



Surface Runoff Estimation for Godavari Eastern Delta Using SCS Curve Number and Geographical Information System

**G. Kishore Kumar^{1*}, M. Raghu Babu², A. Mani¹, M. Martin Luther³
and V. Srinivasa Rao⁴**

¹Dr. NTR College of Agricultural Engineering, ANGRAU, Bapatla, India.

²ANGRAU, LAM, Guntur, India.

³Department of Agronomy, College of Agriculture, ANGRAU, Bapatla, India.

⁴Department of Statistics, College of Agriculture, ANGRAU, Bapatla, India.

Authors' contributions

This work was carried out in collaboration among all authors. Authors MRB and AM planned the experiments. Authors MML and VSR monitored the results and statistically analysed the data and made illustrations. Author GKK did with research, data collection and write up. All authors read and approved the final manuscript.

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ABSTRACT

NRSC-CN for surface runoff estimation is one of the most widely used methods. GIS and remote sensing techniques facilitate accurate estimation of surface runoff from an area. Water availability estimation can be understood by rainfall and runoff is essential. Runoff generated by rainfall is not only dependent on the intensity, duration and the distribution of rainfall, but also soil type, vegetation, and land-use types have significant effects on the runoff pattern. The present study aims to estimate runoff in a study area. The study was carried out in Godavari Eastern Delta in Andhra Pradesh, India. The land use/land cover map, soil map was prepared. The soil and land use map has been prepared by the information available at Andhra Pradesh space application centre. For the rectification of reference, soil and land use map of the study area ERDAS IMAGINE-8.4 software was used. For 30 years surface runoff was estimated, as the runoff value depends on the rainfall,

*Corresponding author: E-mail: dir.kishorekumar@gmail.com;

trend of runoff was found to be highly dependable on the quantity of rainfall received within the entire study area. The yearly trend of rainfall during 1987 was 8.97 it's but the other years, and therefore the runoff was also found to follow an equivalent trend. Similarly, for the year 1995, the runoff was recorded as high, which was also having the highest rainfall.

Keywords: Land use/land cover; geographical information system; Toposheet; SCS-CN; rainfall-runoff; remote sensing; soil conservation service.

1. INTRODUCTION

The potential source of all freshwater is precipitation which is within sort of mist, rain and snow. Runoff is that a part of rainfall, snowmelt and/or irrigation water that runs over the soil surface toward the stream instead of infiltrating into the soil. A surface runoff will occur when the rainfall rate is more than the infiltration capacity of the soil. Runoff water often collects are flowing into rivers. Hence, surface runoff of rain is a major component of the hydrological cycle and is responsible for depositing most of the freshwater on the Earth. A rainfall-runoff model is a mathematical model describing the rainfall-runoff relations of a catchment area, drainage basin or watershed. Every hydrologic design is different as the factors affecting the design, vary with space and time. It is essential to make measurements of factors such as size, slope, soil type and land use, vegetation and flow capacity of the channel. The drainage area, length of the watercourses and mainstream are the most significant variables for prediction of run-off [1]. It is important that Hydrological models and necessary tools for water and environmental resources management. Predictive capabilities of such models are becoming high in demand.

There are several methods available for finding out the runoff such as Rational method, Green-Ampt method, and SCS-CN method. The SCS-CN method is one of the most popular methods for Computing the volume of surface runoff for a given rainfall event it is widely used because of its flexibility and simplicity.

1.1 Study Area

For a present study Godavari, eastern delta part of Godavari delta was selected (Fig. 1). The Godavari Eastern Delta consists of part of Godavari delta, is situated in East Godavari district of Andhra Pradesh in East coast of India. The study area covers about 1138 km² located in the southern part of Godavari delta and is bounded by Bay of Bengal in the Eastern side (Fig. 1). The average annual rainfall in the study area is about 1,157 mm and distributed unevenly over 54 rainy days. About 70 % rainfall occurs during the southwest monsoon season (June–September). During the northeast monsoon (October–December), the rainfall varies from 225 to 450 mm. July is the wettest month contributing to about 26 % of the annual rainfall and nearly 56 % of the SW monsoon rainfall.

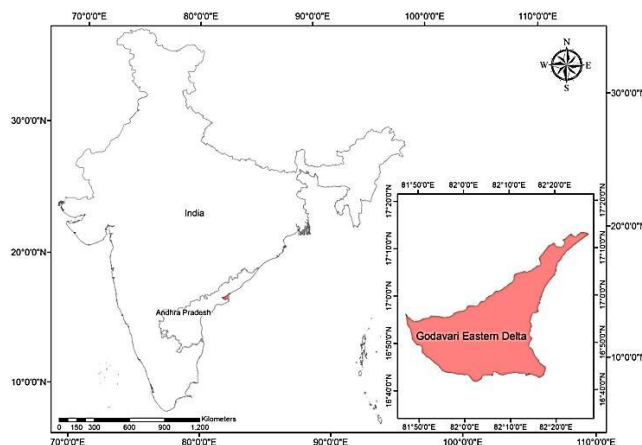


Fig. 1. Location map of the Study area

2. METHODOLOGY

In this method, several important properties of the study area namely soil type, land use and antecedent soil water conditions are taken into consideration. Their runoff producing capability is expressed by a numerical value varying between 0-100. The curve number is a function of land use and hydrologic soil group (HSG). The data sets for this process are Satellite Imagery-Landsat 7 (with resolution 30 m), Soil Map (hydrologic soil group-HSG), Rainfall Data (30 yrs.), and DEM-The Digital Elevation Model. Soil infiltration capacity is classified by the USDA-SCS into four classes called HSG (Hydrologic Soil Group) [2]. Every type of soil has a HSG that indicates an infiltration capacity and a rate of water transmission through the soil, the four types of HSG are presented in [3]. The NRCS-CN method provides a rapid way to estimate runoff change due to land-use change. The main reason behind the selection of the NRCS method is that in the past 30 years the NRCS method has been consistently usable results for runoff estimation. To meet the objectives of the project the following data have been used. The rainfall data is collected from Directorate of Economics and Statistics, Andhra Pradesh for the period of 1987 to 2017 for various

rain gauge stations in Eastern Godavari Delta as in Table 1.

2.1 Estimation of Surface Runoff

Rainfall-Runoff modelling is an essential part for water resources in planning and management. The simulation model SCS-CN analysis runoff volumes from the rainfall. For direct runoff volume in ungauged catchments it is one of the efficient methods to use. [4,6,5]. In this curve number (CN) is to determine the runoff volumes. Land use / Land cover, Hydrologic soil group information and antecedent soil moisture conditions of the catchment are used in this method. Maps used as input files are Land use and HSG of the study area are prepared (Fig. 3 & Fig. 2). The effect of the surface condition of a watershed is evaluated by means of land use and treatment classes. Land use is classified into three groups-poor, fair and good. The LULC map for the year 2014 that was used in the study was prepared using Landsat 8 Operational Land Imager (OLI) satellite data, which was accessed from Earth Explorer data portal (<https://earthexplorer.usgs.gov/>). The variation of curve number under AMC II called CNII for various land conditions. Detailed flow chart of the process as shown in Fig. 4. ERDAS Imagine and ArcGIS tools were used for preparing the required input data sets in the present study.

Table 1. Rain gauge stations

| Mandals | Lat | Long | Mandals | Lat | Long |
|-------------|---------|---------|------------------|---------|---------|
| Alamuru | 16.7833 | 81.9 | mandapeta | 16.8653 | 81.9262 |
| anaparthi | 16.9502 | 81.9334 | kothapalle | 17.0878 | 82.3187 |
| Biccanavolu | 16.4145 | 82.04 | kadium | 16.9136 | 81.8183 |
| kajuluru | 16.7966 | 82.1733 | Pamaru | 16.8653 | 81.9262 |
| Kakinada | 16.9891 | 82.2475 | Samalkota | 17.05 | 82.1679 |
| rayavaram | 16.90 | 82.01 | Pedpudi | 16.9523 | 82.1306 |
| kapilesaram | 16.32 | 81.92 | Ramachandrapuram | 16.8372 | 82.0325 |
| karapa | 16.9001 | 82.1668 | | | |

2.2 SCS – Curve Method

The fundamental hypotheses of the SCS method are:

- After the initial abstraction (I_a) has been satisfied, Runoff starts
- The ratio of actual retention of rainfall to potential maximum retention(S) is equal to the ratio of direct runoff to rainfall minus initial abstraction.
- I_a is related to S as $I_a = aS$. The relationship between runoff depth Q (in mm) and rainfall P (in mm), for Indian conditions rainfall event in the catchment is given as

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

$$Q = \frac{(P-0.1S)^2}{(P+0.9S)} \quad (ii)$$

Where

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

In which CN = a co-efficient called Curve Number

CN depends upon

- HSG-Hydrological soil groups
- Land use
- Antecedent Moisture Condition (AMC)

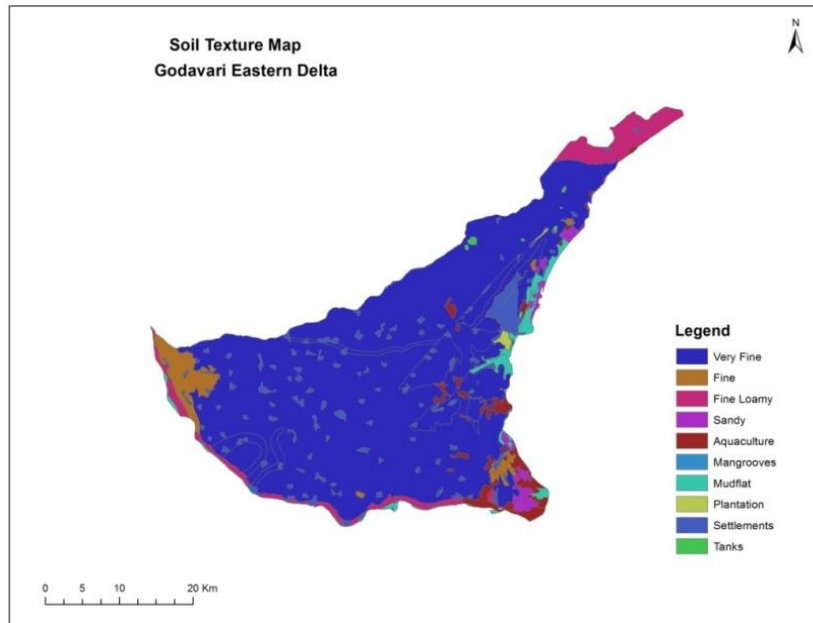


Fig. 2. Soil map of the study area

3. RESULTS

The Hydrological Soil Group map and Land use land cover map for the study area have been developed in GIS as shown in Figs. 2, 3 respectively. Percentage area and Curve number can be used to find out the area-weighted curve number by using Equation. The hydrological soil group classifications were given in Table 2. The land use and land cover categories of the study area were interpreted from satellite data. The daily rainfall data was obtained from the Directorate of Economics and Statistics from 1987 to 2016.

A total of 10 classes were mapped in for the study area: built-up, cropland, fallow land,

plantation, forest, shrubland, grassland, mangrove, barren land, and water bodies (Fig. 4). Antecedent soil Moisture Condition (AMC) for three AMC types in dormant and growing seasons was given in Table 3. Rainfall is the most important parameter that influences all of the water balance components such as runoff. The total rainfall in the study area for the 30 years was given in Table 4. The year 1996 had the highest recorded rainfall, and these values are highly correlated with the rainfall. The runoff value depends on the rainfall. The LULC was derived for the year 2015-16 and rainfall data used was for 30years. The trend of runoff was found to be highly dependable on the amount of rainfall received in the entire study area.

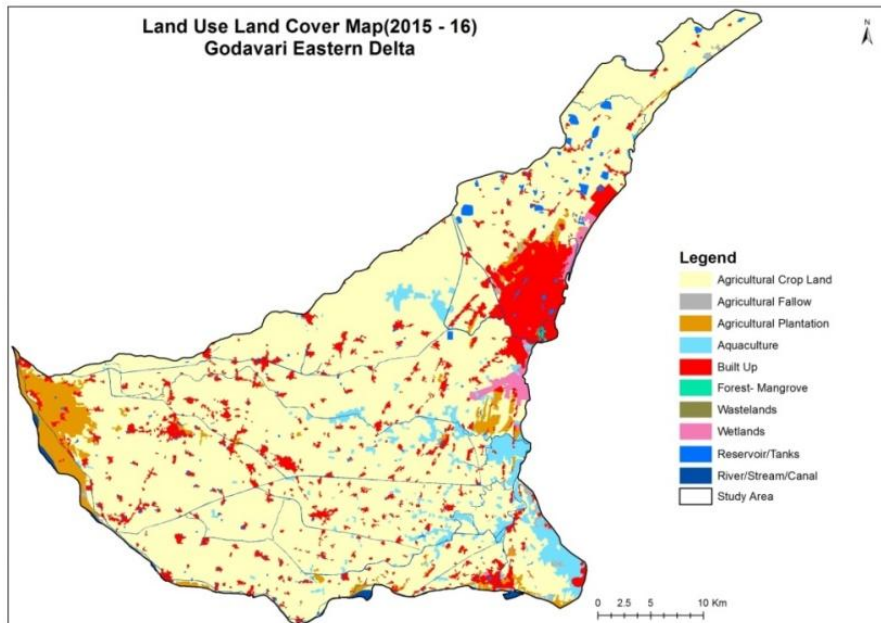


Fig. 3. Land use Land Cover Map of the study area

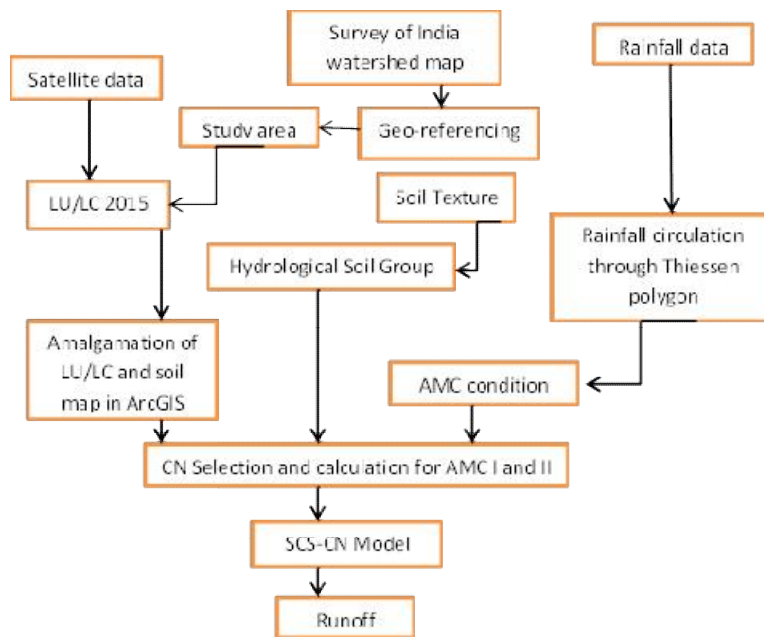


Fig. 4. Flow chart of methodology for Rainfall-Runoff

4. DISCUSSION

The yearly trend of rainfall during 1987 was found to be much less than the other years, and the runoff was also found to follow the same trend. Similarly, for the year 1995, the runoff was recorded as high, which was mainly due to that

year also having the highest rainfall. A decrease in the runoff was observed from 1995 to 2005, which may have been due to the reverse trend in the land-cover conversions and/or human activities. The curve number value for the study area is 84.79 for the catchment of 1470.15. In the year 1999, 75% dependable yield is 98.2mm.

Table 2. USDA-SCS soil classification

| Hydrological soil (Groups) | Type of soil | Runoff potential | Final infiltration rate (mm/hr) | Remarks |
|----------------------------|---|------------------|---------------------------------|-------------------------------------|
| Group A | Deep, well-drained sands and gravels | Low | >7.5 | A high rate of water transmission |
| Group B | Moderately deep, well-drained with moderately fine to coarse textures | Moderate | 3.8-7.5 | Moderate rate of water transmission |
| Group C | Clay loams, shallow sandy loam, soils with moderately fine to fine textures | Moderately high | 1.3-3.8 | Moderate rate of water transmission |
| Group D | Clay soils that swell significantly when wet, heavy plastic and solid with a permanent high water table | high | <1.3 | Low rate of water transmission |

Table 3. Antecedent soil Moisture Condition (AMC)

| AMC type | Total rain in the 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 |

Table 4. Shows the annual rainfall-runoff through SCS-CN model

| Year | Annual rainfall (mm) | Annual runoff (mm) | Year | Annual rainfall (mm) | Annual runoff (mm) |
|------|----------------------|--------------------|------|----------------------|--------------------|
| 1987 | 354.55 | 8.95 | 2002 | 679.31 | 110.88 |
| 1988 | 402.66 | 1.2 | 2003 | 967.53 | 130.4 |
| 1989 | 1038.49 | 326.47 | 2004 | 625.13 | 94.79 |
| 1990 | 1469.30 | 83.2 | 2005 | 1250.80 | 314.22 |
| 1991 | 1081.24 | 189.21 | 2006 | 1291.50 | 404.08 |
| 1992 | 990.01 | 165.89 | 2007 | 1066.68 | 189.32 |
| 1993 | 796.91 | 122.63 | 2008 | 1080.70 | 193.34 |
| 1994 | 1238.75 | 297.17 | 2009 | 627.40 | 31.34 |
| 1995 | 1423.94 | 292.25 | 2010 | 1813.78 | 392.12 |
| 1996 | 1570.93 | 541.99 | 2011 | 838.23 | 64.63 |
| 1997 | 935.66 | 174.5 | 2012 | 1396.56 | 380.89 |
| 1998 | 1538.79 | 376.84 | 2013 | 1095.05 | 280.05 |
| 1999 | 956.11 | 98.2 | 2014 | 705.16 | 21.93 |
| 2000 | 968.05 | 149.86 | 2015 | 1068.74 | 200.39 |
| 2001 | 900.36 | 110.69 | 2016 | 926.75 | 148.39 |

5. CONCLUSIONS

In this study GIS-based, SCS curve number method was used to estimate runoff from the study area. Based on the results of soil classification and land use, the study area was classified into three hydrologic soil groups. Results obtained shows the variation in runoff potential with different land use/land cover and

with different soil conditions. Further, it may conclude that the land use planning and management can be done effectively and efficiently using the SCS-CN number method with GIS. The study demonstrates that SCS –Curve Number with GIS is a powerful tool for estimating runoff of study for better management and conservation purposes.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. BS Prabhakar Rao, Pernaidu Pasala, E Amminedu, TV Rao. Run-off and flood estimation in Krishna River Delta using Remote Sensing & GIS". J. Ind. Geophys. Union. 2011;12(2):101-112.
2. Mihalik EN, Levine SN, Amartya MD. Rainfall-Runoff Modelling of Chapel Branch Creek Watershed using GIS-based Rational, SCS-CN Methods", ASABE, Rhode Island, SUA; 2008.
3. Matei D. Runoff Modeling Using GIS. Application in Torrential Basins in the Apuseni Mountains", Ph. D Thesis, Department of Hydrology and Hydraulic Engineering, Vrije Universiteit Brussel, Brussels, Belgium; 2012.
4. Hawkins RH. Asymptotic determination of runoff curve numbers from data." Journal of Irrigation and Drainage Engineering. 1993;119(2):334–345. DOI: 10.1061/(ASCE)0733-9437(1993)119:2(334)
5. McCuen RH. Approach to confidence interval estimation for curve numbers', J. Hydrol. Eng. 2002;7(1):43–48.
6. Michel C, Vazken A, Charles P. Soil conservation service curve number method: How to mend among soil moisture accounting procedure. Water Resource Res. 2005;41(2).

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