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Estimation of Runoff From Watershed using Remote Sensing and GIS

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***Abstract* – The runoff was estimated for the SA-13 watershed of Ashti, Beed District of Maharashtra state lies 75^0 04' 55" to 75^0 16' 25" E longitude and 18^0 40' 11" to 18^0 56' 20" N latitude with an areas of 21300 ha using remote sensing and GIS techniques. The watershed was divided into 15 micro-watersheds. Multidate satellite data of IRS P-6 LISS III of path 059 and row 096 with 23.5 m resolution was used. Different types of thematic maps like administrative boundary maps, slope map, land use land cover map and rainfall maps were derived from remotely sensed data and overlayed through ArcGIS software to assign the polygon wise curve number. Soil Conservation Curve Number method is used to determine curve numbers and runoff volume distribution in the watershed. The result of the study showed that the average rainfall for the year 2005 in the watershed was 406.50 mm and the average annual runoff was 93.52 mm, amounting 23.01 percent of the total rainfall.**

***Keywords* – Rainfall, Runoff, Watershed, SCS Curve Number, GIS.**

I. 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 functions. Runoff means the draining or flowing off of precipitation from a catchment area though a surface channel after satisfying all surface and sub-surface losses. Rainstorms generate runoff, and its occurrence and quantity are dependent on the characteristics of the rainfall event, the intensity, duration and distribution. Also soil type, vegetation cover, slopes and catchment type affects the occurrence and volume of runoff. However, runoff is one of the most important hydrologic variables used in most of the resources applications. Reliable prediction of quantity and rate of runoff from land surface into stream and river is difficult and time consuming to obtain for ungauged watershed. However, this information is needed in dealing with many watershed development and management problems. Conventional methods for prediction of river discharge require considerable hydrological and meteorological data. Collection of these data is expensive, time consuming and a difficult process. The accurate information on rainfall and runoff is not available in India. But this information is required for the estimation of sediment yield and planning the watershed development and management programmes (Zade et al., 2005). In India, most of the agricultural watersheds are ungauged, having no past record whatsoever of rainfall-runoff processes (Sarangi et al., 2005a, b). Runoff estimation from Remote Sensing data provides quick results for decision-makers as it is one of the best techniques to estimate runoff spatially and accurately. Therefore, in this study remote sensing data and SCS (Soil Conservation Services) Curve Number method modified for Indian conditions is used to determine runoff volume for the watershed.

II. MATERIALS AND METHODS

1. Study Area

Watershed SA-13 selected for the study was located in Ashti tahsil of Beed district in Maharashtra. Watershed SA - 13 spans from 750 04' 55" to 750 16' 25" E longitude and 180 40' 11" to 180 56' 20" N latitude occupying an area of about 21,300 ha (Fig 1). The elevation of the watershed ranges from 730 m above mean sea level at north-east border and gradually decreasing down to 575 m at the confluence of Sina and Talwar river. The maximum temperature of the study area was ranges between 400 C to 420 C and minimum temperature ranges between 120 C to 130 C and mean relative humidity was approximately 52.6 percent. The average rainfall in study area is 794 mm. The mean relative humidity was approximately 52.6 percent.

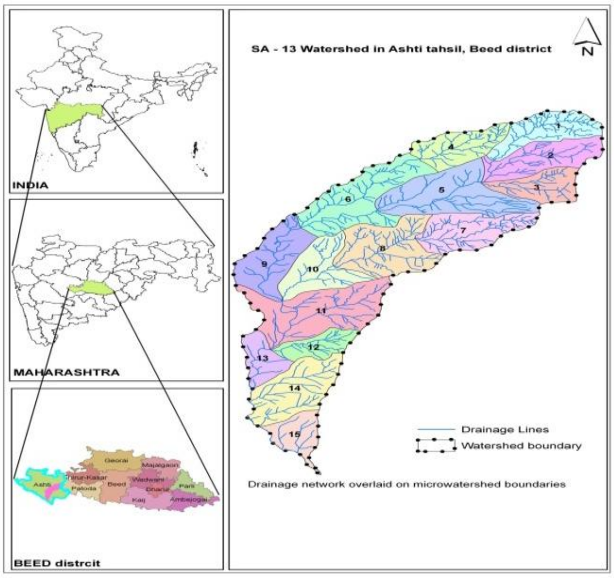

Fig.1. Location map of study area

2. Data Used

2.1 Remote Sensing Data

Multi-date (8thNov, 2005, 19th Jan, 2006 and 25th Apr, 2006) Indian Remote Sensing Satellite data of IRS-P6, Resourcesat-1 of row 059 and path 096 with spatial resolution of 23.5 m was used for the estimation of runoff from the watershed.

2.2 Rainfall data

Daily rainfall data of Ashti rain gauge station for the years 2005 was downloaded from Agriculture Department,

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Govt. of Maharashtra web site of http://www.mahaagri.gov.in and used to estimate the runoff.

3. Methodology

SOI toposheet numbers 47 N/1, 47 N/2 and 47 N/5 on 1:50000 scales were used for delineating the watershed boundary and preparation of base map and drainage map. In order to know the different natural resources, terrain conditions, etc. in the study area, toposheet along with the satellite data was used to prepare different thematic maps, updation of drainage, land use/ land cover, soil map. Fig. 2 shows the methodology flow used to estimate runoff using SCS Curve Number model. Fig. 3 shows the land use/ land cover map of watershed. Daily rainfall data of the year 2005 for rain gauge stations in the watershed for a period of 1998 to 2005 was used for estimation of runoff. Runoff was estimated with the aid of hydrological model using USDA (United States Department for Agriculture) methodology for estimation of surface runoff using SCS (Soil Conservation Service) Curve Number method.

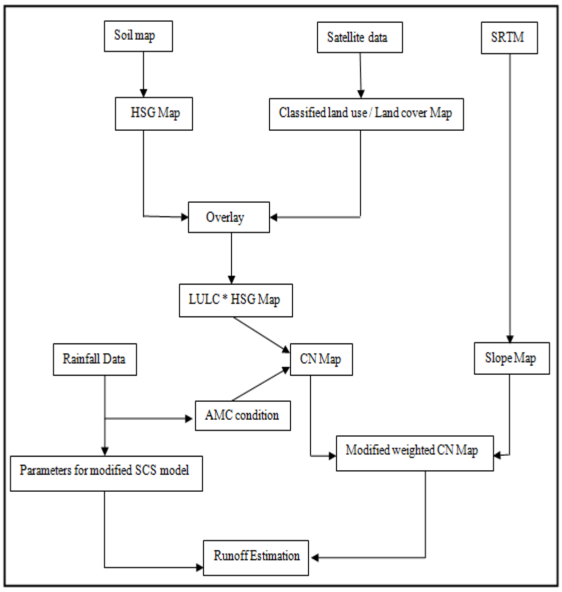

Fig2. Flow Chart for Runoff Estimation

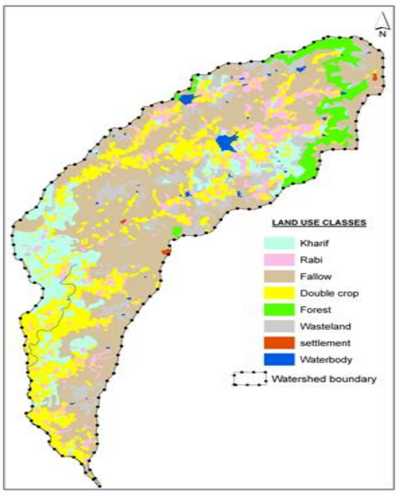

Fig.3. Land Use Land Cover map of watershed

3.1 SCS Curve Number Method

The curve number method (Soil Conservation Services, SCS, 1972) known as the hydrologic soil cover complex method, is a versatile and widely used procedure for runoff estimation. This method includes several important properties of the watershed namely soil permeability, land use and antecedent soil water conditions which are taken into consideration. To estimate the curve number, depth of runoff the land use/land cover and hydrological soil group map showing hydrologic soil groups prepared from IRS satellite data were integrated. The Curve Number method was used for runoff estimation in terms of the depth.

$$S = (24500/CN) - 245$$

Where, S = Maximum recharge capacity of watershed after 5 days rainfall antecedent, mm and CN = Curve Number.

The direct runoff of the watershed was calculated using formula;

$Q = 0$ If $P <= 0.2S$

$Q= (P-0.2S) 2/ (P+0.8S)$ If $P >= 0.2S$

Where, Q is runoff depth, mm, P is rainfall, mm and S is maximum recharge capacity of watershed after 5 days rainfall antecedent, mm.

3.2 Antecedent Moisture Conditions

Antecedent Moisture Condition (AMC) refers to the water content present in the soil at a given time. It is determined by total rainfall in 5 day period preceding a storm. The AMC value is intended to reflect the effect of infiltration on both the volume and rate of runoff according to the infiltration curve. An increase in index means an increase in the runoff potential. SCS developed three antecedent soil-moisture conditions and labeled them as I, II, III, according to soil conditions and rainfall limits for dormant and growing seasons. Classification of Antecedent Moisture Condition is shown in Table 1.

Table 1: Classification of Antecedent Moisture Condition

AMC	**5-days Antecedent Rainfall (mm)**	
	Active growing season	**Dormant season**
I	Dry (< 35)	Dry (< 12.5)
II	Medium (35 to 52.5)	Medium (12.5 to 27.5)
III	Wet (> 52.5)	Wet (> 27.5)

3.3 Hydrological Soil Groups (Hsg) Classification

SCS developed soil classification system that consists of four groups, which are identified as A, B, C, and D according to their minimum infiltration rate. The HSG map developed for the study area was used directly to derive the curve numbers. Fig. 4 shows the Hydrological Soil Group map of watershed.

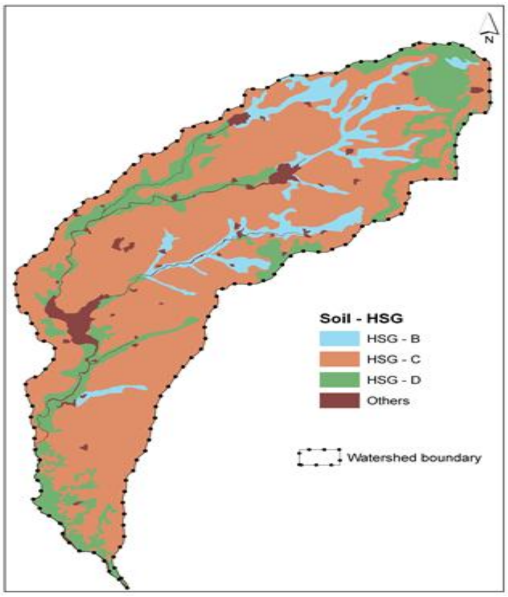

Fig.4. Hydrological Soil Group (HSG) map of watershed

3.4 CN Values

CN values were determined from hydrological soil group and antecedent moisture conditions of the watershed. The CN values for different land uses and hydrologic soil groups were obtained from Technical Release 55, (USDA-NRCS, 1986). The Curve Number values for AMC-I and AMC-II were obtained from AMC-II by the method of conservation. Runoff curve numbers (AMC II) for hydrologic soil cover complex are shown in Table 2. Fig 5 shows the curve number map of watershed.

Table 2: Hydrologic Soil Groups in the Watershed

S. No.	Hydrologic Soil Group	Area (ha)	% of Total Geo-graphical Area
1	B	1885.5	8.85
2	C	14821.0	69.58
3	D	3759.7	17.65
4	Others(Habitation Mask, Water body Mask)	833.8	3.92
Total		21300.0	100.00

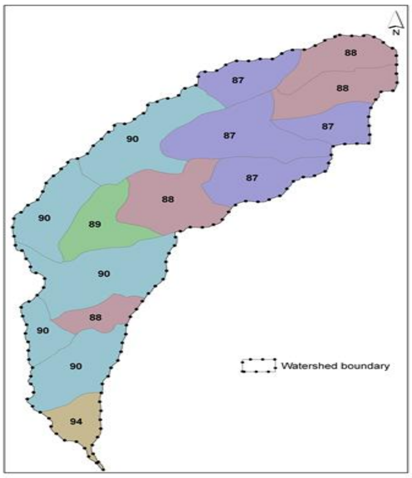

Fig.5. Micro-watershed wise mean CN map of watershed

III. Results and Discussions

The study area constitutes different land use/ land cover, about 83.79 % of the area is occupied by agricultural land, 5.29 % of area is covered by forest land, 9.57 % of area by waste land, 1.20% of area by water body and remaining 0.14 % of the area is occupied by settlement. In general, among the different land cover types the crop land plays the major role for the direct surface runoff. From SCS Curve number, the runoff for the watershed was estimated to be 96.07 mm the year 2005. Table 3 shows the annual rainfall and runoff for watershed during the year 2005.

Table 3: Rainfall and Runoff Depth for the Year 2005

Micro-Watershed	Rainfall (mm)	Runoff (mm)	% Runoff
1	406.5	89.05	21.91
2	406.5	89.05	21.91
3	406.5	83.32	20.50
4	406.5	83.32	20.50
5	406.5	83.32	20.50
6	406.5	102.54	25.23
7	406.5	83.32	20.50
8	406.5	89.05	21.91
9	406.5	102.54	25.23
10	406.5	95.42	23.47
11	406.5	102.54	25.23
12	406.5	89.05	21.91
13	406.5	102.54	25.23
14	406.5	102.54	25.23
15	406.5	143.46	35.29
Average	**406.5**	**96.07**	**23.63**

IV. Conclusion

The estimation of runoff using GIS based SCS curve number method can be used in watershed management effectively. All the factors in SCS model are geographic in character. Due to the geographic nature of these factors, SCS runoff model can be easily molded into GIS. The conclusions that may be drawn are:

- The combination of remote sensing and SCS model makes the runoff estimate more accurate and fast;
- Geographical information system arises as an efficient tool for the preparation of most of the input data required by the SCS curve number model;
- The runoff estimated using SCS curve number model are comparable with the runoff measured by the conventional method; and
- The study demonstrates the importance of remotely sensed data in conjunction with GIS to derive the model parameter to estimate surface runoff from the ungauged watershed. Results obtained clearly shows the variation in runoff potential with different land use/land cover and with different soil conditions.
- This approach could be applied in other Indian watersheds for planning of various conservation measures.

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