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ESTIMATION OF RAINFALL-RUNOFF MODEL OF NANDIAR SUB BASIN USING SCS-CN METHOD AND GIS INTEGRATION

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ABSTRACT Water is essential element in the living being, at present water scarcity is the major crises in Tamil Nadu state is taking into account that hydrologic time series are limited in Tamil Nadu, there is a strong need for hydrologic modeling tools that can be used to assess the effects of land use on the hydrologic cycle at a watershed scale with the available information. These hydrological models developed at a basin scale are required to improve the water resource management, which is a critical issue in most parts of Tamil Nadu, due to the reason we have selected Nandiar subbasin for our study. The objective of the present study is to evaluate the runoff, one of the output components of the hydrologic balance in the Nandiar sub-basin of Thiruvallur District of Tamil Nadu. An empirical rainfall-runoff model indicates the surface aspects of the catchments, which can be estimated by using Natural Resources Conservation Service - Curve Number (NRCS-CN) is a standout amongst those practically generally utilized strategies. Nandiar sub-watershed basin of Thiruvallur District of Tamil Nadu has been evaluated for the rainfall runoff study and for the estimation of precipitated water. The runoff and curve number are determined by the rainfall data; land use and land cover data, soil data and respective maps have been generated using ESRI ARCGIS software.

KEYWORDS :

1.INTRODUCTION

Water is the important asset of the earth water has been recognized as the highest natural resources and basic component in the socioeconomic growth of the nation (Nagarajan N, Poongothai (2012). There are plenty of water available in the earth (97%) in which there are only 3% of the fresh water is available. The readily available fresh water for the beneficial use is only 5% in the world. Nowadays water crises are increasing at rapid rate in all over the world. Many parts of the world covered by arid and semi-arid regions. These regions often facing draught and water crisis problem due to non-available of water sources or limited sources of water due to inadequate rainfall, flash floods and soil erosion because of these conditions the velocity of runoff ae very frequent and high. Runoff estimation plays the main role in mitigation of flood, management of water and sustainable development in these regions. The most frequently encountered issue in hydrological research is the need to estimate runoff from a watershed for which there is a precipitation records and no runoff records.

The connection between rainfall and runoff is very complicated, affected by different features like storm and drainage. There are several methods are there to estimate the runoff, for this study we have chosen SCSCN methodfor estim ating runoff in Nandiar sub basin. The Soil Conservation Service-Curve Number (SCSCN) method established by the U.S. Department of Agriculture (USDA) National Resources Conservation Service (NRSC) in 1969 is a simplest, predictable and stable conceptual technique for estimating direct runoff concentration based on storm precipitation intensity. A rainfall runoff model can be very helpful for the current work in calculating the discharge from the basin. The conversion of rainfall into runoff over a catchment is considered to be a very complicated hydrological phenomenon because this method is extremely nonlinear, time-varying and spatially distributed (T. Gitika and S. Ranjan (2014). The runoff model of the Soil Conservation Services (SCS) is helpful to develop the runoff potential for each function using distinct antecedent moisture condition (AMC) to acquire prospective runoff layer and to calculate maximum runoff frequency. The runoff model of the Soil Conservation Services (SCS) is helpful to develop the runoff potential for each function using distinct background moisture condition (AMC) to acquire prospective runoff layer and to calculate maximum runoff frequency. Can be used to calibrate the standard rational formula with the maximum runoff rate. The water conservation sites rely not only on annual rainfall, but also on other terrain variables such as slope, aspect, ground undulations, soil permeability and space and time variation in land use. SCS CN modified for Indian condition was used in this research to generate the study area runoff. Geospatial Techniques such as Remote Sensing and GIS are more accurate, up-to-date, and faster than conventional techniques. It plays a important role in collection of data in the different aspects of land use and soil cover, which are key parameters in the field of watershed runoff measurement. (Frevert and Singh (2002),GUPTA et al.(2004),Mahboubeh et al. (2012),Ruslin (2011),Sharma et al. (2008).

2.MATERIALS AND METHODS

STUDY AREA

The study area is taken for this study is Nandiar sub-watershed basin. The study area is located in Tamil Nadu & Part of Andhra Pradesh and the geographical coordinates are 13°4' N to 13°18' N and 79°17'E to 79°48'E. It covers the total area of 941 km2. The Nandiar sub watershed basin is located about 70 km from Chennai. The major settlements are Tiruttani, R.K.Pet, Solingur, Vanganur, Ammaiyarkuppam, Maddur, Palasamudram, Arrakkonam. The Nandiar sub-basin located in Thiruvallur district of Tamil Nadu. The river originates from Puttur hill at an altitude of 582 m near Singasamudram in Andhra Pradesh. Then it enters Tamilnadu and feeds the Sholingur tank. The surplus of this tank feeds the Viranatturu tank and from this tank, the river takes a regular course. Nandhiyar then feeds the tanks in Cherukuhuru and Tekkuluru. It then passes through Tiruttani and joins with Nagaririver and then it reaches the SathiamoorthySagar reservoir in Poondi. originates from Sholingur block and passes through Arakonam block and ends at Sholingur anicut. The basin area underlined by crystalline rocks of Archaean age, comprising granite gneiss, charnockite and associated basic igneous and metamorphic rocks. There are four observation wells are in this sub-basin. The winter water level varies from 4.00 m to 8.20 m and the summer water level varies from 5.30m to 9.40m. There are five influencing rain gauge stations in this sub basin. Based on the rainfall analysis the annual rainfall of the sub basin varies from 1601 mm (1996-97) to 576 mm (1986-87). The sub basin receives more rainfall in the southwest monsoon and it varies from 783mm to 214mm. Northeast monsoon varies from 770mm to 193mm, Winter rainfall varies from 133mm to 0mm and summer rainfall varies from 358mm to 8mm. The annual average rainfall of the sub basin is 959mm. The study area map shown in fig.1.

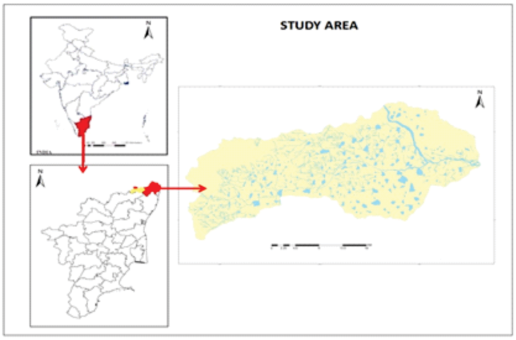

Figure 1. Study area Map (Nandiar Sub Basin)

DATA SOURCES

Survey of India (SOI) topographic maps (57 O/7, 57 O/8, 57 O/11, 57 O/12, 57 O/15 and 57 O/16) on a scale of 1:50,000, was procures and used to identify and demarcate the study area. Resourcesat-1 LISS-III data acquired on 2006, IRS-LISS-III and LISS, PAN merged data acquired for the year 2006 were collected from Indian Remote sensing Centre and used for land use classification. In present study area eleven land use/land cover classes were identified the land use map are shown in figure 2.

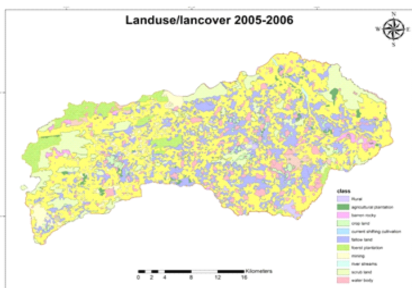

Figure 2. 2006 Land use / Land cover Map

Daily rainfall data (2002-2014) from Indian Meteorological Department, Chennai, were used. The soil data from National Bureau of Soil Survey & Land Use Planning (NBSS & LUP).

Digital Elevation Model (DEM) and Slope map of the study area was obtained by processing SRTM (Shuttle Radar Terrain Mission) and it was shown in figure 3 and 4.

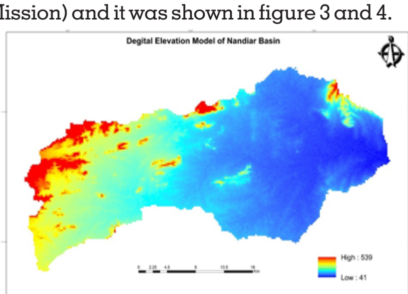

Figure 3. Digital Elevation Model of Nandiar Sub Basin

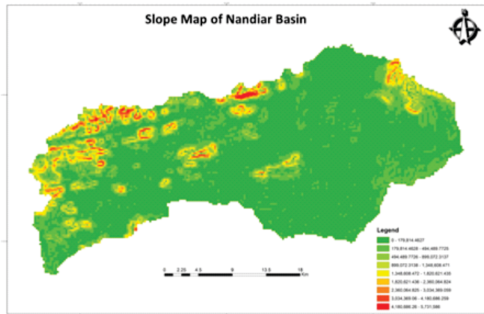

Figure 4. Slope Map of Nandiar Sub Basin

RUNOFF ESTIMATION

Runoff was calculated for each Hydrologic Response units using the Natural Resource Conservation Service (NRCS) Curve Number method (USDA 1986). This is an empiric method that associates the HSG's, land cover, treatment, hydrologic conditions and antecedent runoff condition in a dimensionless parameter (USDA, 1986; Melesse y Shih, 2002), defined as:

$$Q = \frac{(P-Ia)^2}{(P-Ia)+s} \qquad \text{-------------(1)}$$

where Q is the runoff (mm), P is rainfall (mm), Ia is the initial abstraction that includes surface storage, interception and infiltration prior to runoff (mm), and S is the potential maximum retention after runoff begins (mm). As S and Ia can be empirically related (Ia = 0.2S) and S is a function of the soil moisture, then runoff can be estimated once the Curve Number (CN) is estimated (USDA 1986).

$$S = 25.4\frac{(1000)}{CN-10} \qquad \text{--------------(2)}$$

Where CN is the Curve Number of the day, a dimensionless runoff index which is determined based on land use, hydrological soil groups (HSG) and antecedent moisture content (AMC). The curve number (CN) is a function of the soil's permeability, land use, and antecedent soil water content. The daily retention value adjusted for moisture content is calculated by rearranging equation 2 and inserting the retention parameter calculated for the soil which is completely saturated.

$$S = \frac{(25400)}{CN} - 254 \qquad \text{----------------(3)}$$

The curve number (CN) is a function of the soil's permeability, land use, and antecedent soil water content. The equation for the derivation of CN is

$$CN = \frac{\sum(P1A1+P2A2+\cdots+PnAn)}{\sum A} \qquad \text{-----------------(4)}$$

This equation calculates CN values based on hydrological soil groups and land use and land cover classes, where a 5% slope is under consideration.

The present equation calculates CN for AMC 2. The variability in the CN results from rainfall intensity and duration, total rainfall, soil moisture conditions, cover density, stage of growth, and temperature (Chen,(1975), Hjelmfelt, (1991), Holtan and Lopez (1971)). These causes of variability are collectively called the Antecedent Runoff Condition (ARC). ARC is divided into three classes: CN2 for average conditions, CN1 for dry conditions, and CN3 for wetter conditions. CN1 and CN3 can be calculated with the following mathematical equations.

$$CN1 = \frac{(4.2\,CN2)}{C10-0.058CN2} \qquad \text{-----------------(5)}$$

$$CN3 = \frac{(23CN2)}{10+0.13CN2} - 254 \qquad \text{------------------(6)}$$

Either CN1/CN2/CN3 is used for the calculation of Watershed Retention (S) using Equation 5 based on the AMC values.

$$S = \frac{(25400)}{CN1} - 254 \qquad AMC \leq 13$$

$$S = \frac{(25400)}{CN3} - 254 \qquad AMC>28$$

$$S = \frac{(25400)}{CN2} - 254 \qquad 28<AMC>13$$

3.RESULTS AND DISCUSSION

The Hydrological Soil Groups (HSG) and the land use of the Nadiar sub-watershed are integrated to identify the Curve Number (CN) of the specified region. Landuse/Landcover maps have been prepared in raster grid format. This study has adopted the NRCS Curve Number method to estimate the surface runoff. The CN values are calculated by using equations 4, 5 and 6. The surface retention is calculated by using equation 5. The actual direct runoff is estimated by using equation 5 with the values of CN value and surface retention. The result from the actual direct runoff is considered as 5% slope adjusted. The study area is considered to have the average slope of 5±1% (Fig. 4). It is estimated that the mean annual runoff varies from 210.79mm to 643.55mm **(Table1)** and mean annual rainfall varies from 691mm to 1418.5mm **(Table1).** The low mean annual rainfall and runoff recorded in 2014, 566.1mm and 210.79 respectively. The high mean annual rainfall and runoff recorded in 2011, 1418.5mm and 643.55mm **(Table1)** respectively.

The mean annual runoff distribution curve has been made for the study area. The trend line plotted for the mean annual runoff (**Figure 5)** clearly exhibits the negative trend through the years. It is evident that the infiltration rate has been increasing as the runoff decreases. Integration of the runoff result with the land

Table-1 Yearly Runoff and Rainfall (mm)

Year	RunOff (mm)	Rainfall (mm)
2002	290.05	691.0
2003	313.82	662.0
2004	400.92	1056.0
2005	627.67	1301.5
2006	542.04	1226.9
2007	403.58	1062.0
2008	525.39	1240.6
2009	294.22	708.0
2010	479.73	1200.0
2011	643.55	1418.5
2012	248.85	803.0
2013	516.98	1245.0
2014	210.79	556.1

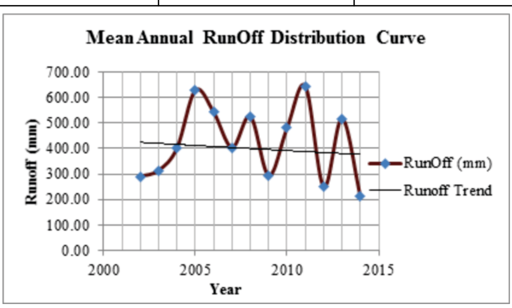

Figure 5. Rainfall-Runoff Trends

Table-2 Area coverage of the Landcover/Landuse (sq.km)

Landcover	2006
Cropland	460.76
Forest	55.31
Barren land	321.60
River streams	1.73
Waterbody	63.23
Rural	30.89
Urban	6.78
Total	940.30

use data would give a clear idea of the trendline. **Table-2** describes the land use in terms of areal coverage of 2006 and 2012. Area of the cropland has increased from 460.76 sq.km to 611.44 sq.km (as there is an increase in rainfall in 2011). Though there is an increase in the urban area (which reduces the infiltration), the percentage of increase is not as much as cropland. Due to the expansion of the cropland, there is much surface retention and infiltration, hence runoff has reduced in a visible manner.

The mean annual rainfall-runoff relationship curve has been plotted on a graph. The resulted curve is shown in the figure-3, which shows a negative relationship in the trendline. If rainfall increases the runoff should increase, but the trendline shown here is revealing the negative relationship between them. The rainfall trendline exhibits positive trend through years where the runoff trendline exhibits near negative trend through the years. The factors affecting the relationship between rainfall and runoff which are observed was land use/land cover changes and the AMC (Antecedent Moisture Content). AMC shows the average moisture content which is estimated using a 5 day rainfall mean. AMC increased with the continuous rainfall occurrence. Through the years, it is observed that the continuation of rainfall has reduced, hence the rainfall-runoff negative correlation can be seen.

CONCLUSION

This study mainly focuses on the estimation of losses due to surface runoff, which is favorably based on the soil infiltration characteristics and the continuation of rainfall occurrences. The knowledge of runoff from individual rainfall is essential to assess the runoff behavior of a catchment area and to obtain an indication both of runoff-peaks which the structure of a water harvesting scheme must withstand any of the needed capacity for temporary surface storage of runoff, for example, the size of an infiltration pit in a micro catchment system. The entire watershed receives relatively a good amount of rainfall. But, when compared to runoff, recharge is relatively low, as the terrain is comprised of crystalline rocks. This runoff potential can be used for the artificial recharge by constructing the farm ponds at suitable sites. Also, constructing the structures like check dams' water can be stored. It will be helpful for the dry summer days to be used as drinking water as well as agricultural purposes.

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