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EFFECTIVE UTILISATION OF PRECIPITATION & ESTIMATION OF RUNOFF IN SASWAD REGION BY IMPLEMENTATION OF SCS-CN METHOD & ARC-GIS SOFTWARE

[1]Roshan Vijay Patil, [2]Sail Ramchandra Parab, [3]Samruddhi Raju Lembhe, [4]Amaan Moinoddin Chiniwar, [5]Dnyaneshwar Murlidhar Jade

[1 2 3 4]Student of Civil Engineering, [5]Assistant Professor in Civil Engineering
Department of Civil Engineering,
Sinhgad Academy of Engineering, Pune, India

Abstract: One of the most significant natural resources and a vital component of a state's and nation's socio-economic growth is water. Due to rising demand and finite supply, water resources in India and around the world are under extreme strain. The only way to close the gap between supply and demand is through effective water management. The hydrologic cycle's main component, rainfall, serves as the main source of runoff. The study was conducted at the Saswad region, which is situated in the Pune districts of Maharashtra State, India, between 18° 20' 34.224" North latitude and E 74° 1' 36.5412" East longitude. Although it is always possible to estimate direct precipitation runoff for the catchment area without sampling, it is not always efficient. The issue of runoff estimation may be resolved by utilizing GIS and remote sensing technologies. This study use the SCS-CN Model as its methodology. The monthly runoff calculation process uses the SCS-CN model and GIS to gather precipitation data from Indian Meteorological Department (IMD) stations, Pune.

***Keywords* – Runoff, GIS, SCS-CN, AMC, ARC-GIS Software.**

I. INTRODUCTION

Among the most significant hydrological factors utilized in the majority of applications involving water resources is runoff. Its frequency and amount are determined by the precipitation event's intensity, length, and distribution. [1] The occurrence and amount of runoff are directly impacted by a number of catchment-specific parameters in addition to these precipitation features. These consist of catchment type, slope, vegetation cover, and soil type. For calculating initial abstraction and runoff as a function of soil type and land use, SCS-CN offers an empirical relationship. Curve number (CN) is an index developed by the Natural Resource Conservation Service (NRCS) to represent the potential for stormwater runoff within a watershed. The CN for a watershed is estimated using a combination of land use, soil, and antecedent soil moisture condition (AMC).

There are four hydrologic soil groups: A, B, C and D. Group-A have (Low Runoff Potential), these soils have high rate of water transmission. [Example: Deep sand, Deep loess and Aggregated silt]. Group-B have (Moderately Low runoff Potential), these soils have moderate rate of water transmission. [Example: shallow loess, sandy loam, red loamy soil, red sandy loam and red sandy soil]. Group-C have (Moderately High Runoff Potential), these soils have moderate rate of water transmission. [Example: clayey loam, shallow sandyloam, soils usually high in clay, mixed red and black soils]. Group-D have (High Runoff Potential), soils having very low infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high-water table, soils with a clay pan, or clay layer at or near the surface, and shallow soils over nearly impervious material. [Example: Heavy plasticclays, certain saline soils and deep black soil].

The Soil Conservation Service Curve Number (SCS-CN) method is often used to predict the direct runoff volume for a given soil group precipitation event. This method was originally developed by the US Department of Agriculture, Soil Conservation Service and documented in detail in the National Engineering Handbook, Sect. 4: Hydrology (NEH-4) SCS, 1956, 1964, 1971, 1985, 1993). The main reason for its success of this method is that it takes into account many of the factors that influence runoff generation, including soil type, land use and treatment, surface characteristics, and antecedent moisture conditions, and combines them into a single CN parameter. In addition, it is the only method that includes easily understood and reasonably well documented environmental influences. It is an established method that is widely accepted in the United States and other countries. On the other hand, the SCS-CN has the following weaknesses: It does not account for the effects of precipitation intensity and its temporal distribution, it does not address the effects of spatial scale, it is very sensitive to changes in the values of its single parameter, and it does not clearly address the effects of adjacent moisture conditions.

Role of ArcGIS

An essential instrument in the examination of factors like land use/cover, soils, topography, and hydrological conditions is geographic information system (GIS), which is made to preserve, alter, retrieve, and display spatial and non-spatial data. Information from remote sensing data must be combined or integrated with a database in a geographic information system (GIS) in order to monitor resources and evaluate areas of interest. Thus, remote sensing and GIS applications assist gather, process, and evaluate data quickly and on a wide scale periodically, which is particularly beneficial for watershed planning.[2] Traditional techniques for estimating runoff using the SCS model are laborious and prone to mistakes. Given that every component of the SCS model has a geographic component, remote sensing and geographic information system (GIS) approaches are therefore being utilized more and more. Because these SCS runoff model components are spatial in nature, modeling them into a GIS is simple. Using satellite data, some Indian researchers have tried to determine the runoff curve number. Using data from Landsat, Ragon and Jackson (1980) calculated the runoff curve of a basin.

Study Area

The study area is located between latitudes 18° 20' 34.224" North and longitude E 74° 1' 36.5412" East in the Pune districts of Maharashtra State, India. The area receives 600.74 mm of rainfall on average per year. The region has recorded mean maximum and lowest temperatures of 102°F (39°C) to a low of 73°F (23°C), respectively. The study area's location is shown in Figure. 1. Using Arc GIS, the watershed's total area was calculated to be 25.38 km2. The soil is 70% of clayey loam.

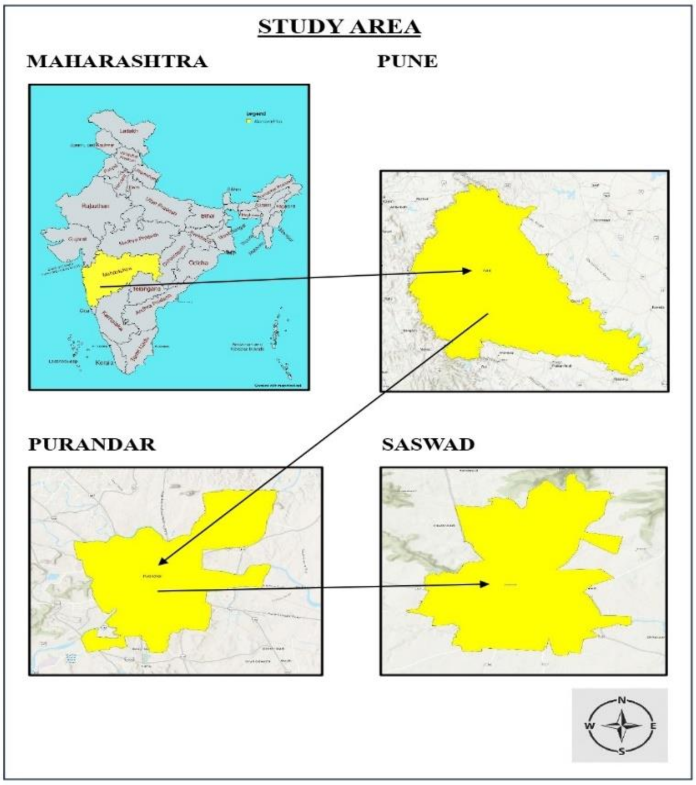

Fig. 1. Location of Study Area

II. LITERATURE SURVEY

With the reference Effective Utilization of Precipitation & Estimation of Runoff by Implementation of Arc-GIS, the various researchers have contributed in estimation of runoff, their study is present below.

(Ashish Bansode, K. A. Patil.) [3] in this research work daily rainfall in the catchment area is studied for a period of 10 years i.e., from 2003 to 2012. The highest daily rainfalloff 111.2mm was recorded on 6th August 2006. The highest monthly rainfall recorded was 367.1mm in the month of September 2008 and the highest yearly rainfall recordedwas 1140mm in the year 2010. In the above 10 years period, July and August months recorded maximum rainfall. The rainfall shows fluctuating nature during the ten years. The runoff for the study area is calculated using SCS method for a period of 10 years i.e., 2003-2012. The calculated yearly runoff in mm for the years from 2003 to 2012 is430, 401, 214, 582, 279, 499, 341, 707, 271 and 135 mm respectively. The monthly runoff and yearly runoff are calculated for the period of 10 years using SCS-CN method.Minimum runoff was observed in the year 2012 and maximum runoff was observed inthe year 2010 by using SCS-CN method. The correlation coefficients for daily, monthlyand yearly runoff are 0.73, 0.97 and 0.99 respectively. The graph for the yearly runoffis best fitted than daily and monthly runoff.

(Abanish Kumar, Shruti Kanga, Ajay Kumar Taloor, Suraj Kumar Singh, Bojan Durin.)[4] Conclude that the SCS-CN method integrated with GIS techniques is beneficial for runoff estimation. This method can also be used in watershed management effectively. Variation in runoff potential is observed in the obtained resultwith different land use/land cover and varying soil conditions in the study area. Most of the river basin indicates a high curve number of more than 70, which means high runoff in the Sind River basin.

(Ganesh V, Ajey Kumar V G, et.al.)[5] Observed that Rapid evolution and encroachment are a major cause of flooding in the city of Bengaluru. The area under consideration is frequently damaged by floods without rainy season constraints. Over 50 per cent of total annual precipitation recorded in August, September and October in 2005 with maximum annual precipitation of 1596 mm. The study field subject maps were generated, such as accumulation of flow, flow direction, drainage, land use, etc. Runoff estimates for Hebbal Valley for the year 2018 were calculated for the 24 micro-watersheds of the research region using SCS-CN TR-55 for an urban hydrologic approach and time of concentration. Studies have also shown that action on present management methods must be taken and storm water management approaches must beintegrated for the city of Bangalore.

(Sarita Gajbhiye.)[6] have suggested the Remote sensing and GIS technique is a very reliable alternative or a dependable support system to our conventional way of surveying, investigation, planning, monitoring, modelling, data storing and decision- making process. The synoptic concept of satellite image is fairly easy for identificationof the broad physical features such as stream network, land use/land cover, soils surface,water bodies etc. The land use/land cover is an important parameter input of SCS modelwhich could be determined very accurately with help of this technique. With the help of RS, GIS and SCS model it is possible to make management plans for usage and development of watershed. Although Curve number method is empirical approach to determine the runoff depth from the watershed. But it can be useful for estimating the runoff for places which do not have runoff record.

(Eshanthini P, P. Vijayalakshmi, P.K. Raji.)[7] conclude that the SCS-CN model is thesimplest model to calculate the runoff for a study area. This SCS model along with GISwill give a more accurate runoff value for ungagged streams and rivers. Remote sensing and GIS are used to identify and create a map for land use and soil type. In the presentstudy remote sensing and GIS were used to calculate CN value which can used to estimate runoff depth for larger area with lesser time period.

III. RESEARCH METHODOLOGY

Land Use and Land Cover

The land use map (Figure 2) downloaded from Bhuvan website was used to prepare a land use pattern of the study area. The original land use types were grouped into five groups as Wetland/Water Bodies/Reservoir, Grass/Grazing, Agriculture/Crop Land, Built-up Area/Urban, Uncultured/Wasteland.

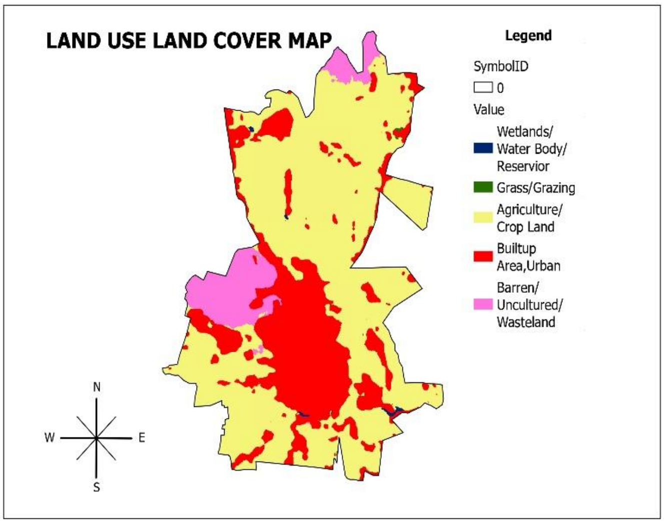

Fig. 2. Land Use Land Cover Map of Saswad Region

Soil Map

Information on soils in the study area were obtained from the maps of soil types which were obtained from https://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/faounesco-soil-map-of-the-world/en/ website . The soil map of Saswad region was prepared using Arc GIS Pro software. The soil map is then classified into hydrological soil group map, which refers to the infiltration capacity of the soil and classified into 4 classes such as A, B, C, D. In our study only two type of soil (Clayed Loam, Clay) was present (Figure 3) which comes under the hydrologic soil group C.

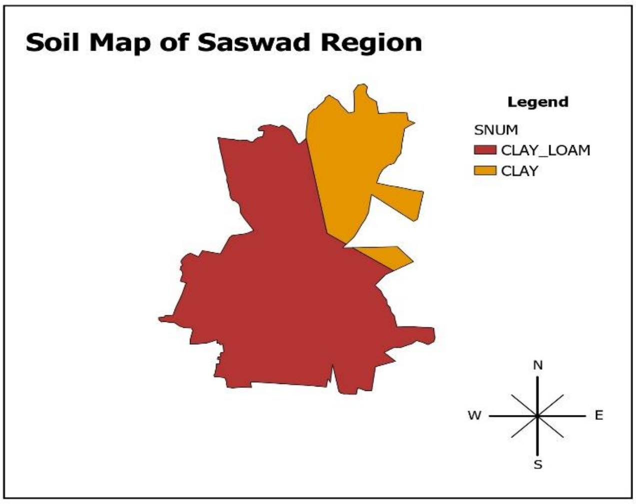

Fig. 3. Soil Map of Saswad Region

Digital Surface Model

A digital surface model (DSM) or digital elevation model (DEM) is a 3D computer graphics representation of elevation data to represent terrain or overlaying objects, commonly of a planet, moon, or asteroid. A DSM (Digital Surface Model) captures both the natural and built/artificial features of the environment and DEM (Digital Elevation Model) Represents the bare-Earth surface, removing all natural and built features. Therefore, digital surface model (DSM) data plays the same role as that of conventional paper contours and relief shading with one additional benefit of it providing a powerful analytical perspective (Figure 4).

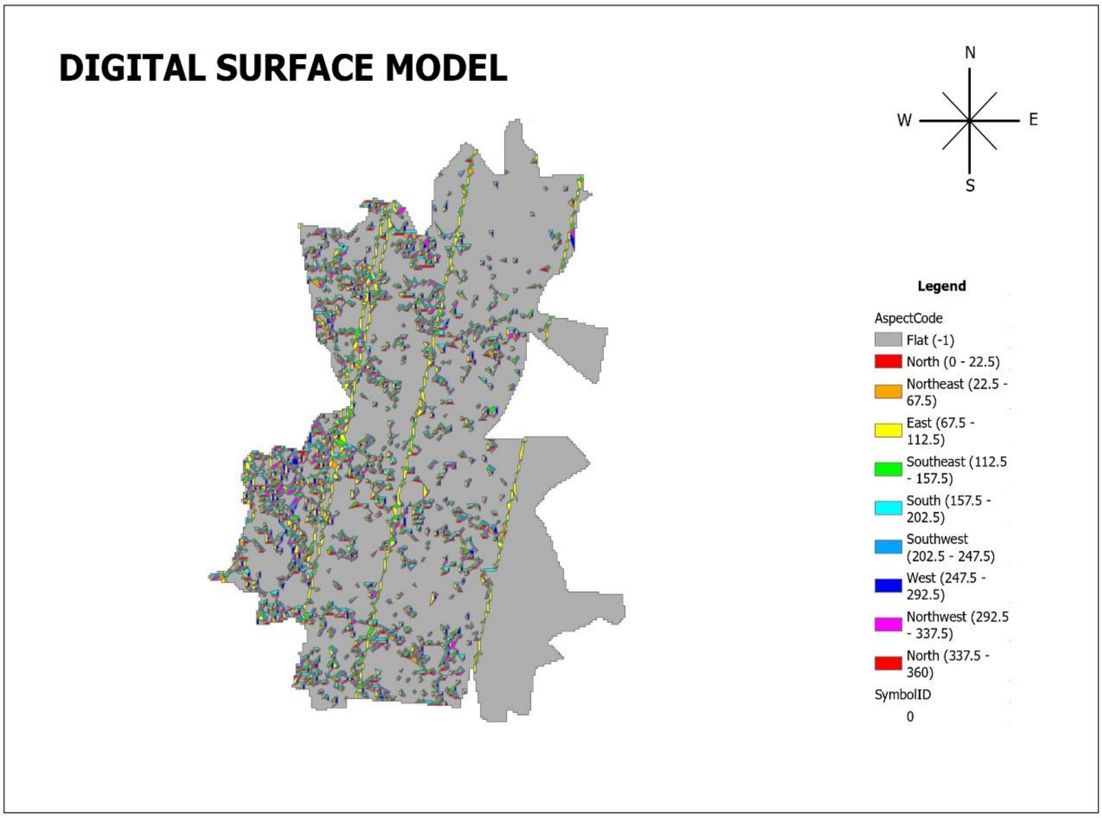

Fig. 4. Digital Surface Model of Study Area

SCS Method

The SCS-CN method is developed in 1954 by the USDA soil conservation service. This method is based on water balance equation and two functional hypotheses. The first hypotheses are that 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. The second hypotheses are that the amount of initial abstraction is some fraction of the potential maximum retention. Water balance equation is,

$$P = I_a + F + Q \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, P= total precipitation, IA= Initial abstraction, F= Cumulative infiltration, Q= direct runoff from first hypotheses,

$$\left(\frac{Q}{P-Ia}\right) = \frac{F}{S} \text{ ……………………………………(2)}$$

From second hypothesis,

$$Ia = \lambda.S \text{ ………………………………………(3)}$$

Combining equation 2 & 3,

$$Q = \frac{P-Ia}{P-Ia+S} = \frac{P-\lambda.S}{P+(1-\lambda)S} \text{ for,}$$

$$P > \lambda.S$$

$$Q = 0 \text{ for } P \leq \lambda.S$$

From Indian soil condition the above relation is modified as

$$Q = \frac{P-0.3S}{P+0.7S}\lambda = 0.3 \text{ ……………………………..(4)}$$

Curve Number

The curve number gives bases on Antecedent moisture condition, soil group and land use and land cover pattern of the study area for convenience in practical application thesoil conservation service (SCS) of USA has expressed S (in mm) in terms of a dimensionless parameter CN (the curve number) as

$$CN = (25400)/S - 254)$$

And has a range of $100 \geq CN \geq 0$.

Antecedent Moisture Condition (AMC)

It refers to the moisture content present in the soil at the beginning of the rainfall-runoffevent under consideration. It is well known that initial abstraction and infiltration are governed by AMC. For purpose of practical application three levels of AMC are recognized AMC are recognized by SCS as follows

- AMC-I: soil is dry but not to wilting point. Satisfactory cultivation has taken place
- AMC-II: Average condition
- AMC-III: Sufficient rainfall has occurred within the immediate past 5 days. Saturatedsoil condition prevails

Table No 1.1: Antecedent moisture condition (AMC) for determination the value of CN

AMC type	Dormant Season	Growing Season
I	Less than 13mm	Less than 36mm
II	13to 28mm	36 to 53mm
III	More than 28mm	More than 53mm

Soil Groups

In the determination of CN, the hydrological soil classification is adopted. The soils are classified into four classes A, B, C and D based upon the infiltration and other characteristics. The important soil characteristics that influence hydrology classification of soils are effective depth of soil, average clay content, infiltration characteristics and permeability. Following is a brief description of four hydrology soil groups:

I. **Group-A: (Low Runoff Potential)** Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands orgravels. These soils have high rate of water transmission. [Example: Deep sand, Deep loess and Aggregated silt]

II. **Group-B: (Moderately Low runoff Potential)** Soils having moderate infiltration rateswhen thoroughly wetted and consisting chiefly of moderately deep to deep, moderatelywell to well-drained soils with moderately fine to moderately coarse textures. These soils have moderate rate of water transmission. [Example: shallow loess, sandy loam, red loamy soil, red sandy loam and red sandy soil].

III. **Group-C: (Moderately High Runoff Potential)** Soils having low infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep. moderatelywell to well drained soils with moderately fine to moderately coarse textures. These soils have moderate rate of water transmission. [Example: clayey loam, shallow sandyloam, soils usually high in clay, mixed red and black soils].

IV. **Group-D: (High Runoff Potential)** Soils having very low infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high-water table, soils with a clay pan, or clay layer at or near the surface, and shallow soils over nearly impervious material. [Example: Heavy plasticclays, certain saline soils and deep black soil].

V. RESULT & CONCLUSION

Estimate of runoff in a specific area starts with taking into account the hydrological factors and how precipitation interacts with terrain, soil, and current land use. Employing GIS as a foundation for data storage, analysis, and visualization provides an effective framework for the aforementioned procedure. The primary focus of the work was on the application of GIS and remote sensing to hydrological modeling. The Saswad Region's soil type, classified as hydrologic soil group 'C', is clayed loam/clay (Figure 3). Antecedent moisture condition (AMC) type is calculated by adding up all of the rain that collected during the preceding five days during the growing and dormant seasons in order to get the value of CN. Rainfall over the last five days has satisfied the AMC-II average criteria, with a value of 90. The SCS approach was used to approximate the runoff from the subbasin. The average yearly runoff in AMC (II) condition was found to be 38.87 mm.

It was determined that the kind of land use and land cover, the state of the soil, and the amount of rainfall all had an impact on the runoff behavior of the study region. It was discovered that greater CN values indicated larger runoff, and lower CN values indicated reduced runoff. The preferred location will be determined after estimating and analyzing precipitation and runoff, ensuring that the water collects at the desired location. The water that has been collected or stored will be sent out through pipelines and canals to be used for domestic, agricultural, and industrial purposes.

VI. ACKNOWLEDGEMENT

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