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# Determination of Surface Runoff in Amreli District Gujarat, India using GIS based SCS Curve Number Method

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## Abstract

Among the most basic challenges of hydrology are the prediction and quantification of runoff of the area. The runoff curve number (CN) is a key factor in determining runoff is the SCS (Soil Conservation Service) based hydrologic modeling method. In this paper soil conservation system (SCS) curve number method is used for rainfall-runoff estimation that consider parameters like slope, vegetation cover, area of watershed. SCS-CN provides empirical relationship for estimating surface runoff as a function of soil type and land use. Surface runoff is calculated for the Amreli district in Gujarat, India where heavy Rainfall occurred in June 2015 using the GIS-based SCS-CN method. The estimated composite curve number for the entire Amreli District is about 87. The present study clearly demonstrates that that the integration of GIS with the SCS-CN method provides a powerful tool for estimating surface runoff in Amreli District.

**Keywords: Surface Runoff, GIS, Amreli, SCS-CN**

## I. INTRODUCTION

Runoff is the drainage of precipitation from a catchment, which flows out through its natural drainage system. After the occurrence of infiltration and other losses from the precipitation, the excess rainfall flows out through the small natural channels on the land surface to the main drainage channel. Most environmental process show complicated interrelations, both time and space, leading to numerical models with a complex mathematical structure. Also environmental models require huge amount of data often coming from many sources like Remote Sensing. Knowledge of runoff that depends upon many factors like precipitation, recharge of the basin, type of soil etc. is one of such important parameter.

Most of the watersheds in dry land areas are un-gauged and very limited hydrological data are available. For most efficient utilization of available rainwater, reasonable accurate estimate of runoff for a given storm for a watershed is essential. Further from a rain fed watershed, along with the assessment of above runoff, the assessment of soil moisture throughout the crop growth period is vital due to erratic distribution of rainfall

Many investigators has developed and applied models based on various levels of physical simplifications. However, there are some important models that fetches enormous application to Indian conditions like rational method, khosla's model, cook's model and SCS Rainfall-Runoff model.

As against all the above models, SCS Rainfall –Runoff Model is well-established model reflecting quite an exhaustive research database all over the world. In India considerable research has been done in different soil climatic regions and succeeded in arriving at various co-efficient used in this method. Most of the parameters that are affecting runoff are taken into account in this model. Each parameter in turn, is classified precisely into a number of classes depending on their runoff producing potential. This method also takes into account the distribution of rainfall with time in the form of AMC conditions. Some of the parameters are amenable from remote sensing data. Since most of the input data is geographic in nature, performance of analyses becomes easier with the use of GIS. Hence, SCS Rainfall-Runoff model has been chosen to study the hydrologic response of a watershed to precipitation and estimate runoff volumes for adopting various water conservation measures.

## II. STUDY AREA

District Amreli is located near the Gulf of Khambhat in western India. Its mainland extends between 20 degree - 45 min and 22 degree – 00 min north latitude and between 70 degree 50 Min and 71 degree - 40-min longitude. District is bound by district Bhavnagar in the East, Junagadh in the West, Rajkot in the North and Arabian Sea in the south. It covers 7381 sq.km Area. It has population of 15, 14,190 as per 2011 census. District has 11 talukas which are Amreli, Babra, Bagasara, Dhari, Jafrabad, Khamba, Lathi, Liliya, Rajula, Savarkundla and Vadiya. Amreli has 9 Urban Local Bodies (ULB), namely Amreli, Bagasara, Chalala,

Damnagar, Jafrabad, Lathi, Rajula, Savarkundla and Babra. District has total 626 revenue villages and population density of 205 inhabitants per square km.

Climate of Amreli district can be regarded as one of the extreme kind with hot summer and cold winter except in the coastal region, where it is generally pleasant throughout the year. The air is humid in costal locations. The temperature at district headquarters ranges from 45 degree centigrade higher in the summer and 4.2 degree centigrade lowest in the winter. The average annual rainfall is 609 mm. Mid June to October is the normal rainy season.

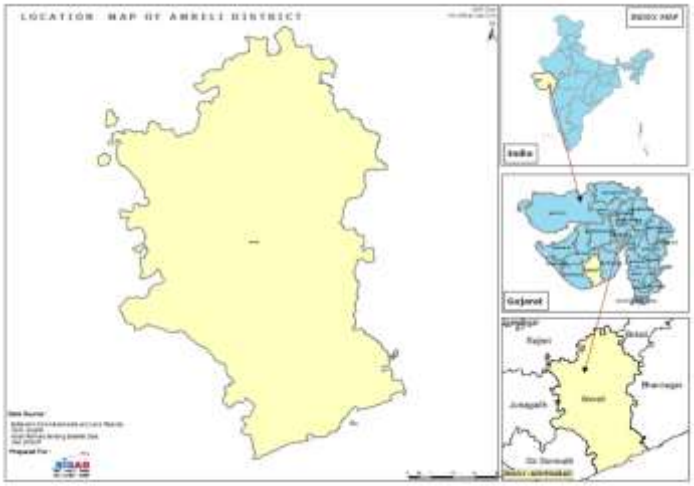



Fig. 1: Location Map of Study Area showing Amreli District

## III. DATA COLLECTION AND DATA GENERATION

### *A. Data Collection:*

Satellite (IRS P-6) LISS-III image data and Geo spatial data are obtained from Bhaskaracharya Institute for Space Application and Geo-Informatics, (BISAG), Gandhinagar, Gujarat, India. Hydrological data like precipitation data are collected from state water data center. DEM data has been obtained from USGS site

### *B. Data Generation:*

Thematic maps like watershed map, soil map and soil cover complex maps were generated in Arc GIS.

## IV. METHODOLOGY

In the early 1950s, the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) (then named the Soil Conservation Service (SCS) developed a method for estimating runoff from rainfall. This method also referred as the CN method.

The SCS curve number method is based on the water balance equation & two fundamental hypotheses which are stated as, 1).ratio of the actual direct runoff to the potential runoff is equal to the ratio of the actual infiltration to the potential infiltration, and 2).the amount of initial abstraction is some fraction of the potential infiltration. (Hand book of Hydrology 1972).

$$Q/(p\text{-}Ia) = F/S \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$F = P(Ia\text{-}Q) \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Substituting eq. (2) in eq. (1) and by solving;

$$Q = (P\text{-}Ia)2/((P\text{-}Ia)+3) \quad \ldots\ldots\ldots\ldots\ldots (3)$$

Where, Q = actual runoff (mm), P = rainfall (mm), Ia = initial abstraction, which represents all the losses before the runoff begins and is given by the empirical equation.

$$Ia = 0.2S \quad \ldots\ldots\ldots\ldots\ldots (4)$$

Substituting eq. (4) in eq. (3); the eq. (3) becomes

$$Q = (P\text{-}0.2S)2/((p+0.8S)) \quad \text{For } P > Ia(0.2S) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

S = the potential infiltration after the runoff begins given by following equation.

$$S = 25400/CN\text{-}254 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where, CN is Curve Number.

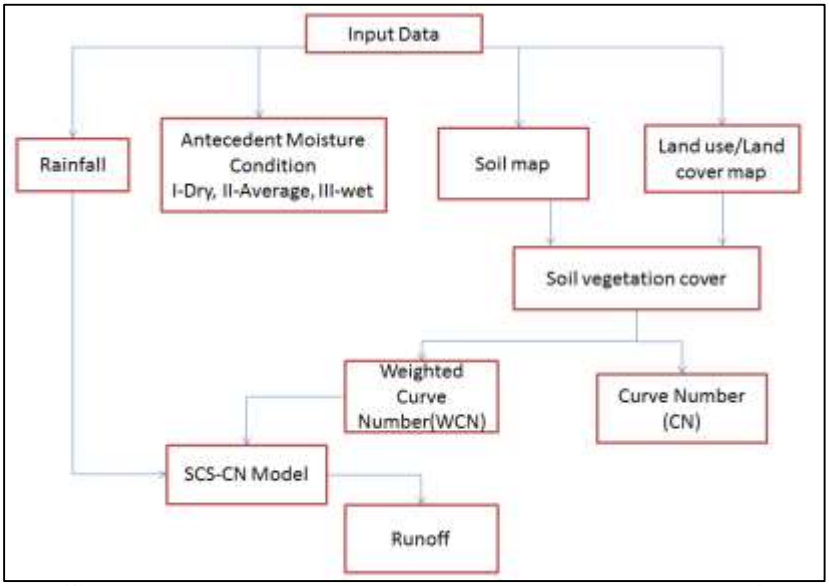
The CN (dimensionless number ranging from0 to 100) is determined from a table, based on land-cover, HSG, and AMC. HSG is expressed in terms of four groups (A, B, C, D), according to the soil's infiltration rate. AMC is expressed in three levels (I, II and III), according to rainfall limits for dormant and growing seasons. CN value was adopted from Technical release (TR-55)

Although, SCS method is originally designed for use in area of 15 km2, it has been modified for application to larger area by weighing curve numbers with respect to watershed/land cover area.

$$CNw=\sum[\ (CNi*Ai)\ ]/A \quad \ldots\ldots\ldots\ldots\ldots\ldots\ (7)$$

Where CNw is the weighted curve number;
CNi is the curve number from 1 to any number;
Ai is the area with curve number CNi; and A the total area of the District

## V. METHODOLOGY FOR SCS-CN METHOD



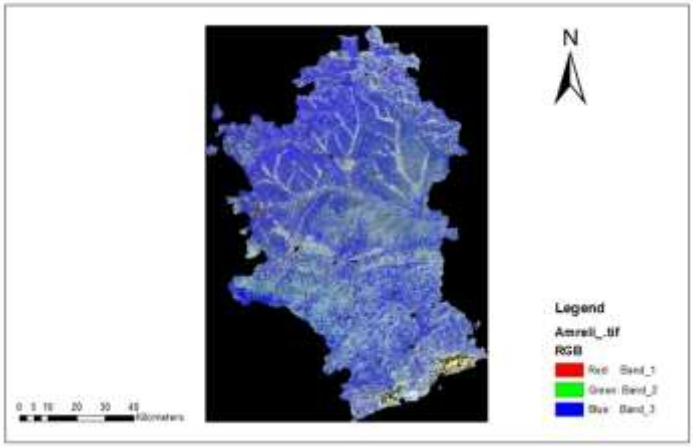




Fig. 2: Satellite Image of Study Area

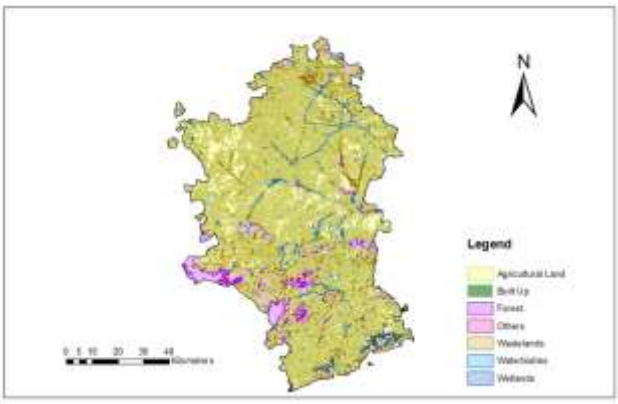



Fig. 3: Land Use Map

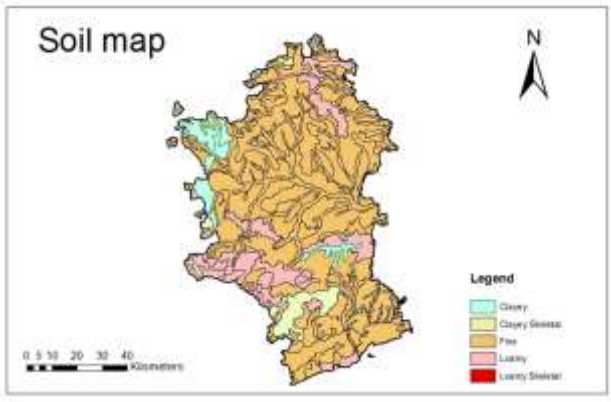



Fig. 4: Soil Map

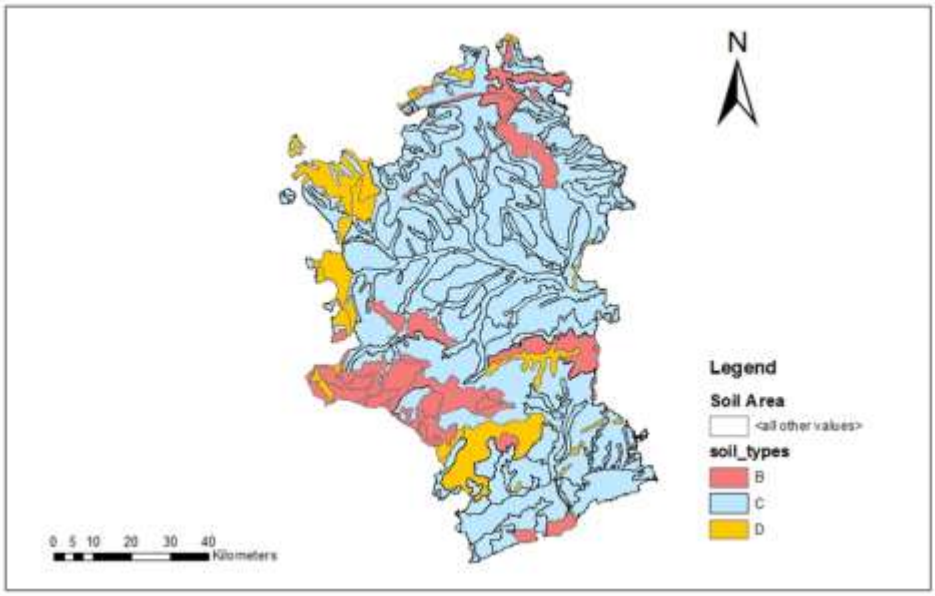



Fig. 5: Hydrologic Soil Group Map

Table – 1
Runoff Curve Numbers (Amc Ii) For Soil Cover

| HSG | Types of Soil | Soil Textures | Runoff Potential | Minimum Rate of Infiltration (mm/hr) | Water Transmission |
|---|---|---|---|---|---|
| A | Deep,well drained soils | sand,loamy sand or Sandy loam | Low | 7.62 - 11.43 | High rate (0.30 in/hr) |
| B | Moderately deep, well drained with moderately fine to coarse textures | silt loam or loam | Moderate | 3.81 - 7.62 | Moderate rate (0.15-0.30 in/hr) |
| C | Moderately fine to fine textures | Sandy clay loam | Moderate | 1.27 - 3.81 | Low rate (0.05-0.15 in/hr) |
| D | Soil which swell significantly when wet,heavy plastic and soil with a permanent high water table | clay loam,silty clay loam,sandy clay,silty clay,clay | High | 0 - 1.27 | Very Low rate (0-0.05 in/hr) |

## VI. RESULT AND DISCUSSION

Surface runoff is estimated using SCS curve number method. Table 2 shows the value of weighted curve number which is 86.58 .Fig.2 shows the graph of rainfall-runoff of 2015 and fig 2 shows the graph of Rainfall-Runoff of 23rd, 24th and 25th june 2015 when highest rainfall occurred in Amreli District Gujarat, India.

Table – 2
Calculation of Weighted Curve Number

| Land Use | soil type | CN | Area in sq.km | % of Area | % of Area*CN | WCN |
|---|---|---|---|---|---|---|
| Agriculture | B | 71 | 148.681 | 2.037814263 | 144.6848127 | |
| | C | 88 | 5710.594 | 78.26911241 | 6887.681893 | |
| | D | 91 | 126.374 | 1.73207565 | 157.6188841 | |
| Built Up | B | 90 | 4.382 | 0.06005947 | 5.405352325 | |
| | C | 94 | 97.206 | 1.332300517 | 125.2362486 | |
| | D | 95 | 3.1274 | 0.042863986 | 4.072078685 | |
| Forest | B | 66 | 29.295 | 0.401515788 | 26.50004199 | |
| | C | 77 | 419.377 | 5.747959942 | 442.5929155 | |
| | D | 83 | 13.881 | 0.190252284 | 15.79093954 | |
| Others | B | 70 | 0.065 | 0.000890887 | 0.06236207 | |
| | C | 74 | 9.286 | 0.127273446 | 9.418235014 | 86.56 |
| | D | 78 | 0.177 | 0.002425953 | 0.189224337 | |
| wasteland | B | 67 | 31.266 | 0.428530214 | 28.71152434 | |
| | C | 77 | 473.83 | 6.494290005 | 500.0603304 | |
| | D | 83 | 12.122 | 0.166143519 | 13.78991205 | |
| waterbodies | B | 100 | 5.223 | 0.071586174 | 7.158617372 | |
| | C | 100 | 153.266 | 2.100656041 | 210.0656041 | |
| | D | 100 | 1.153247 | 0.015806345 | 1.580634503 | |
| wetlands | B | 97 | 1.107 | 0.015172486 | 1.471731141 | |
| | C | 97 | 55.243 | 0.757157763 | 73.44430299 | |
| | D | 97 | 0.446 | 0.006112853 | 0.592946783 | |
| | | | 7296.101647 | 100 | 8656.128591 | |

### *A. Rainfall –Runoff of 2015*

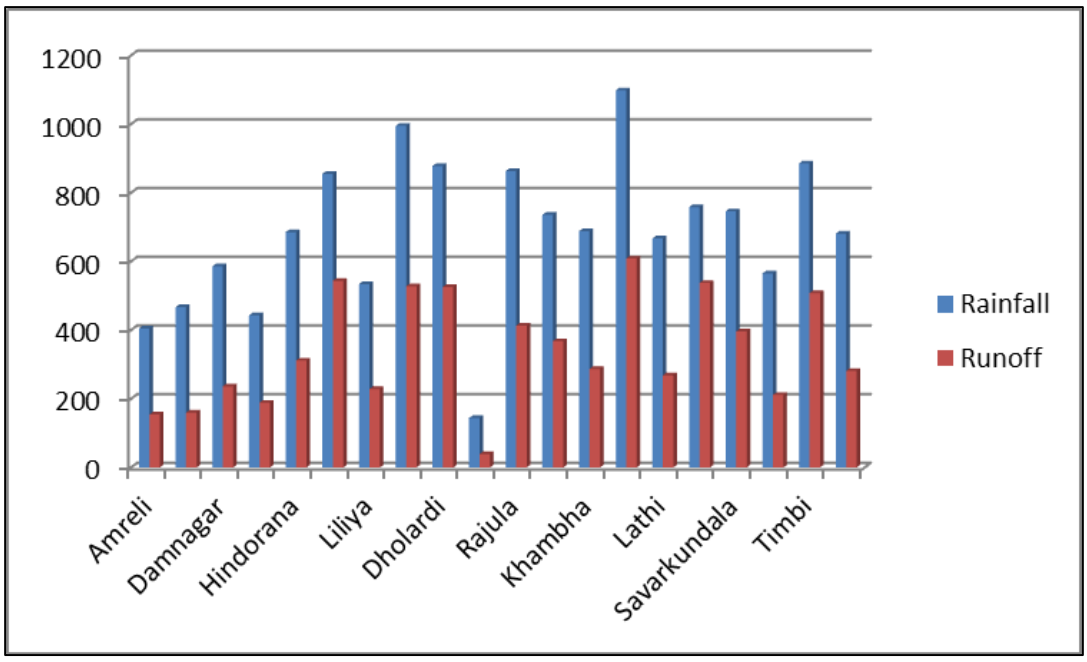



Fig. 6: Rainfall –Runoff of 2015

### *B. Rainfall- Runoff of 23rd, 24th and 25Th June 2015*

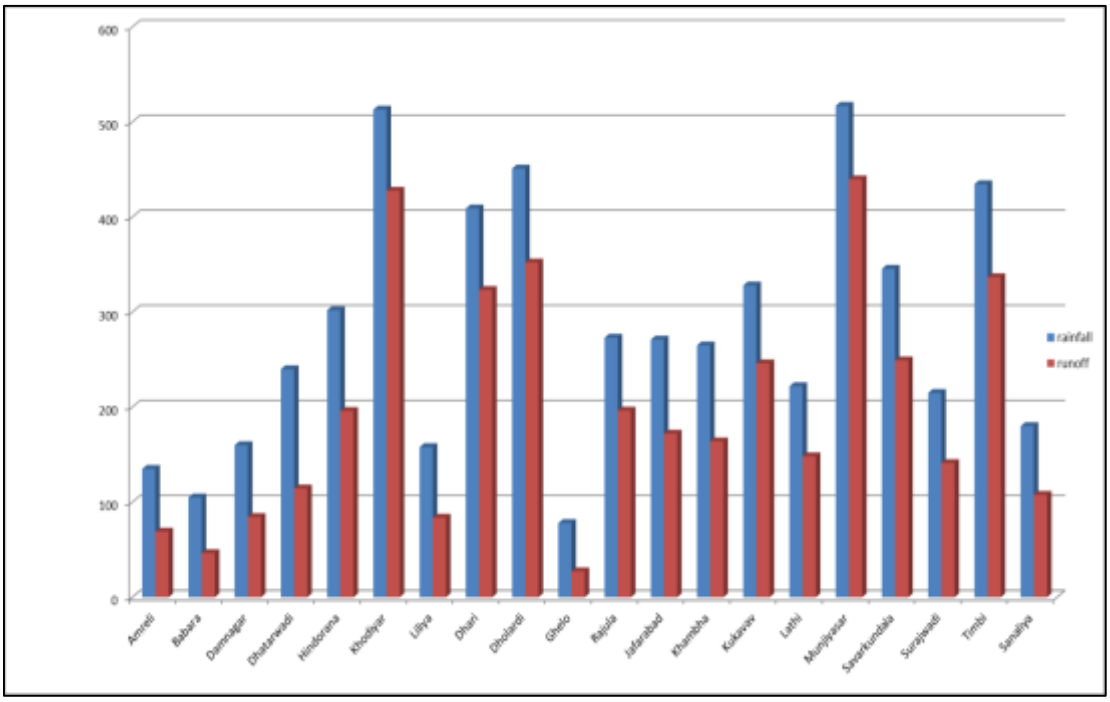



Fig. 7: Rainfall- Runoff of 23rd, 24th and 25Th June 2015

## VII. CONCLUSION

Surface runoff of Amreli district calculated using SCS-CN method for the year (4 months) integrated that the average rainfall is 2700 mm and runoff is 900 mm. Runoff is higher than the rainfall of 3 days where heavy rainfall occurred in June 2015. Therefore the runoff within this period was much higher, which resulted in the water logging of the Amreli District low lying areas.

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