SGVU J CLIM CHANGE WATER
Vol. 4, 2017 pp. 9-12
ISSN: 2347-7741

SCS-CN Method for Surface Runoff Calculation of Agricultural Watershed Area of Bhojtal

Priyanka Dwivedi[1], Abhishek Mishra[2], Sateesh Karwariya[3*], Sandeep Goyal[4], T. Thomas[5]
[1]Research Trainee Centre for policy Studies, Associated with MPCST, Bhopal
[2]Research Associate Madhya Pradesh Council of Science and Technology, Bhopal (MP)
[3*]Research Associate Indian Institute of Soil Science, Bhopal (MP)
[4]Principle Scientist Madhya Pradesh Council of Science and Technology, Bhopal (MP)
[5]Scientist 'C' National Institute of Hydrology WALMI Campus, Bhopal
*Corresponding author: Sateesh.karwariya@gmail.com

ABSTRACT
The Upper Lake, (Bhojtal) is situated in the city Bhopal.Upper Lake is the major source of water for the city Bhopal. Economic as well as recreational activities of the city Bhopal are dependent on the water availability in the upper Bhopal Lake. This receives water as surface runoff only during monsoon period of each and every year. The upper lake has a catchment area of 375.55km2. The Land use Pattern of about 80% of the catchment is an agricultural area. Whereas 5% is of the forest and rest comes in urban area. Since the inset of monsoon in the catchment area is by 15th June in every year. The agricultural area starts contributing by the end of august. Whereas the lake start receiving surface runoff right from the beginning of monsoon season. Bhojtal Basin has a good surface hydro environment potential to reduce the water scarcity problem of the district. Current situation demands to prepare a proper plan for reducing the losses of surface water of the basin.

Keywords: Runoff, Watershed, SCS-CN Method, Agriculture

INTRODUCTION
The relationship between amount of rainfall and the resulting amount of runoff is mainly dependent on soilInfiltration. The type of land use and land cover, agricultural management, hydrologic conditions, soil typeDistribution and soil moisture, these all things are important for rainfall runoff analysis. Method used to estimate rainfall runoff is USDA – SCS (Lamb, 1999), as runoff Curve Number (CN) method (USDA, 1972). The SCS method has been used by many researchers to determine the rainfall runoff relationship (Stuebe and Johnston, 1990; Sharma et al., 2001; Sharma and Kumar, 2002; Mishra et al. 2004; Pandey and Dabral, 2004; Pandey and Sahu, 2004; Pandey et al. 2005; Mishra et al. 2005; Jain et al. 2006). Curve number method depends on land use, management type, hydrologic conditions and hydrologic soil group.

In this paper soil conservation service is used for the curve number (SCS-CN) approach for rainfall-runoff estimation with Antecedent moisture condition (AMC). (SCS-CN) approach is widely used as a simple method for predicting direct runoff volume for a given rainfall event. The CN parameter values corresponding to various soil, land cover, and land management conditions can be selected from tables, but it is preferable to estimate the CN value from measured rainfall-runoff data if available. However, previous researchers indicated that the CN values calculated from measured rainfall-runoff data vary systematically with the rainfall depth. Hence, they suggested the determination of a single CN value observed for very high rainfall depths to characterize the watersheds' runoff response.

The lake considered for study of this Paper is the Upper lake of Bhopal, an established ecosystem for 900 years and a vital source of drinking water. Situated between longitude 77º 30' – 77º 35' E and latitude 23' 25" – 23' 26'N, the total watershed area is 375.55 km2. The catchment area is mainly occupied by agricultural lands. Hillrocks of different altitudes are situated along the southwest and northwest parts of the urban area, forming a continuous belt from the Singarcholi up to the Vindhyachal range, to an elevation of 625 meters. The general ground level is between 460 and 500 meters along the city. The unusual topography has always provided a unique attraction to the city. There are 14 water bodies in and around Bhopal including the two large lakes, the Upper and the Lower Lake.

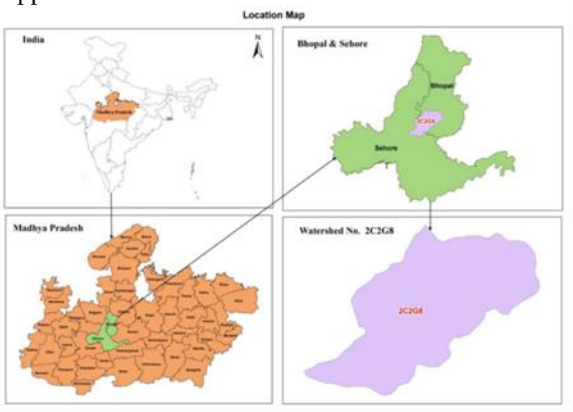

Fig. 1 Location map of study area.

MATERIALS AND METHODS

To assess the rainfall water as a surface runoff, needful thematic layer of soil type of study area is prepared using geological survey of India and LISS-III (2011) image is used for preparation of land use/land cover classes of study area. Curve number method is used for estimation of runoff. The Curve Number Equation is actually a relationship between runoff volume and rain volume. The basic equation is:

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

Where Q is the runoff depth (to get volume, multiply by the watershed area), P is the rainfall depth, Ia is the initial abstraction, and S is the watershed storage. All units of depth are in mm. The initial abstraction is conceptualized as the amount of rain that falls before runoff is initiated; this is usually assumed to be 0.2S. Eq. is usually written as:

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

The S term is determined indirectly from tables relating qualitative land use information to a runoff index called the Curve Number (CN). The CN is related to S with

$$S = \frac{1000}{CN} - 10$$

Or

$$S = \frac{25400}{CN} - 254$$

Land Use / Land Cover of study area has been classified in seven classes viz., Built Up Area, Agriculture Area, Fallow Land, Recreational, Vegetation, Waste Land and River Water Body, Area under each class has been calculated from the attribute table. The Land Use/ Land Cover thematic map and soil map are interpreted. Weighted CN for each sub area is worked out using the following equation,

$$\text{Weighted Curve Number} = \frac{\sum(CN*A)}{\sum A}$$

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 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: Sufficient rainfall has occurred within the immediate past five days. Saturated soil conditions prevail.

Antecedent moisture conditions (AMC) for determining the values of CN

Table: 1 Antecedent moisture conditions (AMC)

AMC GROUP	GROWING SEASON	DORMANT SEASON
I	Less than 35.6mm	Less than 12.7mm
II	35.6mm to 53.3mm	12.7mm to 27.9mm
III	More than 53.3mm	More than 27.9mm

The variation of curve number under AMC II called CNII for various land conditions are commonly found in practice. The conversion of CNII to other two AMC conditions can be made through the following correlation equations,

For AMC-I

$$CN_I = \frac{4.2 \text{ X } CN_{II}}{10 - 0.058 \text{ X } CN_{II}}$$

For AMC-III

$$CN_{III} = \frac{23 \text{ X } CN_{II}}{(10 + 0.13 \text{ X } CN_{II})}$$

RESULTS AND DISCUSSION

Land use/land cover map using IRS-P6 LISS-3 data (figure 2). LU / LC classes are classified by help of ERDAS Imagin-11 software. This figure depicts that there are ten units of land cover/land use pattern in the study area, which are given below and shown on the map.

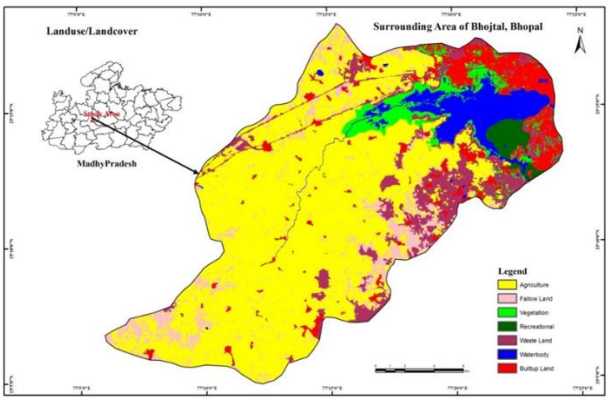

Figure 2: LULC of the study area

Table: 2 Land use/land cover of study area

S.No	LULC Class	Area in km^2
1	Built Up Area	31.64
2	Agriculture Area	266.99
3	Fallow Land	60.32
4	Recreational	6.36
5	Vegetation	15.97
6	Waste Land	39.92
7	River &Water Body	24.29
	Total Watershed Area	**375.55**

Runoff Calculation of Agricultural watershed area of Bhojtal.

Curve Number for Agricultural watershed area of Bhojtal with AMC condition

AMC second condition is an average condition, for this condition weighted curve number is used.

Sl.No.	AMC Cond.	Curve Num.	Ia	S
1	I	69.647	22.139	110.696
2	II	84.528	9.2984	46.492
3	III	92.628	4.0430	20.215

Total estimated runoff for growing season

Table 4: AMC condition with CN value

Total Runoff in 2013 (in rainy season)			
Sl. No.	**Month**	**Runoff in mm**	**Runoff Volume**
1	June	1552.669	0.582794
2	July	1261.31	0.473433
3	August	1453.58	0.545601
4	September	56.2214	0.021103
	Total	**4323.7804**	**1.622931**

Table: 5 Total estimated runoff for growing season

CONCLUSIONS

Study area has been classified into seven classes that can be given as: - Built up area, agricultural area, fallow land, recreational, vegetation, waste land and river water body. The soil of the study area are classified into three hydrology soil group “A”, “B”, and “D” with minimum infiltration rate. The area under Hydrological Soil Group “D” is found to be 304.103 sq. km., soil group “A” is found to be 44.640sq. Km. and soil group “B” is found to be 2.316 sq. km.

Sl No.	LU/LC Class	Soil Group	CN Value	Area in km^2	CN*A
1	Agriculture	D	87	226.2769	19686.0903
2	Agriculture	A	67	0.717141	48.048447
3	Built-up	D	92	31.639792	2910.860864
4	Fallow land	A	76	29.910216	2273.176416
5	Fallow land	D	90	0.252101	22.68909
6	Recreational	A	28	2.629814	73.634792
7	Recreational	B	44	2.098161	92.319084
8	Recreational	D	64	1.646587	105.381568
9	Vegetation	A	49	9.510429	466.011021
10	Vegetation	D	80	6.435952	514.87616
11	Vegetation	B	79	0.023726	1.874354
12	Wasteland	A	71	1.872366	132.937986
13	Wasteland	D	88	37.851246	3330.909648
14	Wasteland	B	80	0.193958	15.51664
15	River & WB	–	100	–	–
	Total			**351.058389**	**29674.32637**

Table: 3 Runoff Calculation of Agricultural watershed area of Bhojtal

The estimated runoff of the growing season for upper lake watershed is 4323.7804mm and total runoff volume for the study area is 1.622931m^3. It is concluded that the fully distributed model is a fairly good model and the results are quite good and can be used throughout the human beings to fulfil their needs up to their requirements. So that they cannot face any scarcity of water in future, which is the major cause going and increasing day by day. The water stored can be used by the people in many different ways like for domestic, industrial, economic, commercial etc.

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