) is assigned to each watershed or portion of watershed based on land-use, antecedent moisture condition (AMC) and soil type.

IV.1.1 DETERMINATION OF HYDROLOGICAL SOIL GROUP

The hydrological soil classification is adopted in the determination of CN. Here, soils are classified in to four classes A, B, C, and D based upon the infiltration, texture, structure and degree of swelling when saturated. Soil groups are formed by finding the soil group classification for soil available in study area.

TABLE-1: Soil Classification for HSG

HSG	*Soil Texture*
A	*Sand, loamy sand or sandy loam*
B	*Silt loam or loam*
C	*Sandy clay loam*
D	*Clay loam, silty clay loam, sandy clay, silty clay or Clay*

IV.I.II ANTECEDENT MOISTURE CONDITION (AMC)

Antecedent moisture condition of the rainfall-runoff event under consideration refers to the moisture content present in the soil at the beginning. It is well known that initial abstraction and infiltration are governed by AMC.

TABLE-2: Classification of Antecedent Moisture Condition

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

The other two conditions of AMC relationship, CNii conversion can be done through the use of the following equations.

For AMC-I:

$$CNi = \frac{CNii}{2.281 - 0.01281 CNii} \quad (7)$$

For AMC-III:

$$CNiii = \frac{CNii}{0.427 + 0.00573 CN ii} \quad (8)$$

CN values are different in different AMC condition, landuse and soil types A table is given below to show the different curve number.

TABLE-3: Hydrological Soil Group for study area

LANDUSE	HSG	CN
Agriculture	B	95
	C	95
	D	95
Scrub Forest	B	47
	D	67
Deciduous (Moist/Dry) Forest	B	44
	C	60
	D	67
Dense/Closed Forest	B	40
	D	61
Built-up	B	86
	C	91
	D	93
Water bodies	B	98
	C	98
	D	98

V. ANALYSIS, RESULT AND DISSCUTIONS

Daily rainfall data for 4 rain gauge station of 30 years (1985-2015) has been analyzed. Average distribution of rainfall (Fig.6) in whole study area is determined by Thiessen polygon (Fig.5)method using ArcGIS tool.

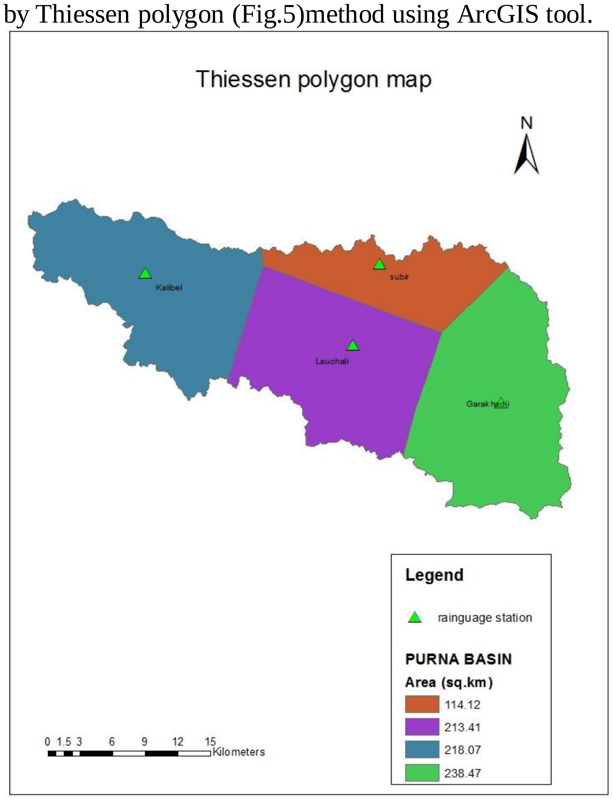

Fig.5: Thiessen Polygon Map of Study Area

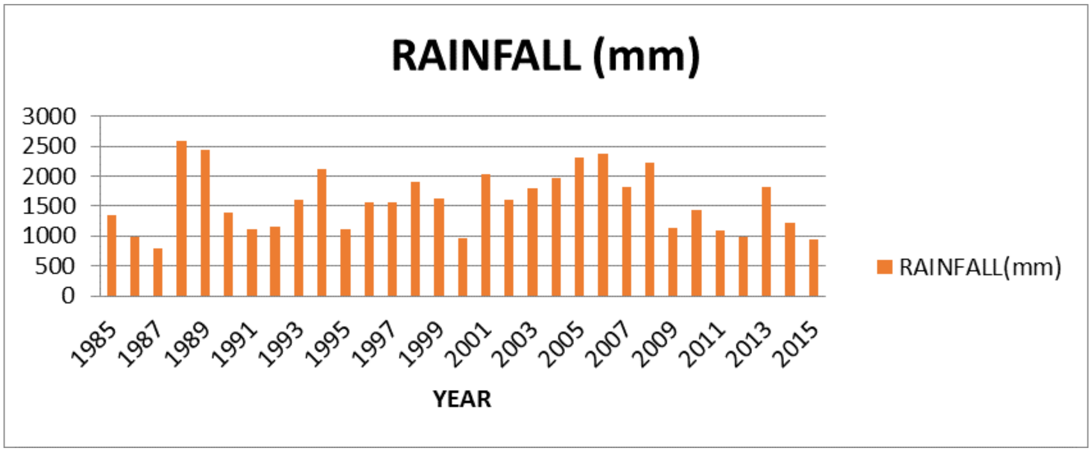

Fig.6: Average Distribution of Rainfall

VI. HYDROLOGICAL SOIL GROUP

Analysis of the data revels that soil present in the area is of three groups B, D and C. In the B group 95% soil is of loamy and loamy skelton, in D 3% soil is clayey and in C group 2% soil is fine. (Figure 7).

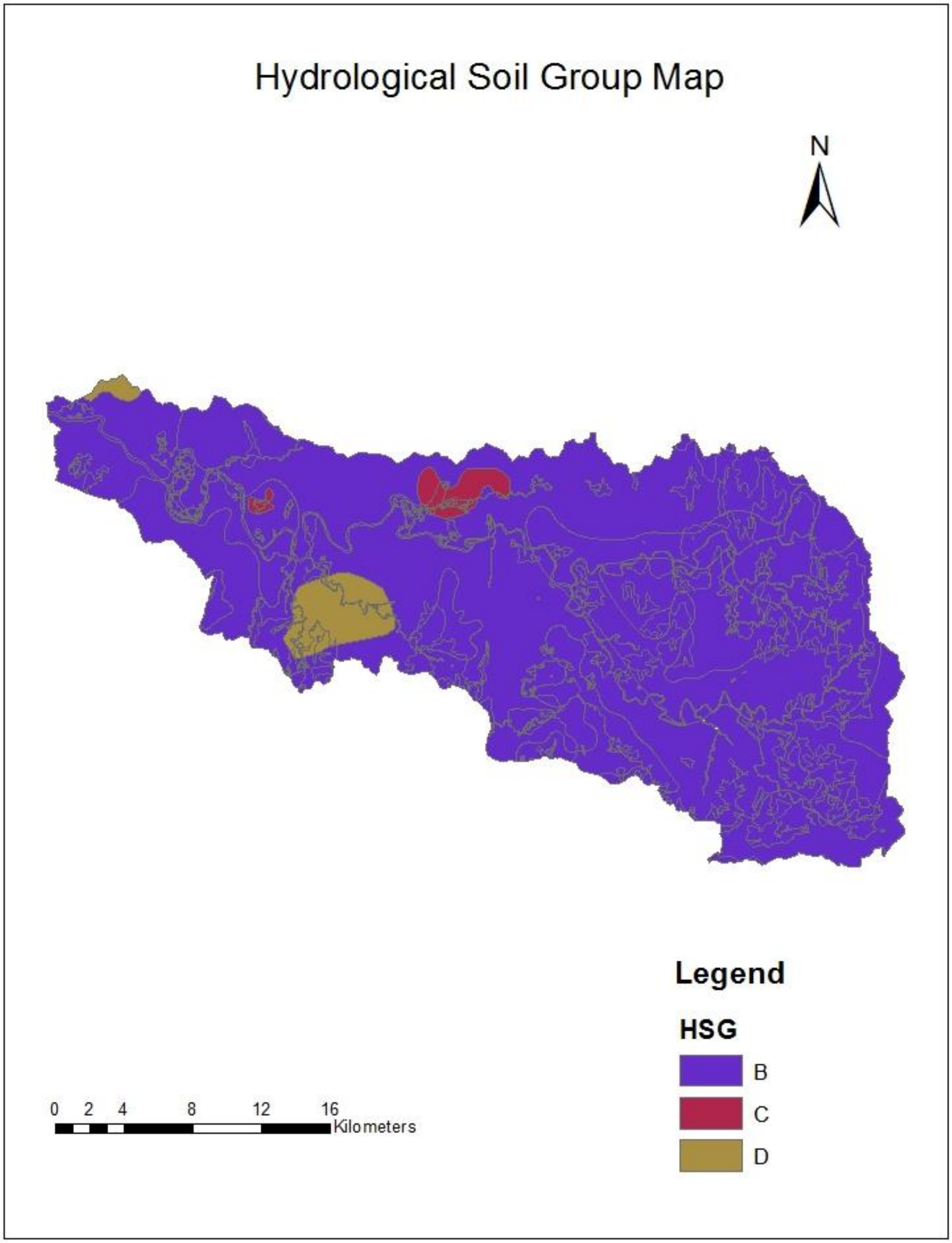

Fig. 7: Hydrological soil group Map

VII. WEIGHTED CURVE NUMBER

The CN value for each soil hydrologic group and corresponding land use classes are presented in Table 2. Weighted curve number for the area was calculated and the value of Weighted CN is 55.07 for AMC-II, CN for AMC-I is35 and AMC-III is 74 as per equation (7) and (8).

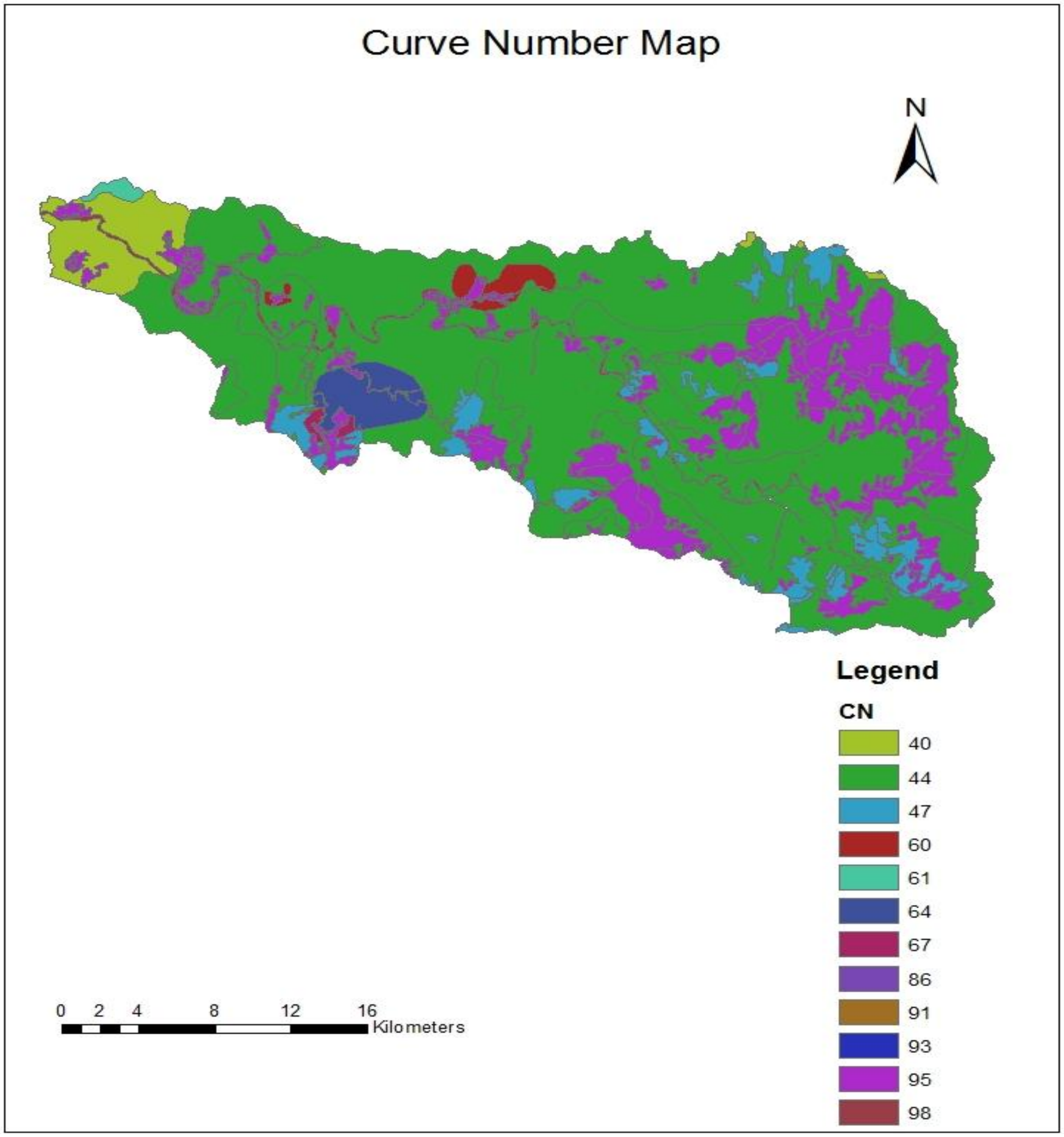

Fig. 8: Curve Number Map

Table –4: Calculation of Weighted Curve Number for AMC II

LANDUSE	HSG	CN	TOTAL AREA IN SQ. KM	% AREA	% WEIGHTED CN	WEIGHTED CN
Agriculture	B	95	137.6181	17.55155049	16.67397296	
	C	95	2.089519	0.266493275	0.253168612	
	D	95	1.677208	0.213907915	0.20321252	
Scrub Forest	B	47	43.0971	5.496522089	2.583365382	
	D	67	1.898799	0.24216921	0.16225337	
Deciduous (Moist/Dry) Forest	B	44	519.5274	66.25953556	29.15419565	55.0782612
	C	60	9.03142	1.151850113	0.691110068	
	D	67	18.08739	2.306831287	1.545576962	
Dense/Closed Forest	B	40	32.90075	4.196099021	1.678439608	
	D	61	2.568044	0.327523443	0.1997893	
Built-up	B	86	0.924212	0.117872239	0.101370126	

	C	91	0.028691	0.003659196	0.003329868	
	D	93	0.029742	0.003793238	0.003527711	
Water bodies	B	98	13.82463	1.763166992	1.727903652	
	C	98	0.138685	0.017687621	0.017333868	
	D	98	0.637757	0.081338314	0.079711547	
TOTAL			784.079447			

VIII. RESULT OF ANALYSIS

Available rain fall data from the year 1985 to 2015 has been evaluated. The results are shown in the table.

Table- 5: Annual Rainfall-Runoff of study area

YEAR	RAINFALL(mm)	RUNOFF(mm)
1985	1348.112	162.32
1986	991.85	15.99
1987	797.13	45.92
1988	2596.93	189.605
1989	2432.39	117.59
1990	1380.09	37.62
1991	1119.04	21.96
1992	1155.112	22.343
1993	1597.193	87.901
1994	2120.197	391.37
1995	1112.027	43.046
1996	1564.69	86.73
1997	1561.85	175.93
1998	1905.391	76.15
1999	1618.04	30.043
2000	957.08	43.61
2001	2039.9	214.79
2002	1598.77	288.161
2003	1796.99	174.27
2004	1975.94	337.86
2005	2316.23	512.8
2006	2363.87	415.038
2007	1811.48	253.49
2008	2227.65	308.79
2009	1123.38	85.211
2010	1437.18	91.19
2011	1090.95	35.72
2012	977.84	58.611
2013	1811.905	164.73
2014	1212.33	175.96
2015	950.1	105.98

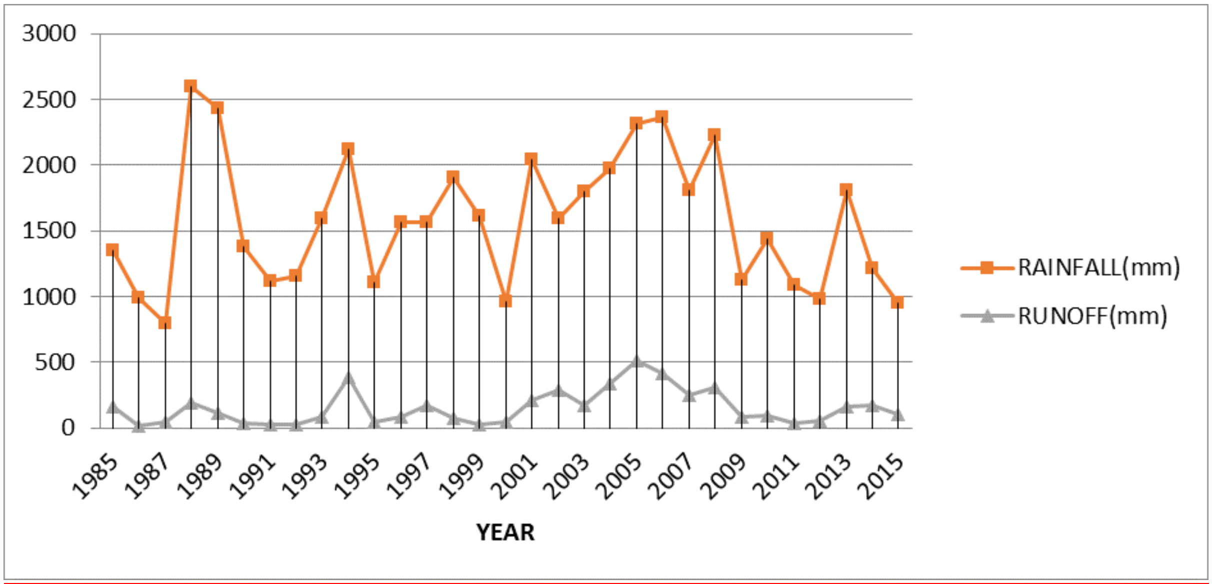

Fig. 9: Rainfall – Runoff Graph

In the present study one year rainfall of 2015 has been analyzed for the estimation of runoff using SCS-CN method to evaluate monthly variation of rainfall. Average rainfall in the year 2015 in the study is calculated and estimated is 950.1 mm and runoff is 150.98 mm (Fig 6 & Fig 10.) The reason for the low run off for this year is due to the fact that rain fall has occurred intermittently during rainy season (and not continuously). Thus abstraction of the water due to infiltration, evaporation and transpiration is more, resulting in estimation of less run off.

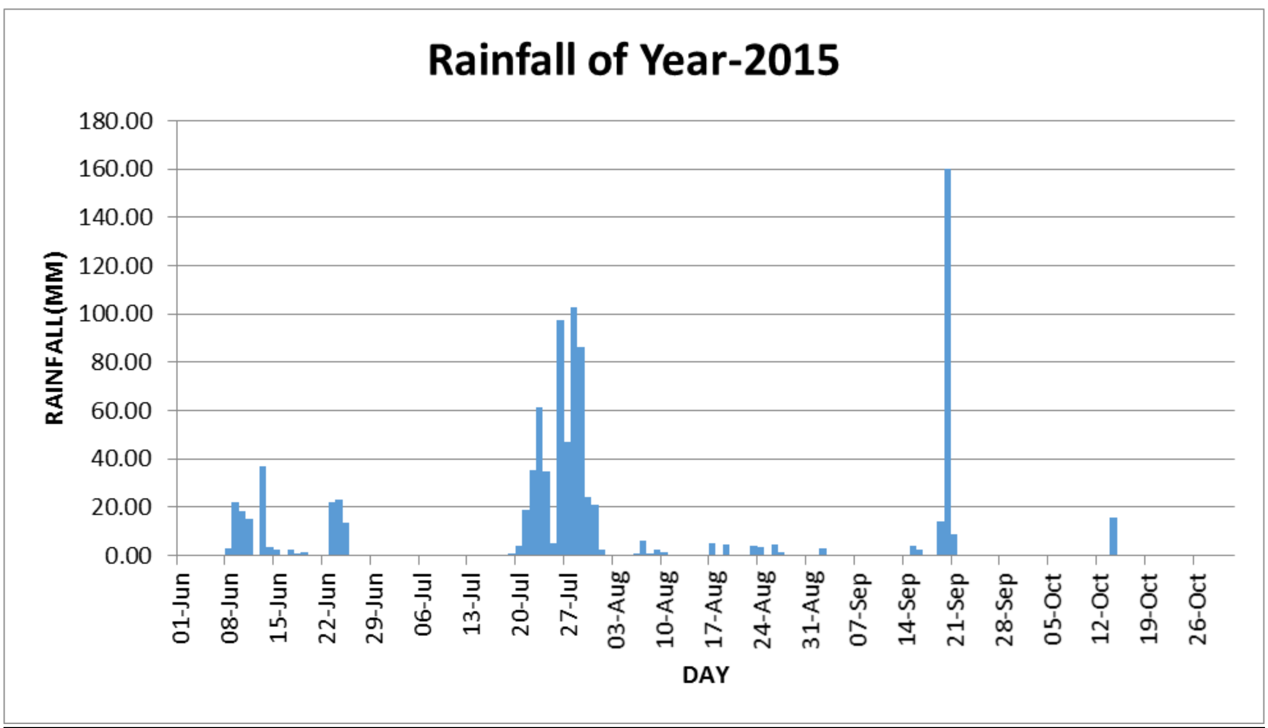

Fig. 10: Rainfall – Runoff of year 2015

IX. CONCLUSIONS

In the Purna River sub basin three types of Hydrological Soil Group namely B, D and C have been determined. Weighted curve number for the study area calculated, using SCS-CN method is 55 for AMC-II, 35 for AMC-I and 74 for AMC-III. Runoff has been calculated for 30 years period (1985-2015). The runoff varies from 15.99 mm to 512 mm and average runoff is 159.02 mm. It has been observed during the year 2015, runoff is low (150.98 mm) despite rain fall in the area is relatively high (950.1 mm). This may be due to non continuous rainfall in the month of June, July, Aug, Sept and Oct resulting in more infiltration, transpiration and evaporation and thus less runoff. The Runoff calculated and estimated for the Purna River Sub basin can be used for the planning and management of the watershed of the study area.

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