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Rainfall-Runoff Estimation Of Palakonda Watershed By Using Scs-Curve Method, Parvathipuram, Manyam District, Andhra Pradesh

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Abstract
One of the most important hydrological parameters used in the great majority of applications involving land and water assets is runoff. It is a vital aspect to consider soil and water protection practices in a watershed at a smaller scale level. Rainfall-induced runoff is a crucial part of the hydrological cycle. For the design of hydrological structures and drainage systems in watersheds, runoff estimation is essential. Runoff is impacted differentially by various soil types, land uses, and water management techniques. In actual watersheds, runoff is spatially varying due to variations in land use, soils, and weather conditions across the watershed's geographic region. Additionally, the majority of watersheds are a part of bigger drainage basins or larger watersheds made up of numerous smaller watersheds. Every sub-watershed is hydrologically related to the others the basin's various sub-watersheds. In addition, the SCS-CN(NRCS-CN) Natural resources conservation service- curve number model requires a number of necessary inputs, including the Hydrological Soil Characteristics (HSG), precipitation (P), Potential Maximum Retention (PMR), Antecedent Moisture Condition (AMC), and Weighted Curve Number (WCN). Palakonda watershed results are average rainfall in this study area is 1181.6mm and 75%dependable yield in runoff is 263 mm and capacity is74.54 mcft and ayacut area 1065.8 acres and utilization in 159.8 mcft and balance yield is 131.7 mcft in this watershed covered in 110 tanks and peddagadda stream and Nagavali left canal passes through in this area. The issue with conventional methods for calculating runoff can be resolved with the help of remote sensing and GIS technology.

Key Words: Natural resources conservation service- curve number, Hydrological Soil Characteristics, Potential Maximum Retention (PMR), Antecedent Moisture Condition (AMC), and Weighted Curve Number (WCN).

Introduction:

A watershed is a region where all water entering it flows to a single outflow, also known as a drainage basin or catchment area. It is bordered by the ridgeline, which is the highest contour, from which precipitation is gathered by surface and subsurface flows and discharged by the natural river.
The area of all the land that produces runoff water to a single location is known as a watershed. In Palakonda, the majority of sites hardly ever include up-to-date information about runoff. However, the information on runoff has become necessary due to the acceleration of watershed management plans for conservation and the growth of natural resource management. The main hydrologic factor in assessing water resources is rainfall and runoff. There are many ways to calculate runoff from rainfall, but the SCS-CN approach is still the most well-known and often applied method because its key component, runoff curve number (CN), is dependent on LULC (land use/land cover), soil type, and antecedent soil moisture (AMC) Its occurrence and output are influenced by the intensity, duration, and dispersion of rainfall events. The need to estimate runoff from a watershed where there are records of precipitation but no records of runoff present the problem that hydrological studies run into the most frequently. Comparing runoff characteristics to those of watershed characteristics is one strategy for solving this issue. When the rain gauge is placed outside of the basin, this poses many difficulties for the discharge prediction. Some utilities, like hydrological modelling, require spatially continuous rainfall data as a result. Therefore, the quality of the continuous spatial rainfall is used to gauge the quality of such a result. Different spatial interpolation methods have also been employed in the past to generate representative rainfall over the entire basin or sub-basins The process through which rainfall is converted to runoff is extremely complicated, dynamic, nonlinear, and characterised by temporal and spatial variability. It is additionally impacted by a variety of characteristics and frequently connected physical issues (C. Chatterjee et al 2013). Depending on the

small- or large-time length, the amount of rainfall on the watershed results in high or low runoff. Depending on how long the water is left in the watershed, the infiltration and evaporation losses will change. For hydrologists, engineers, and agriculturalists, establishing a solid correlation between rainfall and runoff for a watershed has been one of the most challenging issues.

Factors Affecting SCS Curve Number:

The Curve Number is a dimensionless parameter that describes the drainage basin's characteristic runoff response. In the Curve Number Method, the CN is connected to the drainage basin's antecedent soil moisture condition, hydrological condition, land use, land treatment, hydrological soil group, and hydrological condition.
GIS in particular helps in integrating various data sets and perform spatial analysis for decision making. The objective of this study is to estimate the runoff using Remote Sensing (RS) and Geographic Information System (GIS) by SCS-CN method.

Study Area:

The Palakonda Watershed Area North Region of Andhra Pradesh state (INDIA) is selected for the present study. Geographical area of the Palakonda watershed area covers in Manyam District. Palakonda watershed lies between $18^0$46'26" to $18^0$35'12" North latitudes and $83^0$39'1" to $83^0$46'15" East longitudes. The major river is Nagavali river are following in this region. In this study area $18^0$29'07" N to $83^0$48'31" E is located on peddagadda sub- tributary in the upstream of madduvalasa reservoir. The study area of Palakonda watershed is 120.59 sq.km. The maximum and minimum elevations are 838 m and 68 m. Total waterbodies covered in watershed is 82 Nos. Average annual rainfall in Palakonda watershed is 1167.71 mm.
The study area covered in five Raingauge stations (Palakonda, Vangara, Regidiamadalavalasa, Setha-mapeta, Viragatum).

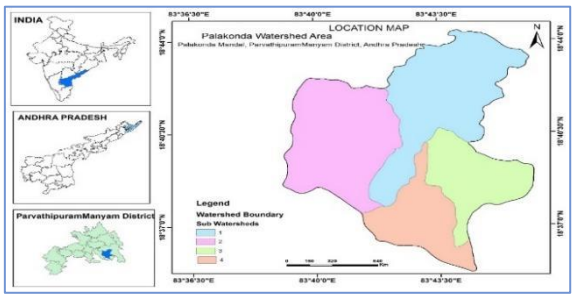

Fig 1: Study area of Palakonda Watershed

Methodology:

Methodology chart

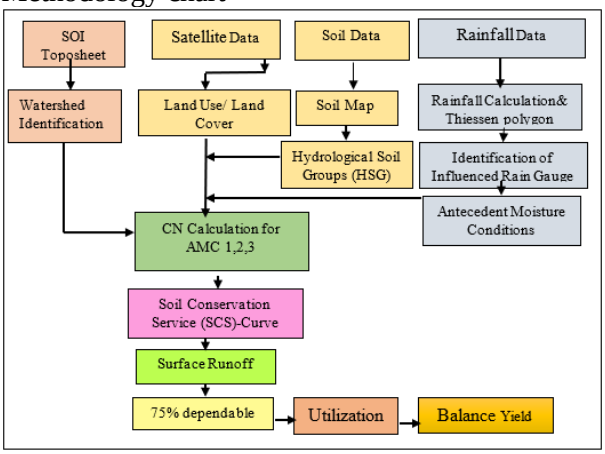

Table 1 : Data Table

Input data	Data	SOURCE
Toposheet	SOI	APSAC (Andhra Pradesh Space Applications Centre)
Satellite Data	Sentinel-2A (Resolution is 10mts)	USGS Earth Explorer web site
Soil Map	soil map (1:50000)	NBSC&LUP
Rainfall Data	1989-2022	APSDPS& DES (Department of Economic and Statistics) and APSAC

SCS-Curve Number Method:

P = Ia + F+ Q (water balance equation)----------1

$$\frac{Q}{P-Ia} = \frac{F}{S} \text{ ---------- 2}$$

Ia = λS ----------3

Where, P is the total precipitation (mm), Ia is the initial abstraction before runoff (mm), F is the cumulative infiltration after runoff begins (mm), Q is direct runoff (mm), S is the potential maximum retention (mm), and λ is the initial abstraction (ratio) coefficient. SCS (2004) introduced general equation

$$Q = \frac{(P - Ia)^2}{(P - Ia + S)} \quad \text{for } P > Ia \text{ ----------4}$$

The initial abstraction Ia is all the losses before runoff begins. It includes the water retained in surface depressions and the water intercepted by vegetation, evaporation, and infiltration. So, Ia is highly variable, but generally is correlated with soil and cover parameters. After several studies, Ia was found to be approximated by the following empirical equation

Ia = 0.2S --------5

It is found the above equation is not correct under all circumstances Louis Berger International, Inc.,

and water and Power Consultancy Services (India) Ltd., found the following equations better suited than Eq. (4) for Indian conditions. According to them, for all regions including black soil area with AMC- I

$$Ia = 0.3S \text{--------- } 6$$

And for regions with black soils and with AMC II and AMC III, it is given by

$$Ia = 0.1\ S \text{ ---------} 7$$

$Q = \frac{(P - 0.3S)}{(P + 0.7\ S)}$ Black soils all region AMC-1 -------8

And eq. (3.7) results of

$$Q = \frac{(P - 0.1S)}{(P + 0.9\ S)} \text{ --------} 9$$

Q = Runoff depth, mm

P = Rainfall, mm

S = Maximum recharge capacity of watershed after 5 days rainfall antecedent

Ia = 0.3 S (Initial abstraction of rainfall by soil and vegetation, mm)

CN = Curve Number, CN is found out from the table.

The potential maximum retention S (mm) can vary in the range of $0 \leq S \leq \infty$, and it directly linked to CN. Parameter S is mapped to the CN using

$$S = \frac{25400}{CN} - 254 \text{ ----------} 10$$

Overlaying the land use map and hydrologic soil group maps, identifying each unique land use soil group polygon and determination of the area of each polygon.

- Assigning a curve number to each unique polygon, based on standard SCS curve number table.
- Finding the weighted curve number and calculating potential maximum retention (S) using eq. (10) and Initial Abstraction (Ia) using eq. (5).
- Calculation of the daily, monthly and annually runoff using eq. (9).

Antecedent Moisture Condition (AMC):

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

- AMC-I: Soils are dry but not to wilting point. Satisfactory cultivation has taken place.
- AMC-II: Average conditions
- AMC-III: Sufficient rainfall has occurred within the immediate past five days. Saturated soil conditions prevail.

Table 2: AMC in total 5 days

AMC Type	Total rain in previous 5 days	
	Dormant Season	Growing Season
1	Less than 13 mm	Less than 36 mm
2	13 to 28 mm	36 to 53 mm
3	More than 28 mm	More than 53 mm

The variation of curve number under AMC II called CNII for various land conditions are commonly found in practice. SCS-CN manual provides the average condition of a watershed AMC II (CNII) value (USDA, 1985). The CN value of AMC I (CNI) and AMC III (CNIII) can be adjusted by applying the equations.

$$CN1 = \frac{4.2 \times CN1}{10 - 0.058 \times CN2} \text{----------} 11$$

For AMC-3

$$CN3 = \frac{23 \times CN2}{(10 + 0.13 \times CN2)} \text{----------} 12$$

Thematic Maps Used:
Land Use/Land Cover Classification Map:

- The land-use/land cover is one of the significant variables for runoff estimation. Land use map prepared by using sentinal-2A (Resolution 10 mts) satellite imagery data available in APSAC using ARCGIS software10.3.1.
- The LU/LC classes identified in the study area are agricultural land, built-up area, forest, wastelands, and water bodies. The detailed statistics of land use/land cover of the study area are shown in table.
- Agriculture Land is 60.11 sq.kms, agriculture plantation is 8.11 sq.kms, built up is 3.27 sq.kms, water tanks is 2.50 sq.kms, wasteland is 8.50 sq.kms, forest is 36.95 sq.kms.
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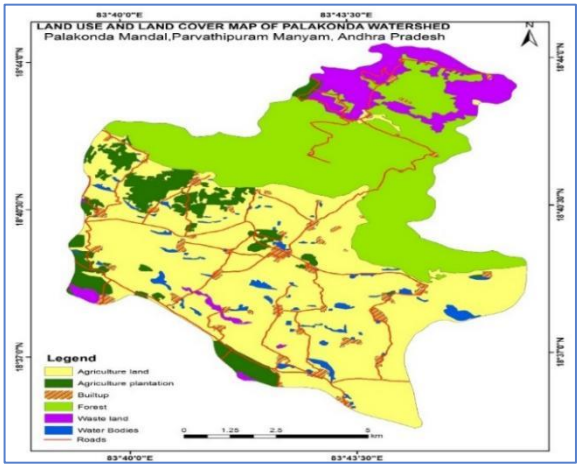

Fig3: land use and land cover classification map

Soil Map:

The soil maps, which were created at a scale of 1:50000, were obtained from the National Bureau of Soil Survey and Land Use. The obtained soil maps were scanned, tic-point registered, and corrected. The corrected maps were also projected. Finally, every individual projected map was combined into one layer. The projected soil map was then superimposed on the map of the study region after which the soil map relevant to the study area was extracted in the GIS environment. ArcGIS was used to digitise the soil class polygons and the borders of various soil textures. The soils of the study area classified into five types of soil textures are found in the Palakonda watershed area namely in fine, fine loamy, fine silty, coarse loamy, loamy skeletal.

Table 3: Soil Textures in watershed

SL.NO	Soil textures	Area in Sq.kms
1	Coarse Loamy	0.093
2	Fine Loamy	21.684
3	Fine Silty	4.078
4	Fine	62.20
5	Loamy skeletal	32.53
	Total	120.55

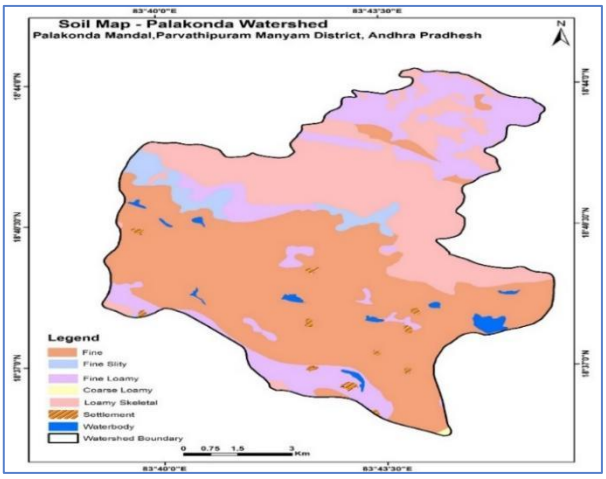

Fig 4: Soil classification map

Hydrological soil Groups:

Soil groups are A, B, C, D are depended on infiltration rate of soil and must be taken into different soils types are described in the Palakonda watershed. Soil texture map is represented with B and C hydrologic soil groups (HSG) are recognized in figure 5. The soils of group B indicated moderate infiltration rate, moderately well drained to well drained. The soils of group C pointed to moderately fine to moderately rough textures, moderate rate of water transmission. In the Palakonda watershed area present soil groups are B, C, D. Group B: Soils in this group have moderately low runoff potential and moderate infiltration rate when thoroughly wet. Water transmission through the soil is moderate; Group C: Soils in this group have moderately high runoff potential and low infiltration rate, when thoroughly wet. Water transmission is somewhat restricted through the soil; Group D: Soils in this group have high runoff potential and low very low infiltration rate, when thoroughly wet.

Table 4: Hydrological Soil Groups in Agriculture land in Acres

HSG	Area (ac)
B	7,461
C	21,837
D	355
Total	29,653

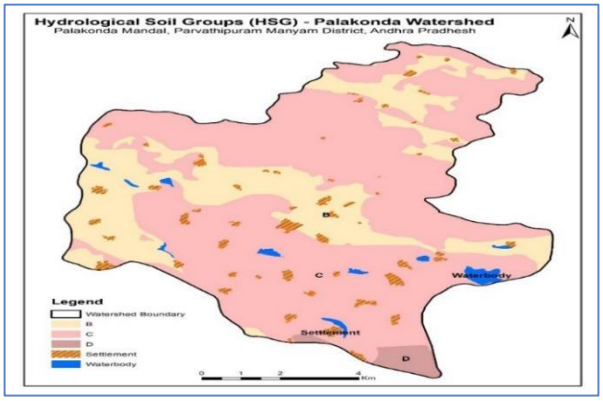

Fig 5: Hydrological soil groups map

Table5: Infiltration ratio Hydro soil Groups

Sl.No	HSG	Soil textures	Infiltration/Transmission	Runoff	Infiltration
1	A	Sand, loamy sand,	>0.30 in/hr	Very low	Very heigh
2	B	Silt loam or loam	0.15 -0.30 in/ hr	Low	Heigh
3	C	Sand clay loam	0.05-0.15 in /hr	Heigh	Low
4	D	Clay loam	0.0-0.05 in/hr	Very heigh	Very low

Weighted Area Curve Number:

Different layers of land use/land Cover, soil, HSG were added in Attribute table was using ArcGIS 10.3. by using Tool box Union of the above layers are prepared. The result obtained from union

attribute was used to compute weighted area CN of the study area and is shown in Table 4.

Table 6: Weighted Curve Number Values

Sl. No	LULC	HSG	Area (Sq.km)	CN	TCN	WCN
1	Agriculture land	B	18.43	75	1382	74.98
2	Agriculture land	C	39.35	81	3187	80.99
3	Agriculture land	D	2.25	83	187	83.11
4	Agriculture Plantation	B	5.00	53	265	53
5	Agriculture Plantation	C	3.80	67	255	67.10
6	Built up	B	1.27	86	110	86.61
7	Built up	C	1.98	91	180	90.90
8	Forest	B	4.78	44	210	43.93
9	Forest	C	32.09	60	1926	60
10	Waste Land	B	2.64	69	182	68.93
11	Waste Land	C	6.31	79	499	79.08
12	Water Body	B	0.60	83	50	83.33
13	Water Body	C	1.86	88	163	87.63
14	TOTAL		120		8596	959.59

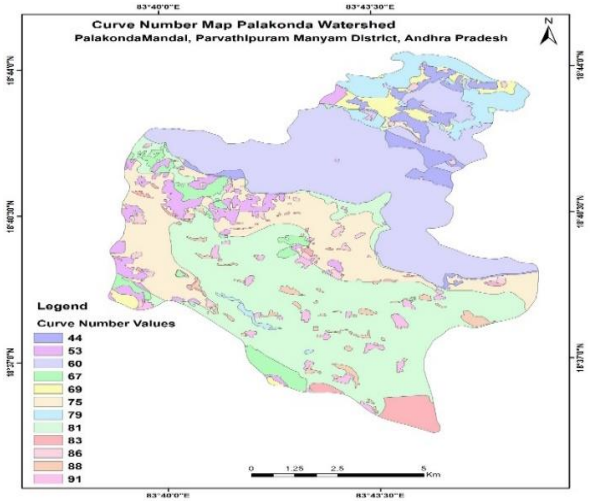

Fig 6: Curve Number Map

Calculation Rainfall- Runoff using SCS-Curve Number Method:

In the present study area total rain gauge stations are in the Palakonda watershed rainfall yearly in 1181.61 mm. Palakonda watershed is covered in five Rain gauge stations they are Palakonda, Regidiamadalavalasa, vangara, seethamapeta, Viragatum. Available daily rain fall data from the year 1989 to 2021 has been evaluated. Below Table shows the annual rainfall and runoff for Palakonda watershed for the period 1989 to 2021 From SCS Curve number, the maximum runoff for the watershed was estimated to be 399.10 mm in the year 2006 and minimum runoff of 48.93 mm in the year 2002 which is shown in Table5.

Table 7: Result of Rainfall- Runoff

Year	RAINFALL (mm)	RUNOFF (mm)
1989	1137.72	125.54
1990	1901.68	86.10
1991	1139.64	103.19
1992	1176.88	125.84
1993	967.08	18.99
1994	966.72	24.96
1995	1491.48	100.40
1996	740.94	70.96
1997	1043.28	53.36
1998	1105.04	29.95
1999	1057.64	104.24
2000	1200.48	99.74
2001	1105.70	53.21
2002	889.80	48.93
2003	1141.64	153.09
2004	1011.86	74.16
2005	1151.66	139.82
2006	1480.42	399.10
2007	1361.68	204.20
2008	1445.40	151.94
2009	934.98	61.61
2010	1449.88	127.93
2011	1082.40	67.99
2012	1285.48	160.60
2013	1103.24	112.04
2014	1471.04	201.13
2015	1093.76	65.21
2016	1217.66	80.00
2017	961.32	67.20
2018	1189.94	168.94
2019	1134.94	105.71
2020	1188.82	66.86
2021	1363.06	148.44

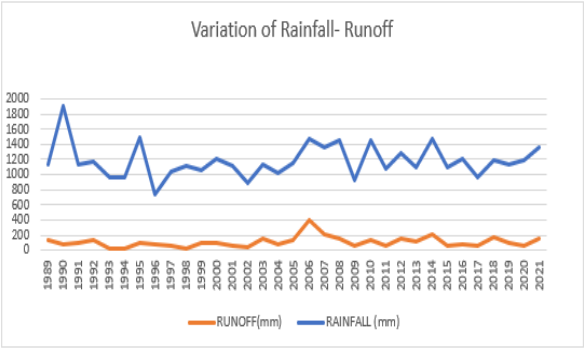

Fig 7: Yearly Variation Rainfall- Runoff

Overall Runoff Watershed Calculation:

Runoff calculations total overall watershed is In the Palakonda overall watershed covered in 110 tanks in their major tanks are 92 and minor tanks are 18. Total Palakonda watershed area is 120.55 sq.kms. Water tanks separation based how many tanks below 10 ,10-40,>40 hectares. Total Curve Number in Palakonda watershed is 8419.3 and total

weighted curve number is 282.8. Palakonda watershed area of ayacut is 1065.8 and capacity of the catchment area of ayacut is 74.54 mcft and 75% available yield is 263.6 mcft and utilization in watershed is 159.8 mcft and balance yield of watershed is 131.7mcft.

Table 8: Overall watershed Details

Watershed	**Palakonda**
No. of Tanks	110
Area (sq.km)	120.559
Sum of Ayacut	1065.8
Sum of Capacity (Mcft)	74.54
Runoff (mm)	66.86
75% Available Yield (Mcft)	263.6
Utilization (Mcft)	159.8
Balance Yield	131.7

Conclusions:

- The land use/land cover in the Palakonda watershed is classified as follows: agricultural, built-up areas, water bodies, forests, and plantations. According to the experiment's findings, there are four different types of soil in the Palakonda watershed: fine, fine silt, loamy soils, and fine loamy soils.
- To estimate the runoff from the Palakonda watershed, the results of soil classification, infiltration rates, and land use were used to identify the hydrological soil groups and the related curve numbers for typical, dry, and wet circumstances.
- The results of the SCS-CN method's calculations in the Palakonda watershed show that there has been a majority of actual depth runoff during the past 33 years and that the watershed as a whole is 120.559 square kilometres.
- The Palakonda watershed's statistics include 1181.61 mm of rainfall, 1065.82 mm of ayacut area, 74.54 mcft of capacity, runoff is 263.60 mcft of 75 percent reliable yield, 159.87 mcft of utilisation, and 124.76 mcft of balance yield.

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