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Estimation of Surface Runoff Potential using SCS-CN Method Integrated with GIS

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Abstract

This paper deals with estimation of surface runoff potential from rainfall for Thiruporur Block, Kancheepuram District in Tamil Nadu, India, through Arc GIS version 10.2 by SCS CN number method which is a widely used and efficient method for determining the amount of runoff from a rainfall event in a particular area. The runoff curve number is one of the most widely accepted and frequently used techniques for the estimation of storm runoff. The surface runoff is mapped for whole of Kancheepuram District, from which the runoff of Thiruporur block boundary is delineated in order to obtain higher accuracy of surface runoff. The seasonal variation of rainfall runoff of the study area is also depicted. The surface runoff potential estimated through SCS-CN method can further be used for the management of water resources and land.

Keywords: GIS, Rainfall, SCS-CN, Surface Runoff

1. Introduction

Of all planets, Earth deserves to be called as the water planet. The potential source of all fresh water is precipitation which is in the form of mist, rain and snow. Runoff is the part of rainfall, snowmelt and/or irrigation water that runs over the soil surface toward the stream rather than infiltrating into the soil. Surface runoff will occur when the rainfall rate is higher 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 fresh water on the Earth[1]. Runoff helps to provide suitable circumstances for many types of ecosystems, scheduling of irrigation, water for hydroelectric power plants.

1.1 Surface Runoff

Surface runoff occurs if precipitation rate is greater than infiltration capacity. Environmental conditions that affect these three processes are broadly broken down into two major categories: natural influences and human activity influences. Natural processes can have a variety of influences, but human activity typically results in less water entering the soil profile and thus more runoff at the ground surface.

Here, the objective starts with creation of digital database using GIS, assess the surface runoff using GIS based SCS-CN method. The digital database is creating using the data collected from Remote Sensing applications and conventional techniques.

2. Study Area

The study has been done in Thiruporur Block. Thiruporur block is situated in Kancheepuram District of Tamil Nadu, India as shown in Figure 1. Thiruporur is located on Old Mahabalipuram Road and is flanked by Kelambakkam on one side and Alathur Pharmaceutical Industrial Estate on the other side, both of which are also on Old Mahabalipuram Road. As of 2001 India census, Thiruporur had a population of 8302. Male constitute

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50% of the population and female 50%. Thiruporur has an average literacy rate of 70%, higher than the national average of 59.5%. Thiruporur block comprises of 50 villages.

3. Materials and Methodology

3.1 Materials

In order to meet the objectives of the project the following data have been used. The rainfall data is collected from The Public Work Department, Chennai for the period of 2004 to 2014 for various rain gauge stations of Kancheepuram district as in Table 1. The rain gauge stations considered for the study are as follows.

The data on Land use/Land cover for Kancheepuram District has been collected from Institute for Remote Sensing, Anna University, Chennai. The soil Map for Kancheepuram District has been collected from Geological Survey of India.

Table 1. Rain gauge stations

Station name	Latitude	Longitude
Madurantakam	12°30’33”	79°53’08”
Sriperumbudur	12°58’01”	79°56’37”
Tambaram	12°56’06”	80°07’37”
Kancheepuram	12°50’00”	79°42’07”
Uthiramerur	12°36’55”	79°45’22”
Kelambakkam	12°46’56”	80°13’42”
Cheyyur	12°21’11”	79°59’53”

3.2 Methodology

3.2.1 Assessment of Surface Runoff

The integration of GIS and Soil Conservation Service-Curve Number Method is used to estimate the surface runoff. The Soil Conservation Service Curve Number (SCS-CN) method is widely used in determination of direct surface run-off in long-term (continuous) hydrologic simulation models[2]. In this approach, GIS is used to create a spatial database that represents hydrologic characteristics of the watershed. Base map, land use and soil coverages of the study area are created using GIS. The appropriate area-weighted curve number for the study area is computed using overlaying tool of GIS. Then the daily rainfall database is incorporated in the analysis to estimate the direct runoff. The result obtained is useful for water management and irrigation scheduling of the study area.

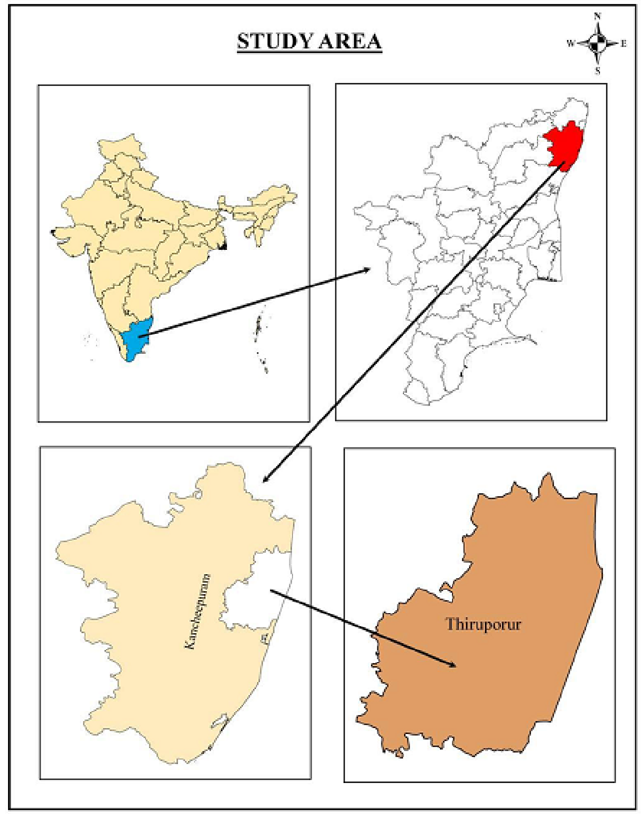

Figure 1. Study area map.

3.2.2 GIS based SCS-CN Method

In hydrological modeling, the runoff estimation is the most important aspect. There are number of empirical methods for its estimation. The most commonly and widely used empirical method is the Soil Conservation Service-Curve Number Method (SCS, 1972) developed by United States Department of Agriculture and Soil Conservation Service (USDA-SCS) to estimate surface runoff. This method is very popular due to its simplicity, flexibility and requirement of a single parameter called Curve Number (CN) for computation of runoff. Hydrologic soil group number, land use type, vegetation cover is the basic catchment characteristics used for curve number calculations[3].

The equation for surface runoff is given by[4],

$$Q = \frac{(P - I_a)^2}{(P - I_a + S)} \quad (1)$$

Where, Q - Accumulated runoff or rainfall excess in mm
P – Rainfall depth in mm
I_a – Initial abstraction in mm
S – Potential maximum retention in mm

Table 2. USDA-SCS soil classification

Hydrological Soil	Type of soil	Runoff Potential	Final Infiltration Rate (mm/hr)	Remarks
Group A	Deep, well-drained sands and gravels	Low	>7.5	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 soils with a permanent high water table	High	<1.3	Low rate of water transmission

The US Soil Conservation Service has found by experience that,

$I_a = 0.2S$

The term S is given by

$$S = \frac{25400}{CN} - 254 \tag{2}$$

Where, CN – Curve Number

For Indian conditions some modifications were done by soil and water conservation Department, Ministry of Agriculture, New Delhi. For Indian conditions $I_a = 0.3S$.

Equation *(1)* can be written as

$$Q = \frac{(P - 0.3S)^2}{(P - 0.7S)} \tag{3}$$

Knowing the value of CN, the runoff from the watershed is computed from equations *(2)* and *(3)*. The SCS curve number is a function of the ability of soils to allow infiltration of water, land use and the antecedent soil moisture condition. According to the U.S. Soil Conservation Service, soils are divided into four hydrologic soil groups such as Group A, Group B, Group C and Group D. Table 2 with respect to the rate of runoff potential and final infiltration rate[5]. The depth or volume of runoff from watersheds with different land users can be obtained (i) by determining the volume of runoff from each land use and then summing these amounts or (ii) by calculating an area-weighted curve number for the study area and then using this single value in equations *(2)* and *(3)*.

3.2.3 Antecedent Soil Moisture Condition (AMCs)

The method acknowledges observed CN (or runoff) variation between events based on basin factors, originally explained as "AMC" or Antecedent Moisture Condition[6]. Antecedent soil Moisture Condition has a significant effect on runoff. AMCs are defined in Table 3. The runoff curve numbers (AMC II) for hydrologic soil cover complexes and curve number adjustments for AMCs (AMC I and AMC II) for Indian conditions are presented in the Tables 2 and 3.

Table 3. Classification of Antecedent soil Moisture Condition (AMC)

AMC Group	Soil characteristics	Total 5-day antecedent rainfall (mm)	
		Dormant season	Growing season
I	Soils are dry but not to wilting point; satisfactory cultivation has taken place	Less than 13	Less than 36
II	Average condition	13-28	36-53
III	Heavy rainfall or light rainfall and low temperatures have ocured within the last 5 days; saturated soil	Over 28	Over 53

3.2.4 Preparation of Various Theme Layers

The base map, soil map and land use map coverage's (theme layers) of the study area using Geomedia Professional – GIS package. The land use map and hydrological soil map of the study area are prepared and used for the further analysis.

4. Results and Discussion

4.1 Rainfall Distribution in Thiruporur Block

The rainfall distribution of 2014 in Kancheepuram

District is mapped by interpolation tool using ArcGIS 10.2 from the rainfall data recorded by seven rain gauge stations within Kancheepuram District. The Thiruporur block maps are delineated and displayed in Figure. 2.

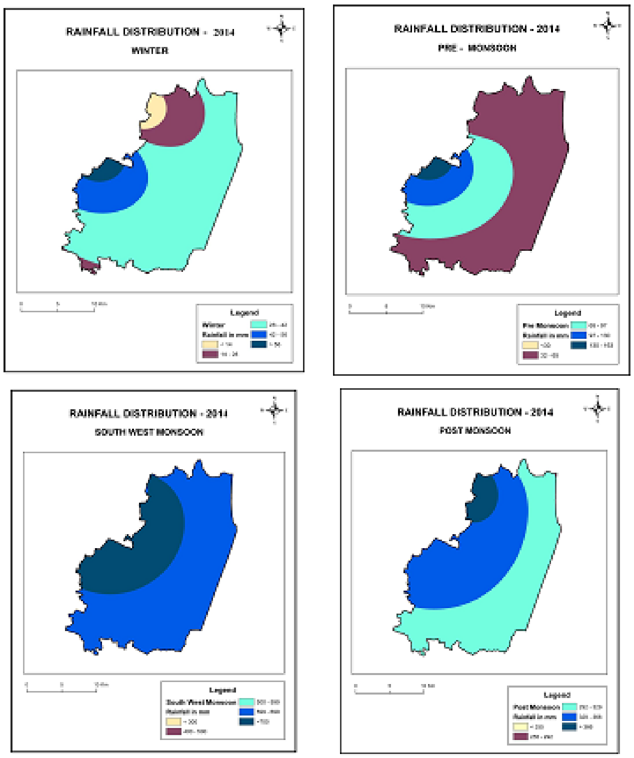

Figure 2. Rainfall distribution of various seasons.

4.2 Soil and Land Use/Land Cover

The soil group classification database is fed into ArcGIS 10.2 and the map is drawn. It is to be noted that the study area has only A, C and D HSG as shown in Figure 3. The landuse/land cover map is drawn with 10 types of classification that are available in the data acquired are shown in Figure 3.

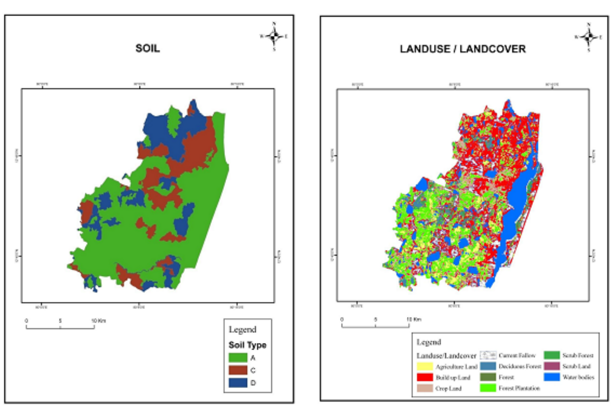

Figure 3. Soil and landuse/land cover map.

4.3 Overlay Analysis of Soil and Landuse / Land Cover Map

Overlay analysis of landuse/land cover map and soil map of Thiruporur block is done and the area of various land use classification for each hydrological soil group is obtained from this map are shown in Figure 4.

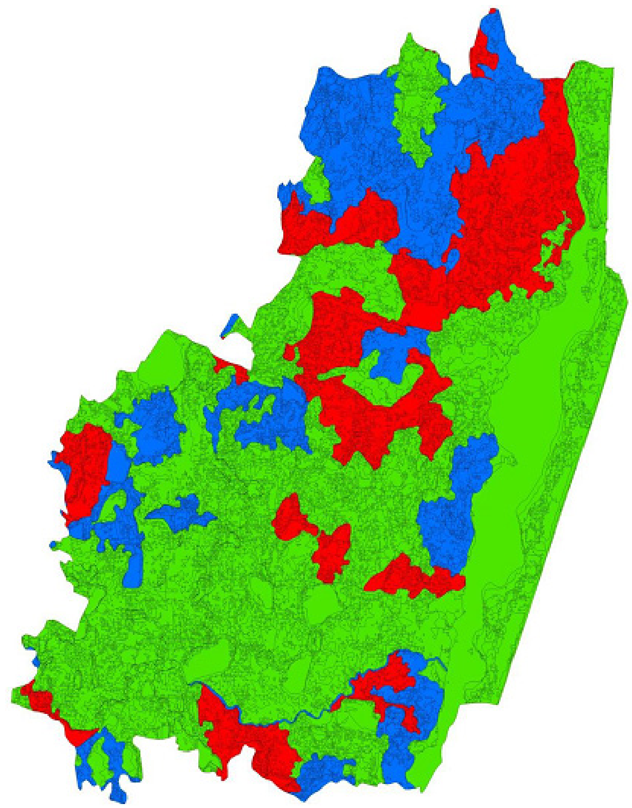

Figure 4. Overlay map of soil and landuse/land cover.

4.4 Surface Runoff Depth

Using the Curve Number obtained from the result of overlay of soil and land use/land cover maps and the seasonal rainfall recorded in each rain gauge station, the surface runoff is calculated and the runoff depths are obtained for HSG A, C and D, in millimetre shown in Figure 5. The rainfall runoff maps of Thiruporur Block are created in ArcGIS 10.2 using Inverse Distance Weight (IDW) interpolation and the seasonal runoff depth maps are depicted in this section. For all the seasons the runoff depth is more in the inner part of the Thiruporur block, where we can install the proper water harvesting structures.

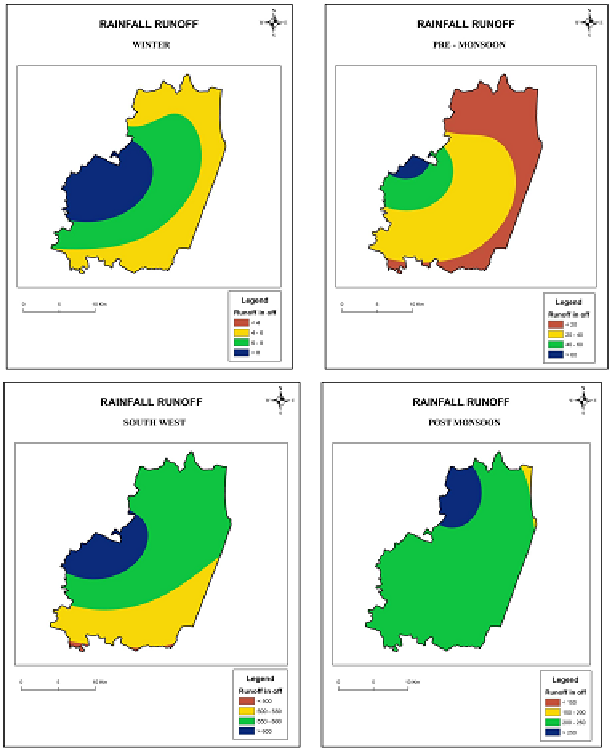

Figure 5. Surface runoff depth of various seasons.

5. Conclusion

The estimated surface runoff is used to plan for proper water and land management in the study area. In this direction, rainfall – runoff model will help in knowing the amount of runoff so that the alternate cropping pattern can be suggested for the available water[7]. The result from surface runoff helps us to take up provide water conservation measure .Water management practices can be broadly classified into two groups namely vegetative measures and engineering measures. Both these measures are necessary and equally important. Some of the popular engineering management practices are terrace construction, channel diversion, gully plugs, farm ponds, provision of gabions, recharge pits, etc. Similarly, vegetative measures include seeding and fertilizing of pastures, strip cropping, affore station measures, fruit trees, shrubs, etc. Land treatment measures which bind the soil and increase infiltration rates of the study area in the places of degraded land can be effective in reducing the amount of run-off, especially during less intense storm events. The Soil Conservation Service Curve Number (SCS-CN) approach is widely used as a simple method for predicting direct runoff volume for a given rainfall event[8]. The volume of rainfall predicted can be used for t he planning of land use and the careful management of soil, water and vegetation resources, through such means as the use of appropriate conservation practices and structural works, can retard run-off, increase the infiltration rate, improve production and enhance the productivity and sustainability of the land.

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