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Hydrological modelling of Guntur basin using remotesensing and Gis

V. Venkata Jyothi*
K. Jyothi Pavan**
Balakrishna Penta***
M. Anupama****

Abstract

The runoff characteristic of a particular catchment area is mainly depends on rainfall characteristics, catchment characteristics and climatic factors etc. The main influence factor among these three is catchment characteristics like soil, land use/cover, slope, geology, shape and drainage. The geology of the basin is significant to the amount of deep percolation losses. The study of catchment characteristics is mainly stimulating the runoff for a basin. The land use/cover plays an important role in creating infiltration and evapotranspiration opportunities and retarding of runoff. Soil Conservation Services and Curve Number (SCS-CN) method broadly suggested the runoff volume calculation. Arc-GIS tool is used to develop boundary, drainage, digital elevation, flow direction, flow accumulation and land use/cover map etc. of the selected basin. For producing runoff, land use/cover and soil maps are used as input for the conceptual SCS-CN method. Guntur District, is one of the basin and it is located in Andhra Pradesh is taken into consideration for the present study. Arc-GIS tool is used to develop selected basin maps. Attribute table is developed from the Arc-GIS by overlapping of land use/cover and soil maps and it is used as an input in the SCS-CN method for calculation of runoff volume for a given catchment area. By the application of Arc-GIS software, identified the exact location of the maximum accumulation point and the investigations are done about the storage structure at that location if available. If not proposal is made for a suitable hydraulic structure to manage the accumulated runoff volume.

Keywords:

Runoff;
SCS-CN method;
Arc-GIS tool;
Land use/cover map;
Soil map.

*Assistant Professor, Civil Engineering Department,VLITS, Vadlamudi, Guntur, A.P.India
**U.G.Student , Civil Engineering Department,VLITS, Vadlamudi, Guntur, A.P.India
***Research Scaholar, Department of Geo-Engneering, Andhra niversity,Visakhapatnam,A.P.India
*** *U.G.Student , Civil Engineering Department,VLITS, Vadlamudi, Guntur, A.P.India

Author correspondence:

V. Venkata Jyothi,
Assistant Professor, Civil Engineering Department,
VLITS, Vadlamudi, Guntur, A.P.

1. Introduction

Changes in climate and frequent extreme events, as well as the population growth and changing market demands will impact the use and availability of fresh water resources. The impacts due to climate change on fresh water resources, agriculture production and food security is inadequate in developing countries. In countries like India, where water is a limited resource, this will lead to a redistribution of water resources between the different sectors and user groups. Developments of our society are dependent on the availability and use of adequate water. This precious resource is sometimes scarce, sometimes abundant but unevenly distributed, both in space and time.

Hydrological modeling is a powerful technique of hydrologic system investigation for both the research hydrologists and practicing water resource engineer involved in the planning and development of integrated approach for management of water resource. Hydrologic models are symbolic or mathematical representation of known or assumed function expressing various components of the hydrologic cycle [9]. Accurate stream flow forecasts are an important component of watershed planning and sustainable water resources management [1]. The modern burst of development in deterministic modeling of rainfall-runoff processes started from the 1930's, and the unit hydrograph concepts of Sherman [3, 7].

The first models that predicted runoff from rainfall were developed as early as halfway the nineteenth century [5,6] used SCS-CN method for computation of direct runoff from long duration rains for five Indian watersheds. They derived curve numbers from long-term daily rainfall runoff data and Antecedent Moisture Condition (AMC) related with antecedent duration. Rainfall-runoff modeling can be undertaken on different catchment discertization scales: starting from representative volumes of a few centimeters, going up to the whole catchment being treated as one element [8].

Many researchers [2, 4] used land use / land cover information derived from satellite data of Landsat, SPOT, & IRS Satellite and integrated them with GIS to estimate SCS-CN and runoff.

2. Research Method

Runoff for a particular catchment area is calculated using SCS-CN method and it was developed by soil conservation services (SCS) of USA in 1969. It is simple, can predict accurately, and a stable conceptual method for estimation of direct runoff depth based on rainfall depth and catchment characteristics. It depends on only one parameter, CN. Water balance equation of the rainfall in a known interval of time is the basis of the method, which can be expressed as given below

$$P = Ia + F + Q \tag{1}$$

Where P = Total precipitation

I_a = Initial abstraction

F = Cumulative infiltration excluding I_a

Q = Direct surface Runoff

The first concept is that the ratio of actual amount of direct runoff (Q) to maximum amount of potential runoff (=P-I_a) is equal to the ratio of actual infiltration (F) to the potential maximum retention (or infiltration), S. The proportionality concept can be represented as

$$\frac{Q}{(P-I_a)} = \frac{F}{S} \tag{2}$$

The second concept is that the amount of initial abstraction (Ia) is some fraction of the potential maximum retention(S). Thus

$$I_a = \lambda S \tag{3}$$

Combining equation (2) and (3)

$$Q = \frac{(P-\lambda S)^2}{(P-\lambda S+S)} \tag{4}$$

Where P = Daily Rainfall

Q = Daily Runoff from the catchment.

The parameter S represents the potential maximum retention. It depends up on the soil-vegetation-land use complex of the catchment and also up on the antecedent soil moisture content in the catchment just before the starting of the rainfall event. For convenience in practical application the soil conservation service of USA has expressed S (in mm) in terms of dimension less parameter *CN* (Curve number) as

$$S = \frac{25400}{CN} - 254 \tag{5}$$

And it is in the range of $0 \leq CN \leq 100$. A CN value of 100 represents a condition which has zero potential retention i.e. impervious catchment a CN=0 represents an infinitely abstracting catchment with S. The curve number CN depends upon soil type, land use/cover and antecedent moisture condition. For the present study using Arc-GIS the value of CN is obtained by overlapping the digitized soil and land use/cover map. Digitization means convertion of raster image to vector shape file and it consists of attribute table. There are three different CN conditions like CN-I, CN-II and CN-III responding to different AMC conditions.

2.1 Antecedent Moisture Condition (AMC)

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

AMC-I: Soils are dry but not to wilting point.

AMC-II: Average condition

AMC-III: Sufficient rainfall has occurred with in the last 5 days saturated soil condition prevails.

The limits of these three AMC classes, based on total rainfall magnitude in the previous 5 days are shown in Table 2.1[10]. This depends up on two seasons 1) growing season 2) Dormant season.

Table 2.1 AMC for determining the value of CN

AMC Types	Total rain in previous 5 days	
	Dormant season	Growing season
I	Less than 13mm	Less than 36 mm
II	13 to 28 mm	36 to 53 mm
III	More than 28 mm	More than 53 mm

By the application of Arc-GIS software, identified the exact location of the maximum accumulation point and the investigations are done about the storage structure at that location if available. If not proposal is made for a suitable hydraulic structure to manage the accumulated runoff volume.

3. Results and Analysis

The methodology discussed in above is applied to the selected study area, i.e., the Guntur basin. Final attribte table is obtained by overlapping the digitized land use/cover and soil maps using Arc-GIS. The obtained attribute table consists of 24935 location points. For each location assigned CN value from standard tables [10].Using annual maximum average daily rainfall and CN values, runoff depth is calculated using above methodology for 24935 points. Here the results are presented in the form of table and graph for 55 location points. The graph 3.1 represents the annual maximum rainfall depth for corresponding 55 location points. The table 3.1 and graph 3.2 represents the runoff depth for corresponding 55 location points. The table 3.2 and graph 3.3 represents the runoff volume for corresponding 55 location points.

Graph 3.1 Annual Maximum Rainall Year

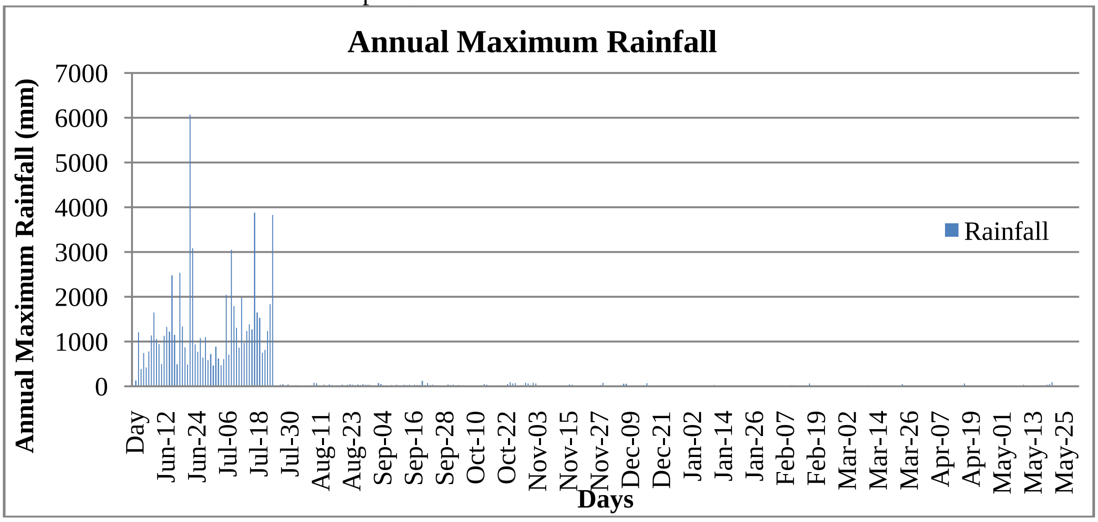


Table 3.1 Runoff depth in mm

Location Points	866	867	868	869	870	871	872	873	874	875	876	877	878	879
Runoff Depth (mm)	65625	69840	72410	72410	72730	72730	72410	72410	74161	69047	65625	69047	65625	65625
Location Points	880	881	882	883	884	885	886	887	888	889	890	891	892	893
Runoff Depth (mm)	65625	69047	69047	69047	69047	69840	65625	65625	69840	65625	65625	69840	69840	65625
Location Points	894	895	896	897	898	899	900	901	902	903	904	905	906	907
Runoff Depth (mm)	72410	72410	74161	72410	73411	72730	74161	74575	68785	69310	71215	73411	73411	74575
Location Points	908	909	910	911	912	913	914	915	916	917	918	919	920	
Runoff Depth (mm)	59913	64523	68785	59913	64523	69310	69310	72730	72730	64523	72730	68785	68785	

Graph 3.2 Runoff Depth

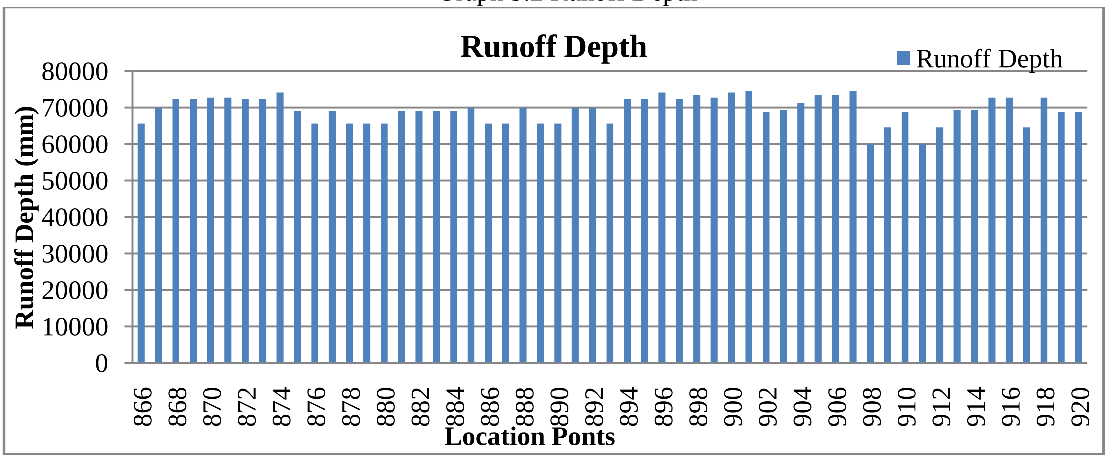
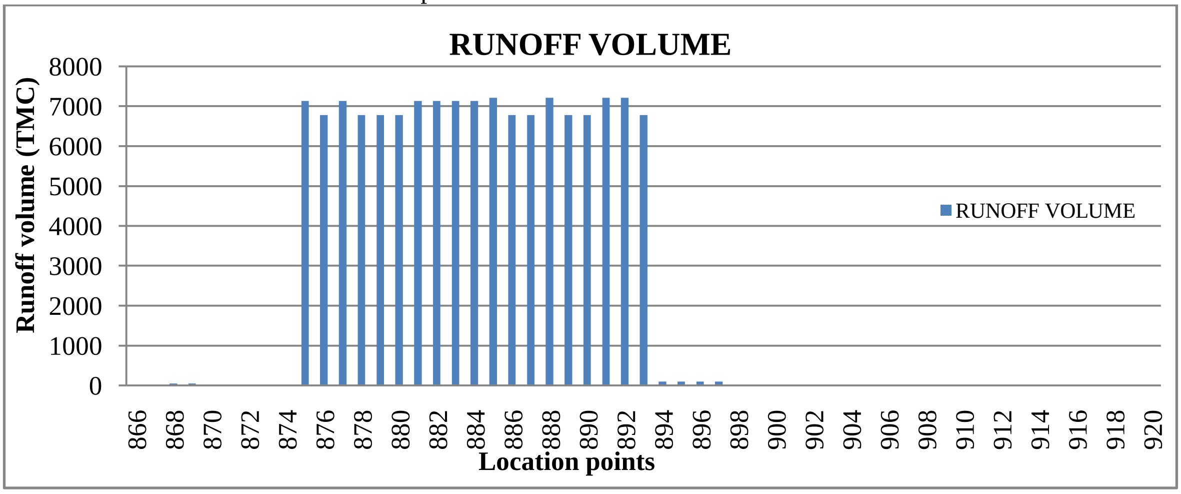


Table 3.2 Runoff Volume in TMC

Location Points	866	867	868	869	870	871	872	873	874	875	876	877	878	879
Runoff Depth (TMC)	10.5	11.2	45.9	45.9	8.57	8.57	1.34	1.34	1.37	7134	6780	7134	6780	6780
Location Points	880	881	882	883	884	885	886	887	888	889	890	891	892	893
Runoff Depth (TMC)	6780	7134	7134	7134	7134	7216	6780	6780	7216	6780	6780	7216	7216	6780
Location Points	894	895	896	897	898	899	900	901	902	903	904	905	906	907
Runoff Depth (TMC)	97.3	97.3	99.64	97.3	1.67	1.67	1.87	1.88	0.69	0.69	1.1	1.1	1.1	0.05
Location Points	908	909	910	911	912	913	914	915	916	917	918	919	920	
Runoff Depth (TMC)	5.02	5.4	5.77	0.78	0.84	0.91	0.91	0.24	0.16	0.42	0.11	0.23	0.15	

Graph 3.3 Runoff Volume in TMC



4. Conclusion

The graph 3.1 shows the variation of rainfall in mm for different seasons. The graph 3.2 shows the runoff depth in mm. Finally graph 3.3 shows the runoff volume in terms of TMC for 55 location points.

- The maximum runoff depth is 74575 mm
- The maximum runoff volume is 7216 TMC

The maximum runoff volume is obtained in Mutukuru reservoir forest area. The obtained results are analysed by using past 30 years rainfall data. Based on these results a major storage structure can be constructed for different purposes.

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