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Derivation of runoff coefficient for a wasteland treated with micro-catchment

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ABSTRACT
The study was undertaken at the field of wasteland development project at Bharathiar University Campus, in Coimbatore district of Tamil Nadu, characterized by low annual mean rainfall and degraded land. The total area of watershed was 45.36 ha. Curve number technique was used for runoff estimation from watershed. Analysis showed that the daily runoff value came to be negligible, so seasonal runoff value was taken for computation of runoff coefficient. The runoff coefficient values for the study watershed for 25 years seasonal runoff producing rainfall events for AMC I, II and III were 0.087, 0.126 and 0.306 respectively.

Key words : Runoff Coefficient, Curve number technique, Micro-catchment, Watershed.

INTRODUCTION

Runoff management is one of the major components of Watershed development. It is achieved by gully plugging, nala bunding, construction of farm ponds and percolation tanks along with inter-terrace and terrace level conservation structures that not only reduce the erosion hazards and induce groundwater recharge, but also increase productivity of land per unit area and time. In India, 53.3 million hectares of land is considered as wasteland (1985, Report of the National Remote Sensing Agency, Hyderabad). In India, some soil and water conservation practices were followed for conserving valuable soil and water. But wasteland needs some in situ moisture conservation techniques due to which moisture availability in wasteland is increased and some less water requirement plants like cashew, energy plants are grown.

Some techniques were available for finding out runoff coeffiecient for watershed. But no such study had been conducted to find runoff coefficient for wasteland-based watershed treated with microcatchment for area where no runoff measurement is available. Therefore it was necessary to develop runoff coefficient for this condition.

The soil conservation service curve number (USDA – SCS, 1972) was one of the most widely used methods for runoff estimation for small watersheds. The curve number method was simple that provided reasonably accurate results under certain conditions (Pathak *et al.*, 1989). In this method, rainfall, land use surface infiltration conditions and hydrological soil groups were considered.

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MATERIALS AND METHODS

The site selected for the research study was located at the Bharathiar University Campus, Coimbatore district of Tamil Nadu, India at the foothills of Maruthamalai hills. It had a sandy loam soil type along with 840 mm average annual rainfall. Under a wasteland development project, in situ moisture conservation treatments in the field were Microcatchments and Compartmental bunds. Some of the Agroforestry plants like Neem, Tamarind, Amala, Mahogany, Rosewood were planted in microcatchments.

Estimation of runoff :

Out of different methods of runoff estimation the method used was US- Soil Conservation Service Curve Number Technique (also known as Hydrological Soil Cover Complex Method).

SCS curve number technique :

The development of the technique has originated from following relationship

$$\frac{F}{S} = \frac{P_e}{P - I_a} \qquad \text{------- (a)}$$

The depth of excess precipitation or direct runoff, P_e is always less than or equal to the depth of precipitation, P likewise. After runoff starts, the additional depth of water retained in the catchment, F is less than or equal to the potential maximum retension, S. There is some amount of rainfall, I_a (Initial abstraction) for which more runoff occurs. So the potential runoff is (P- I_a).

The assumption of this method was that the ratio of the two actual and potential quantities (retension and runoff) is equal. Thus,

$$\frac{F}{S} = \frac{P_e}{P - I_a}$$

From continuity principle,

$$P = P_e + I_a + F \qquad \text{------ (b)}$$

Substitute the value of 'F' from the equation (3.14) and solving the equation for P_e gives

$$P_e = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad \text{------- (c)}$$

This is the basic equation for computing runoff by SCS curve number method (1972).

Based on extensive studies for different watersheds in United States, the USDA – SCS has developed a lumped model known as hydrological soil cover complex method. In this method, the lumped parameter, 'Curve Number ' (CN) has been evolved for different types of land uses and conservation practices. The maximum potential retension, S was transformed by the following equation:

$$\frac{CN}{254 + S} = 25400 \qquad \text{------ (d)}$$

CN values vary from 0 to 100 depending upon runoff producing characteristics.

According to Antecedent Moisture Condition (AMC) and soil type, I_a is taken as 0.1S, or 0.2S, or 0.3S. Here, I_a denotes the interception losses, depression storage and the initial infiltration that must be satisfied by any precipitation before runoff starts. The AMC is assessed from the five day Antecedent Rainfall by the use of seasonal rainfall limits (Dormant or growing seasons) as defined by USDA- SCS (1972). The norms of AMC conditions are shown in Appendix I.

The following values for different AMC conditions developed by Ministry of Agriculture, New Delhi, India (1972) were adopted for the study.

Soil type and conditions	I_a
Black soil region , AMC II and AMC III	0.1S
Black soil region , AMC I	0.3S
All other regions, AMC I, AMC II, AMC III	0.3S

The equivalent curve numbers for dry condition (AMC I) or wet condition (AMC III) were deducted from the normal condition (AMC II) by following relationships (SCS, 1972).

$$CN\ (I) = \frac{4.2\ CN\ (II)}{10 - 0.058\ CN\ (II)} \qquad \text{------- (e)}$$

$$CN\ (III) = \frac{23\ CN\ (II)}{10 + 0.13\ CN\ (II)} \qquad \text{------- (f)}$$

Data collection :

The following data was needed for computing runoff in the CN method:

(i) Land use particulars
(ii) Rainfall data
(iii) Infiltration characteristics and assessment of hydrological soil group
(iv) Catchment area
(v) General surface morphological characteristics.

The area was divided into different land use groups based on survey. Twenty-five years available daily rainfall data was collected from meteorological department, TNAU, Coimbatore (about 6 km from study area.). Infiltration rates of soils were computed by using double ring infiltrometer method in the field. Textural analysis of soil was done and other physical characteristics were found out by conducting experiment at soil science laboratory. The hydrological soil groups were assessed by following the norms of USDA – SCS (1972). Catchment area and location of different structures were decided by topographical survey.

Based upon the analysis of the long-term data, it was found that there was no 50 per cent and 75 per cent dependable rainfall during January to September. So North East monsoon (October to December) contributed runoff to study area and so this season was taken in to consideration for analysis.

Development of runoff coefficient :

Twenty-five years seasonal rainfall data was analyzed by Curve number model to get runoff from a study watershed. Curve numbers were used for each area based on AMC condition, hydrological soil group and hydrological condition. The weighted curve number for the entire area was found out for AMC II and this curve number was converted into AMC I and AMC III using formula (Eq. e and f). Visual basic progamme was prepared and runoff depths were found out. The runoff coefficient was found out based on runoff producing events for different AMC condition by formula:

$$\text{Runoff coefficient} = \frac{\text{Runoff}}{\text{Rainfall}} \qquad \text{------- (g)}$$

RESULTS AND DISCUSSION

Based on the data collected on soil texture, permeability class and the basic infiltration rates obtained for different soils of the study area through experiments, the hydrological soil groups were identified as per the norms of USDA- SCS (1972).

From the Table 1, it was clear that the soils in the study area were under hydrological soil group 'B' and 'C'. The fraction of different land use categories and hydrological condition of the selected area are furnished in Table 2. It was inferred that major land area was treated with compartmental bunding, followed by pasture. In microcatchmented area the agro forestry plants like Rosewood, Neem, Mahogany, Tamarind, Amla were planted. Amla was the major crop in microcatchmented area. The percentage of forest area was very small as compared to others. The hydrologic condition was 'fair' under pasture and 'good' for other land use.

Table 1: Physical characteristics and hydrological group of soils in the study watershed.

S.No	Land use	Soil texture	Infiltration rate (cm/hr)	Permeability class	Hydrological group
1	Cultivated land with bunding	Sandy loam	2.50	Moderate	B
2	Cultivated land with microcatchments	Sandy clay loam	0.50	Slow to moderate	C
3	Forest without under storye cover	Sandy loam	2.50	Moderate	B
4	Pasture	Sandy loam	2.50	Slow to moderate	B

Table 2: Percentage land use and hydrological condition of study watershed.

S .No	Land use	Hydrological condition	Percentage of land use	Curve No for AMC II
1	Cultivated land with bunding	Good	33.40	69
2	Cultivated land with microcatchments	Good	28.50	76
3	Forest without Understorye cover	Good	6.80	55
4.	Pasture	Fair	31.30	69

Runoff estimation :

The predicted runoff values for 25 years seasonal rainfall with different AMC conditions for the study area are given in Table 3. The average seasonal rainfall for AMC I found to be 76.25 mm and runoff depth 6.64 mm, for AMC II average rainfall was 64.3 mm and runoff was 8.11 mm whereas for AMC III rainfall was 43.96 mm and runoff was 13.46 mm. From Table 3, it was seen that there was very low runoff for some of the events even though rainfall was more. This was because the runoff calculated by Curve number techniques estimated values of runoff depending on the five days preceding rainfall condition (AMC).

From the Table 3, For AMC I average seasonal rainfall was found 76.25 mm and runoff value was 6.64 mm. The ratio of runoff to rainfall, known as runoff coefficient, was observed as 0.087 for AMC I, for AMC II average rainfall was 64.32 mm and runoff 8.11 mm, hence runoff coefficient for AMC II was 0.126 and for AMC III, the rainfall was 43.96 mm and runoff value was 13.46 mm, runoff coefficient for AMC III was 0.306. The runoff coefficient value increased as AMC condition changed from AMC I to III. The runoff coefficient value found less for all AMC conditions because the whole area was treated with in situ moisture conservation treatments and also the area was covered with permanent grasses. Most of runoff water abstracted and very small amount passed to outlet. Also runoff was stored in number of depressions and storages. The predicted value of runoff coefficient from curve number method was not checked with actual value because there was no rainfall event during study period.

Table 4 furnished runoff producing rainfall events

Table 3: Twenty-five years seasonal runoff producing events and runoff values from curve number technique for different AMC conditions.

AMC I				AMC III			
S. No	Rainfall (mm)	Runoff (mm)	Runoff coefficient	S. No	Rainfall (mm)	Runoff (mm)	Runoff coefficient
1	112.5	4.150		1	42.30	10.500	
2	40.0	9.132		2	29.30	3.671	
Avg	76.25	6.64	0.087	3	25.70	2.262	
				4	32.00	4.886	
AMC II				5	58.00	21.096	
				6	58.40	21.389	
1	94.2	22.301		7	28.00	3.133	
2	73.0	10.956		8	57.00	20.368	
3	62.0	6.266		9	29.90	3.930	
4	57.0	4.478		10	98.00	53.619	
5	49.0	2.153		11	22.00	1.114	
6	46.0	1.473		12	29.40	3.714	
7	69.0	9.140		13	23.00	1.391	
Avg	64.32	8.11	0.126	14	26.20	2.442	
				15	36.80	7.331	
				16	30.00	3.974	
				17	36.00	6.900	
				18	90.00	46.726	
				19	30.00	3.974	
				20	52.60	17.241	
				21	32.00	4.886	
				22	30.00	3.9738	
				23	25.00	2.020	
				24	70.00	30.244	
				25	30.00	3.974	
				26	85.00	42.494	
				27	35.00	6.375	
				28	45.00	12.176	
				29	23.00	1.391	
				30	47.00	13.462	
				31	49.40	15.051	
				32	100.20	55.538	
				33	26.40	2.5155	
				34	62.20	24.216	
				Avg	43.96	13.460	0.306

Table 4: Runoff producing rainfall events in year 2004.

S. No.	Rainfall (mm)	AMC condition	Runoff (mm)	Runoff coefficient
1	49.4	III	15.05	0.31
2	100.2	III	55.54	0.55
3	26.4	III	2.53	0.095
4	62.2	III	24.27	0.39
Total	238.2		97.33	
Runoff coefficient = 0.41				

for year 2004. The close examination of the values revealed the following information.

It was observed that the runoff producing characteristics of the given area depend upon the AMC condition and rainfall event. The curve numbers showed the values in the descending order from AMC III to AMC I condition. As the soil became wet, the runoff under AMC III condition in a given watershed was more.

The incremental rainfall produced different amounts of runoff under low and high rainfall events in the same AMC condition. This was due to non-linear behavior of rainfall – runoff relationship of the watershed.

Based on analysis of 25 years rainfall data, if daily events were taken then the runoff values were very negligible. Hence seasonal rainfall and runoff value for 25 years was taken for computation of runoff coefficient.

As actual runoff data was not available for study watershed, curve number technique was used to estimate runoff potential from the area. The effect of in situ moisture conservation treatments on runoff was taken under various inputs for curve number technique. The area was divided in to different land uses. The data for 25 years seasonal rainfall (North East Monsoon) was analyzed to get antecedent moisture condition. Curve numbers corresponding to land use, hydrological soil group, hydrological conditions and AMC were selected from USDA-SCS (1972). The visual basic programme was prepared for runoff computation. The Average rainfall for AMC I was 76.25 mm and runoff depth was 6.64 mm, for AMC II condition average rainfall value was 64.32 mm and 8.11 mm runoff. For AMC III, average rainfall was 43.96 and 13.46 mm runoff. The runoff coefficient values for AMC I, II and III conditions were 0.087, 0.126 and 0.306 respectively.

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REFERENCES

Chow, V.T., Maidment, D.R. and Mays, L.W. (1988). Applied Hydrology. McGraw-Hill Book Company.

Ghyoor, H.A. (1991). Prediction of peak runoff from rainfall in a temperate area. Water Resour. Management, **5:** 63-84.

Mann, H.S., Gupta, J.P., Murthy, K.N.K. and Issac, V.C. (1980). An estimation of runoff from some rocky catchments of Western Rajasthan and its utilization potential for crops. Indian Journal of Soil Conservation, **8(1) :** 20-24.

Murthy, K.N.K., Issac, V.C. and Gupta, B.S. (1980). Validity of theoretical runoff prediction equation for arid rocky and semi – rock Kailana lake watershed. *Indian Journal of Soil Conservation,* **8(2):** 25-29.

Hauser, V.L. and Jones, O.R. (1991). Runoff curve numbers for the southern high plains. Trans. of the ASAE, **34(1):** 142-144.

Hawkins, R.H. (1979). Runoff curve numbers from partial area watersheds. J. Irrig. and Drainage Div., **105 (IR4):** 375-389.

Pathak, P., Laryea, K.B. and Sudi, R. (1989). A runoff model for small watersheds in the semi- arid tropics. Trans. of the ASAE, **32 (5):** 1619-1624.

Soil Conservation Service (1972). National engineering handbook. Section 4 Hydrology. US Department of Agriculture, Washington, DC

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