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A STUDY ON ESTIMATION OF RUNOFF BY SCS CURVE NUMBER METHOD USING GIS

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ABSTRACT

Reliable prediction of quantity and rate of runoff from land surface into streams and rivers is needed in dealing with many water resources planning, designing of hydraulic structures and management problems. Conventional methods of runoff estimation are expensive, time consuming and difficult process and these method of runoff measurement are not easy for hilly and inaccessible terrain. The problem most often encountered in hydrological studies is the need for estimating runoff from a watershed for which there is record of rainfall and no record of runoff. Geographic Information System (GIS) can effectively use to manage spatial and non spatial database that represent study, an attempt has been made to estimate runoff a catchments using SCS CN method which is a widely used and popular method.

In present study land use land cover description of catchment have been use satellite image of IRS LISS II. The major part of the area has steep to very steep slopes associated with undulating landscapes. the soil and Land cover that have been identified in the part of catchment is clay and agriculture, middle part of catchment is confined by loam soil and forest land cover.

KEYWORDS: A Study on Estimation of Runoff by SCS Curve Number Method Using GIS

INTRODUCTION

In engineering hydrology runoff due to storm event is often a major subject of study all abstractions from precipitation ,viz. those due to evaporation, transpiration, infiltration, surface detention and storage, are considered as losses in the production of runoff. Rainfall being the predominant form of precipitation causing stream flow, especially the flood flow in majority of rivers in India. Runoff means the draining or flowing off of precipitation from a catchment area through a surface channel. It represents the output from the catchment in a given unit of time. . Discharge values are necessary for ungauged catchments for the design of various hydraulic structures such as small dam. Geographical Information System (GIS) is computer based system design tool applied to geographical data for integration, collection, storing, transforming and display spatial data for solving complex and management problems.

STUDY AREA

The Man Project is being constructed at village Jeerabad of Manawar Tehsil of District Dhar, Madhya Pradesh. The project site is about 2 km from village Jeerabad located on Khalghat-Manawar-Amjhera district road and is about 22 km from Manawar. The dam being built on the river Man, drained by the Narmada is one of the 30 major dams being built in the Narmada Valley - a part of the controversial Narmada Valley Development Authority (NVDA). The total catchment area at Man Project site is 713.76 sq. km. The geographical location of the Man catchment is 22° 24’ 20” N latitude and

75° 05'40" E longitude.

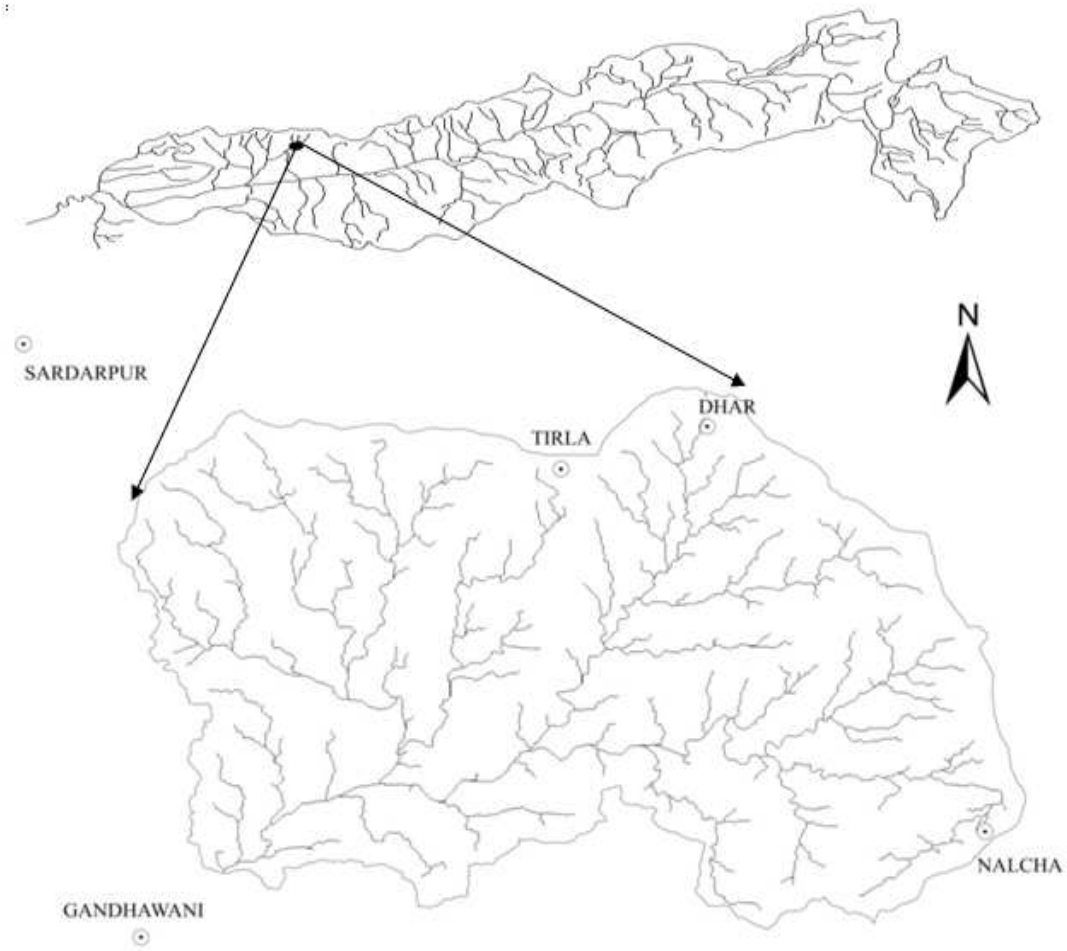

Figure 1: Index map showing Man Catchment in Narmada Basin and Rain Gauge

METHODOLOGY AND RESULT ANALYSIS

SCS Curve Number Method

The RCN (runoff curve number) method was originally established by the SCS in 1954. It was originally designed to be an in "inter agency" tool for the estimation of runoff it was therefore never subjected to peer or journal review by anyone outside the SCS.

The SCS curve number procedure in its standard form is a well established modeling method developed in the mid of 20th century by Soil Conservation Service (SCS) and since than it has been widely used both as a research tool and for solving practical programs.

The SCS curve number is water balance equation based. The formula of effective rainfall is derived as a result of transformation

$$\mathbf{Q} = \frac{(\mathbf{P}-\mathbf{Ia})^2}{\mathbf{P}-\mathbf{Ia}+\mathbf{S}} \quad . \qquad (1)$$

Where, P= total precipitation (mm), Ia = initial abstraction (mm), and S= potential maximum retention (mm). Q=0, for P - Ia. The initial abstraction is related to S by the equation:

$$I_a = \lambda \cdot S$$

In the SCS method it is assumed that the value of λ coefficient equals 0.2, although for Indian context pertaining to the black soil region.

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)} \quad (2)$$

The potential maximum retention by the soil is given by relating it to a dimensionless parameter known as the curve number (CN) that depends upon the hydrologic soil groups, antecedent moisture conditions as well as land use land cover factors in the catchment area.

$$S = \frac{25400}{CN} - 254 \quad (3)$$

Antecedent Moisture Condition (AMC)

AMC refers to the moisture content present in the soil at the beginning of the rainfall runoff event under consideration. It is well known that initial abstraction and infiltration and are governed by AMC. For purposes of practical application three level of AMC are recognized by SCS as follows:

AMC-I: Soils are dry but not to wilting point satisfactory cultivation has taken place.

AMC-II: Average conditions.

AMC-III: Wet condition.

Soils

In determining the CN values, the hydrological classification is adopted. Here soils are classified into four classes A, B, C, and D based on the infiltration and other characteristic. The important soil characteristics that influence hydrological classification of soils are effective depth of the soil, average clay content, infiltration characteristics and the permeability. Following is the brief description of four hydrologic soil groups.

Group A (Low Runoff Potential)

Group B (Moderately Low Runoff Potential)

Group C (Moderately High Runoff Potential)

Group D (High Runoff Potential)

DATA COLLECTION

Rainfall

The rainfall data have been collected for the period June 2004 to October 2013 of five Raingauge Stations Dhar, Sardarpur, Gandhwani, Nalcha and Tirla under Man catchment from Land Record Department, Office of Collectorate, district Dhar, Madhya Pradesh.

Toposheet

Survey of India Toposheet No. 46 N/2,46 N/3, 46 N/6, 46 N/7 of scale 1:50,000 are collected from Narmada Valley Development Authority (NVDA), Indore (M.P.).

Soil group and Land Use and Land Cover (LULC) map

The Sheet No.2 of Madhya Pradesh Soil Map and Mapping Unit under Man catchment has been collected from National Bureau of Soil Survey and Land Use Planning (NBSSLUP), Nagpur Govt. of India.

National land use/land cover mapping is downloaded for Dhar district of Madhya Pradesh using IRS-LISS III 1:50,000 scale which is downloaded from the website of BHUVAN having portal name as www.bhuvan.nrsc.gov.in

Table 1: Distribution of Land use and Land Cover (LULC) of Man Catchment

Cover Description	No. of Pixel	Area (Sq.Km)	Percentage of Area
Agriculture , Crop Land	345814	311.233	43.60%
Scrub land ,Barren ,West Land	25198	22.678	3.18%
Scrub Forest ,Forest	45645	41.081	5.76%
Deciduous ,Forest	225528	202.975	28.44%
Wetlands ,Water Bodies , River Stream , Canal, Reservoir, Pond	28427	25.584	3.58%
Fallow ,Agriculture	90921	81.829	11.46%
Built up, Rural	5305	4.775	0.67%
Barren/ Unculturable / Waste Land, Scrub land	21547	19.392	2.72%
Builtu p, Urban	3127	2.814	0.39%
Grass , Grazing	1261	1.135	0.16%
Evergreen/Semi Evergreen	18	0.016	0.002%
Built up , Urban	284	0.256	0.04%
	Total	**713.76**	**100%**

Computation of Weighted Average Curve Number

The average value of curve number for AMC-I, AMC-II and AMC-III as given in Table 2 have been appropriately used in the equation suggested by SCS to compute the direct runoff depth in mm using the average value of daily rainfall in mm.

Calculate weighted curve number by $= \frac{\sum \mathbf{CNi \times Ai}}{\mathbf{Ai}}$ (4)

After the getting values of, CN-II are given and CN-I and CN-II given by equation 5 and 6. CN-I and CN-III the potential retention S is computed using the equation 7 and Initial Abstraction Ia are given by 0.2S.In Arc GIS to apply in raster calculator in this equation and find out daily runoff by spatial distribution show in figure 5.

$$\mathbf{CN_I for\ AMC - I = 0.39 \times CN_{II} \times e^{(0.009 \times CN_{II})}} \quad (5)$$

$$\mathbf{CN_{III}\ for\ AMC - III = 1.95 \times CN_{II} \times e^{(-0.00663 \times CN_{II})}} \quad (6)$$

In Arc GIS above equation used in Raster calculator tool to calculate direct runoff flow chart show in figure 5. Spatial Distribution of runoff show in figure 6

Table 2: Area Weighted Average CN of Man Catchment

Antecedent Moisture	AMC-I	AMC-II	AMC-III
Condition, (AMC)	Dry	Average	Wet
Average Curve Number, CN	62.75	76.97	88.31
Potential Retention, S	150.73	75.97	33.61
Initial abstraction, I_a= 0.2 S	30.14	15.19	6.72

The calculation of CN's for large areas or many drainage basins can be cumbersome and time consuming, therefore a GIS is an appropriate tool to use for such an application. The composite curve number for normal condition is 76.97, where for the dry and wet conditions are 62.75 and 88.31 respectively. The forest cover retains the rainfall for maximum period and moderates the direct surface runoff having minimum value of curve numbers.

Table 3: Computation of Average Curve Number

Soil Type	Land Use Description	Area (Sq.Km.)	CN_II	Area x CN_II	CN_I	Area x CN_I	CN_III	Area x CN_III
B	Agriculture , Fallow	15.636	83	1297.82	68.3	1068.31	93.4	1459.69
D	Agriculture , Fallow	66.125	93	6149.59	83.8	5538.79	97.9	6472.90
B	Agriculture , Fallow	0.081	78	6.34	61.4	4.99	90.7	7.37
B	Agriculture ,Crop Land	0.003	55	0.15	35.2	0.10	74.5	0.21
B	Agriculture ,Crop Land	78.153	78	6095.92	61.4	4797.10	90.7	7087.34
D	Agriculture ,Crop Land	228.207	91	20766.80	80.5	18370.52	97.1	22150.39
D	Agriculture ,Crop Land	4.862	93	452.21	83.8	407.30	97.9	475.98
B	Scrub land, Barren ,Waste Land ,	5.848	80	467.85	64.1	374.86	91.8	536.77
D	Scrub land, Barren ,Waste Land ,	15.383	88	1353.69	75.8	1165.59	95.7	1472.89
B	Barren ,Waste Land ,Scrub land	1.464	93	136.18	83.8	122.65	97.9	143.34
B	Unculturable / Barren /Wasteland ,Scrub land	0.172	80	13.73	64.1	11.00	91.8	15.76
D	Unculturable / Barren /Wasteland ,Scrub land	19.195	88	1689.12	75.8	1454.41	95.7	1837.86
B	Built up , Rural	0.987	66	65.12	46.6	46.00	83.1	81.98
D	Built up ,Rural	3.771	83	313.03	68.3	257.67	93.4	352.07
D	Built up ,Urban	3.081	83	255.74	68.3	210.52	93.4	287.64
B	Forest ,Deciduous	0.708	47	33.26	28.0	19.80	67.1	47.50
B	Forest ,Deciduous	200.193	55	11010.64	35.2	7044.54	74.5	14910.14
D	Forest ,Deciduous	2.113	82	173.28	66.9	141.36	92.8	196.19
B	Forest ,Evergreen /Semi Evergreen	0.016	40	0.62	22.4	0.35	59.8	0.93
B	Scrub Forest , Forest ,	34.836	47	1637.31	28.0	974.77	67.1	2337.94
B	Scrub Forest ,Forest	4.316	55	237.40	35.2	151.89	74.5	321.48
B	Scrub Forest ,Forest	1.913	67	128.16	47.8	91.35	83.8	160.28
D	Grass ,Grazing	1.134	89	100.91	77.3	87.67	96.2	109.07
D	Water Bodies ,River ,Stream ,Canal	25.568	100	2556.79	95.9	2452.59	100.5	2569.17
		713.765		54941.679		44794.123		63034.878
			AMC-I= 76.974		AMC-II= 62.757		AMC-III=88.313	

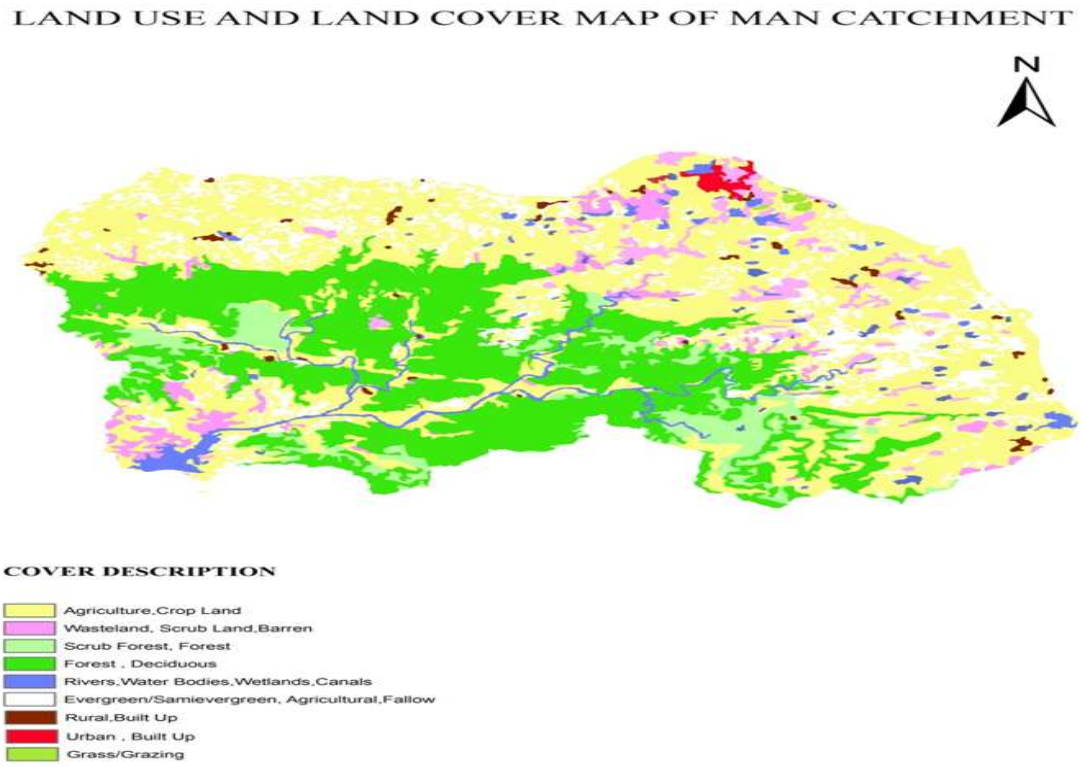

Figure 2: Cover Description of Man Catchment

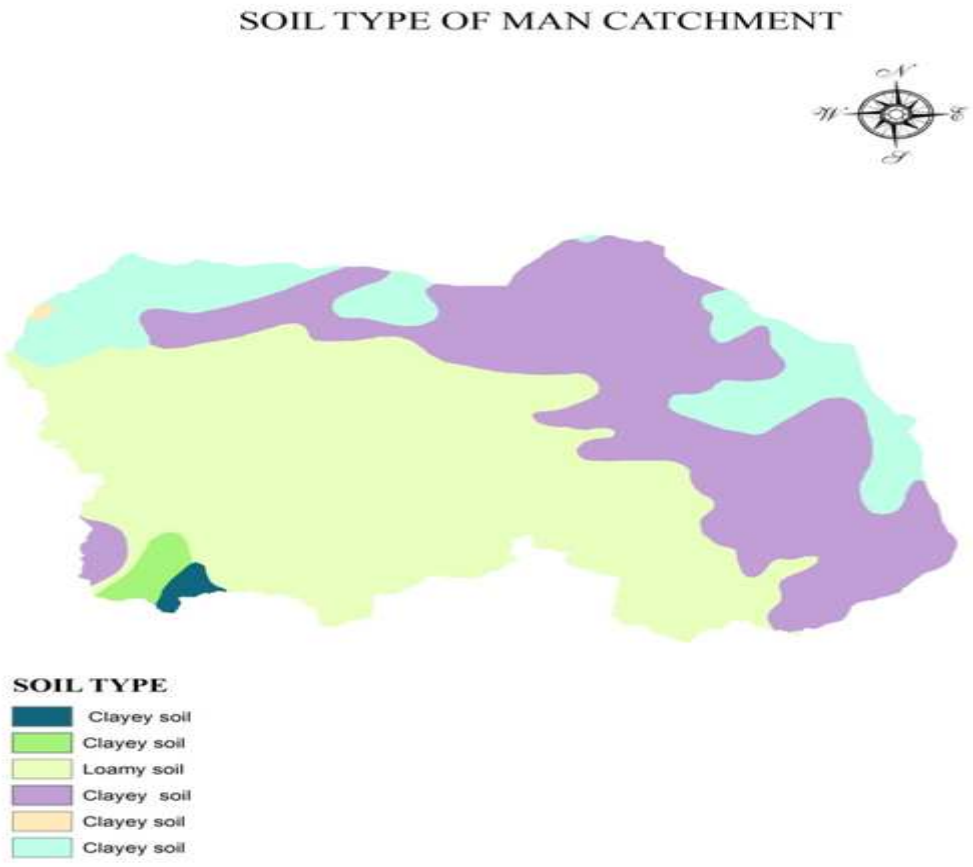

Figure 3: Soil Map of Man Catchment

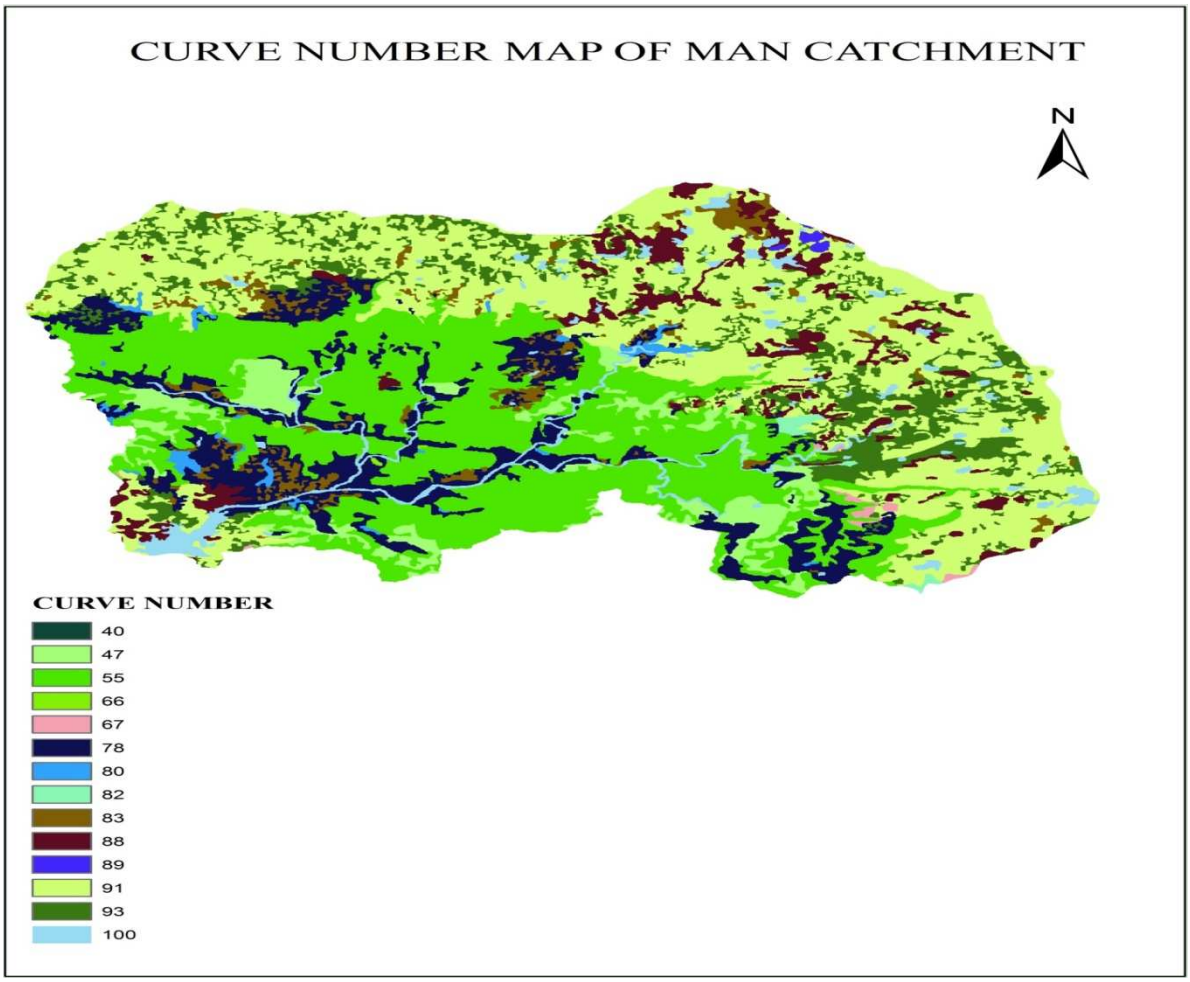

Figure 4: Curve Number (CN-II) Map of Man Catchment

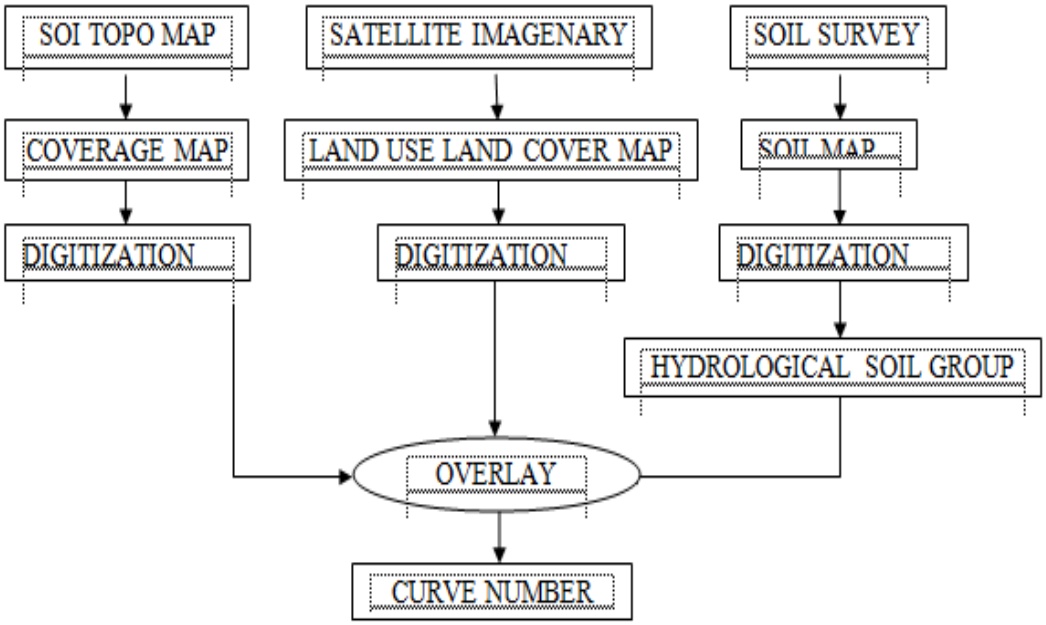

Figure 5: Methodology adopted for Computation of Curve Number

Table 4: Using SCS CN of Man Catchment Rainfall and Runoff in mm

Year	Mm	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2004	RAINFALL	0.00	0.00	0.00	0.00	0.00	49.80	197.46	401.88	84.86	27.34	0.00	0.00	761.34
	RUNOFF	0.00	0.00	0.00	0.00	0.00	0.00	44.44	134.04	0.00	0.00	0.00	0.00	178.48
2005	RAINFALL	0.00	0.00	0.00	0.00	0.00	44.26	260.76	80.68	207.60	1.72	0.00	0.00	595.02
	RUNOFF	0.00	0.00	0.00	0.00	0.00	0.00	95.86	18.86	33.67	0.00	0.00	0.00	148.39
2006	RAINFALL	0.00	0.00	0.00	0.00	0.00	73.66	296.10	551.48	164.16	0.00	0.00	0.00	1085.40
	RUNOFF	0.00	0.00	0.00	0.00	0.00	0.00	80.75	225.15	13.14	0.00	0.00	0.00	319.04
2007	RAINFALL	0.00	0.00	0.00	0.00	0.00	126.36	459.24	370.56	194.46	42.79	0.00	0.00	1193.41
	RUNOFF	0.00	0.00	0.00	0.00	0.00	16.04	219.58	159.13	18.93	0.00	0.00	0.00	413.68
2008	RAINFALL	0.00	0.00	0.00	0.00	0.00	22.90	184.24	136.04	310.18	73.70	0.00	0.00	727.06
	RUNOFF	0.00	0.00	0.00	0.00	0.00	0.00	13.87	1.67	69.47	0.00	0.00	0.00	85.01
2009	RAINFALL	0.00	0.00	0.00	0.00	0.00	85.96	333.44	118.48	89.16	53.34	0.00	0.00	680.38
	RUNOFF	0.00	0.00	0.00	0.00	0.00	25.51	90.88	17.46	6.16	0.00	0.00	0.00	140.01
2010	RAINFALL	0.00	0.00	0.00	0.00	0.00	97.32	219.34	374.78	182.60	0.00	0.00	0.00	874.04
	RUNOFF	0.00	0.00	0.00	0.00	0.00	2.45	32.24	86.46	48.65	0.00	0.00	0.00	169.81
2011	RAINFALL	0.00	0.00	0.00	0.00	0.00	20.18	232.62	392.58	65.92	1.80	0.00	0.00	713.10
	RUNOFF	0.00	0.00	0.00	0.00	0.00	0.00	34.76	79.04	12.09	0.00	0.00	0.00	125.89
2012	RAINFALL	0.00	0.00	0.00	0.00	0.00	28.86	302.44	227.70	313.48	65.52	0.00	0.00	938.00
	RUNOFF	0.00	0.00	0.00	0.00	0.00	0.00	104.43	35.45	104.85	0.00	0.00	0.00	244.73
2013	RAINFALL	0.00	0.00	0.00	0.00	0.00	256.66	433.40	326.78	254.54	0.00	0.00	0.00	1271.38
	RUNOFF	0.00	0.00	0.00	0.00	0.00	62.72	169.18	56.16	58.64	0.00	0.00	0.00	346.70

CONCLUSIONS

In this study an attempt is made to study the hydrologic features of Man catchment. the amount of runoff from same watershed were the records of runoff is not available. Many methods can be used to determine the runoff from ungaged watershed. Soil Conservation Service (SCS) Curve Number method is a simple, widely use and efficient method for determining the amount of runoff from a rainfall even in a particular area. In the present study, the method was used to estimate the direct surface runoff from Man catchment and with the help of Geographical Information System (GIS).

- The results in the present study shows that runoff in the catchment can be studied for reliable accuracy along with the spatial variation of soil type and land use type.
- The SCS curve number method which is used for runoff estimation is most accurate and in future we can compare it with other conventional method which is also used for runoff estimation.
- The analysis can be extended to assess the impact of land use changes. on the rainfall runoff relationship.
- The catchment area in which runoff data is available then comparison between actual runoff and observed runoff can be easily prepared.

REFERENCES

1. Al-Jabari, S., Sharkh, M. A., and Al-Mimi, Z. (2009). “Estimation of Runoff for Agricultural Watershed using SCS Curve Number AND GIS.” Thirteenth International Water Technology Conference, IWTC 13 2009, Hurghada, Egypt.
2. Chai, S,. Yoon, K.S., and Han, K.H. (2011). “Estimation of SCS Runoff Curve Number for Agricultural Reservoir Watershed by Analysis of Reservoir Operation Record.” ICID 21st Congress, Tehran, October 2011.

3. Dhawale, A., (2013). "Runoff Estimation for Darewadi Watershed using RS and GIS." ISSN: 2277-3878, Volume-1, Issue-6, January, 2013.
4. Chowdary, V.M., Desai, V.R., Gupta, M., Jeyaram, A., and Murthy, Y.V.N.K., (2012). "Runoff Simulation using Distributed Hydrological Modelling approach, remote sensing and GIS Techniques: A Case Study from an Indian Agricultural Watershed." International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XXXIX-B8.2012.
5. Ebrahimian, M., Nuruddin A.A., Mohd Soom, M. A. B., Sood. A. M.,(2012). "Application of NRCS –Curve Number method for Runoff Estimation in a Mountainous Watreshed" CASPIAN JOURNAL OF ENVIRONMENTAL SCIENCES VOLUME 10.
6. Elhakeem, M., and Papanicolaou A.N.,(2008). "Estimation of The Runoff Curve Number via Direct Rainfall Simulator Measurements in the State of Iowa,USA.
7. Geena, G.B., and Ballukraya, P.N.,(2012). "Estimation of Runoff for Red hills Watershed Using SCS Method and GEOGRAPHIC INFORMATION SYSTEM.
8. Gupta, P.K., Punalekar, S., Panigrahy, S., Sonakia, A., and Parihar, J.S. (2012) "Runoff Modelling in an Agro-Forested Watershed Using Remote Sensing and GIS. "American Society of Civil Engineers.
9. Kadam, A.K., Kale, S.S., Pande, N.N., Pawar, N.J., and Sankhua, R.N., (2012). ''Identifying Potential Rainwater Harvesting Sites of a Semi-arid, Basaltic Region of Western India, Using SCS-CN Method". WATER RESOURCES MANAGEMENT (2012).
10. Latha, M., Rajendran, M., and Murugappan, A., (2012). ''Comparison of GIS Based SCS-CN and Strange table Method of Rainfall Runoff Models for Veeranam Tank, Tamil Nadu, India. International Journal of Scientific & Engineering Research, Volume 3, Issue 10, October-2012 ISSN 2229-5518
11. Mishra, S.K., and Singh, V.P., (1999). "ANOTHER LOOK AT SCS-CN METHOD" JOURNAL OF HYDROLOGIC ENGINEERING.
12. Mishra, S.K., Singh, V., Pandey, A., Jain, M.K. (2008)"A Rain Duration and Modified AMC – Dependent SCS CN Procedure for Long Duration Rainfall-Runoff Events." Water Resour Manage (2008).
13. Nayak T., Verma, M.K., and Bindu, H. (2012). "SCS curve number method in Narmada basin." INTERNATIONAL JOURNAL OF GEOMATICS AND GEOSCIENCES.