International Journal of Civil Engineering (IJCE)
ISSN 2278-9987
Vol. 2, Issue 1, Feb 2013, 13-20

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

SCS AND GIS BASED RUNOFF ESTIMATION FOR JAKKUR LAKE CATCHMENT OF BANGALORE, KARNATAKA

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ABSTRACT

Runoff is one of the most important hydrological variables used in most of the water resources applications. .In this study, estimation of runoff for Jakkur lake catchment, located in north of Bangalore district of Karnataka state, India is carried out using SCS and GIS techniques. The study area is located between 13° 2′ to 13°12′ N Latitude and 77°31′ to 77°39′ E Longitude forming a part of Cauvery river basin. The study area covers an area of 81.6 km^2 and comprises of sixteen micro watersheds draining into river Pinakini in Bangalore district of Karnataka. Physiographically the area is characterized by undulating topography with plains and shallow valleys. The Soil Conservation Service Curve Number (SCS CN) also known as hydrologic soil group method was used in this study. This method is a versatile and popular approach for quick runoff estimation and is relatively easy to use with minimum data and it gives adequate result. From the study, monthly as well as annual rainfall and corresponding runoff were estimated.

KEYWORDS: Estimation, Infiltration, Landuse, Rainfall, Runoff, Watershed

INTRODUCTION

A watershed is the area covering all the land that contributes runoff water to a common point. It is a natural physiographic or ecological unit composed of interrelated parts and function. Each watershed has definite characteristics such as size, shape, slope, drainage, vegetation, geology, soil, geo-morphology, climate and land use. Watershed management implies proper usage of water to land and other natural resources in a watershed for estimation of runoff which is required for planning, developing and managing the water resources. Runoff is one of the most important hydrologic variables used in most of the water resources applications. Direct measurement of runoff provides excellent and timely data but it is limited in use to the exact location where it was collected. In this study the Soil Conservation Service Curve Number (SCS-CN method) also known as hydrologic method was used. This method is a versatile and popular approach for quick runoff estimation and is relatively easy to use with minimum data and it gives adequate results. Runoff estimates are based upon the soil types, land-use practices within a basin and the influence of the antecedent soil moisture conditions.

The Geographic Information System (GIS) has become a critical tool in hydrological modeling in view of its capacity to handle large amount of spatial and attribute data. Some of its features such as map overlay and analysis help to derive and aggregate hydrologic parameters from different sources such as soil, land cover and rainfall data (Cheng et. al 2006; Mahboubeh Ebrahimian et. al 2009). In recent days, an integrated study of runoff modeling using SCS-CN and GIS technique has gained significance for estimation of surface runoff (Amutha et. al 2009; Soulis et. al 2009; Ratika Pradhan et. al 2009, Paul et. al 2012). These works mainly aims the estimation of runoff in watershed using SCS-CN method.

STUDY AREA

Jakkur lake is located at in North-East corner of Bangalore city at about 200 meters east of NH-4.This Lake is the main Lake in the chain of Lakes comprising Yelahanka Lake & Rachenahalli Lake, in the chain. The study area is located between Latitude 13° 2′ to 13°12′ N and Longitude 77°31′ to 77°39′ E forming a part of Cauvery river basin. The study area covers an area of 81. 69 km^2 and comprises of sixteen micro watershed draining into river Pinakini in Bangalore district of Karnataka. physiographically the area is characterized by undulating topography with plains and shallow valleys. The area includes different litho units such as gneisses, granites, schists, laterites and dolerite dykes. The study area is located at north of Bangalore. Bangalore is the capital of Karnataka state however the district does not have any major river flowing the district falls in Cauvery River basin. The study area attains maximum elevation of 940 m and a minimum of 880 m above mean sea level. The district is well connected by highways and other main roads. The study area shows that the average depth of annual rainfall for the study area is 811 mm. The location map of the study area is shown in Fig 1.

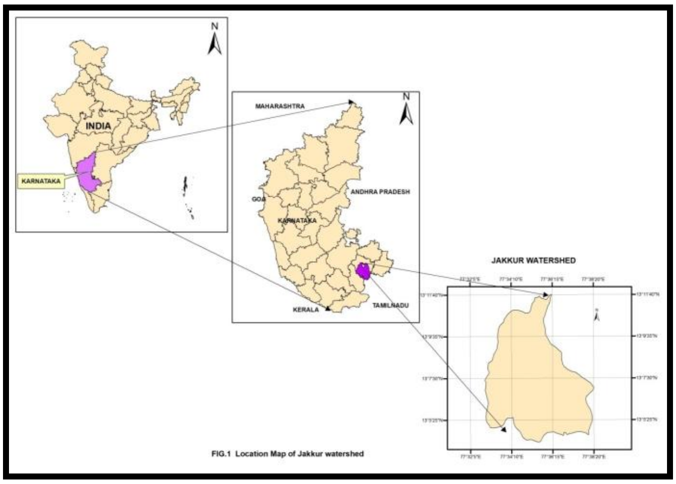

Figure 1: Location Map of Study Area

METHODOLOGY

In this study, Survey of India topographic sheets of 57G/12 is used to delineate the watershed boundary, drainage and contour. Remote sensing data of 1:50,000 for delineating land use/land cover map and soil map. Hydrologic soil group map (Fig.2) was prepared according to soil characteristics and type of land use/land cover (Fig.3) for the estimation of runoff from watershed. Daily rainfall data from rain gauge stations at Yelahanka, Hebbal and Gandhi Krishi Vignan Kendra (GKVK) for the years 1998 to 2009 (12 years) data were used to calculate the runoff using SCS-CN method.

SCS Curve Number Method

Soil Conservation Service Curve Number (SCS-CN) model is one of the method to estimate surface runoff from watershed. The infiltration losses are combined with surface storage by the relation of

$$Q = (P-Ia)^2 / (P-Ia+S) \tag{1}$$

Where, Q is the accumulated runoff or rainfall excess in mm, P is the rainfall depth in mm, Ia is the initial abstraction in mm and includes surface storage, interception, and infiltration prior to runoff in the watershed and empirical relation was developed for the term Ia and it is given by,

$$Ia = 0.2S \tag{2}$$

For Indian condition the term S in the potential maximum retention and it is given by,

$$S = (25400/CN) – 254 \tag{3}$$

Where, CN is known as the curve no which can be taken from the handbook of hydrology, section – 4(USDA, 1972).

Now the equation 1 can be rewritten as,

$$Q= (P-0.2S)^2 / (P+0.8S) \quad (4)$$

Knowing the value of CN, the runoff from the watershed was computed from Eq.3 and 4.

The CN (dimensionless number ranging from 0 to 100) is determined from a table, based on land cover, antecedent soil moisture condition (AMC) and hydrologic soil group (A, B, C and D), Fig.2 shows the Hydrological Soil Group map prepared by assigning hydrological soil group based on the infiltration rate. AMC is expressed in three levels (I,II and III), according to rainfall limits for dormant and growing seasons.

HSG and Antecedent Soil Moisture Condition (AMC)

The hydrologic soil group is an attribute of the soil mapping unit. Each soil mapping unit is assigned a particular hydrologic soil group: A, B, C, or D according to the soil's minimum infiltration rate, which is obtained for a bare soil after prolonged wetting (Table 1). Antecedent Moisture Condition (AMC) refers to the water content present in the soil at a given time. The AMC value is intended to reflect the effect of infiltration on both the volume and rate of runoff according to the infiltration curve.

The SCS developed three antecedent soil-moisture conditions and labeled them as AMCI, AMCII & AMCIII according to rainfall limits for dormant and growing seasons (Table 2). Prior to estimating runoff for a storm event, the curve numbers was adjusted based on the season and total 5 day antecedent precipitation.

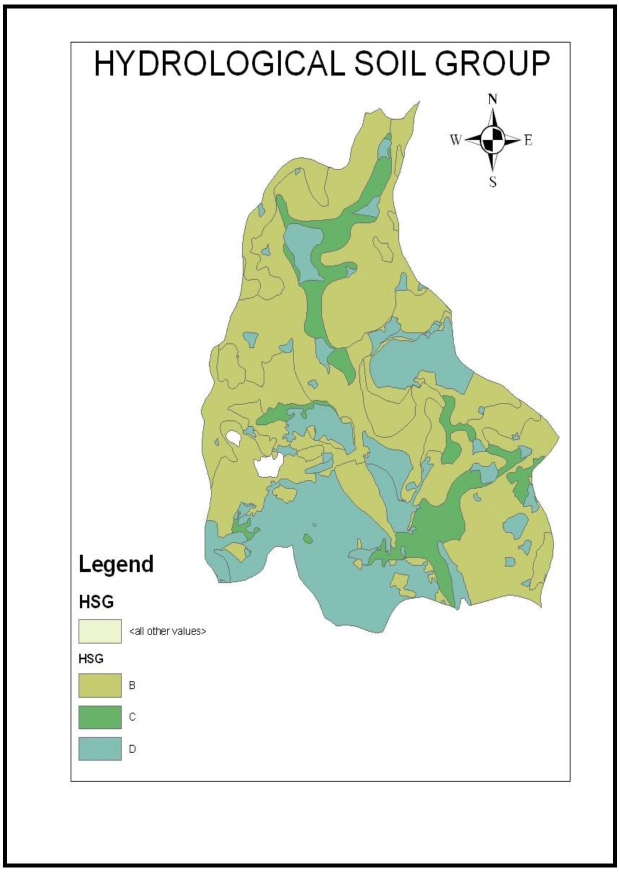

Figure 2: Hydrologic Soil Group Map

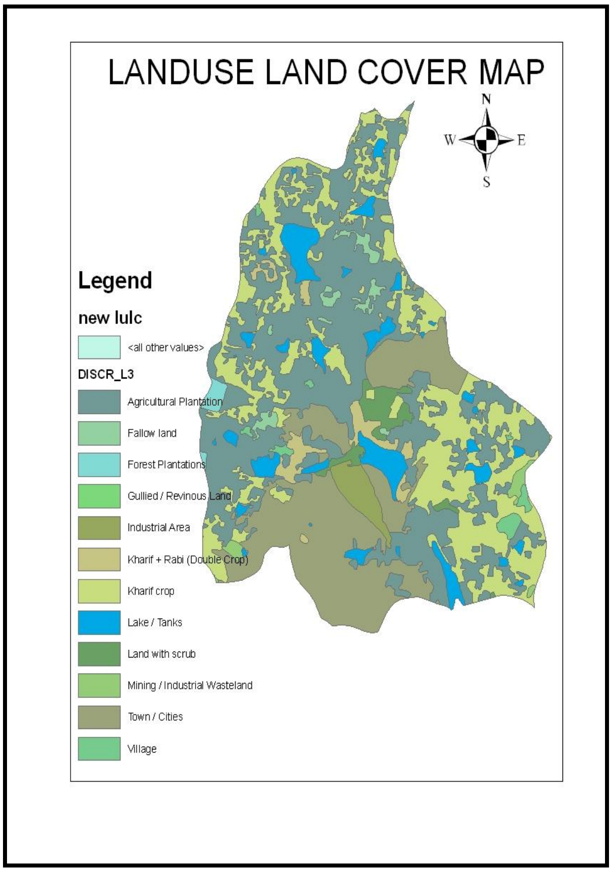

Figure 3: Land Use / Land Cover Map

Table 1: USDA-SCS Soil Classification

Group	Minimum Infiltration Rate (cm/hr)	Runoff Potential
A	0.76	Low
B	0.38-0.76	Moderate
C	0.13-0.38	Moderate
D	0.0-0.13	High

Table 2: Classification of Antecedent Soil Moisture Classes (AMC)

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

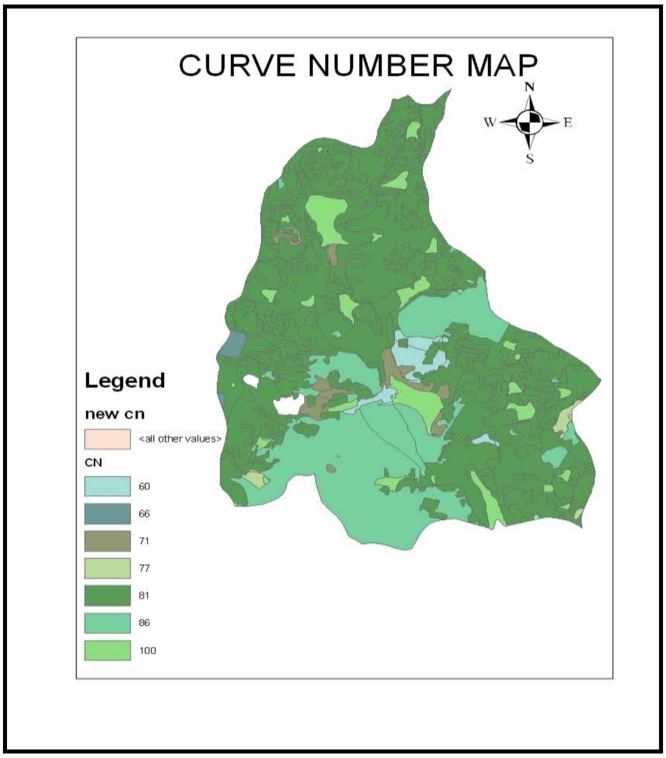

Figure 4: Curve Number Map of the Study Area

Area Weighted Curve Number

The different layers of soil, HSG and land use/land cover (Fig.3) were overlaid one by one and the new Polygon Attribute Table (PAT) was obtained using ArcGIS software (Fig.4). The result obtained from this PAT was used to compute the total area weighted curve number of the study area to calculate the AMC II,AMC I and AMC III refer Table 3.

Estimation of Rain Fall- Runoff

The daily rainfall data from 1998 to 2009 (12 years) and the area weighted curve number were input to the SCS formula and daily runoff values were obtained. The detailed monthly rainfall and calculated runoff for 12 years are given Table 4.

Table 3: Curve Number of Various Land Use and Hydrological Soil Groups in the Study Area

No	Description	HSG	Area (km2)	CN 2	CN1	CN3	AXCN1	A X CN2	AXCN3
1	Agricultural Plantation	B	31.494759	81	65.1	90.9	2051.71	2551.08	2862.74
		C	0.939457	81	65.1	90.9	61.20044	76.096	85.3927
		D	0.294219	81	65.1	90.9	19.16674	23.8317	26.7433
2	Fallow land	B	1.01187	81	65.1	90.9	65.91775	81.9615	91.9748
		C	0.29468	81	65.1	90.9	19.19678	23.8691	26.7852
3	Forest Plantations	B	0.433784	66	46.0	82.0	19.94354	28.6297	35.5569
4	Gullied / Revinous Land	B	0.000057	66	46.0	82.0	0.002621	0.00376	0.00467
5	Industrial Area	B	1.383545	86	72.9	93.5	100.8911	118.985	129.362
6	Kharif + Rabi (Double Crop)	B	1.833779	71	51.8	85.1	94.93201	130.198	156.145
		C	0.042675	71	51.8	85.1	2.209221	3.02993	3.63374
7	Kharif crop	B	15.287344	81	65.1	90.9	995.8861	1238.27	1389.56
		C	3.300466	81	65.1	90.9	215.0072	267.338	299.999
		D	0.943441	81	65.1	90.9	61.45998	76.4187	85.7549
8	Lake / Tanks	D	4.890806	100	100.0	100.0	489.0806	489.081	489.081
9	Land with scrub	B	1.632778	60	39.7	77.8	64.77564	97.9667	127.097
		C	0.016098	60	39.7	77.8	0.638641	0.96588	1.25309
10	Mining / Industrial Wasteland	B	0.304454	77	59.5	88.7	18.10784	23.443	27.0015
		C	0.178649	77	59.5	88.7	10.62541	13.756	15.8441
		D	0.054312	77	59.5	88.7	3.230285	4.18202	4.81683
11	Town / Cities	B	0.020613	86	72.9	93.5	1.503144	1.77272	1.92733
		D	16.603322	86	72.9	93.5	1210.75	1427.89	1552.42
12	Village	D	0.737132	86	72.9	93.5	53.75325	63.3934	68.9223
Total			**81.69824**				**5559.988**	**6742.16**	**7482.01**
				AMC I=68.1		**AMC II=82.5**		**AMCIII=91.6**	

RESULTS AND DISCUSSIONS

Hydrologic soil groups B, C and D were found in the study area (Fig.2). About 46 percent of soil was placed in group B and 32 and 22 percent of soil were placed in group C and D respectively (Table 3). Using the landuse and soil maps the weighted curve number values obtained are 68.1, 82.5 and 91.6 respectively. The monthly as well as annual runoff estimated using the above equations are given in table 4.

The monthly and annual runoff calculated in mm and the study area is predominated by southwest monsoon. An average annual rain fall of 811 mm was obtained in the area during the study period. It is seen that approximately about 70mm rainfall per month is required to generate any runoff. In drought years such as 2002, 2003 and 2006 the runoff generated were very low. The trend line for the average rainfall indicates that rainfall has decreased from 1998 to 2009 due to irregular climatic season in the recent years (Fig.5).

Even though in the years 2007 and 2009 an average rainfall of above 750 mm was received but low runoff was generated, it is because of low AMC compared to rest of the years. The rainfall runoff results shows that there is no high runoff taking place in the study area since 40% of the area consists of agriculture land and 20% of crop area.

Table 4: Lake Catchment Rainfall and Runoff in mm

YEAR	(mm)	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1998	RAINFALL	0.0	0.0	0.0	55.9	49.1	51.5	119.2	276.8	179.3	196.5	31.9	5.7	966.0
	RUNOFF	0.0	0.0	0.0	1.9	0.0	0.0	2.0	68.1	25.0	65.3	1.9	0.0	164.3
1999	RAINFALL	0.0	4.8	0.0	45.4	141.2	70.6	51.3	142.5	198.8	224.3	53.4	16.1	948.4
	RUNOFF	0.0	0.0	0.0	0.0	19.1	0.0	0.0	16.4	78.6	64.2	2.4	0.0	180.7
2000	RAINFALL	0.0	98.2	0.0	63.2	78.7	95.8	78.8	258.5	194.4	189.7	1.9	5.3	1064.5
	RUNOFF	0.0	40.5	0.0	3.4	4.8	35.1	0.0	71.2	48.1	31.1	0.0	0.0	234.1
2001	RAINFALL	0.0	0.0	1.3	216.9	25.0	17.2	96.3	57.7	261.2	114.3	22.3	6.1	818.2
	RUNOFF	0.0	0.0	0.0	95.2	0.0	0.0	28.8	1.9	80.3	2.0	0.0	0.0	208.3
2002	RAINFALL	0.0	0.0	0.0	2.8	122.2	91.5	26.8	28.7	27.7	106.8	30.5	2.0	439.0
	RUNOFF	0.0	0.0	0.0	0.0	68.5	1.6	0.0	0.0	0.0	12.8	5.4	0.0	88.3
2003	RAINFALL	0.0	0.0	10.9	26.1	1.1	27.7	60.6	79.1	54.1	250.7	6.0	0.0	516.2
	RUNOFF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63.6	0.0	0.0	63.6
2004	RAINFALL	6.8	0.5	4.6	42.0	159.2	68.5	144.0	50.7	223.7	163.0	18.5	0.0	881.4
	RUNOFF	0.0	0.0	0.0	2.1	38.8	20.6	28.5	0.0	77.9	16.7	0.0	0.0	184.6
2005	RAINFALL	3.9	2.4	5.7	72.9	98.0	65.4	84.4	136.7	222.1	323.3	44.1	3.5	1062.4
	RUNOFF	0.0	0.0	0.0	3.0	0.7	0.0	0.0	22.7	50.7	100.7	0.0	0.0	177.7
2006	RAINFALL	0.0	0.0	69.0	10.2	115.4	140.5	68.7	48.0	36.1	18.9	64.3	0.6	571.6
	RUNOFF	0.0	0.0	3.5	0.0	2.4	55.8	0.0	0.0	0.0	0.0	5.5	0.0	67.2
2007	RAINFALL	0.0	0.3	0.0	109.8	44.6	38.1	117.5	122.6	184.0	122.3	7.3	20.9	767.4
	RUNOFF	0.0	0.0	0.0	24.4	0.0	0.0	8.8	3.1	8.8	2.3	0.0	0.0	47.4
2008	RAINFALL	0.0	1.1	69.9	17.7	64.0	25.4	136.8	247.3	128.4	191.1	26.2	2.5	910.3
	RUNOFF	0.0	0.0	14.5	0.0	0.0	0.0	0.4	74.0	17.9	17.3	0.0	0.0	124.1
2009	RAINFALL	0.0	0.0	1.4	51.2	126.2	62.5	42.2	111.2	249.0	79.0	51.3	13.5	787.5
	RUNOFF	0.0	0.0	0.0	1.1	11.3	0.0	0.0	5.7	37.3	1.4	0.0	0.0	56.8

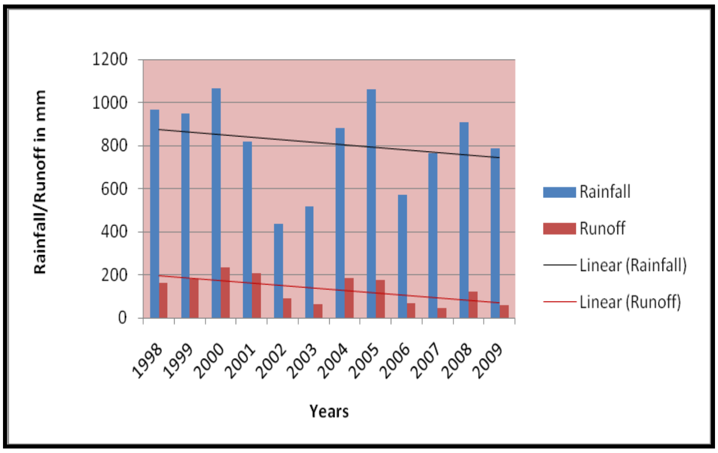

Figure 5: Average Rainfall vs Average Runoff

CONCLUSIONS

It may be inferred that estimation of runoff by SCS-CN method integrated with GIS technique can be used in watershed management effectively. The results of the study shows that runoff in the watershed can be studied for reliable accuracy along with the spatial variation of soil type and land use type. By assessing the variation in annual runoff, the water can be used for agricultural activities and other uses. After synchronizing the available flow in the watershed a real world model can be arrived in the efficient water management of the watershed.

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