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Sensitivity of Curve Number and Initial Abstraction Coefficient on SCS-CN Method of Runoff Estimation in an Ungauged Watershed Intergrated With RS & GIS

Nambi Harish	PG student,S. V. University, Tirupathi
T. Hemalatha	Assitant Professor, S. V. University, Tirupathi.
C. Mahesh Babu	PG student, S.V. University, Tirupathi.

ABSTRACT

In the present study an attempt has been made to investigate the influence of the Curve Number (CN) and Initial abstraction coefficient (λ) on runoff estimation using SCS-CN method. The study area is an ungaugedwatershed delineated from IWRIS (C18PAL37) which falls within the Chittoor district. A study period of 14 years was considered in the investigation. The duration was classified into two models, i.e. Water-Year (WY) models and Rainfall-Event (RE) models. Each model was further classified into three models based on the CN values considered. Model-1, Model-2 and Models-3 for Pre monsoon, Post monsoon and Pre monsoon-Post monsoon CN values respectively. The CN values were developed by using LANDSAT imageries for the month of March and October during the years 2000 and 2010. With each model the initial abstraction values varied from 0 to 0.3 at 0.1 raise. The runoff was estimated for recorded daily rainfall depths using the standard SCS-CN equation. The resulted depths of runoff were checked for accuracy using R2-test.

KEYWORDS SCS-CN, Ungauged Watershed, Daily rainfall, WYmodel, REmodel, Initial Abstraction Coefficient.

INTRODUCTION

India has a geographical area of about 328.6 Mha, with the average annual rainfall varying from as low as 100 mm in the west to as high as 11,000 mm in the northeast. Of the $4x10^{12}$ m^3 average annual precipitation over India, the utilisable surface and groundwater resources have been estimated at $6.9x10^{11}$ m^3 and $6.9x10^{11}$ m^3, respectively, due to topographical, geologic, hydrologic and economic constraints (Sharda and Juyal, 2006) [1]. Also the land and water availability per capita is decreasing daily. With a projected annual population growth of 1.8% and per capita water availability in most parts of India touching the water stress level (< 1700 m^3/person/year), it is a challenging task for the agricultural scientists in India to sustain the required level of grain production. In the coming decades, the population growth, surface water pollution and climate change together may produce a drastic decline in fresh water supply. With the above factors in mind, the quantification and conservation of surface water resources are required to ensure sustainability. Estimation of surface runoff is essential to assess the potential water yield of a watershed, to plan water conservation measures, including the recharging of the ground water zones and the reduction of the sedimentation and flooding hazards downstream. Also, it is an essential prerequisite of integrated watershed management (IWM). In India, accurate information on runoff is scarce and only available in a few selected sites. Thus, there is an urgent need to generate information on basin runoff and sediment yield for the acceleration of the watershed development and management programs (Zade et al., 2005) [2]. Also, most of the agricultural watersheds in India were ungauged, having no past records of the rainfall–runoff processes (Sarangi et al., 2005) [3,4]. This has led to the development of techniques for estimating surface runoff from ungauged basins (Chattopadhyay and Choudhury, 2006) [5].

The SCS-CN method is based on the water balance equation and two fundamental hypotheses (Mishra and Singh 2003) [6].

The water balance equation states that:

$$P = Ia + F + Q \qquad (1)$$

The first hypothesis states that the ratio of the actual amount of direct runoff to the maximum potential runoff is equal to the ratio of the amount of actual infiltration to the amount of the potential maximum retention:

$$\frac{Q}{P-Ia} = \frac{F}{S} \qquad (2)$$

The second hypothesis states that the amount of initial abstraction is some fraction of the potential maximum retention.

$$I_a = \lambda S \qquad (3)$$

Where:

P = total precipitation (mm);

I_a = initial abstraction (mm);

F = cumulative infiltration excluding I_a (mm);

Q = direct runoff (mm);

λ = Initial abstraction ratio

S = potential maximum retention or infiltration;

The current version of the SCS-CN method presented in the National Engineering Handbook (NEH4) considers λ equal 0.2 for the usual practical applications. As the initial abstraction component accounts for factors like surface storage, interception and infiltration before runoff begins, λ can also take other values depending on the application. In theory, λ can take any value between 0 and ∞ (Mishra and Singh 1999)[7] but most of the current applications use the suggested value of 0.2.

Combining equations (1) and (2), the main equations for the SCS Curve Number Method are obtained:

$$Q = (P - Ia)^2/(P - Ia + S) \qquad (4)$$

$$I_a = 0.2*S \qquad (5)$$

By replacing Ia in equation (4), an equation with only two parameters is obtained as:

$$Q = \frac{(P-0.2*S)}{(P+0.8*S)} \qquad (6)$$

The potential maximum soil retention (S), can be obtained according to the CN value.

$$S = \frac{25400}{CN} - 254 \qquad (7)$$

The equations are based on the trends observed in data obtained from the study areas, so they are empirical equations rather than equations based on physical laws. The CN is a hydrologic parameter that relies implicitly on the assumptions of extreme runoff events and represents a convenient representation of the potential maximum soil retention (S) (Ponce and Hawkins 1996) [8]. The origin of the original CN array tables seems to be lost; Rallison (1980)[9] and Fennessey (2001b)[10] have published the only known papers indicating what watersheds the original data may have come from.

However, there also appears to be a misconception as to the scale of data that were actually used to develop the CN array table, or the CN's accuracy for use in making peak runoff rate estimates. The lack of information on the origins of the method and the lack of scientific testing of the results raised some doubts when very accurate results are needed, but the method is used everywhere in the world when a simple way to estimate some discharge values is needed.

MATERIAL USED:

A. Satellite data:

The LANDSAT imageries for the montha of March and October during the years 2000 and 2010 whih covres the study area were downloaded from LANDSAT archieves.

B. Meteorological data:

Daily rainfall data recorded at the stations with in the study area for the period of 2000 to 2014 was collected from IMD, Hyderabad

C. Software Used:

ArcGIS 10.1V was used to develop the LULC maps of respective preiods.

STUDY AREA:

***Location*:**

The major part of study area is covered by Chandragiri mandals, Pulicherla – Chinnagottigallu mandals on NorthWest, Pakala- Puthalapattu on South West, Ramachandrapuram on South East and Tirupati (Urban & Rural) on North East. It is located 13°26′ to 13° 45′ N and 79° 6′ to 79° 22′ E and covering an area of 545.79 Sq.Km. It is included in the Survey of India Topographical sheets of 57 [illegible] , 57 [illegible] and 57 [illegible] on a scale of 1:50,000.

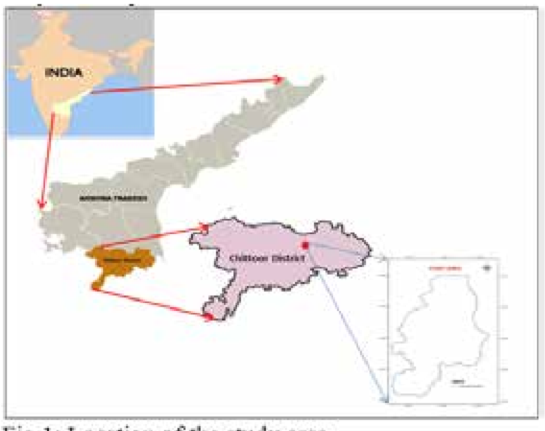

Fig 1: Location of the study area

METHODOLOGY:

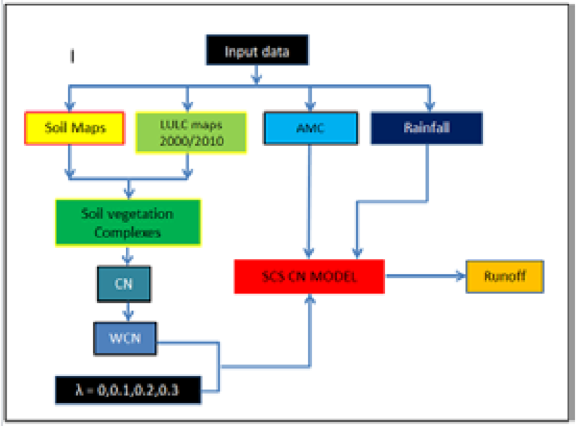

Fig: 1 Methodology to estimate surface runoff by SCS CN models

The Soil maps were downloaded from IWRIS website and the same was used for determining the Hydrological Soil Group in the study area. The LULC maps for the years 2000 and 2010 were developed using ArcGIS with Ground truth verification. The CNIII and CN I were derived by using the standard equation given for CNII. The Anticdent Moisture Condtions for respective CN-values are considered from the standard version of SCS-CN method. Finally the observed daily rainfall data were converted into mean precipitation over the watershed using the Theissen polygon method in ArcGIS. The daily mean depths of rainfall were considered to estimate the runoff depths.

CONCLUSIONS:

The daily runoff was estimated using SCS-CN method and the following results are observed.

- At λ = 0, $WY_{models(1,3)}$ resulted higher depth of runoff when compared with $RE_{models(1,3)}$ and RE_{model2} resulted higher depth of runoff when compared with $WY_{model2.}$
- At λ = 0.1, all the $RE_{(models1,2,3)}$ resulted higher depth of runoff when compared with $WY_{model(1,2,3)}$.
- At λ = 0.2, all the $RE_{(models1,2,3)}$ resulted higher depth of runoff when compared with $WY_{model(1,2,3)}$.
- At λ = 0.3, all the $RE_{(models1,2,3)}$ resulted higher depth of runoff when compared with $WY_{model (1,2,3).}$

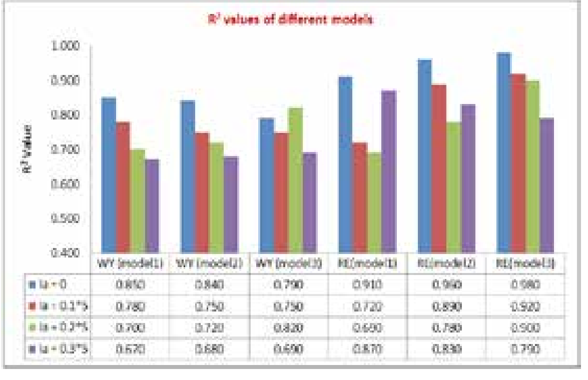

Fig 2:Comparison graph of Correlation coefficient (R^2) values of the models considered.

- The highest correlation value was obtained in RE_{models} for Initial abstraction coefficients 0.1 and 0.2.
- The runoff in the watershed was estimated with different

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combinations of available data i.e. WY_{models} and RE_{models}.

- The estimated runoff was correlated with a mean depth of rainfall, whichresulted in higher values for RE_{model3}.

- Based on the results it is determined that the SCS CN methodfits well with higher correlation between runoff estimated and rainfall for shorter durations (RE_{models}) when compared with longer duration models (WY_{models}).

- It is determined that the SCS CN method gives the best results by using the CN values derived from the respective time periods (LULC maps of pre monsoon and post monsoon) rather than using one set of data throughout the study period.

SCOPE OF THE STUDY IN FUTURE

To determine the best model out of considered models in this project work which gives an accurate runoff estimation for an ungauged watershed can be determined by adopting these models for a gauged watershed. The results obtained from the analysis of gauged watershed are further checked for Root-mean square error (RMSE), t-test and other regression checks apart from correlation analysis

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