International Journal of Civil Engineering (IJCE)
ISSN 2278-9987
Vol. 2, Issue 4, Sep 2013, 93-100

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

RUNOFF ESTIMATION FOR WEST SUVARNAMUKHI RIVER BASIN USING REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM

MANJUNATH H. N & SURESH T. S
Department of Geology, Bangalore University, Bangalore, Karnataka, India

ABSTRACT

The water resources of late is becoming scarce due to various reasons *Viz.*, vagaries of monsoon, overexploitation, contamination etc. The available water resource in a basin has to be managed in a judicious way. Hence understanding the hydrological behavior in depth is essential for such management. Remote sensing and GIS are effective in managing the spatial and non-spatial database to elucidate the hydrologic characters in a basin in more realistic way .The study area falls under the semi-arid climatic zone and the average annual rainfall is 530 mm. Runoff estimation for the present study makes use of Soil Conservation Service Curve Number method (SCS-CN). The integration of SCS-CN with Remote Sensing and GIS techniques improves the runoff prediction and that too by making use of limited data parameters. Water resource Planning and managemental activities in a basin depends on the rainfall-runoff values estimated. In the present runoff estimation rainfall data from 1998-2010 has been used. The average runoff is 123.5mm. Thus the estimated rainfall-runoff model can be used for planning the planning of the precious water resource for optimum use in the basin.

KEYWORDS: Basin, Remote Sensing and GIS, Rainfall-Runoff, SCS-CN

INTRODUCTION

Hydrological modeling uses various methods and techniques for the estimation of the runoff. Each model uses certain specific parameters as inputs for the analysis of runoff. The soil conservation services (SCS) curve number method developed by the U.S. Department of Agriculture (SCS,1972) is used to estimate the runoff based on the rainfall data and the curve number as an input parameters (Sharma and Singh,1992; Nayak and Jaiswal, 2003). SCS method is a popular method for runoff estimation as it is easy to understand and require only a handful of parameters such as soil type, rainfall and land use. It provides reasonable and useful results for average conditions.

STUDY AREA

The West Suvarnamukhi river basin lies geographically between latitude 13^0 15' to 13^0 55' N and longitude 76^0 20' to 76^0 55' E. The areal extent of the basin is 1751 Sq. km (Figure 1). The major part of the basin lies in Tumkur district and a small northern portion of the basin is in Chitradurga district. The West Suvarnamukhi river basin is elongated and nearly spindle shaped with narrow ends in southern and northern portion and wider in the middle. The study area falls under the semi-arid climatic zone and the average annual rainfall is 530 mm. The study area is a erosional landscape in the advanced stage of peneplanation with undulating and rolling topography.

The schistose hills which covers larger area exhibits rolling topography, while the granitic hills and gneisses exhibit a rugged topography. The high altitude hill ranges are confined to the eastern margin of the basin. The land use and land cover pattern includes agricultural plantations, waterbodies, settlements, cropland, barren waste, fallow land and other land uses. The soils seen in the study area are red loamy, red sandy, mixed red and black soils.

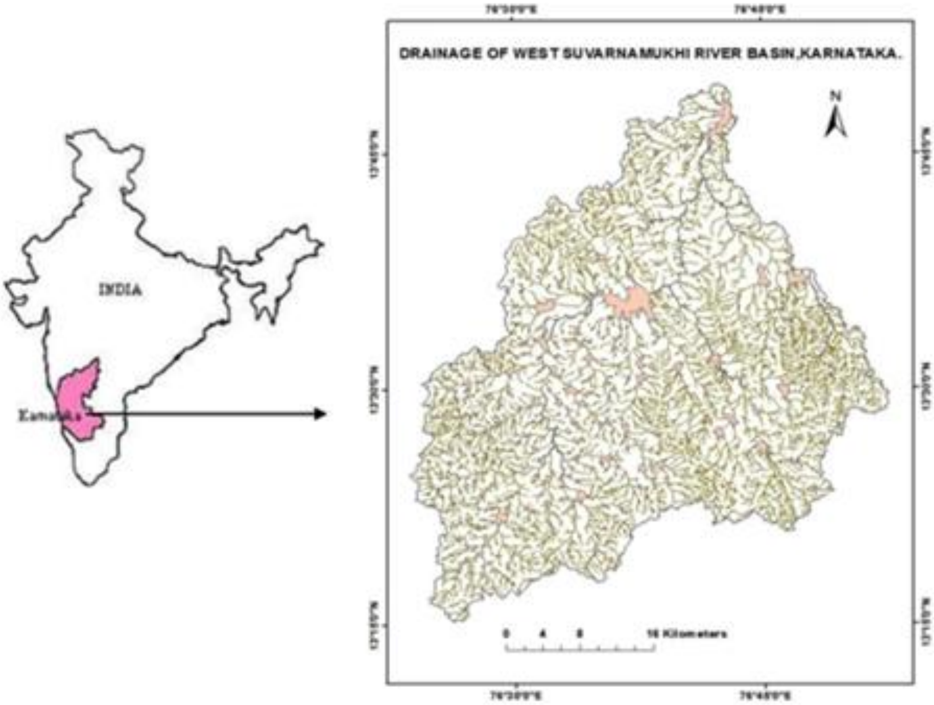
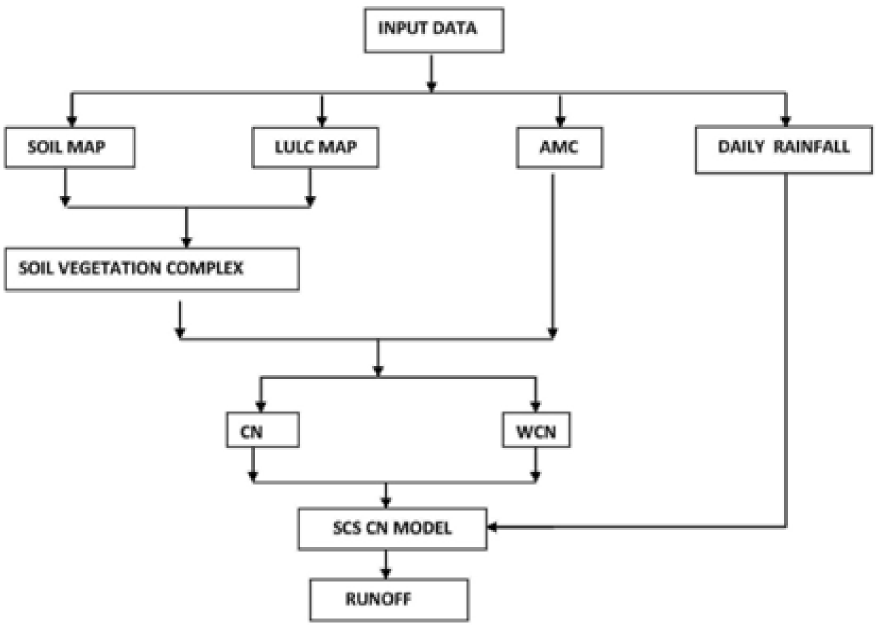


Figure 1: Location Map of Study Area

METHODOLOGY



Development of Curve Number

Surface runoff is mainly controlled by the amount of rainfall, initial abstraction and moisture retention of the soil. Moisture retention inturn depends on soil condition and crop cover. The curve number is mainly based on relationship between retention-runoff and water balance equation. The runoff-retention can be stated as the ratio of actual retention to potential retention is equal to the ratio of actual runoff to potential runoff. Which can be given as

$$\frac{\mathrm{Fa}}{\mathrm{S}} = \frac{\mathrm{Pe}}{(\mathrm{P}-\mathrm{Ia})} \quad \ldots\ldots(\mathrm{i})$$

where,

Fa = Actual infiltration, S = Potential infiltration, Ia = Initial abstraction, P = Rainfall

From the water balance equation,

$$P = Pe + Ia + Fa \ldots\ldots (ii)$$

Combining the eq. (i) and (ii)

$$Pe = \frac{(P - Ia)^2}{P - Ia + S} \ldots\ldots (iii)$$

The above equation computes the direct runoff for a storm event. Many studies on watershed have given the relationship between Ia and S as:

Ia = 0.2S

Substituting the value of Ia in equation (iii)

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

The Standard initial abstraction coefficient recommended by SCS is 0.2 (Springer et. al., 1980) found that 'Ia' varies from 0.0 to 3.0 for a small, humid and semiarid catchments. The Potential maximum retention (S) is expressed by CN

i.e., $S = \frac{2540}{CN} - 25.4$

Where CN = curve number

Hydrologic Soil Group

Soils are classified by the Natural Resource Conservation Service into four hydrologic soil groups based on the soils runoff potential. The four hydrologic soil groups are A,B,C and D (Figure 3), where 'A' generally has the smallest runoff potential and 'D' is the greatest.

Group 'A' covers sand, loamy sand or sandy loamy type of soils. It has low runoff potential and high infiltration rates. This group of soils consists of deep, well drained sands or gravels and have high water transmission capacity. The soils included in Group 'B' are loam and silt loam. This type has moderate infiltration rate and consist of moderately deep, well drained soils with moderate to fine structure.

Group 'C' soils have low infiltration rate when wetted and consists of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. The water transmission rate is low in this group. Group 'D' consists of soils with higher runoff potential. Water movement through the soil is restricted. These soils have greater than 40% of clay, less than 50% of sand. These type of soils have low rate of water transmission.

Land Use and Land Cover

Different land use classes are classified (Figure 2) using satellite imagery (IRS - 1C, FCC, LISS-III, 1996). The land use and land cover map prepared shows the study area having about 40.36% of agricultural plantations, 24% of lakes and tanks, 7% of cropland, 7.6% of barren waste, 6% of fallow land and 13% of other land use types including settlements.

Antecedent Moisture Condition (AMCs)

AMCs is the preceding relative moisture of the pervious surfaces prior to the rainfall event. Antecedent moisture is considered to be low, when there has been little preceding rainfall and high when there has been considerable preceding rainfall prior to the modeled rainfall event.

The SCS developed three AMCs and they are designated as AMC-I, II and III. The soil condition in AMC-I is dry but not to the wilting point. Average soil condition is seen in AMC-II and low to high with low temperature have occurred within last 5 days, saturated soils.

The Curve Number values for AMC-I and III is obtained by AMC-II. The equations for computation of CN1 and CN3 are as follows:

$$\mathrm{CN1} = \frac{\mathrm{CN2}}{(2.281 - 0.01281) * \mathrm{CN2}}$$

$$\mathrm{CN3} = \frac{\mathrm{CN2}}{(0.427 + 0.00573) * \mathrm{CN2}}$$

Depending upon the total rainfall in 5 days period preceding a storm, the rainfall Curve Number method has three levels of Antecedent moisture. (USDA-SCS,1985).

SPATIAL TOOLS AND OVERLAY ANALYSIS

The study area boundary was delineated using SOI toposheets. The thematic map Lu/Lc map was prepared using Satellite imagery.

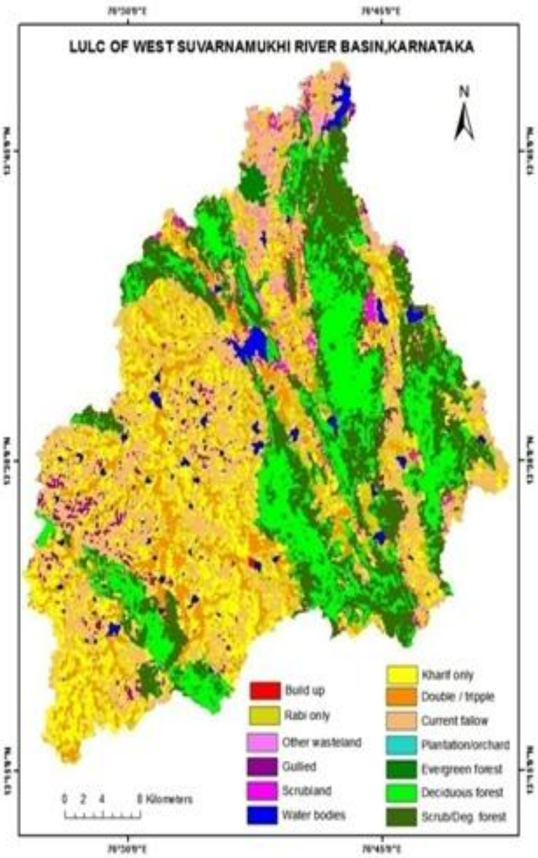


Figure 2: Land Use / Land Cover

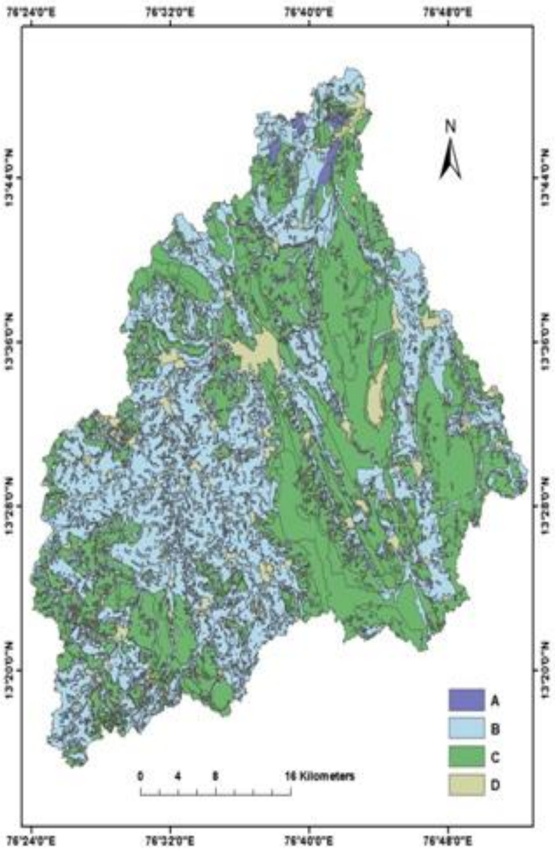


Figure 3: Hydrologic Soil Group

AMC Class	Five Days Antecedent Rainfall (mm)	
	Dormant Season	Growing Season
I	< 12.7	< 35.56
II	12.7- 27.94	35.56 - 53.34
III	> 27.94	> 53.34

(Ven Te Chow, 1981)

Hydrologic Soil Group	Minimum Infiltration Rate (mm/hr)
A	7.62 - 11.43
B	3.81 - 7.62
C	1.27 - 3.81
D	0 - 1.27

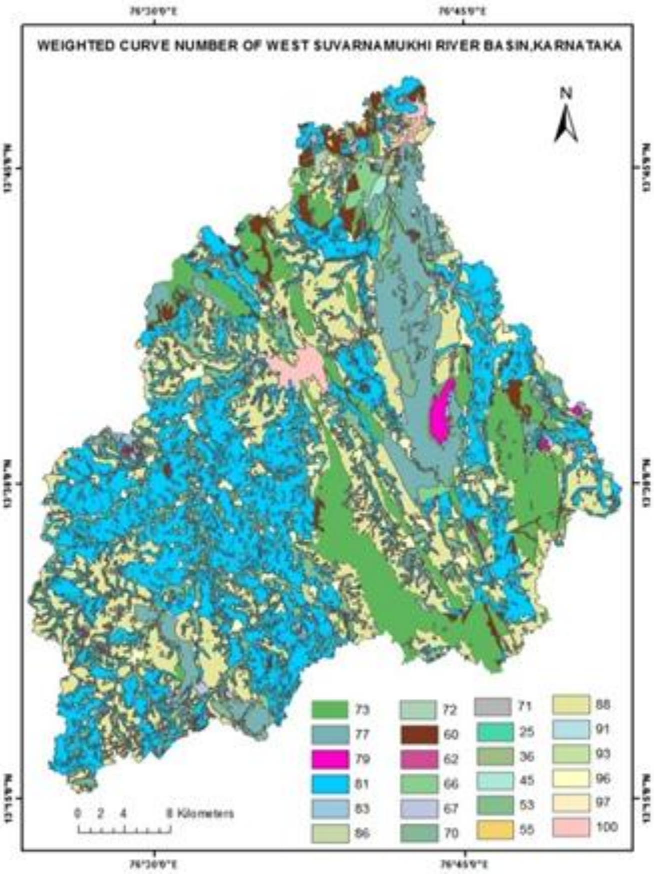


Figure 4: Curve Numbers of Study Area

The generated Lu/Lc map and Hydrologic Soil Group (HSG) maps were integrated in GIS environment. This was done using Arc GIS 10 software. The generated map of landuse - soil group is assigned by corresponding Curve Number (Figure 4). The weighted value of Curve Number is calculated by the equation,

$$CN_{avg} = \frac{\sum_{i=1}^{n}(\mathbf{CNi*Ai})}{\sum_{i=1}^{n} Ai}$$

where

CN_i = Curve Number for each land use soil group polygons

A_i = The area of respective combination , $\sum A$ = Total area of Basin.

The calculated weighted Curve Number represents the AMC II condition. Then the AMC II was converted to Curve Number values for AMC III and AMC I by equations of CN I and CN II.

RESULTS AND DISCUSSIONS

Landuse/Landcover, Hydrological Soil Groups, rainfall and Curve Numbers are the basic parameter from which the runoff is estimated. The curve numbers are generated by integrating Lu/Lc with the HSG. The Weighted CN for AMC-II is 77.67 for the entire basin. Similarly the CN for AMC- I and AMC-II are calculated which are 60.40 and 89.06 respectively. The calculated values are used in runoff modeling.

Table 1

Year	Station	Mean Rainfall (mm)	Mean Runoff (mm)
1998	Anakasandra	403	65
1999	Boranakanve	524	95
2000	Bukapatna	667	192
2001	C.N.Halli	811	193
2002	D.Ennigere	424	112
2003	Hagalavadi	369	46
2004	Halkurke	704	200
2005	Huliyar	598	125
2006	J.G.Halli	588	114
2007	Mathighatta	404	66
2008	Nittur	488	86
2009	Settikere	572	122
2010	Tiptur	807	189

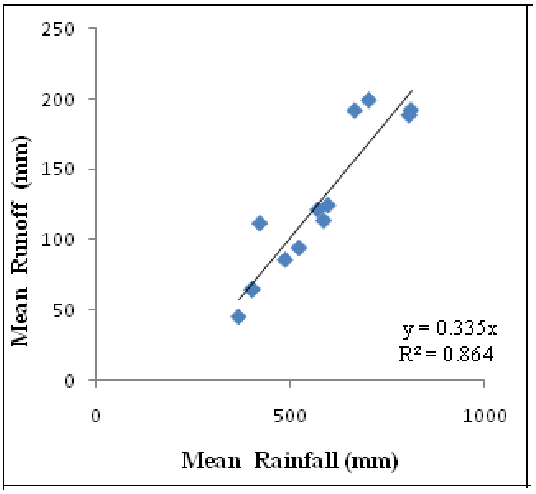


Figure 5: Regression of Mean Rainfall and Runoff

Daily rainfall data of 13 rain gauging stations in the study area for 13years (1998-2010) has been used. The missing rainfall data for the stations were calculated by normal ratio method. This rainfall data has been used in runoff estimations. The mean runoff value of the study area from the year 1998 to 2010 is shown in Table-1.The average runoff of the study area is 123.46 mm. The regression equation obtained is satisfactory.The weighted curve number for the study area is calculated and tabulated in Table-2. Study area comprises of all the four HSG among which groups B, C and D occupies most of the study area indicating slow infiltration rate. The HSG covered in the study basin are shown in Figure 3. It was observed that the study area experienced minimum runoff in the year 2003 and maximum in the year 2004 during the period of investigation.

Table 2: Weighted CN for Study Basin

Sl. No.	Land Use Type	HSG	CN	Area	Area*CN	Weighted CN
1	Agricultural Plantation	B	53	183.43	8131.79	
2	Agricultural Plantation	C	67	38.91	2606.97	
3	Agricultural Plantation	D	72	0.68	48.96	AMCI=60.40
4	Stony waste	B	66	5.01	330.66	
5	Stony waste	C	77	3.69	284.13	
6	Stony waste	D	83	2.47	205.01	
7	Crop land	B	81	493.92	40007.52	
8	Crop land	B	71	11.31	803.01	
9	Crop land	C	88	354.09	31159.92	
10	Crop land	D	91	6.92	629.72	
11	Degraded forest	B	66	49.79	1966.14	
12	Degraded forest	D	83	4.82	400.06	
13	Degraded forest	C	77	182.2	10179.4	AMCII=77.67
14	Fallow land	C	77	4.87	374.99	
15	Fallow land	B	66	10.89	718.74	
16	Forest plantations	B	55	2.71	149.05	
17	Forest plantations	C	70	23.92	974.4	
18	Gullied / Revinous Land	B	66	3.94	260.04	
19	Gullied / Revinous Land	C	77	2.24	172.48	
20	Lake/Tank	D	96	58.58	5623.68	
21	Land with Scrub	B	60	31.3	1878	
22	Land with Scrub	C	73	90.14	6580.22	
23	Land with Scrub	A	36	1.74	62.64	
24	Reservoir	D	100	19.23	1923	AMCIII=89.06
25	River/stream	D	97	4.71	456.87	
26	Scruby forest	C	73	151.56	9603.88	
27	Scruby forest	B	60	21.79	1307.4	
28	Settlements	D	86	7.87	676.82	
29	Salt effected area	B	66	1.29	85.14	
30	Mining/Industrial wasteland	C	77	0.43	33.11	

CONCLUSIONS

GIS based SCS-CN method is an effective way to estimate runoff. The conventional methods of runoff estimation for large areas is tedious and time consuming. Thus the integration of SCS-CN with Remote Sensing and GIS techniques improves the runoff prediction economically and easily making use of limited data parameters available. Planning and managemental activities of a basin depends up on the rainfall-runoff values estimated. Accuracy in CN values mainly depends on land use conditions. Thus it is reliable to integrate physiographic, storm, soil and land use characteristics of the study basin with certain degree of reliability. The accuracy in runoff estimation by using SCS-CN method is possible by taking more number of years of rainfall data into consideration. The present study evaluates the performance of the procedure using LULC data base from Remote Sensing and GIS techniques in runoff estimation.

ACKNOWLEDGEMENTS

The authors acknowledge the financial assistance received from the University Grant Commission, New Delhi as a Major Research Project in carrying this research work .

REFERENCES

1. **Ghanshyam Das.,** Hydrology and Soil Conservation Engineering (II edition), pp 79-98.

2. **Hafeezunnisa.,** Runoff estimation and Quantitative Morphometric analysis using RS and GIS techniques, Dissertation, M.E-Civil,(unpubl.) UVCE, Bangalore University, Bangalore, 2011.

3. **Nayak. T.R. and Jaiswal R.K..,(2003).,** "Rainfall-runoff modeling using Satellite data and GIS for Bedas river in Madhya Pradesh", Indian Institute of Engineers (India) Journal ,Vol. 84, May, pp: 47-50.

4. **Sharma. K.D and S. Singh, 1992.,** Runoff estimation using landsat thematic mapper data and the SCS model; Hydrological Sciences 37(1) : 39-51.

5. **Springer, E.P, McGurk, B.J. Hawking, R.H. and Coltharp, G.W (1980).,** "Curve numbers from watershed data" Proc., ASCE Irrig. and Drain. Symp. on watershed Mgmt. ASCE, New York, Vol. - II, 938-950.

6. **US Soil Conservation Service, Hydrology:** National Engineering Handbook, Section 4, Washington DC, 1972.

7. **U.S. Dept. Agric., Soil Conservation Service, 1985**, National Engineering Handbook, Section 4; Hydrology. U.S.Govt. Printing Office , Washington, D.C.

8. **Ven Te chow (1981).,** Handbook of Applied Hydrology, Mc Graw Hill Book Company .