

Estimation of runoff for agricultural watershed using SCS Curve Number and Geographic Information System**Ashish Pandey¹, V.M. Chowdary², B.C.Mal³ and P.P.Dabral¹****ABSTRACT**

Soil Conservation Service (SCS) model has been applied in the present study for the estimation of runoff from an agricultural watershed. The Karso watershed is about 2793 ha, is a part of Damodar Barakar catchment, which is situated in Hazaribagh district of Jharkhand State. This method involves various types of information related to Hydrologic soil Group, vegetation and antecedent moisture condition of the watershed. The soil map, land use map have been prepared by the information available at Soil Conservation Department, Damaodar Valley Corporation, Hazaribagh and topographical maps were collected from Survey of India, Calcutta. ERDAS IMAGINE-8.4 software was used for the rectification of reference map, soil map and land use map of the watershed. The vector layers were generated in ARC/INFO and used as input to derive modified Soil Conservation Service (SCS) Curve Number for study area. The SCS model was then applied to estimate the runoff for daily storm and was validated comparing it with the measured runoff of few selected events of monsoon period for the year 1993.

Key words: GIS, SCS model, Runoff, watershed, land use

¹**Corresponding Author:** E-mail: apandey@nerist.ernet.in, p.ashish@lycos.com and ppd@nerist.ernet.in, Phone: +91-360-257401-5 Ext. 6210 (O), +91-360-257 357 (R)

Fax: +91-360-244 307 (O)

¹Department of Agricultural Engineering, NERIST, Nirjuli, Itanagar, Arunachal Pradesh India-791 109, ² Regional Remote Sensing and Service Centre, Kharagpur, ³Department of Agricultural and Food Engineering, IIT, Kharagpur, India-721 302

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. In India, the availability of accurate information on runoff is scarcely available in few selected sites. However, quickening of the watershed management programme for conservation and development of natural resources management has necessitated the runoff information. Advances in computational power and the growing availability of spatial data have made it possible to accurately predict the runoff. The possibility of rapidly combining data of different types in a Geographic Information System (GIS) has led to significant increase in its use in hydrological applications. The curve number method (SCS, 1972), also 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's permeability, land use and antecedent soil water conditions which are taken into consideration. In the present study, the runoff from SCS (Soil Conservation Services) Curve Number model modified for Indian conditions has been used by using conventional database and GIS for Karso watershed (Hazaribagh, India).

MATERIALS AND METHODS**Study area**

The study area, Karso watershed, which lies within Damodar Barakar catchment is situated between $85^{\circ} 23' 30''$ to $85^{\circ} 28'$ E longitude and $24^{\circ} 12'$ to $24^{\circ} 18'$ N latitude with an elevation ranging from 390-650 m above MSL (Mean Sea Level) and extends over a total area of 2793 ha. The watershed receives an average annual rainfall of 1300 mm and more than 80% of the rainfall is received during the monsoon season (June to September). The minimum and maximum temperature varies in the range of 3° C to 42° C. The mean relative humidity varies from a minimum of 40% in April to a maximum of 85% in the month of July. The overall climate of the area can be classified as sub-humid tropical. The soil is mainly sandy loam type occupying the maximum area with a land slope varying from 0 to 8 %, maximum slope of some hilly parts of the watershed is upto 22% and the soil depth ranges from 0 to 45 cm.

Land use / Land cover map

The conventional land use/ land cover map of the watershed was obtained from the Soil conservation department of Damodar valley Corporation, Hazaribagh, Jharkhand State. Boundaries of different land use were digitized in ARC/INFO and the attributes were given. Five land use/ land cover were categorised in the watershed (Table. 1 and Fig 1).

Soils

The soil map of the watershed was traced, scanned and rectified in ERDAS IMAGINE 8.4 by using the registered topographic maps. Boundaries of different soil textures were digitized in ARC/INFO and the polygons representing various soils class were assigned and different colours for recognition (Fig. 2). hydrologic soil groups i.e. A, B, C, and D were considered for the classification of soils of the watershed. The soils of group A were of low runoff potential, high infiltration rate, the soils of group B were of moderate infiltration rate, moderately well drained to well drained. The soils of group C were of moderately fine to moderately coarse textures, moderate rate of water transmission and the soils of group D were of slow infiltration and high runoff potential.

The Curve Number Method

The Curve Number method (SCS, 1972), also known as the Hydrologic Soil Cover Complex Method, is a versatile and widely used procedure for runoff estimation. In this method, runoff producing capability is expressed by a numerical value varying between 0 - 100. In the past 30 years, the SCS method has been used by a few researchers because it gives consistently usable results (Rao *et al.*, 1996; Sharma *et al.* 2001; Chandramohan and Durbude, 2001; Sharma and Kumar, 2002) for runoff estimation. The SCS method with initial abstraction consideration is given below:

The curve number method assumes that

$$S = \frac{25400}{CN} - 254 \quad (1)$$

$$Q = \frac{(P - 0.3S)^2}{(P + 0.7S)} \quad (2)$$

Where,

Q = Runoff depth, mm

P = Rainfall, mm

S = Maximum recharge capacity of watershed after 5 days rainfall antecedent

$I_a = 0.3 S$ (Initial abstraction of rainfall by soil and vegetation, mm)

CN = Curve Number, CN is found out from the table.

$$CN = \frac{\sum (CN_i \times A_i)}{A} \quad (3)$$

Where, CN = weighted curve number.

CN_i = curve number from 1 to any no. N.

A_i = area with curve number CN_i

A = the total area of the watershed.

The land use/ land cover map and soil map were intersected in command tools of ARC/Info. The areas of different land use class and soil combinations were obtained in the attributes selection menu by using logical expression and accordingly different CN (Curve-Number) values were assigned. Thus weighted value of CN for the whole watershed was worked out. The CN values for AMC II condition can be converted in to CN values for AMC I and AMC III condition by using available conversion factors as suggested by Suresh, 1997. Putting the value of Curve Number in formula (1), the recharge capacity 'S' was calculated. The direct runoff of the watershed was calculated using formula (2) .

The daily rainfall data for the years 1993 of the study area and the values of maximum potential retention, S obtained from the weighted CN for the watershed area were used for the estimation of runoff from SCS (model). The estimated runoff was then validated by comparing it with the four selected events of monsoon season.

RESULTS AND DISCUSSION

Based on the hydrological soil group, the maximum area of Karso watershed was observed to be under hydrological soil group B (84.32%) followed by (15.23 %) C and (0.45 %) group A. Similarly, the study area was identified in the five major land use classes namely agricultural land (42.98%), dense forest (34.74 %), wasteland (19.64 %), settlement (2.05%), and hard surface (0.59%). The major area of the watershed was under agricultural land. The agricultural land was divided into three categories i.e. area under paddy cultivation (19.35%), straight row crops (12.27%) and poor contoured (11.36%) crops. The USDA curve number table (Tripathi, 1999) modified for Indian condition was used for the determination of the curve number for the watershed. By intersecting the land use map and soil map the curve number was assigned to the each combination of land use and soil type. Weighted value of CN were found out to be 71.42 52.75 and 85.7 for AMC II, AMC I and AMC III conditions respectively. The daily rainfall data for the year 1993 were collected and the weighted curve number of the watershed was used for the estimation of runoff. The calculated runoff was found out to be 244.40 mm for monsoon season of the year 1993 which is approximately 35.52 per cent of the total rainfall.

In order to validate the SCS model output, estimated runoff was compared with measured runoff for four selected events of the monsoon season (Table 3). The maximum and minimum deviation were observed to be 28.33 and 3.27 per cent respectively, which are within the permissible limit.

CONCLUSIONS

In the present study the methodology for determination of Runoff for Karso watershed using GIS and SCS model was described. This approach could be applied in other Indian watersheds for planning of various conservation measures.

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Table: 1. Land use / cover classes present in the study area (Year 1993)

| Sl.No. | Land Use/ Land Cover | Area (ha) | Area (%) |
|--------|--------------------------|-----------|----------|
| 1 | Agricultural Land | | |
| | Paddy | 540.45 | 19.35 |
| | Poor Contoured | 131.35 | 11.36 |
| | Straight Row | 342.85 | 12.27 |
| 2 | Settlement | 57.25 | 2.05 |
| 3 | Dense Forest | 970.1 | 34.74 |
| 4 | Waste Land (i.e. fallow) | 548.50 | 19.64 |
| 5 | Hard surface | 16.55 | 0.59 |
| | Total Area | 2793.00 | |

Table: 2. Status of different soil group presents in the study area

| No. | Sl. | Soil Group | Area (ha) | Area (%) |
|-----|-----|------------|-----------|----------|
| 1 | | A | 13.09 | 0.47 |
| 2 | | B | 2354.72 | 84.30 |
| 3 | | C | 425.19 | 15.23 |
| | | | 2793.00 | |

Table: 3. Comparison of estimated runoff with the observed runoff

| Storm Date | Rainfall (mm) | AMC Condition | Runoff Observed (mm) | Estimated Runoff (mm) | Percent deviation |
|------------|---------------|---------------|----------------------|-----------------------|-------------------|
| 11-07-1993 | 43.00 | II | 1.54 | 1.37 | 11.03 |
| 25-07-1993 | 21.1 | I | 17.18 | 12.33 | 28.33 |
| 21-08-93 | 105.6 | III | 85.92 | 63.78 | 25.76 |
| 13-10-1993 | 72.2 | III | 34.37 | 34.73 | 1.04 |

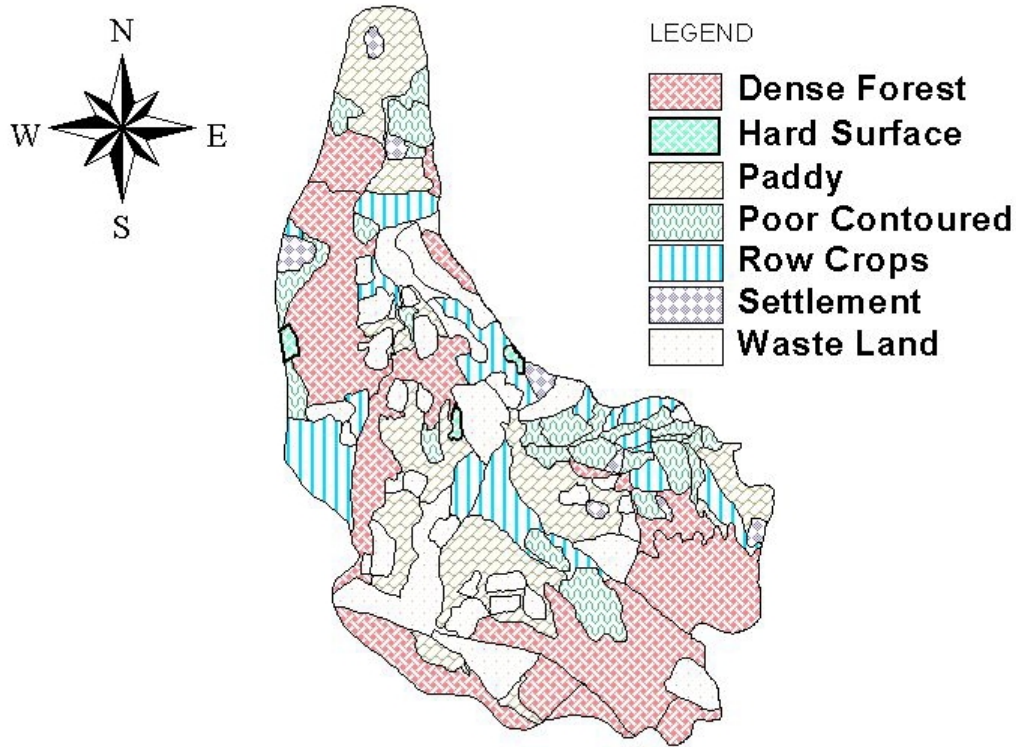


Fig.1 Land use/Land cover present in the watershed

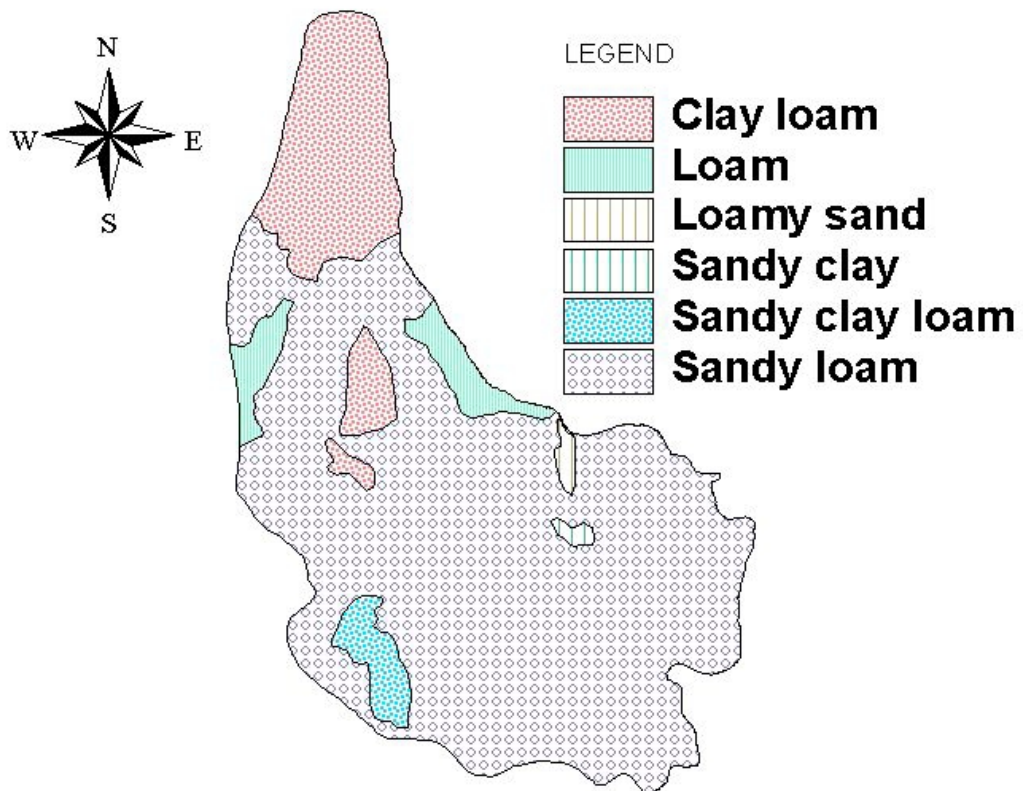


Fig.2. Soil Map of the watershed

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