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Estimation of Surface Runoff For Ahmedabad Urban Area using SCS-CN Method and GIS

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Abstract

Soil conservation Service (SCS) model was used for the estimation of surface runoff for Ahmedabad urban area. Sub-watershed level areas covering Ahmedabad urban area are considered for the estimation of runoff. The daily rainfall data of 4 rain gauge stations (1988-2012) is collected. Thiesson polygon method is used for finding average distribution of rainfall in whole study area. Landuse/Landcover map was prepared from the satellite image and soil map of study area was prepared using GIS. Landuse/Landcover map and Soil map are used to estimate curve number for SCS method. Antecedent Moisture Conditions (AMC-I, AMC-II and AMC-III) are also used for selecting suitable curve number in study area. SCS-CN method was used to determine the runoff depth distribution using remote sensing and Geographic Information System.
Keywords: AMC-I, AMC-II and AMC-III), SCS

I. INTRODUCTION

Runoff corresponding to rainfall is an important characteristic of a watershed. Remote sensing techniques are more reliable and faster method for data collection than any other conventional techniques. Satellite images are useful for preparation of landuse/landcover map, which is essential parameter in SCS runoff estimation. Use of GIS as a spatial data management and an analysis tool is effective for hydrological studies. In this study SCS-CN modified for Indian condition has been used for generation of runoff in the study area. The Soil Conservation Service (SCS) runoff model is useful for estimating runoff depths for different antecedent moisture condition (AMC).

II. STUDY AREA

Urban area of Ahmedabad city covered by Sub-watershed boundary is selected for the study area in Gujarat, India. Ahmedabad city lies between 22˚ 55’ and 23˚ 08’ North Latitude and 72˚ 30’ and 72˚ 42’ East Longitude.

A. Data Source:

IRS P6 LISS-IV satellite image were used for the preparation of landuse/landcover map of study area. Soil map was collected from Bhaskaracharya Institute for Space Application and Geo-Informatics (BISAG), Gandhinagar, Gujarat. Daily rainfall data of 4 raingauge station for the year of 1988-2012 (25 years) were collected from the State Water Data Centre (SWDC), Gandhinagar, Gujarat. ArcGIS 9.3 is used at BISAG, Gandhinagar, Gujarat.

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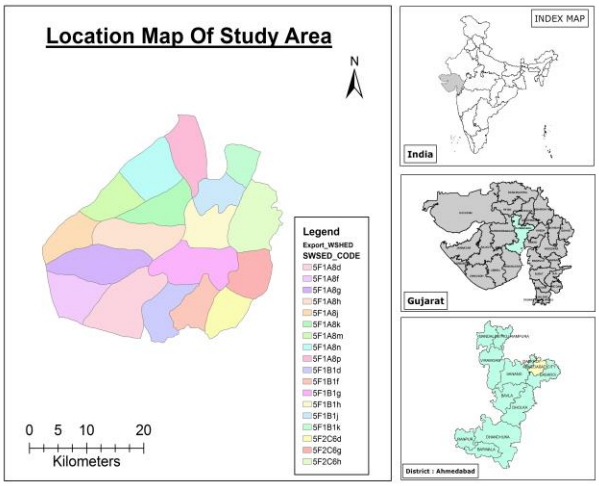

Fig. 1: Location Map of Study Area

III. METHODOLOGY

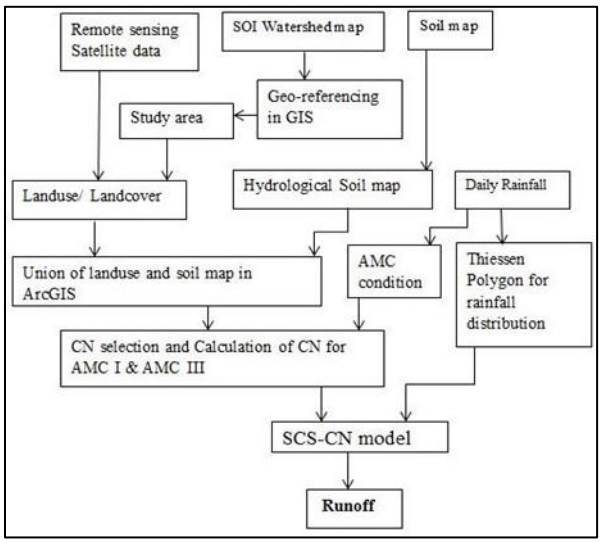

Fig. 2: Methodology for Rainfall-Runoff Estimation

A. SCS Curve Number Method:

Soil Conservation Model is distributed watershed modelling. The soil conservation service model developed by United States Department of Agriculture (USDA) computes direct runoff through an empirical equation that requires the rainfall and a watershed coefficient as inputs (T.R. Nayak et.al.2003). The general equation for the SCS curve number method is as follows:

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

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,

$$P = I_a + F + Q \qquad (2)$$

The value of the initial abstraction I_a to be approximately equal to 30% of the watershed storage S, as per Handbook of Hydrology as follows (Kumar et al., 1991).

$$I_a = 0.3\,S \qquad (3)$$

Solving equation 1 and 2 simultaneously,

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

The watershed storage S and Curve Number CN related by,

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

$$CN_w = \frac{\sum(CN_{II\,i} * A_i)}{A} \qquad (6)$$

Where CN_w is the weighted curve number; CN_i is the curve number from 1 to any number N;
A_i is the area with curve number CN_i; and A the total area of the watershed.
The parameter CN, having a range of values between 0 and 100 is called the curve number. In this method, a curve number (CN) is assigned to each watershed or portion of watershed based on soil type, landuse and antecedent moisture condition (Hydrology Handbook, 1996).

B. Antecedent Moisture Condition (AMC):

Antecedent moisture condition 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.

Table - 1
Classification of Antecedent Moisture Condition

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

The conversion of CNII to other two AMC conditions can be made through the use of following correlation equations.

For AMC-I:

$$CN_I = \frac{CN_{II}}{2.281 - 0.01281\,CN_{II}} \qquad (7)$$

For AMC-III,

$$CN_{III} = \frac{CN_{II}}{0.427 + 0.00573\,CN_{II}} \qquad (8)$$

C. Thiesson Polygon:

Daily rainfall data for 4 rain gauge station of 25 years (1988-2012) is collected from the state water data center. Thiesson polygon method is used for finding average distribution of rainfall in whole study area. Thiesson polygon is prepared using ArcGIS 9.3.

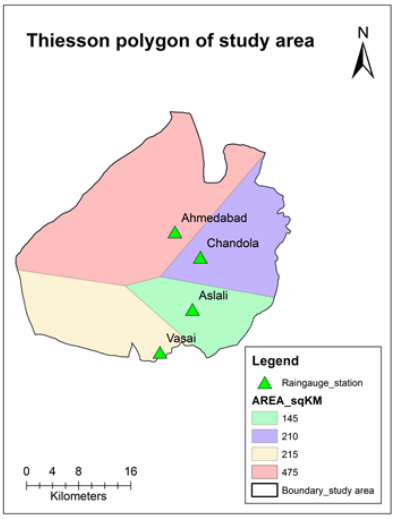

Fig. 3: Thiesson Polygon for Rainfall Distribution

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D. Hydrologic Soil Groups:

In the determination of CN, the hydrological soil classification is adopted. 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. In the present study, areas under different soil group were found 32% and 68% for B and C group of soil, respectively. The figure 4 shows the HSG map of study area.

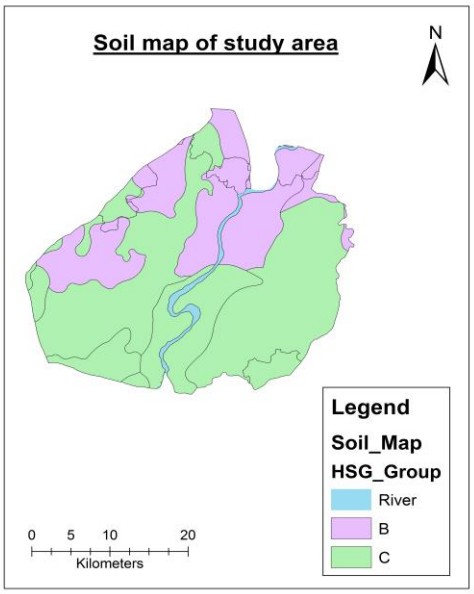

Fig. 4: Hydrological Soil Group Map of Study Area

E. Landuse/ Landcover Map:

Landuse/landcover map is prepared by mapping form the satellite map in GIS. Landuse map is prepared using visual interpretation technique from satellite image.

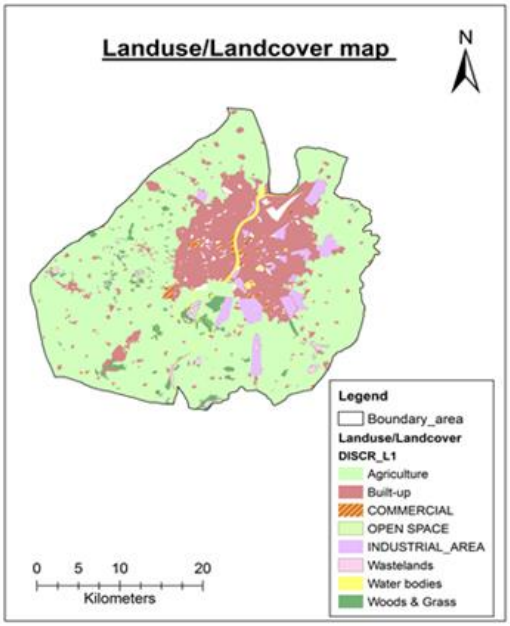

Fig. 5: Landuse/Landcover Map

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F. 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 85.81 (Taking CN=86) for AMC-II, CN for AMC-I=73 and AMC-III=94 are calculated from equation (7) and (8).

Table - 2
Calculation of Weighted Curve Number for
AMC II

LANDUSE	*HSG*	*CN*	*Total area in sq. km*	*% AREA*	*% Weighted CN*	*Weighted CN*
AGRICULTURE	*B*	*78*	*171.79*	*16.44*	*12.8208*	*AMC-II=85.81*
	C	*85*	*541.74*	*51.83*	*44.0592*	
BUILT-UP AREA	*B*	*92*	*117.71*	*11.26*	*10.3613*	
	C	*94*	*91.42*	*8.75*	*8.2220*	
COMMERCIAL AREA	*B*	*92*	*2.95*	*0.28*	*0.2598*	
	C	*94*	*2.82*	*0.27*	*0.2533*	
OPEN SPACE	*B*	*79*	*7.79*	*0.75*	*0.5889*	
	C	*86*	*3.07*	*0.29*	*0.2528*	
INDUSTRIAL	*B*	*88*	*9.45*	*0.90*	*0.7958*	
	C	*91*	*32.81*	*3.14*	*2.8567*	
WASTELAND	*B*	*86*	*2.41*	*0.23*	*0.1981*	
	C	*91*	*6.18*	*0.59*	*0.5379*	
WATERBODIES	*B*	*100*	*14.51*	*1.39*	*1.3887*	
	C	*100*	*19.14*	*1.83*	*1.8313*	
WOODS-GRASS COMBINATION	*B*	*58*	*6.13*	*0.59*	*0.3400*	
	C	*72*	*15.23*	*1.46*	*1.0491*	

IV. RESULT

Table - 3
Annual Rainfall - Runoff for Study Area

YEAR	*RAINFALL*	*RUNOFF*
	mm	*mm*
1988	*748.99*	*186.00*
1989	*674.43*	*184.38*
1990	*1044.41*	*424.95*
1991	*638.71*	*309.38*
1992	*553.88*	*62.64*
1993	*745.42*	*362.15*
1994	*1246.66*	*501.65*
1995	*365.89*	*57.89*
1996	*684.22*	*144.10*
1997	*1230.29*	*589.26*
1998	*845.09*	*166.94*
1999	*507.16*	*212.54*
2000	*618.68*	*190.07*
2001	*600.84*	*55.33*
2002	*260.53*	*12.32*
2003	*810.88*	*269.56*

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2004	*753.04*	*361.97*
2005	*1173.04*	*620.26*
2006	*917.58*	*280.11*
2007	*726.87*	*227.11*
2008	*422.04*	*65.47*
2009	*403.38*	*97.22*
2010	*1017.62*	*384.43*
2011	*609.27*	*146.83*
2012	*546.67*	*149.79*

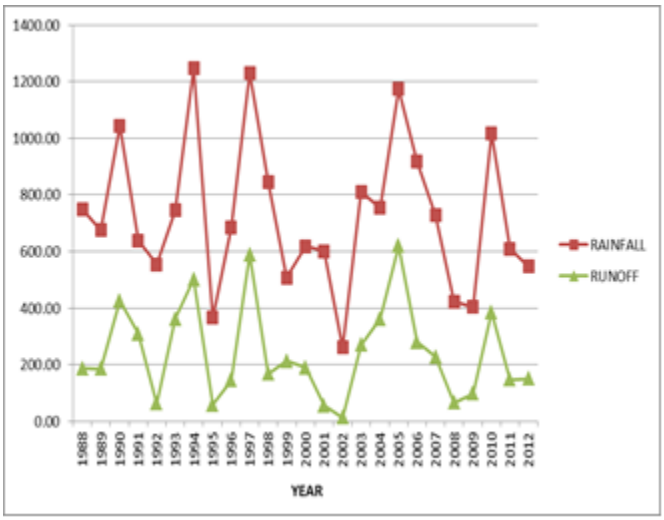

Fig. 6: Annual Rainfall Vs Annual Runoff

V. CONCLUSION

GIS is an effective tool for preparation of input parameters of SCS-CN model and it's also helpful in presentation of input parameters in form of various thematic maps.
Average runoff was calculated from the average rainfall using SCS-CN method integrated with remote sensing and GIS.

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