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PREDICTION OF RUNOFF USING SCS-CN METHOD FOR MAHARUWA MICRO WATERSHED OF AMBEDKAR NAGAR DISTRICT (U.P.)

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Abstract: In this study surface runoff was estimated using the USDA Soil Conservation Service curve number (SCS-CN) method in Maharuwa micro-watershed. The total geographical area of the micro-watershed is 1028.00 ha, located between 83^0 54’ 29’’ to 82^0 54’ 32” North latitude and 25^0 64’ 44” to 25^0 55’ 38” East longitude which is situated at Maharuwa village of Ambedkar Nagar district, Uttar Pradesh. A total of 11yearrainfall event were selected between the years 2010 and 2020 for the study. Antecedent moisture content (AMC) was calculated by taking preceding five days rainfall events which gave three conditions AMC I, AMC II and AMC III. Weighted Curve Number for the entire selected micro-watershed was calculated based on site information of the watershed by land use land cover classification using ArcGIS and found to be 82.905 for AMC II. The CN values corresponding to AMC I and AMC III were 68.011 and 91.907 respectively. The runoff for each storm events was estimated using Curve Number method and it is found that among the selected year events maximum rainfall occurred in year 2013 giving runoff value of 162.27 mm and minimum rainfall occurred in year 2015 with runoff value of 49.15 mm. Runoff volume of the Maharuwa micro-watershed for each year events were also calculated, and maximum runoff volume was1668208.616 m^3found in year 2013 and minimum runoff volume was505326.247 m^3in year2015. By using previous year runoff values, prediction of runoff for next five year was also done. The prediction of runoff was done using Forecast tool available in Excel 2016 (FORECAST.ETS). It was found that the maximum runoff was expected in the year 2025 and minimum runoff was expected in year 2023. From the present study it was concluded that the SCS-CN method gives significant values of runoff, with the R^2 value of 0.8514. The predicted values from the study could be useful for design of soil and water conservation structures and also useful for preparation for the next Storm event.

Index Terms – runoff, SCS-CN method, potential maximum retention, rainfall, AMC and micro-watershed.

I. INTRODUCTION

Water is one of the most important natural resources for human being, and a key element in the socio-economic development of a State and Country. Though there is plenty of water (97.5 %) available in the universe but only 2.5 % of the water in the universe is fresh water. It is the basic need for the survival of all forms of life on the Earth. Runoff is one of the important hydrologic phenomena used in the water resources applications and management planning. However, quickening of the watershed planning management programme for conservation and development of natural resources management has necessitated the runoff information. In the planning and projecting soil and water conservation structures in small catchments, it is necessary to know the relationship between precipitation and runoff.

A watershed is a basin like as a natural feature of the landforms (earth's surface), defined by peaks which are connected by ridges that descend into lower elevations and small valleys. It carries rainwater falling on it drop by drop and channels it into soil, streams and rivulets flowing into large rivers and in due course sea. Rainfall is the primary source of water for runoff over the land surface. Uncontrolled runoff leads to soil erosion and posing serious threat to floods,

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environment, social and economic security in the country. To control soil erosion and water scarcity, it is essential to build up a strong base of water and land management and this can be achieved only through watershed development. In India, the availability of accurate information of runoff is scarcely available in few selected sites. However, quickening of the watershed management program for conservation and development of natural resources management programmed for conservation and development of natural resources management has necessitated the runoff information.

The SCS-Curve Number (also known as Curve Number-Method) is an empirical parameter used in hydrology for estimation of direct runoff depth or infiltration from rainfall excess. The curve number method was developed of USA by the USDA Natural Resources Conservation Service, which was formerly known as the Soil Conservation Service (SCS) — the curve number is still popularly known as a "SCS-CN method". The CN method was developed from an empirical analysis of small catchments and hill slope plots monitored by the USDA.

Curve Number method can be successfully used to estimate the runoff for fulfillment the need of permanent soil conservation and water harvesting structure. Keeping above in view the proposed study has been undertaken in Maharuwa Watershed construction of water impoundment structures and storage of runoff structure is the only solution.

Realizing the importance of the above-mentioned variables, the present study entitled “Prediction of Runoff Using SCS-CN Method for Maharuwa micro watershed of Ambedkar Nagar District (U.P.)”was undertaken with the following objectives:

1. To Estimate the runoff using SCS - CN Method of the study area using Arc-GIS.
2. To develop a relationship between Estimated and observed runoff.
3. To test the validity of the relationship between Estimated and observed runoff using statistical parameters.

II. MATERIALS AND METHODS

In this chapter general feature of Maharuwa watershed, collection of hydrological data and its analysis, description of curve number method, estimation of rainfall, and runoff hydrographs have been described.

2.1 The Study Area

For the present study the Maharuwa micro-watershed situated in the Maharuwa village. in Bheti block of Ambedkar Nagar district has been chosen. It is located on Azamgarh to the Ayodhya highway and is 30 km away from the Ambedkar Nagar head quarter & 5 to 10 km from the block. The total geographical area of the micro-watershed is 1028.00 ha.

2.2 Data Collection

The Maharuwa micro watershed is being introduced under the Department of Land Development & Water Resource, IWMP-II, Ambedkar Nagar. Digital Elevation model (DEM) derived from USGS Website and Rainfall, Runoff Data collected daily rainfall data from year 2010 to 2020, from Indian Metrological Department of statical reports and Central Ground Water Board of India.

2.3 Generation of Curve Number

When the data of accumulated rainfall and runoff for long-duration, high-intensity rainfalls over small drainage basins are plotted, they show that runoff only starts after some rainfall has accumulated, To describe these curves mathematically, Soil Conservation Service assumed that the ratio of actual retention to potential maximum retention was equal to the ratio of actual runoff to potential maximum runoff, the latter was rainfall minus initial abstraction. In mathematical form, this empirical relationship is,

$$\frac{F}{S} = \frac{Q}{P - I_a} \quad \dots (2.1)$$

Where,
F = actual retention (mm)
S = potential maximum retention (mm)
Q = accumulated runoff depth (mm)
P = accumulated rainfall depth (mm)
I_a = initial abstraction (mm)

After runoff has started, all additional rainfall becomes either runoff or actual retention (i.e., the actual retention is the difference between rainfall minus initial abstraction and runoff).

$$F = P - I_a - Q \quad \dots (2.2)$$

Combining Equations 2.1 and 2.2.

$$Q = \frac{(P - I_a)^2}{P - I_a + S} \quad \dots (2.3)$$

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2.4 Estimation of potential maximum retention (S)

This potential maximum retention mainly represents infiltration occurring after runoff has started. The parameters S dependents upon the characteristics of the Soil-Vegetation-Land use (SVL) complex and antecedent soil moisture condition in a watershed. For each SVL complex, there is lower limit of S. The soil conservation services expressed S as a function of Curve Number.

This relationship is

$$CN = \frac{1000}{(S+10)} \quad \dots (2.4)$$

Where, S is in inches.

For SI unit of S (mm) the Eq. (2.4) is modified to

$$CN = \frac{25400}{254+S} \quad \dots (2.5)$$

2.5 Runoff curve number determination

The determination of the CN value for a watershed is a function of soil characteristics, hydrologic condition and cover or land use.

2.5.1 Hydrological Soil Group

Group	Soil characteristics	Minimum infiltration rate(inch/h)
A	Deep sand, deep loss, and aggregated silts	0.3-0.45
B	Shallow losses and sandy loam	0.15-0.30
C	Clay loams, shallow sandy loam, soils in organic content, and soils usually high in clay	0.05-0.15
D	Soils that swell upon wetting, heavy plastic clays, and certain saline soils	0-0.05

Source: (Anon. 2022d)

2.5.2 Antecedent Moisture Condition (AMC)

The soil moisture condition, in the drainage basin before runoff occurs is another important factor influencing the final CN value. In the Curve Number Method, the soil moisture condition is classified in three Antecedent Moisture Condition (AMC) Classes:

AMC I: The soils in the drainage basin are practically dry (i.e., the soil moisture content is at wilting point).

AMC II: Average condition.

AMCIII: The soils in the drainage basins are practically saturated from antecedent rainfalls (i.e., the soil moisture content is at field capacity).

Table 2.1 AMC for determining the value of CN

AMC Type	Total Rain in Previous 5 days	
	Dormant season	**Growing Season**
I	Less than 13 mm	Less than 36 mm
II	13 to 28 mm	36 to 53 mm
III	More than 28 mm	More than 53 mm

Source: (Anon. 2022e)

2.6 Converting values of CN I and CN III to CN II

For conversion of CNI and CNIII into CNII, a method has been suggested by Chow et. al. (2002). In the study, the same method has been adopted for conversion of CN I and CN III into CN II. The procedure for conversion is given below-

$$CNI = \frac{CNII}{2.281 - 0.01281\ CNII} \quad \dots (2.6)$$

$$CNIII = \frac{CNII}{0.427 + 0.00573 CNII} \quad \dots (2.7)$$

Weighted Curve Number for the entire selected Maharuwa micro watershed was calculated based on site information of the watershed. The equation is given below,

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$$CN = \frac{\sum(CNiXAi)}{A} \quad \ldots (2.8)$$

Where,

CN = weighted curve number.
CNi = curve number from 1 to n.
Ai = area with curve number CNi
A = the total area of the watershed.

2.7 Analysis of variance

An ANOVA test is a type of statistical test used to determine if there is a statistically significant difference between two or more categorical groups by testing for differences of means using variance. This relationship is

$$F = \frac{MST}{MSE} \quad \ldots (2.9)$$

Where,
F = ANOVA coefficient
MST = Mean sum of squares due to treatment.
MSE = Mean sum of square due to error.
The data of rainfall and calculated runoff is statistically analyzed using Excel 2019, Data Analysis tool. Statistical significance level was set at $P<0.05$. Confidence interval was 95%. Regression line was also generated on the basis of calculated and Measured runoff of given area.

III. RESULTS AND DISCUSSION

The whole study is done for prediction of runoff using soil conservation service curve number method. It was designed to find effectiveness of watershed in respect of rainfall and runoff.

3.1 Rainfall-Runoff Analysis

The recorded data was taken from the year 2010 to 2020. The rainfall occurred in this region from the month January to December. The data used in prediction was taken as mean of rainfall and runoff. The given data is shown in Table 3.1. It can be easy visible in Fig. 3.1.

Table 3.1 Event Rainfall and Runoff Data Analysis

Year	Measured Rainfall (mm)	Measured Runoff (mm)
2010	1035.30	176.20
2011	1051.70	91.30
2012	958.00	110.55
2013	1336.20	161.30
2014	780.30	99.10
2015	660.06	56.22
2016	799.40	80.12
2017	783.30	115.56
2018	783.00	78.23
2019	907.00	134.34
2020	1144.52	105.20

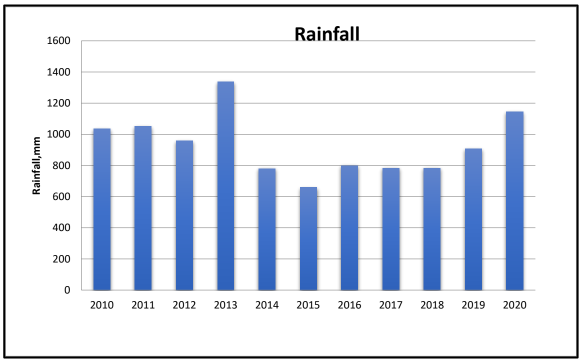

Fig. 3.1 Showing Rainfall from year 2010 to 2020

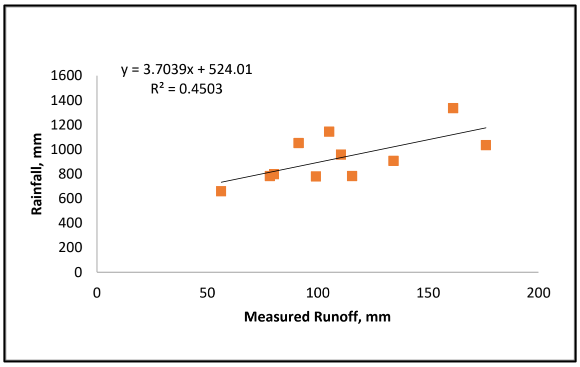

Fig. 3.2 Relation between Measured rainfall and

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measured runoff

Table 3.2 Estimated runoff (mm) and runoff volume (m^3)

Year	Estimated runoff (mm)	Estimated runoff volume (m^3)
2010	155.29	1596454.483
2011	86.01	884246.973
2012	119.55	1229033.801
2013	162.27	**1668208.616**
2014	80.87	831375.184
2015	49.15	**505326.247**
2016	96.88	995930.256
2017	104.88	1078166.533
2018	86.65	890840.295
2019	155.11	1594632.671
2020	91.81	943826.141

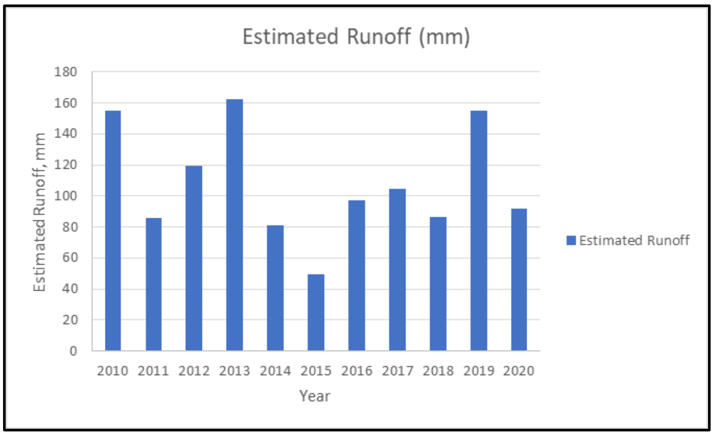

Fig. 3.3 Estimated runoff (mm) from year 2010 to 2020

3.2 Comparison between Measured and Estimated Runoff (mm)

Measured and Estimated Runoff was given in Table 3.3, which shows the minor difference between estimated and measured runoff. The minor difference between the measured and estimated runoff was found because of difference in soil group found on difference places, which affects the overall runoff from the given area. The statistical test was also done to check the significance of the estimated runoff values from actual measured values.

Table 3.3 Comparison between Measured and Estimated Runoff (mm)

Year Event	Measured Runoff (mm)	Estimated Runoff (mm)
2010	176.20	155.29
2011	91.30	86.01
2012	110.55	119.55
2013	161.30	162.27
2014	99.10	80.87
2015	56.22	49.15
2016	80.12	96.88
2017	115.56	104.88
2018	78.23	86.65
2019	134.34	155.11
2020	105.20	91.81

For the evaluation of predicted values, correlation coefficient is used which showed r = 0.8541. The comparison between the estimated and measured runoff is show in the Table 3.3.

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3.3 Runoff Prediction

Runoff prediction for next five-year events from year 2021 to 2025 was given in below Table 3.4.The predicted values shown on the basis of each previous year events, the direct runoff value was estimated using SCS-CN Method, of 11 years. The selected five-year events maximum runoff value157.40 mm will occur in year 2025, and minimum runoff value93.97 mm will occur in year 2023. The prediction is done with the help of MS Excel 2016, in which used forecast tool (FORCAST.ETS), and plotted graph was shown in Fig. 3.4.

Table 3.4 Estimated and Predicted runoff values

Year	Estimated runoff (mm)
2010	155.29
2011	86.01
2012	119.55
2013	162.27
2014	80.87
2015	49.15
2016	96.88
2017	104.88
2018	86.65
2019	155.11
2020	91.81
2021	**99.41**
2022	**149.42**
2023	**93.97**
2024	**108.11**
2025	**157.40**

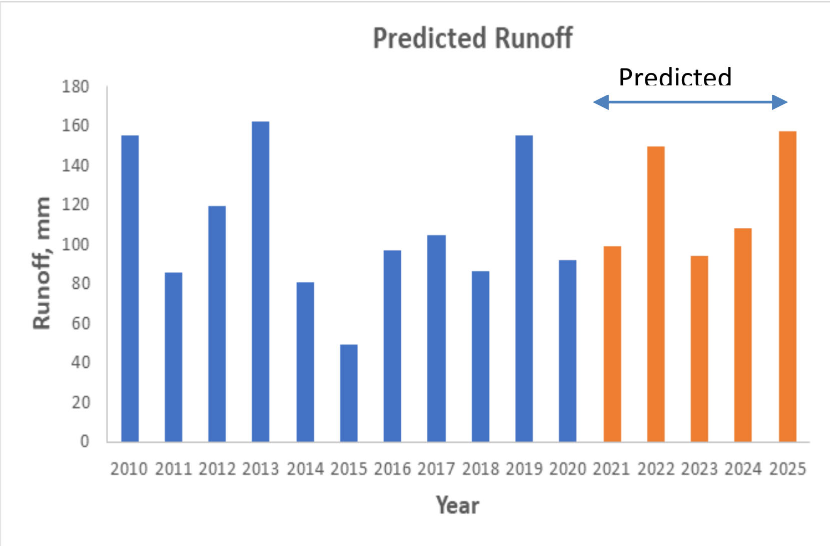

Fig. 3.4 Predicted values of runoff using previous runoff values

IV. SUMMARY AND CONCLUSION

The study is conducted with the prime objective to estimated runoff for Maharuwa micro watershed of Ambedkar Nagar district, Uttar Pradesh, and total area of the Maharuwa watershed is 1080 ha. The rainfall data was collected of 11 years, from the year 2010 - 2020 and used to estimate the runoff.

- The Maharuwa micro watershed was delineated using ArcGIS, situated in the Maharuwa village, in Bheti block of Ambedkar Nagar district. The large area covers cultivated land, and stream was generated with the help of ArcGIS tools.

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- The agriculture soils in the watershed have diversified texture i.e., clay loam, sandy clay loam, and Kankar. The heavy soils texture almost used by paddy crop during rainy season. The sodic soils also have hard calcium pan at variable depths.
- Rainfall data of every day from year 2010 to 2020 was collected, from statical reports of Indian Metrological Department and Central Ground Water Board of India.
- The model adopted for estimation was Soil Conservation Service Curve Number (SCS-CN) method. (SCS, 1956) and it was widely used in hydrology and environmental engineering for computing the amount of runoff from given amount of rainfall. The Curve number selected on the basis of AMC condition.
- Antecedent moisture content (AMC) was calculated by taking preceding five days rainfall events which gave three conditions AMC I, AMC II and AMC III.
- The average of AMC was calculated weighted Curve Number, for the entire selected area based on land use land cover classification using Arc-GIS. The obtained CN value to help in calculation for Potential maximum retention.
- Potential maximum retention (S) mainly represents infiltration occurring after runoff has started. The value of S was obtained after all initial abstraction occurred.
- The Initial abstraction (Ia) in the CN method was assumed value 0.2S, this assumption was recommended for Indian soil. The values Ia was used in runoff calculations.
- The runoff for each storm events was estimated by Curve Number method and it was found that among the selected year events maximum and minimum runoff occurred.
- The scatter-plotted to analysis of Rainfall-Runoff, indicates a good linear relationship between the maximum daily rainfall and SCS-CN runoff estimated.
- Difference between estimated and measured values of runoff was minor, and the values were statistically verified by ANOVA, with the confidence interval of 95%. Regression line was also generated on the basis of calculated and measured runoff.
- After analysis the prediction was done for next five years of runoff, using Forecast tool available in Excel 2016 (FORECAST.ETS).

Following conclusions are drawn from the study:

In eleven years, the runoff estimation by SCS-CN method was required soil characteristics, hydrologic condition of soil and previous five days rainfall, which helped to obtained curve number. After obtaining the curve number the potential maximum retention was calculated, which gives the value of runoff. According to the calculated runoff, the highest runoff was occurred in year 2013 whereas minimum runoff was occurred in year 2015. By using previous year runoff values, prediction of runoff for next five year was also done. It was found that the maximum runoff was expected in the year 2025 and minimum runoff was expected in year 2023. This value could be useful for design of soil and water conservation structures. For determination of shape and properties of watershed, Arc-GIS software was used. Watershed delineation was done to obtain the properties of the watershed. From the study it was found that the Soil Conservation Service Curve Number (SCS-CN) method was very accurate and gives reliable values, and it is recommended to use this method for runoff estimation. The runoff estimation by SCS- CN method is not depended only on rainfall, it also requires soil characteristics, soil hydrologic condition, and uniform rainfall and distributed uniformly over the watershed area.

REFERENCES

1. Calero Mosquera, D., Hoyos Villada, F. and Torres Prieto, E., 2021. Runoff Curve Number (CN model) Evaluation Under Tropical Conditions. Earth Sciences Research Journal, 25(4), pp.397-404.
2. Krisnayanti, D.S., Bunganaen, W., Frans, J.F., Seran, Y.A. and Legono, D., 2021. Curve Number Estimation for Ungauged Watershed in Semi-Arid Region. Civil Engineering Journal, 7(6), pp.1070-1083.
3. Al-Ghobari, H. and Dewidar, A.Z., 2021. Integrating GIS-based MCDA techniques and the SCS-CN method for identifying potential zones for rainwater harvesting in a semi-arid area. Water, 13(5), p.704.
4. Mandal, S. and Biswas, S., 2021. Runoff Prediction Using Artificial Neural Network and SCS-CN Method: A Case Study of Mayurakshi River Catchment, India. In Water Security and Sustainability (pp. 27-42). Springer, Singapore.
5. Munna, G.M., Alam, M.J.B., Uddin, M.M., Islam, N., Orthee, A.A. and Hasan, K., 2021. Runoff prediction of Surma basin by curve number (CN) method using ARC-GIS and HEC-RAS. Environmental and Sustainability Indicators, 11, p.100129
6. Walega, A., Amatya, D.M., Caldwell, P., Marion, D. and Panda, S., 2020. Assessment of storm direct runoff and peak flow rates using improved SCS-CN models for selected forested watersheds in the Southeastern United States. Journal of Hydrology: Regional Studies, 27, p.100645.
7. Ajmal, M., Waseem, M., Kim, D. and Kim, T.W., 2020. A pragmatic slope-adjusted curve number model to reduce uncertainty in predicting flood runoff from steep watersheds. Water, 12(5), p.1469..

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DOI: 10.17148/IARJSET.2022.9807

8. Kang, M. and Yoo, C., 2020. Application of the SCS–CN method to the Hancheon basin on the volcanic Jeju Island, Korea. Water, 12(12), p.3350.
9. Ranjan, A., Mishra, H. and Singh, I., 2020. Estimation runoff by using curve number (CN) method for Kaushambi micro-watershed, Allahabad region, Uttar Pradesh. Journal of Pharmacognosy and Phytochemistry, 9(2), pp.208-214.
10. Ling, L., Yusop, Z. and Chow, M.F., 2020. Urban flood depth estimate with a new calibrated curve number runoff prediction model. IEEE Access, 8, pp.10915-10923.
11. Gandhi, F.R. and Patel, J.N., 2019. Estimation of Surface Runoff for Sub-watershed of Rajkot District, Gujarat, India using SCS–Curve Number with Integrated Geo-Spatial Technique. International Journal of Engineering and Advanced Technology, 8, pp.33-41.
12. Dwivedi, D.K. and Shrivastava, P.K., 2019. Rainfall and runoff estimation of micro watersheds of coastal Navsari. Journal of Soil and Water Conservation, 18(1), pp.43-51.
13. Nanjundi, P. and Inayathulla, M., 2019. Runoff Estimation by SCS Curve Number Method for Bangalore North Taluk, Karnataka, India. Jour of Adv Research in Dynamical &Control Systems, 11(1), pp.1987-1991.
14. Kayet, N., Pathak, K., Chakrabarty, A. and Sahoo, S., 2018. Evaluation of soil loss estimation using the RUSLE model and SCS-CN method in hillslope mining areas. International Soil and Water Conservation Research, 6(1), pp.31-42.

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