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Critical Evaluation of MS (Mishra and Singh) Model for Runoff Estimation

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Abstract: **Rainfall is the major component of the hydrologic cycle and this is primary source of runoff. Rainfall generated runoff is a most important part in the water resource development. Worldwide many attempts have been made to model and predict rainfall behavior using various empirical, statistical, numerical and deterministic techniques. In the present work, estimation of mean rainfall over the Mahanadi basin lying in Odisha and its total five sub-basins has been done using different deterministic methods including SCS-CN(Soil Conservation Service - Curve Number) and SCS-CN based MS Model (Mishra and Singh model) . There are many approaches for the determination of runoff from rainfall and one of that is the SCS-CN(1956) method converts rainfall to surface runoff (or rainfall-excess) using a CN derived from watershed characteristics. The daily rainfall data of five rain gauge stations in and around the watershed (2003-2013) was used to estimate the daily runoff from the watershed using SCS-CN method. The objective of the project work is to compare the simulation performance of the runoff for both the original SCS-CN and MS model in the five sub-basins. From this result we concluded that the performance of the MS model is better proving then the original SCS-CN method in all the five sub-basins.**

1. INTRODUCTION

Rainfall-runoff modeling has a great importance in hydrology and water resources management. Many hydrological models have been developed in the past (Singh 1989; Singh and Frevert 2006) for transformations of rainfall into stream flow because of easy availability of rainfall data for longer time periods at different locations. In many of these models, soil conservation service curve number (SCS-CN) model has been widely used for surface runoff computations. The primary reason for its wide applicability and acceptability lies in the fact that it accounts for major runoff generating watershed characteristics, namely, soil type, land use/treatment, surface condition and antecedent moisture condition (Mishra and Singh 2002; Mishra and Singh 2003a; Ponce and Hawkins 1996). Research conducted on the applicability of the SCS-CN method suggests a need for improvement (Ponce and Hawkins 1996). Although several modifications of the method have been suggested and reported in the literature, further improvement of the method is needed (Mishra and Singh 2002). Therefore, Mishra and Singh modified the original SCS-CN model in the year 1999. Along with this it was proved better from the previous model in the U.S Watersheds.

Yu (1998) provided a theoretical framework in which the SCS method can be tested. He described the proportionality between retention and runoff and the SCS equation would follow if the temporal distribution of rainfall intensity and the spatial distribution of the maximum rate of infiltration are independent and described by exponential probability distributions. Further, he remarked that the maximum retention S could be seen as the product of the spatially averaged maximum rate of infiltration and the effective storm duration.

Mishra and Singh (1999) modified the existing SCS-CN method by taking 0.5(P - Ia) in place of (P - Ia) .The existing SCS-CN method and the proposed modification are compared and the modified version is found to be more accurate than the current version.

Akhondi (2001) used curve number method in estimating flood utilizing geographical information system in north Karoon River field.

Mishra et al. (2004) modified the existing SCS-CN method, which is based on the Soil Conservation Service Curve Number (SCS-CN) methodology but incorporates the antecedent moisture in direct surface runoff computations and named it as MS model. They evaluated the modified version and by comparing with the existing SCS-CN method they found that the modified MS model performs far better than the existing SCS-CN model. In 2005, they applied the MS model with its eight variants at field using a large set of rainfall-runoff events and revealed that the performance of the existing version of the SCS-CN method was significantly poorer than that of all the model variants.

S.K. Mishra et. al presented a rain duration-dependent procedure based on the popular Soil Conservation Service Curve Number (SCS-CN) methodology for computation of direct surface runoff from long duration rains. Curve numbers has been derived from long-term daily rainfall-runoff data, and antecedent moisture condition (AMC) related with antecedent duration. S.K .Mishra et. al investigated to link AMC with the antecedent (rain) duration for more accurate runoff estimation than the existing.

S.K Mishra et. al has contributed:

(1) A proposal for simple approach for CN derivation for three levels of AMC from long-term daily rainfall-runoff data using long-duration rainfall information from five Indian watersheds,
(2) They investigated the impact of rain duration on curve numbers and propose a more rational procedure for determination of AMC,
(3) Their test proposed an approach on separate, measured rainfall-runoff events independently derived from the available daily data.

2. ORIGINAL SCS-CN MODEL

The SCS-CN method is developed in 1954 by the USDA Soil Conservation Service (Rallison 1980), and is described in the Soil Conservation Service (SCS) National Engineering Handbook Section 4: Hydrology (NEH-4) (SCS 1985) (Ponce and Hawkins, 1996). The SCS-CN method is based on the water balance equation and two fundamental hypotheses. The first hypothesis states that the ratio of the actual amount of direct runoff to the maximum potential runoff is equal to the ratio of the amount of actual infiltration to the amount of the potential maximum retention. The second hypothesis states that the amount of initial abstraction is some fraction of the potential maximum retention .The water balance equation and the two hypotheses can be expressed mathematically, respectively, as follow:

$$P = I_a + F + Q$$

$$Q/(P-Ia) = F/S$$

where P is total precipitation, Ia is initial abstraction, F is cumulative infiltration excluding Ia, Q is direct runoff, S potential maximum retention or infiltration, and λ initial abstraction coefficient accounting for surface storage, interception, and infiltration before runoff begins.

$$Q = \frac{(P-Ia)^2}{P-Ia+S}, \text{ if } P>Ia$$

$$= 0 \text{ otherwise} \quad (1)$$

$$Ia = \lambda S \quad (2)$$

Further the parameter S(in mm) is being represented in the form of CN , which is

$$S = \frac{25400}{CN} - 254 \quad (3)$$

The potential maximum retention (S) for each of the maximum annual storm volume Q, and the rainfall volume P can be computed using the following expression

$$S = 5(P+2Q-\sqrt{(4Q^2-5PQ)}\ ) \quad (4)$$

In this equation λ=0.2 is substituted in the original equation .

3. MISHRA AND SINGH MODEL:

Mishra and Singh (1999) modified the popular form of the existing SCS-CN method (equation 1) for direct runoff and proposed its general form as:

$$Q = (P-Ia)^2/[S+a(P-Ia)] \quad (5)$$

where a is considered equal to 0.5.

Using the C=Sr concept, where C is the runoff coefficient (Q/(P-Ia)) and Sr is the degree of saturation, Mishra and Singh (2002) modified the equation of direct runoff for antecedent moisture M as:

$$Q = \frac{(P-Ia)(P-Ia+M)}{(P-Ia+M+S)} \quad (6)$$

Where M is the antecedent moisture (mm) and is computed as:

$$M = 0.5\ [-(1+\lambda)S + \sqrt{(1-\lambda)S^2+4P_5S}\ ] \quad (7)$$

This method advantageously obviates sudden jumps in CNs and hence computes runoff through incorporation of the expression of M replacing the three AMCs. It does not show an explicit dependency of Ia on M. Further, in this method, S is optimized as a parameter, which is, in fact, a varying quantity depending on M for a given watershed.

According to Mishra and Singh (2004), by assuming λ equal to 0.2, M can be computed as:

$$M = 0.5[-\ 1.2*S + \sqrt{(0.64*S^2+\ 4*P_5*S}\ ] \quad (8)$$

Now S can be determined by coupling the equation 5 with equation 1&2

$$\frac{S}{P} = \frac{[\,4\lambda+2C-\lambda C]-\sqrt{C[C(2-\lambda)^2+16\lambda]}}{4\lambda^2} \quad (9)$$

4. METHODOLOGY

A. Original SCS-CN Method:

Here the procedure to execute the desire result in the SCS-CN method is:

1. Prepare a series of available daily rainfall(P) and runoff(Q) data in same bunits for the period the data are available.
2. Filter the data by selecting the pairs of P-Q data which lies between the runoff factor(Q/P) value 0 to 1.
3. Sort the remaining P-Q data in the descending order of P and by taking the P-Q data S can be calculated using the equation- 4, and S can be transformed to CN scale using the empirical relation of equation – 3.
4. After that, the column is set in the descending order and then the median of the total CN values in the column is determined and is to be taken as CN-II which is the normal condition. After that CN-I and CN-II is calculated by using the formulae given below:

CN I = CN II / (2.281 – 0.01281 CN II)

CNш = CN II / (0.427 + 0.00573 CN II)

This formulae of CN-I(dry condition), CN-II(normal condition) and CN-III(wet condition) was proposed by Hawkins et al. (1985) as the AMC-dependent CN conversion formulae.

6. After the CN-I,II and III values are determined then the S can be again calculated by depending upon the CN values by using the equation-4
7. At last the runoff can be calculated by using the combined equation 1&2 , where the λ is taken as 0.2 which is the universal value.

B. Mishra and Singh Model(M-S Model):

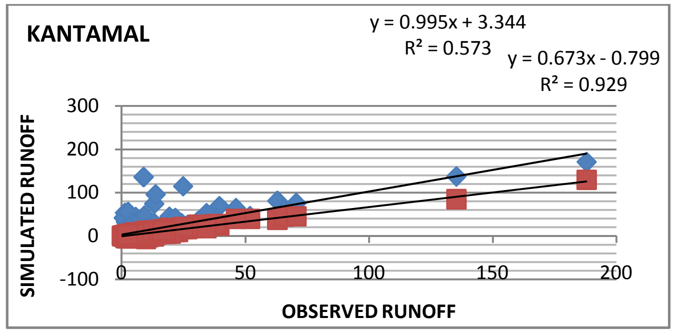
Here the procedure to execute the the desire result in the SCS-CN based M-S Model is:

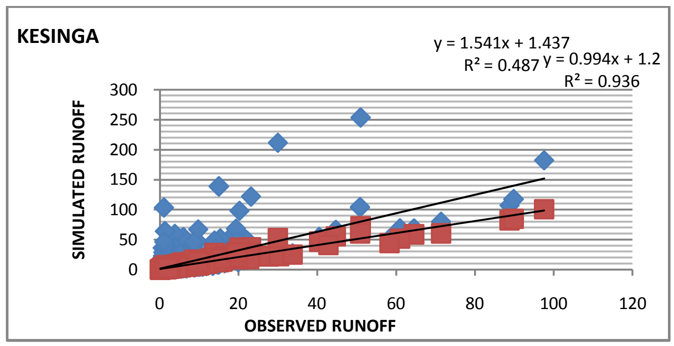
1. Available data set is to be prepared in the form of P and Q , then the P5 (5 days cumulative rainfall) is being determined from the daily rainfall (p).
2. Filter the data by selecting the pairs of P-Q data which lies between the runoff factor(Q/P) value 0 to 1.
3. From these values now the S can be calculated by using the equation- 9 in which the value of λ=0.2 and the runoff factor (C=Q/P) is used.
4. After the determination of S now M can be calculated easily by using the equation- 8 , here M depends upon the S values.

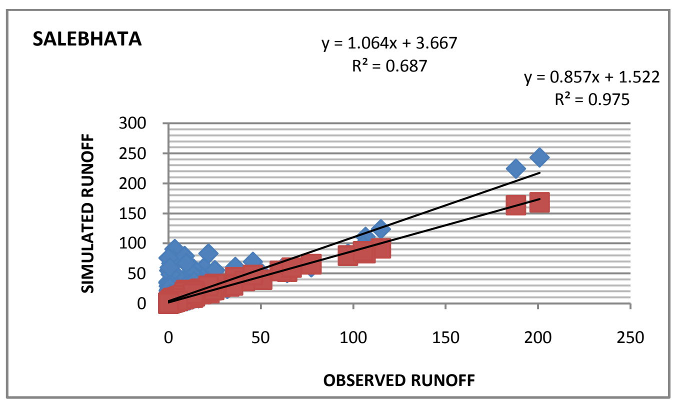
At last , the runoff is determined using equation- 6 .

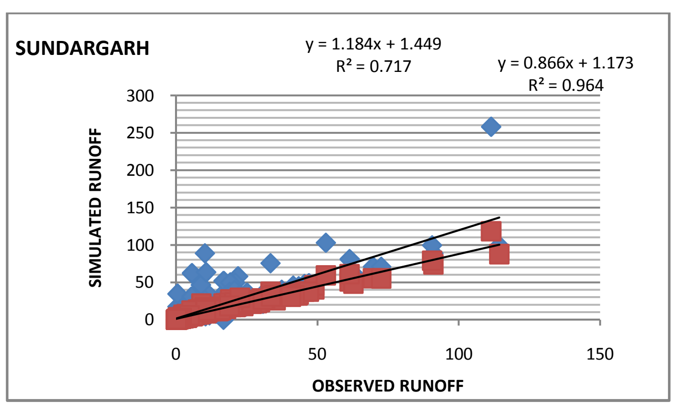
5. RESULT AND DISCUSSION

As applying the above procedure described in both the methods we can get the result and the comparison can also be done between both the methods.









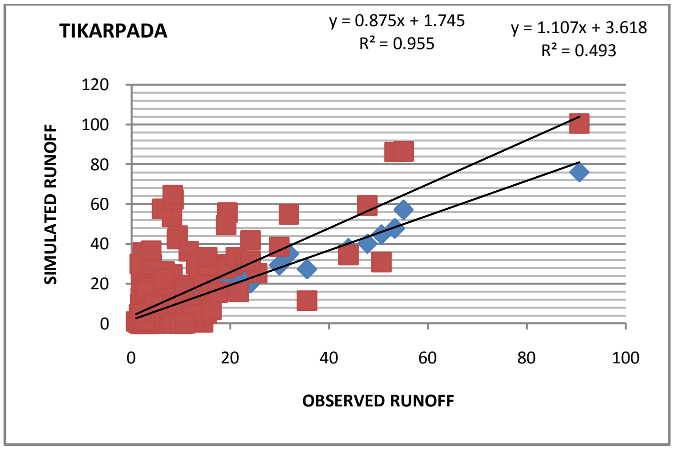


Fig: Daily simulation performance of original SCS-CN method and MS model

TABLE: Comparision of the R2 value in the Original SCS-CN method and the Mishra and Singh Model

SUB-BASINS	R^2 VALUE	
	ORIGINAL SCS-CN METHOD	MISHRA AND SINGH(MS)MODEL
KESINGA	0.487	0.936
KANTAMAL	0.573	0.929
SALEBHATA	0.687	0.975
SUNDARGARH	0.717	0.964
TIKARPADA	0.493	0.955

The above graph shows the daily simulated performance for the five sub-basins in the term of the scatter plot which shows the R^2 value. The above table represents the comparison between the R^2 values of both the method in the five sub-basins.

Here we found out that the result of the MS model was better than the original SCS-CN method. MS model performed better than the original method because in the method instead of the AMC I, II & III it takes the M value and instead of the daily rainfall here P5 (means five days rainfall) is taken into consideration. So, for the P5 and the M value we get better result in the MS model.

6. CONCLUSION

After comparing both the method in the all five sub-basins it is concluded that the Mishra and Singh performs better than the original SCS-CN method.

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