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Estimation runoff by using curve number (CN) method for Kaushambi micro-watershed, Allahabad region, Uttar Pradesh

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Abstract
This study aims to determine the runoff depth using the USDA Soil Conservation Service curve number (SCS-CN) method in Rukma Khurd-I micro-watershed, located between 25º 4' 56.60''-25˚ 6' 38.09'' N Latitude and 81^0 56' 48.56''-80^0 58' 11.37'' E Longitude which is situated at Manikpur block of Chitrakoot district, Uttar Pradesh. A total of 30 single storm events were selected between the years 2008 and 2016 for the study. Antecedent moisture content (AMC) was calculated by taking preceding five days rainfall 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 and found to be 90.507 for AMC II. The CN values corresponding to AMC I and AMC III were 80.694 and 95.706 respectively. The runoff for each storm events was estimated following Curve Number method and it is found that among the selected storm events maximum rainfall of 184mm occurred in July 7, 2016 giving runoff value of 170.997mm and minimum rainfall of 35mm occurred in July 13, 2013 with runoff value of 6.242mm. Runoff volume of the micro-watershed for each storm events were also calculated and maximum runoff is found be 775266.971m^3. This value will be useful for design of soil and water conservation structures in watershed.

Keywords: Antecedent moisture content (AMC), curve number (CN), micro-watershed

Introduction
Runoff is one of the important hydrologic variables used in the water resources applications and management planning. However, quickening of the watershed 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. Knowing the amount of runoff from a catchment, is of vital importance particularly for planning the hydraulic structure and taking necessary erosion control measure, in catchments where there is not runoff information. One of the most important objectives of engineering hydrology is to calculate the water yield of the catchments to determine the flood flows for planning the discharge facilities of water storage structures. In situation where there is not sufficient and reliable data the calculation based on empirical methods lead to mistakes in determining the dimensions of water structures. A good runoff model includes spatially variable parameters such as rainfall, soil types and land use/land cover etc. (Kumar; 1997) [21]. Identification of runoff is also of critical importance where the basic reservoirs support drinking water needs of the populace.
United States Department of Agriculture, Soil Conservation Service developed an empirical method for determining approximate amount of direct runoff from small agricultural catchments with different soil groups, vegetation covers and land uses by examining measured precipitation and runoff amounts, and named it as "Soil Conservation Service Curve Number Method". The Soil Conservation Service Curve number (SCS-CN method) (SCS, 1972) [41] also known as hydrologic soil group method, is a versatile and popular approach for quick runoff estimation and is relatively easy to use with minimum data and it gives adequate results (Ashish *et al* 2003) [2]. American Soil Conservation Service (SCS) Runoff Curve Number Method is widely and efficiently used for planning the structures aimed at water storage and erosion and flood control. Generally the model is well suited for small watersheds of less than 250km^2 and it requires details of soil characteristics land use and vegetation condition. The method requires numeric catchments of interest that define the runoff potential. Hydrologic soil group number, land use type, vegetation cover, soil conservation measure, antecedent soil moisture conditions are the basic catchments characteristics used for curve number calculation. For that reason, the most important step in

the calculation of flood discharge is to determine and calculate these characteristics accurately. Hawkins (1973) [10] has shown the existence of strong relationship between Curve Number and rainfall as well as Rao (1996) [33] had studied the applicability of Curve Number method for estimation of runoff from daily rainfall data. A significant research on several issues related with the CN methods have been worked in the recent past years by many authors viz. Hjelmefelt *et al.* (1983) [15], Chong and Teng (1986) [5], Hauser *et al.* (1991) [9], Hawkins (1993) [12], Simantan *et al.* (1996) [38], Lewis *et al.* (2000) [24], Mishra *et al.* (2003) [23], Bonta (2005) [3] Tejaswini (2011) [46], Tedela *et al* (2016) etc.

Rukma Khurd-I micro-watershed which is under Bundelkhand region was in a grip of severe drought continuously from 2010 to 2009. The area is under treatment of Integrated Watershed Management Programme (IWMP-VII) starting in year 2010-2011. In the region, more than 85% of open wells were dried up due to deficit rainfall. Cattle were abandoned due to shortage of water and fodder. Most part of the region was dependent on drinking water supply through tanker. Over exploitation of existing vegetation, expansion of agricultural activities on degraded lands without due care of soil and water resources and faulty cultural practices on medium to shallow soils has aggravated the situation as resulted in wide spread erosion, land degradation and exposed parent rock. Even most of the agricultural land has been converted to wasteland. Due to reduction in vegetal cover and no provision for surface water storage, all the rain water runs along with soil particles. Ground water recharge is negligible on account of rocky sub strata causing slow growth of trees and low yields of crops. This situation can certainly be corrected by *in-situ* water harvesting and planting of trees in agricultural fields, on bunds and wasteland. Because of all these reasons conservation of water generated as runoff in the region is very necessary for the development of region. Realizing the importance of the above mentioned views the present study was undertaken to estimate the runoff in the micro-watershed using Soil Conservation Service Curve number method.

Materials and Methods

Study Area

For the present study Rukma Khurd-I micro-watershed which is situated in block Manikpur of Chitrakoot district, Uttar Pradesh has been selected. The total geographical area of the micro-watershed is 439.38 ha, out of which 378.00 ha is the treatable. The entire watershed is Rainfed and 38% area has lifesaving irrigation mainly through open shallow dug wells. The area is under treatment of Integrated Watershed Management Programme (IWMP-VII) starting year 2010-2011. Geographically it is located between 25˚ 4´ 56.60´´-25˚ 6´ 38.09´´ N Latitude and 81˚ 56′ 48.56´´-80˚ 58′ 11.37´´ E Longitude. It consists of three villages Rukma Khurd, Kelha and Madeyan.

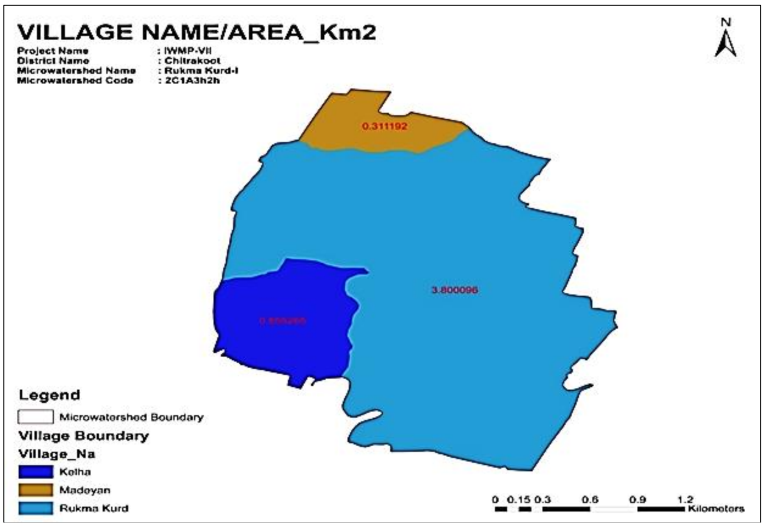

Fig 1: Location map of Rukma Khurd-I micro-watershed

Figure 1: shows the location of the catchment.

Agro-climatic data of Rukma Khurd-I

Rukma Khurd-I micro-watershed falls in agro-climatic zone of Central Plateau Region representing a transitional zone of tropical sub-humid to semi-arid and comes under hot moist semi-arid ecological sub-region. The agro-climate of the watershed is characterized by dry and hot summer, warm and moist rainy season and cool winter with occasional rain showers. Mean annual temperature ranges from 23 to 24 ˚C. The mean summer (April-May-June) temperature is 36 ˚C which may rise to maximum 47 to 48 ˚C during the month of May and June. The mean winter temperature (December-January-February) is 15 ˚C which may drop to 2-4 ˚C in December and January. The mean relative humidity varies between 38 and 56%. The annual rainfall of the Bundelkhand region part of Uttar Pradesh varies from 815 to 935mm, about 87% of which is received during South-West monsoon period (Singh *et al.* 2002).

Soils information of Rukma Khurd-I

Soil of the micro-watershed is categorized into three groups as per natural condition of the watershed.

1. **Course grained soil:** These soils are coarse textured with small hard rocky fragments of sandstone. They are mainly found on hillocks of the ravenous area of the watershed. The fertility status of the soil is not very good because they are having low organic matter and mostly found in rainfed condition. Locally these soils are called as 'Rakar' soils.
2. **Sandy loam soil:** These soils are found in the undulated and plain areas of watershed and generally brown in colour. Fertility status is better than Rakar soils and locally these soils are called "Parwa" soils.

3. **Fine grained black soil:** These soils are fine textured generally black in colour and mostly found in the plain areas of the watershed. Fertility status is very good and locally called as "Kabar" soils.

Land use and cropping pattern

The land use of this watershed can be mainly divided into four categories viz. agriculture, forest, hills and habitation. Out of the total area 69% area is under rainfed cultivation. The major crops cultivated in the micro-watershed area are lentil, chickpea, durum wheat, field pea and wheat and linseed mixed with mustard in *Rabi* season. Out of the total cultivated area of micro-watershed pulses alone occupied 57% area. Rest of the area is occupied by wheat oilseed crops. During *kharif* season urd and moong is the major pulse crop sown during monsoon season and entirely depends on rain. During *Rabi* season major pulses are lentil, chickpea and field pea which was grown by the farmers on conserved moisture during rainy season. Fig. 2 shows the classified land use map of the study watershed. The micro-watershed is classified under Class II, Class III and Class IV.

Slope

Slope and aspect of a region are vital parameters in deciding suitable land use, as the degree and direction of the slope decide the land use that it can support. Slope is also very important while determining the land irrigability and land capability classification and has direct bearing on runoff. The dominant slope category in the micro-watershed were 0-5% followed by 5-8%.

Data collection

The data related to the characteristics of Rukma Khurd-I micro watershed were collected from Department of Land Development and Water Resources, IWMP-VII, Manikpur, Chitrakoot, Uttar Pradesh. In this study, daily rainfall data (2008 to 2016) were collected from Tulsi Krishi Vigyan Kendra, Ganivan (Banda), Chitrakoot, Uttar Pradesh to estimate the runoff.

SCS-CN method for runoff estimation

The CN method is based on these two phenomena. The initial accumulation of rainfall represents interception, depression storage, and infiltration before the start of runoff and is called initial abstraction. After runoff has started, some of the additional rainfall is lost, mainly in the form of infiltration; this is called actual retention. With increasing rainfall, the actual retention also increases up to some maximum value: the potential maximum retention. To describe these curves mathematically, SCS 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 being rainfall minus initial abstraction. In mathematical form, this empirical relationship is

$$\frac{F}{S} = \frac{Q}{P-Ia} \qquad \text{............... (1)}$$

Where,
F = actual retention (mm)
S = potential maximum retention (mm)
Q = accumulated runoff depth (mm)
P = accumulated rainfall depth (mm)
Ia = 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).

$$F = P - Ia - Q \qquad \text{................ (2)}$$

$$Q = \frac{(P-Ia)^2}{P-Ia+S} \qquad \text{................ (3)}$$

To eliminate the need to estimate the two variables I_a and S in Equation 3, a regression analysis was made on the basis of recorded rainfall and runoff data from small drainage basins. The data showed a large amount of scatter (Soil Conservation Service 1972) [41]. The following average relationship was found

$$Ia = 0.2\,S \qquad \text{................. (4)}$$

Combining Equations 3 and 4 yields

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)} \text{ For } P > 0.2\,S \qquad \text{................ (5)}$$

Equation 5 is the rainfall-runoff relationship used in the CN method. It allows the runoff depth to be estimated from rainfall depth, given the value of the potential maximum retention S. This potential maximum retention mainly represents infiltration occurring after runoff has started. This infiltration is controlled by the rate of infiltration at the soil surface, or by the rate of transmission in the soil profile, or by the water-storage capacity of the profile, whichever is the limiting factor. The S can be obtained from CN by using the relationship given in Equation 6. As the potential maximum retention S can theoretically vary between zero and infinity, Equation 6 shows that the CN which is a dimensionless number can range from one hundred to zero.

$$CN = \frac{25400}{254+S} \qquad \text{................ (6)}$$

Antecedent moisture condition (AMC)

AMC is an indicator of watershed wetness and availability of soil moisture storage prior to a storm, and can have a significant effect on runoff volume. AMC is used as an index of watershed wetness. AMC condition of Rukma Khurd-I micro-watershed has been calculated by taking five days preceding rainfall data of each storm event.

Converting values of CN I and CN III to CN II

The CN values documented in the present case is AMC-II (as per the criteria of USDA, 1985) [47]. To adjust the CN values for the cases of AMC-I and AMC-III, equations (1) and (2) (Chow, 1988) given below are used where, CN(I), CN (II) and CN (III) represents curve numbers for normal, dry and wet conditions respectively.

$$CNI = \frac{4.2CNII}{(10-0.058CNII)} \qquad \text{.................. (7)}$$

$$CNIII = \frac{23CNII}{(10 + 0.13CNII)} \quad \text{.................. (8)}$$

Where, CN is a dimensionless parameter. It is determined based on hydrologic soil group, land use, land treatment, and hydrologic conditions.

$$CN = \frac{\Sigma(CNi \times Ai)}{A} \quad \text{.................. (9)}$$

Where,
CN = weighted curve number.
CNi = curve number from 1 to any no. N.
Ai = area with curve number CNi
A = the total area of the watershed.

Computation of estimated runoff of Rukma Khurd-I micro-watershed
In the present study, thirty storm events were selected between 2008 and 2016 for calculation of runoff for Rukma Khurd-I micro-watershed. Weighted CN of the watershed is calculated from the hydrologic conditions of the watershed like characteristics of the soil, vegetation, including crops and land use using equation 9. The hydrologic soil group of the micro-watershed is taken as ‘C’. Once the CN value is calculated, potential maximum retention S can be estimated from equation 6. Thus, corresponding direct runoff depth of each storm event is estimated by using SCS-CN equation 5. Runoff volume of each storm event was also computed.

Results and Discussion
Curve Number
The calculation of runoff generation in the SCS model mainly relied on CN values, which is a function of AMC, slope, soil type and land use. Under the given precipitation condition, low CN values mean that the surface has a high potential to retain water whereas high values mean more surface runoff and that the rainfall can be stored by structures like tanks. For calculating CN value of Rukma Khurd-I micro-watershed, the hydrologic soil group in watershed was considered as ‘C & D’. Using information collected about the land use pattern, treatment adopted, cropping pattern, areal extent, AMC condition of Rukma Khurd-I micro-watershed weighted CN for the entire micro-watershed was calculated and found to be 90.507. This CN values is corresponded for AMC II. CNII value was converted to CNI and CNIII based on AMC condition of each storm event and found to be 95.706 and 80.694 respectively for CNIII and CNI. Values are presented in Table 1. From the table it is revealed that higher the values of CN lesser is the potential maximum retention S and vice versa for different AMC condition.

Potential maximum retention values (S)
Potential maximum retention values S were estimated and results are presented in Table 1. The table shows that the value of Potential maximum retention varies from 2.279mm to 12.154mm, which also indicates that S values are in minimum for AMC III values. This basically shows that soil is fully saturated and value of runoff will be more. S value for AMC II is found to be 5.328mm. For the storm events which belongs to AMC I and AMC II the S values is much higher than that of AMC III which shows that soil condition is dry thus absorbing maximum amount of rainfall falling on it will lead to generation of less amount of runoff.

Estimated Runoff and Runoff Volume
Direct runoff value Q of each storm event was calculated by SCS-CN and values are presented in Table 1and the estimated runoff was depicted in the form of graph as shown Fig.3. From figure it is noted that among the selected storm events maximum rainfall of 184mm occurred in July 7, 2016 giving highest runoff value of 170.997mm and minimum rainfall of 35mm occurred in July 13, 2013 with runoff value of 6.242mm. Runoff volume of each storm event was also calculated considering the total area of watershed and values are presented in Table 2. The values were also depicted in bar graph form as shown in Fig. 3. It is found that maximum value of runoff volume is 775266.971m³ for storm event July 7, 2016 and minimum value of runoff volume is 28300.927m³ for storm event July 13, 2013.

Table 1: Computation of estimated runoff

Storm Events	**Rainfall (P)**mm	**AMC Condition**	**Curve Number**	**Potential Maximum Retention Values (S)** mm	**Initial Abstraction (0.2 S)** mm	**Estimated Run off** mm
June 16,2008	95	III	95.706	11.396	2.279	82.572
July 3,2008	50	I	80.694	60.769	12.154	14.524
September 21,2008	75	I	80.694	60.769	12.154	31.951
June 28,2009	96	III	95.706	11.396	2.279	83.560
July 28,2009	80	I	80.694	60.769	12.154	35.790
August 17,2009	50	I	80.694	60.769	12.154	14.524
September 10,2010	126	III	95.706	11.396	2.279	113.286
July 21,2010	82	III	95.706	11.396	2.279	69.750
August 29,2010	62	I	80.694	60.769	12.154	22.462
October 22,2010	36	I	80.694	60.769	12.154	6.720
February 11,2011	109	I	80.694	60.769	12.154	59.507
May 19,2011	75	I	80.694	60.769	12.154	31.951
August 3,2011	68	III	95.706	11.396	2.279	56.009
September 19,2011	77	I	80.694	60.769	12.154	33.475
June 27,2016	75	I	80.694	60.769	12.154	31.951
July 25,2016	88	III	95.706	11.396	2.279	75.662
July 3,2016	86	III	95.706	11.396	2.279	73.690

July 13,2013	35	I	80.694	60.769	12.154	6.242
August 14,2013	126	I	80.694	60.769	12.154	74.226
September 8,2013	106	I	80.694	60.769	12.154	56.961
February 12,2014	45	I	80.694	60.769	12.154	11.524
July 19,2014	56	I	80.694	60.769	12.154	18.377
September 14,2014	47	II	90.507	26.641	5.328	25.420
June 21,2015	112	III	95.706	11.396	2.279	99.397
August 12,2015	51	III	95.706	11.396	2.279	39.485
September 4,2015	70	I	80.694	60.769	12.154	28.210
July 7,2016	184	III	95.706	11.396	2.279	170.997
July 24,2016	120	III	95.706	11.396	2.279	107.331
August 5,2016	83	III	95.706	11.396	2.279	70.735
September 15,2016	105	III	95.706	11.396	2.279	92.463

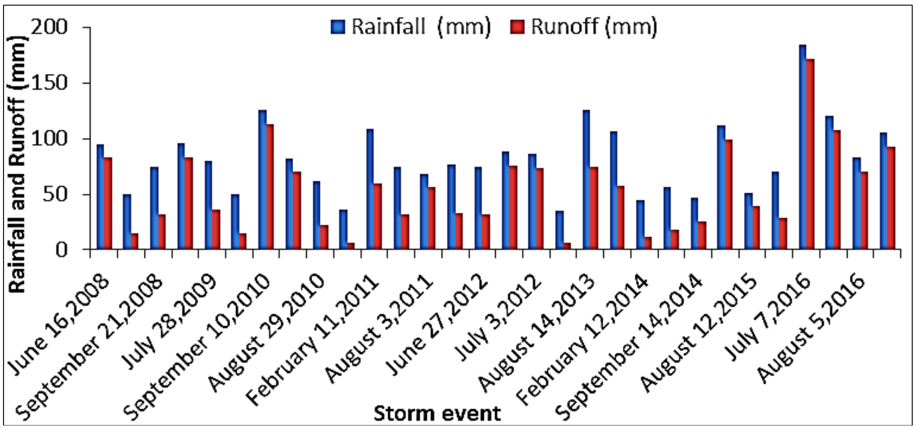

Fig 2: Estimated runoff of Rukma Khurd-I micro-watershed with respect to rainfall

Table 2: Runoff volume

Storm Events	**Rainfall** (mm)	**Runoff** (mm)	**Runoff volume (m³)**
June 16,2008	95	82.572	374365.069
July 3,2008	50	14.524	65850.642
September 21,2008	75	31.951	144859.317
June 28,2009	96	83.560	378845.069
July 28,2009	80	35.790	162262.865
August 17,2009	50	14.524	65850.642
September 10,2010	126	113.286	513615.372
July 21,2010	82	69.750	316232.530
August 29,2010	62	22.462	101837.838
October 22,2010	36	6.720	30468.288
February 11,2011	109	59.507	269791.292
May 19,2011	75	31.951	144859.317
August 3,2011	68	56.009	253932.485
September 19,2011	77	33.475	151770.436
June 27,2016	75	31.951	144859.317
July 25,2016	88	75.662	343036.091
July 3,2016	86	73.690	334095.974
July 13,2013	35	6.242	28300.927
August 14,2013	126	74.226	336524.021
September 8,2013	106	56.961	258251.002
February 12,2014	45	11.524	52249.588
July 19,2014	56	18.377	83316.066
September 14,2014	47	25.420	115250.345
June 21,2015	112	99.397	450645.892
August 12,2015	51	39.485	179017.013
September 4,2015	70	28.210	127899.679
July 7,2016	184	170.997	775266.971
July 24,2016	120	107.331	486615.076
August 5,2016	83	70.735	320696.179
September 15,2016	105	92.463	419207.500

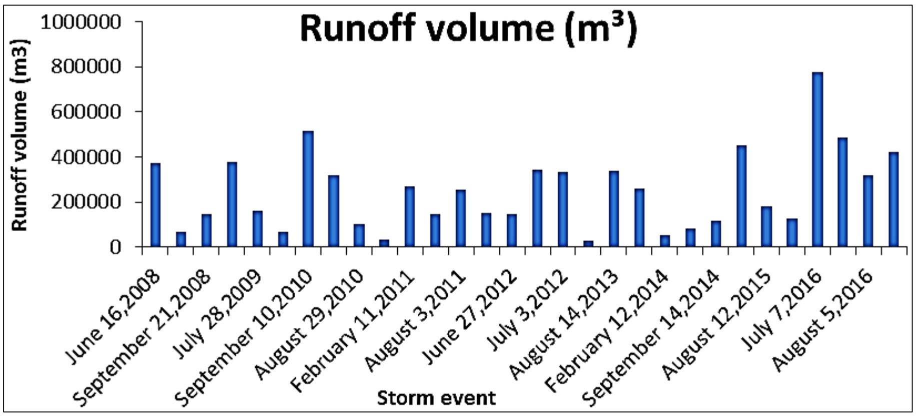

Fig 3: Runoff volume (m^3)

Conclusions

The study was undertaken to assess the surface runoff potential in the Rukma Khurd-I micro-watershed of Chitrakoot District, Uttar Pradesh for its optimal use in agriculture and other sectors. The study involves the analysis of soil, land use, cropping pattern, hydrologic soil groups and AMC condition of Rukma Khurd-I for assigning appropriate curve number and estimation of surface runoff with USDA's SCS Curve Number method. The results of the study show that it is conveniently possible to estimate the runoff for many areas by SCS-CN method. The study also found that there is good runoff potential in the region which can be harvested to supplement the canal and ground water for productive agriculture. As the problem of water scarcity in Rukma Khurd-I micro-watershed is very severe for the recent past years harvesting and utilization of surface runoff can be helpful in increasing the water availability in the area which will facilitates increased crop production, crop diversification and overall profitability, will indeed help in achieving the desired goal. The study will also help in design and construction of various Soil and water conservation structures like spillways, drains, ponds, reservoirs etc. for assessing the water yield of the watershed and for determining potential for different uses or purposes like irrigation, domestic use, and power generation in the region.

References

1. Aron Gert MASCE, Arthur C, Miller JR, David F. Lakatos associate Member. ASCE. Infiltration formula based on SCS Curve Number. Journal of the Irrigation and Drainage Division, 1R4, 1977, 419-427.
2. Ashish P, Dabral PP, Chowdary VM, Mal BC. Estimation of runoff for agriculcura, 2003.
3. Bonta JV. Determination of watershed curve number using derived distributions, Journal of Irrigation and Drainage Division. 2005; 123(1):28-36.
4. Cheng-Lung Chen MASCE. Infiltration formula by curve number procedure. Jornal of hydraulics division, ASCE. 1981; 108(7):823-829.
5. Chong SK, Teng TM. Relationship between the runoff Curve Number and hydrology soil properties. Journal of Hydrology. 1986; 84:1-7.
6. Chow VT, Maidment LW. Applied Hydrology, McGraw Hill, New York, 1988.
7. Cole JA, Sherriff JDF. Some single and multi-site models of Rainfall within Discrete Time Increments. Journal of Hydrology. 1972; 17:97-113.
8. Gupta SK, Tejwani KG, Ram B. Drainage Coefficient for surface drainage of agricultural land for different parts of the country. Journal of Central Board of Irrigation and Power. 1971; 28:53-60.
9. Hauser VL, Jones OR. A runoff Curve number for the Southern High Plains. Transaction of the ASCE. 1991; 34(1):142-148.
10. Hawkins RH. Improved prediction of storm runoff in mountainous watersheds. ASCE. 1973; 99(1R4):519-523.
11. Hawkins RH. The importance of accurate curve numbers in the estimation of storm runoff. JAWRA. 1975; 11(5):887-891.
12. Hawkins RH. Asymptotic determination of Curve number from rainfall runoff data. Journal of Irrigation and Drainage Division ASCE. 1993; 119(IR2):334-345.
13. Hawkins RH, Hjelmfelt AT, Zevenbergen AW. Runoff probability, storm depth and curve numbers. J Irrig. Drain. Eng. 1985; 111(4):330-340.
14. Hjelmfelt AT, Kramer LA, Burwell RE. Curve numbers as random variable. In Proc. Int. Symp. on Rainfall-Runoff Modeling (ed. V. P. Singh), Water Resour. Publ., Littleton, CO, 1982, 365-373.
15. Hjelmfelt AT. Curve Number a personal interpretation in proc. especially conf. Advances in irrigation and drainage surviving external pressure. New York ASCE, 1983, 208-2215.
16. Jat ML, Singh RV, Balyan JK. Drought over Rajasthan during the year 1987. J Agrometrology. 2005a; 7(1):110-114.
17. Jat ML, Singh RV, Balyan JK, Jain LK. Analysis of weekly Rainfall for Udaipur Planning in Udaipur region. J Agric Engg. 2005b; 42(2):35-41.
18. Journal of Agricultural Engineering. July-September, 2006, 43(3).
19. Vaze J, Post DA. Conceptual rainfall-runoff model performance with different spatial rainfall inputs Journal of Hydrometeorology, 2011, 234.
20. Kumar D. Runoff estimation using antecedent rainfall probabilities. Indian Journal of Soil Conservation. 1995; 23(1):13-16.
21. Kumar P, Tiwari KN, Pal DK. Establishing SCS runoff curve number form IRS digital database. J Indian Soc. Remote Sens. 1997; 19(4):246-251.
22. Lange J *et al*. "Tracer Techniques in Sprinkling Tests to Study Runoff, 2000.
23. Larsen CL, Reich BM. Relationship of observed rainfall and runoff recurrence intervals Floods and Droughts, Water Res. Pub., Ft. Collin, Co, 1973.

24. Lewis DJ, Singer MJ, Tate KW. Applicability of SCS Curve Number Method for a California Oak Woodland Watershed. J Soil and Water Conservation. 2000; 55:226-230.
25. Mishra SK, Singh VP. SCS-CN method: part I: derivation of SCS-CN based models. Acta Geophys. Pol. 2002a; 50(3):457–477.
26. Mishra SK Singh VP. SCS-CN based hydrologic simulation package. In Mathematical Models in Small Watershed Hydrology (ed. Singh VP, Frevert DK). Water Resources Publication, Littleton, CO, 2002b, 391-464.
27. Mishra SK, Singh VP, Sansalone JJ, Aravamuthan V. A Modified SCS-CN Method: Characterization and Testing. Water Resource Management. 2003; 17(1):37-68.
28. Mishra SK, Singh VP. Long-term hydrologic simulation based on the soil conservation service curve number. Hydrol. Process. 2008a; 18:1291-1313.
29. Mishra SK, Jain MK, Singh VP. Evaluation of the SCS-CN based model incorporating antecedent moisture. Water Res. Manage. 2008a; 18:567-589.
30. Murthy VVN. Water Management Engineering. Kalyani Publishers, New Delhi, 2008a.
31. Ponce VM, Hawkins RH. "Runoff Curve Number: Has it reached its maturity? J of Hydrologic Engg., ASCE, 1996, 1(1).
32. Naill PE, Momani M. Rainfall Data in Jordan Analysis American Journal of Environmental Sciences. 2009; 5(5):599-604:2009.
33. Rao KB, Bhattacharya AK, Mishra K. Runoff estimation by curve number method-case studies. Journal of Soil and Water Conservation. 1996; 40:1-7.
34. Rao KB, Singh DK, Bhattacharya AK. Applicability of Curve Number method for estimation from extended duration rainfall. Journal of Soil and Water Conservation. 2002; 1(2&3):163-170.
35. Ray CR, Senapati PC, Lal R. Investigation of Drought from Rainfall data at Gopalpura (Orrisa). Indian J Soil Conservation. 1987; 15(1):15-19.
36. Shi ZH, Chen LD, Fang NF, Qin DF, Cai CF. Research on the SCS-CN initial abstraction ratio using rainfall-runoff event analysis in the Three Gorges Area, China. Catena. 2009; 77(1):1-7.
37. Shirmohamadi A, Yoon KS, Rawls WJ, Smith OH. Evaluation of Curve Number procedure to predict runoff in GLEAMS. Journal of American Water Resource Association. 1997; 33(5):1069-1076.
38. Simanton JR, Hawkins RH, Mohseni-Saravi M, Renard KC. Runoff curve number variation with drainage area, Walnut Gultch, Arizona. Transaction of the ASAE. 1996; 39(4):1391-1394.
39. Singh M, Bhattacharya AK, Sarkar TK, Singh C. Consecutive day rainfall prediction from one-day rainfall. Indian Journal of Agricultural Engineering. 1992; 2(3):192-196.
40. Singh VP. An evaluation of the mathematics and physical significance of the soil conservation service curve number procedure for estimating runoff volume, 2002.
41. Soil Conservation Services, ed. National Engineering Handbooks, Section-4 Hydrology, Washington DC, 1972.
42. Subramanyam K. Engineering Hydrology. Second Edition. Tata McGraw-Hill Publishing Company limited. New Delhi, 188-191.
43. Suresh R. Soil and Water Conservation Engineering. Standard Publishers Distributers. 1705-B Nai Sarak, New Delhi. Second Edition, 45-50.
44. Thyer, Mark, Frost, Andrew J. Parameter estimation and model identification for stochastic models of annual hydrological data: Is the observed record long enough?, Journal of Hydrology, 2006; 330(1-2)::313-328.
45. Tedela NH, McCutcheon S, Rasmusse T, Hawkins R, Swank W, Campbell J *et al*. Runoff Curve Numbers for 10 Small Forested Watersheds in the Mountains of the Eastern United States. J Hydrol. Eng. 2007; 17(11):1188–1198.
46. Tejaswini NB, AmbaShetty, Hegde VS. Land Use Scenario Analysis and Prediction of Run-off Using SCS-CN Method: A Case Study from the Gudgudi Tank, Haveri District, Karnataka, India. International Journal of Earth Sciences and Engineering. 2011; 4(5):845-853.
47. USDA, Soil Conservation Service. National Engineering Handbook. USA, 1985.
48. Van Dijk AIJM. Selection of an appropriately simple storm runoff model, Hydrol. Earth Syst. Sci. 2010; 14:447-458. Doi:10.5194/hess-14-447-2010, 2010.
49. Weeks WD, Hebbert RHB. A Comparison of Rainfall-Runoff Nordic Hydrology. 1980; 11:7-24.
50. Williams JR, Laseur WJ. Water yield model using Soil Water Conservation Curve Number. Journal of hydraulics division ASCE. 1976; 102(HY9):1241-1253.
51. Wong, Heung. Ip,: Hydrological forecasting, Journal of Hydrology. 2007; 332(3-4):337-347.
52. Liu XZ, Li JZ. Application of SCS modelin estimation of runoff from small watershed in Loess Plateau of China. Chin. Geogra. Sci. 2008; 18(3):235-241.
53. Yi Lin, Jian, Cheng. Discharge prediction, Hydrological sciences journal. 2006; 51(4):599-6.