Runoff Depth Estimation using RS & GIS - NRCS-CN Method

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***Abstract*:- Estimation of Runoff depth is essential for the water resources planning and rainwater conservation techniques. Tiruchirappalli district is a semi-arid region which is selected for the study. River Cauvery flows seasonly over the district. hence rainwater conservation become necessary to overcome the demand. GIS based NRCS-CN method is used for the runoff depth estimation. For the assessment of runoff depth, base map, land use map, soil map was created in Arcgis10.5. After the intersection of these thematic maps with rainfall map, CN value is assigned and CN map was generated. By mathematical calculations, spatial distribution of runoff depth over the district was obtained.**

Key words: Land use, Soil Texture, Rainfall, Runoff Depth, NRCS-CN method, Remote Sensing (RS) and Geographic Information System (GIS).

1. INTRODUCTION

Water is fundamental for all living things and is utilized in various courses, such as, food production, drinking, domestic, industrial, power production and recreational utilize. As per the World Bank report (Anon., 2002), India will be water stress zone by the year 2025 and water scare zone by 2050. The water table is abruptly falling with unregulated over exploitation of Groundwater. The rainwater conservation schemes are relatively equitable and environmentally sound (J.P. Singh, 2009). For any rainwater conservation practices, runoff depth estimation is necessary to make decisions and planning over the various water conservation methods. Hence runoff depth was estimated for Tiruchirappalli district using GIS based NRCS-CN method.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

Tiruchirappalli is centrally located in Tamil Nadu and is 320 kms away in southern direction from Chennai. The district has an area of 4509 sq.kms spread over between 10 and 11.30 degree Northern latitude and 77.45 degree on the Eastern longitude. The high temperatures have been attributed to the presence of two rivers, Cauvery and Kollidam. As the city is on the Deccan Plateau, the days are extremely warm and dry (census, 2011). Tiruchirappalli experiences a tropical savannah climate with no major change in temperature between summer and winter. Rainfall is highest between October and December because of the north-east monsoon winds, and from December to February the climate is cool and moist (census, 2011). The district has a high mean temperature and a low degree of humidity. The location map of study area is shown in the figure 2.1.

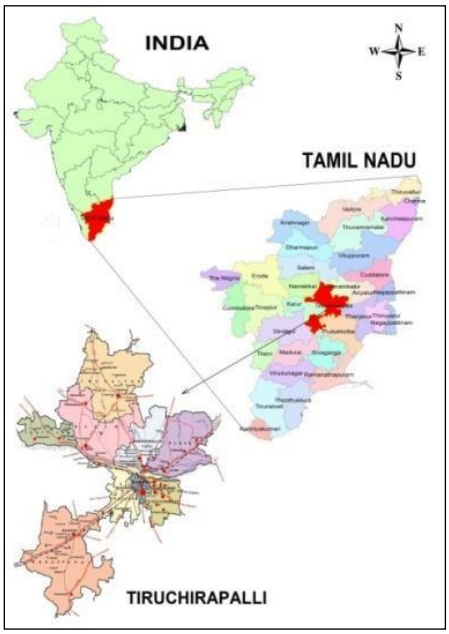

Figure 2.1 Location map of Tiruchirappalli district

2.2 Data Source

The data used for this study are discussed as follows. The base map of the Tiruchirappalli district was prepared from 1:50,000 scale Survey of India (SOI) toposheets. The land use map was generated from Resourcesat -1/2 Linear Imaging Self Scanning Sensor (LISS-III) 2016. The soil texture map of the study area was prepared from the soil survey report of the National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) and the state soil survey and land Use organisation, Department of Agriculture, Tamilnadu. The Rainfall data of the Tiruchirappalli district for past 35 years from 1979 to 2014 was obtained from SWAT global weather data.

2.3 Software Used

Arc GIS 10.5 software was used for creating, managing and generation of different layer and maps. The Microsoft excel was used for mathematical calculations.

2.4 Methodology

Runoff depth was estimated using GIS based NRCS-CN method as shown in the figure 2.2.

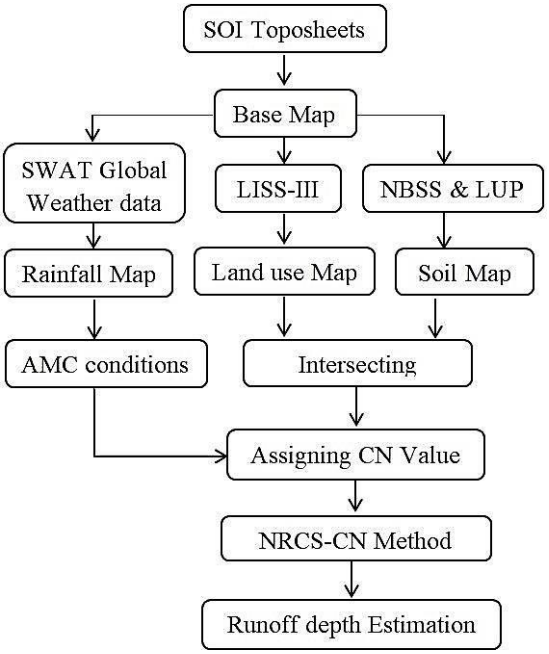

Figure 2.2 Methodology

2.5 Generation of Various Thematic Maps

2.5.1 Base Map Preparation

Preparation of the base map is important to show the district and taluk boundaries and its headquarters, national and state highways, district roads, river/stream network, colleges and hospitals. The various thematic maps were prepared by keeping the base map as foundation. The base map of the Tiruchirappalli district was prepared from 1:50,000 scale Survey of India (SOI) toposheets No.58I/4, 58I/7, 58I/8, 58I/11, 58I/12, 58I/16, 58J/1 to 58J3, 58J/5 to 58J/7, 58J/9 to J/14, 58M/4 of 2011 as shown in the figure 2.3.

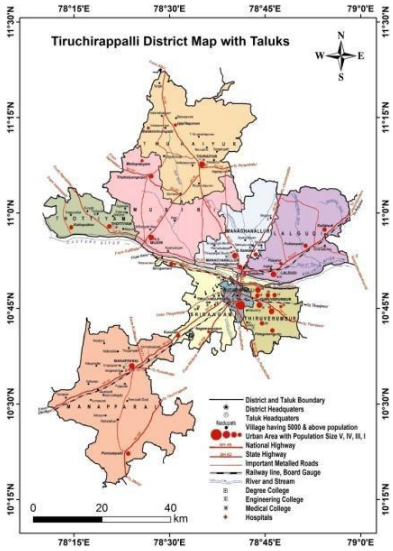

Figure 2.3 Tiruchirappalli district Map

2.5.2 Land Use Map

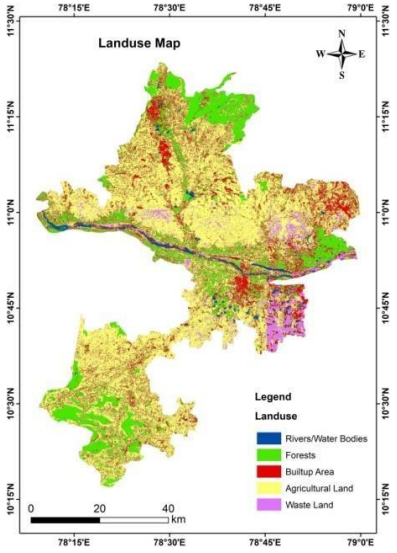

Figure 2.4 Land Use Map

Landuse of the study area was classified by using isocluster unsupervised classification tool in arcgis 10.5 software. The land use of Tiruchirappalli district were categorized into builtup area, forests, agricultural land, rivers/water bodies, and waste lands. The land use map is shown in Figure 2.4.

2.5.3 Surface Soil Texture Map

Therefore the study of Soil is a very important parameter for the estimation of surface runoff. The types of soil texture found in the study area are Sandy Loam, Sandy Clay Loam, Clay, Clay Loam, Loamy Sand, Sandy Clay and Rock Land. Figure 2.5 shows the Surface Soil Texture map.

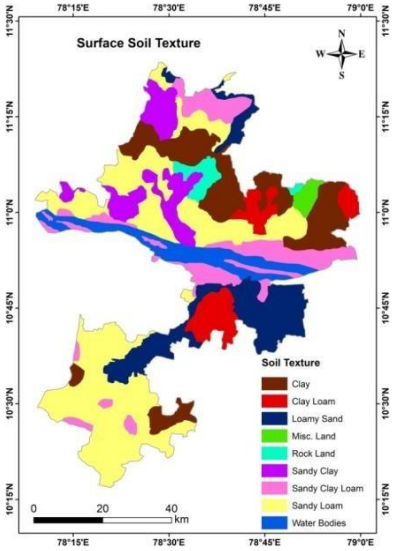

Figure 2.5 Surface Soil Texture Map

2.5.4 *Rainfall Distribution Map*

The Rainfall data of the Tiruchirappalli district for past 35 years from 1979 to 2014 was obtained from SWAT global weather data. After that the average yearly rainfall value was computed and plotted a graph between year and average rainfall corresponding to the rain gauge stations as shown in the figure 2.6. The latitude, longitude, elevation, average rainfall of the rain gauge stations were discussed in the table 2.1.

Table 2.1 Rainfall Characteristics in the District

Rain gauge Stations	Longitude	Latitude	Elevation (m)	Average Rainfall (cm)
1	78.125	10.45969963	303	4.61
2	78.4375	10.45969963	209	4.96
3	78.4375	10.77190018	125	3.75
4	78.75	10.77190018	68	3.36
5	78.4375	11.08409977	152	4.15
6	78.75	11.08409977	120	3.55
7	78.4375	11.39640045	522	6.17

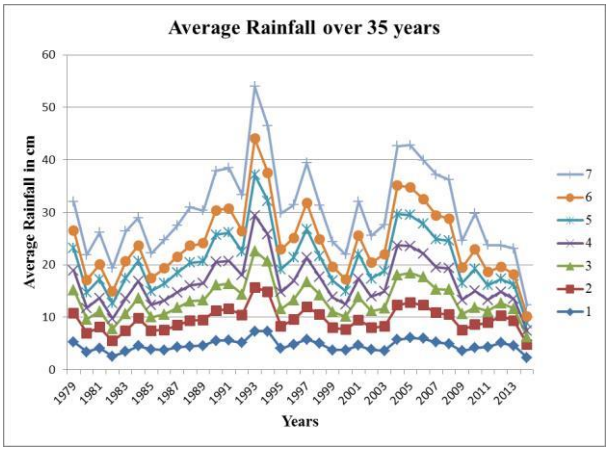

Figure 2.6 Rainfall Characteristics Graph

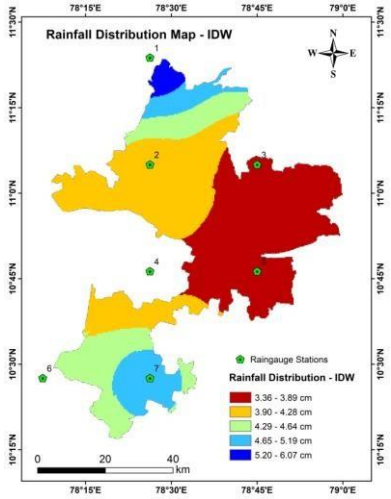

Figure 2.7 Rainfall Distribution Map - IDW

The location of rain gauge stations in the Tiruchirappalli district is plotted as the point data in Arcgis. Then Inverse distance weighted (IDW) interpolation tool is used to distribute the rainfall data in each rain gauge stations spatially. The rainfall distribution map of the Tiruchirappalli district using IDW is shown in the figure 2.7.

2.5.5 *NRCS-CN equation and runoff calculation*

After generating CN map the next step was to determine maximum potential retention (S). S value was calculated for each polygon using eqn (1). Runoff depth was estimated for each rainfall event by using eqn (2).

$$Q=\frac{(P-0.3S)^2}{P+0.7S} \qquad (P>0.3S) \qquad (1)$$

$$S = \frac{2540}{CN} - 25.4 \qquad (2)$$

Where Q is runoff depth (cm); P is rainfall (cm); S is potential maximum retention (cm); S is initial abstraction of rainfall by soil and vegetation (cm) and CN is Curve Number.

3. RESULTS AND DISCUSSIONS

3.1 *Runoff Estimation by NRCS-CN Method*

The Natural Resources Conservation Service (NRCS) method is generally used for calculating direct runoff volume for a given rainfall event (Soulis & Valiantzas 2012). The CN values were selected from the USDA-NRCS table based on land use/ land cover, soil and land management conditions. The land use and soil maps were processed using GIS techniques for the selection of runoff curve numbers.

3.1.1 *Land use*

The influence of land use on storm runoff generation is very complicated (Gary Coutu & Carmen Vega 2007). In this regard, the area and percentage of coverage of different land uses over the Tiruchirappalli district is presented in figure 3.1 and 3.2.

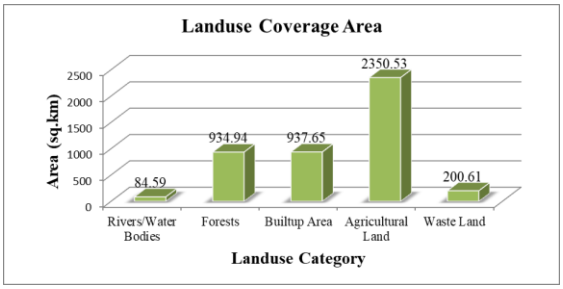

Figure 3.1 Different Land use Coverage Area

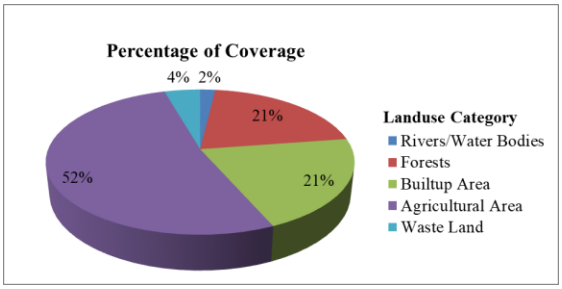

Figure 3.2 Percentage of Coverage of Land use over Study Area

Agriculture covers most of the area of the district with a percentage of 52.14. The forest and built up land occupy more or less equal area with the percentage of 20.74 and 20.80 respectively. Rivers/ water bodies occupies least area with the percentage of 1.88.

3.1.2 Soil Texture

Figure 3.3 and 3.4 shows that Coverage Area and percentage of coverage of the different soil textures present in the study area.

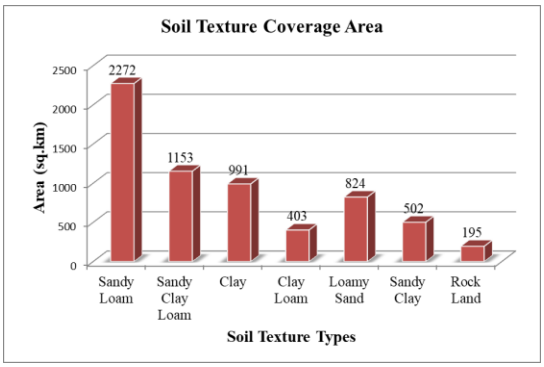

Figure 3.3 Different Types of Soil Texture Coverage Area

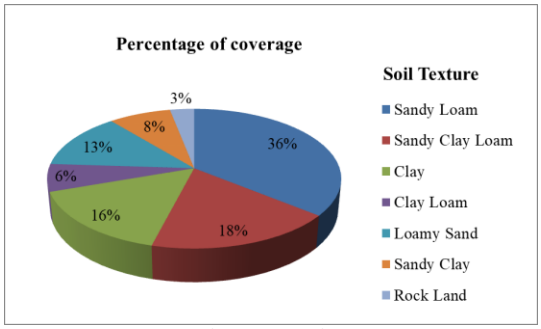

Figure 3.4 Percentage of Coverage of Soil Textures over Study Area

3.1.3 Hydrological Soil Group (HSG)

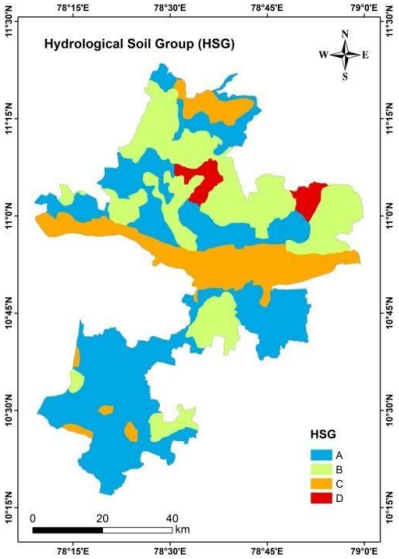

Figure 3.5 Hydrological Soil Group of the study area

The hydrological soil group is used to determine the curve number with respect to different land uses (NEH, 2007). In this regard, the hydrological soil groups of the Tiruchirappalli district were classified into four groups such as HSG A, HSG B, HSG C and HSG D. The HSG map is shown in Figure 3.5.

3.1.3.1 HSG distribution over the Land uses

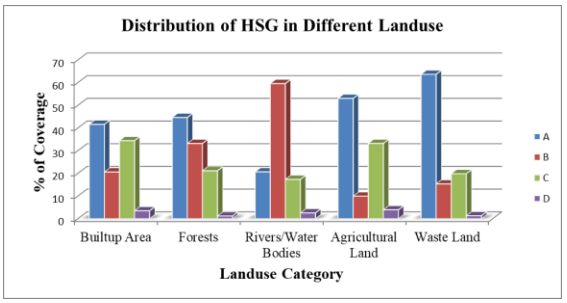

Figure 3.6 Distribution of HSG in different land use

Figure 3.6 shows that percentage of the Hydrological Soil Group (HSG) distribution over different land uses.

3.1.4 Curve Number Distribution

The CN values corresponding to HSG were assigned based on standard NRCS curve number table and presented in Table 3.1. It is observed that the lowest CN value was found to be 26 in forests and highest CN value was found to be 100 in rivers/water bodies.

Table 3.1 Curve number with respect to HSG and land uses

Sl. No.	HSG / Land use	A	B	C	D
		Curve Number (CN)			
1.	Agricultural land	95	95	95	95
2.	Forests	26	40	58	61
3.	Built-up area	77	86	91	93
4.	Rivers/water bodies	100	100	100	100
5.	Waste lands	71	80	85	88

After assigning the curve number to every pixel of the study area, the curve number map was created. The curve number distribution of the study area was classified into five classes such as very low (26 to 58), low (59 to 77), medium (78 to 85), high (86 to 91) and very high (92 to 100) by natural break classification system (Michael de Smith et al. 2009). The curve number distribution for the study area is given in Figure 3.7.

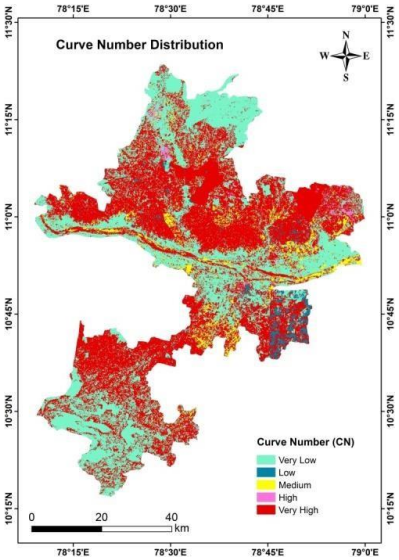

Figure 3.7 Curve number distribution in the study area

3.1.5 *Calculation of runoff depth*

For calculation of surface runoff depth for the Tiruchirappalli district the spatial distribution map of curve number and rainfall were created in ArcGIS environment. They were intersected and then runoff depth was estimated using NRCS-CN formula in Ms-excel to find out the spatially distributed runoff depth over the district. The runoff was generated for rainfall event was distributed as low (0 - 0.57cm), very low (0.58cm – 1.13cm) medium (1.14cm – 2.13cm), high (2.14cm
- 3cm) and very high (3.01cm - 6cm) by natural break classification system (Michael de Smith et al. 2009) and shown in Figure 3.8. It shows that the runoff values increases with an increase in the amount of rainfall in the study area.

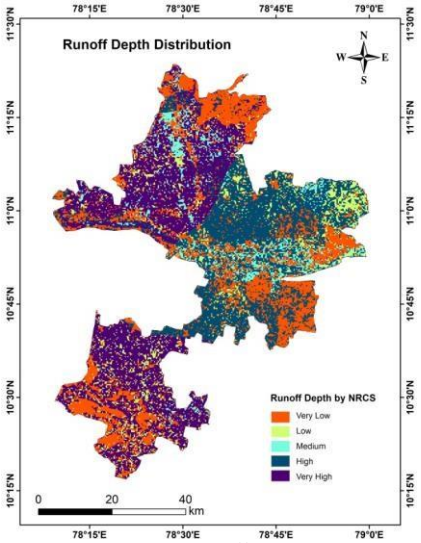

Figure 3.8 NRCS-CN runoff depth in the study area

3.1.6 *Runoff Depth under Land Uses*

The agricultural land had the highest runoff with 52.14% of runoff depth due to its higher coverage area in the district. The builtup had runoff next to agricultural land with 20.80% due its low infiltration rate. Waste land had the lowest runoff producing capacity (0.01%).

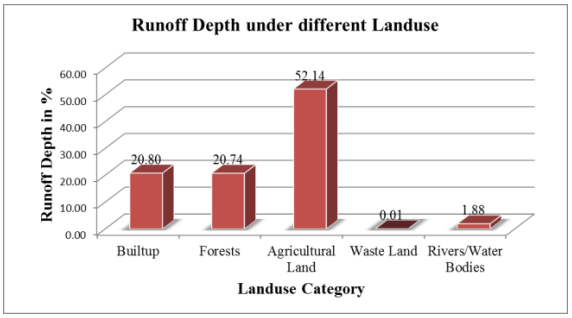

Figure 3.9 runoff depth under different land use in the study area

4. CONCLUSION

Next to Agiculture, the increasing area of built-up area gives more runoff to the study area and low infiltration depth. With the help of base map, all the required thematic maps such as Landuse map, Surface soil texture map, Slope map, Rainfall map are created using the software Arcgis 10.5. Runoff is estimated using GIS based NRCS-CN method. Even though the land use, soil texture and rainfall influences the runoff depth in NRCS-CN method, there is another one important factor percentage of area coverage of land use and soil texture influences the percentage of runoff depth in the study area.

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