Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(4): 3419-3427
Received: 16-05-2019
Accepted: 18-06-2019

Aherwar P
Department of Soil and Water Engineering, Jawaharlal Nehru Krishi Vishvavidyalaya, Jabalpur, Madhya Pradesh, India

Aherwar H
Department of Agricultural Chemistry and Soil Science Powarkhera Agriculture College, Hoshangabad, Madhya Pradesh, India

Correspondence
Aherwar P
Department of Soil and Water Engineering, Jawaharlal Nehru Krishi Vishvavidyalaya, Jabalpur, Madhya Pradesh, India

Comparison of rainfall runoff simulation by SCS-CN and NAM model in Shipra river basin of Madhya Pradesh, India

Aherwar P and Aherwar H

Abstract
Rainfall Runoff computation of any basin plays an important role in water resources planning and management. Here we have developed two conceptual models viz. the SCS-CN model and NAM model to study the hydrological behavior of the river. The two models were evaluated on the basis of coefficient of determination (R^2), coefficient of correlation (r), Nash-Sutcliffe Efficiency and Root Mean Square Error. The estimated or simulated values were compared with the observed data which showed good consistency. The SCS-CN model showed Nash-Sutcliffe efficiency is 72% and 53%, coefficient of determination R^2 values 0.616 and 0.44, coefficient of correlation is 0.78 and 0.66 and Root Mean Square Error is 83.09 and 130.06 for the period of calibration and validation respectively which were satisfactorily close to the observed values. The NAM model showed Nash-Sutcliffe efficiency is 76% and 85%, coefficient of determination R^2 value is 0.72 and 0.502, coefficient of correlation is 0.76 and 0.84 and Root Mean Square Error is 68.26 and 64.4 for the period of calibration and validations respectively were found to be closer to the observed values in comparison to the SCS-CN model. The comparative study of the two models indicates that the NAM model is more superior to the SCS-CN model and is suitable for the hydrological study of the Shipra river basin of Madhya Pradesh in India.

Keywords: Rainfall run off modeling, curve number, MIKE 11 NAM, accuracy criteria, shipra basin

Introduction
Water is the natural important resource which needs preservation, control and management. The water resources can be managed by implementing and improving the engineering practices. In water resources planning and development process, it is essential to measure available water resources in the river system. In India the river gauging network is not adequate and data availability is very poor. In such circumstances the rainfall is transformed to generate the runoff by developing relationship between rainfall and runoff or by using suitable rainfall runoff model. A rainfall runoff model is a mathematical model that describes catchment and gives relationship between precipitation and runoff. Specifically, a rainfall runoff model produces the surface runoff hydrograph when precipitation is given as an input (Das, 2012) [4]. Important need of rainfall runoff modelling for practical problem in water resources assessment, design of engineering channels, flood forecasting, predicting population incidents and many more purposes. Modelling existing catchments for which input-output data exist, runoff estimation on ungauged basins and prediction of effects of catchment change. A rainfall runoff model is helpful in computation of discharge from a basin (Das, 2012) [4]. In most of the locations we have the rainfall data but the discharge or the runoff data is not available or is available in gaps. Modelling gives information to hold up the decision making of water management policies (Chander, 2014) [2]. The widely known rainfall-runoff models identified are the rational method (Mcpherson, 1969) [12], SCS-CN method (Maidment, 1993) [11], and Green-Ampt method (Green and Ampt, 1911) [11]. Many researchers conducted number of rainfall runoff modeling using different models and techniques. Watershed as a series of identical reservoirs and prepared a conceptual rainfall runoff models by routing a unit inflow through the reservoirs (Nash, 1958) [16]. Pathak *et al*., (1984) [18] developed a model to predict runoff volume from small watershed to simulate daily, monthly and annual runoff volume quite accurately. Kumar and Rastogi (1989) [9] developed a mathematical model of the instantaneous unit hydrograph based on time area histogram for a small watershed at Pantnagar. Mishra and Singh (1998) have worked on SCS-CN method. Das (2004) [4] developed a hydrological model for estimation of runoff in a small watershed.
The rainfall runoff modeling has an important role in water resources planning of the region for simulation of long term runoff using rainfall and catchment characteristics as an input. Researchers have always tried to develop and compare various rainfall runoff models to

identify suitable model for the river basin of their interest so that it can be applied effectively in the region. In this paper, two rainfall runoff model i.e. SCS-CN and NAM model has been developed and compared based on performance criteria such as Root Mean Square Error (RMSE), Efficiency Index (EI) and correlation coefficient (R^2) on Shipra river basin located in Madhya Pradesh, India. The SCS-CN is widely used as a simple method for predicting direct runoff volume for a given rainfall event. The basic data required to apply SCS-CN method is the rainfall, soil retention or soil storage, soil group/type which depends on the infiltration rate, initial abstraction and curve number. However NAM rainfall runoff model is a module in MIKE 11 professional engineering software developed by Danish Hydraulic Institute (DHI), Denmark. It has been used worldwide for many water resources development programmes. NAM is the abbreviation of the Danish ‘Nedbor Afstromnings Model’, meaning precipitation runoff model. It is deterministic, lumped and conceptual rainfall-runoff model that operates by continuously accounting for the moisture content in three different and mutually interrelated storages that represent overland flow, interflow and base flow (DHI, 2003) [3]. The NAM model has been applied to a number of catchments around the world, representing many different hydrological regimes and climatic conditions. Fleming (1975) [6], Arcelus (2001) [1], Shamsudin and Hashim (2002) [19], Galkate *et al*., (2014) [7] and many other researchers carried out rainfall runoff modeling using MIKE 11 NAM model.

The main objective of this study was to develop rainfall runoff model for runoff simulation using SCS-CN and NAM model for Shipra river basin of Madhya Pradesh in India and compare these two models, which model is best suited for estimating runoff.

Materials and methods

Experimental site

The Shipra river of Madhya Pradesh, India traverses a total course of about 190 km through four districts namely Dewas, Indore, Ujjain, and Ratlam before joining Chambal River near Kalu-Khera village. The majority of the Shipra basin area falls in Indore and Ujjain districts however a small part of it is being found come under Ratlam and Dewas districts. Shipra River has been extended between $76^0$06’20” and $75^0$55’60” North Latitude and $22^0$97’00” and $23^0$76’20” East Longitude and covers an area of 5679 sq. km. It is one of the sacred rivers in Hinduism. The holy city of Ujjain is situated on its right bank. The Shipra also known as the Kshipra, originates from Kakribardi hills in Vindhya Range north of Dhar and flows north across the Malwa Plateau to join the Chambal River**.** After every 12 years, the Kumbh Mela (Also called Simhastha) takes place at Ujjain on the city's elaborate riverside Ghats, besides yearly celebrations of the river goddess Kshipra. There are hundreds of Hindu shrines along the banks of the river Shipra. Over the years the river has lost its perennial nature and now runs dry for a period of 5 to 6 months per year. The water of the Shipra is used for drinking, industrial use and lift irrigation purposes. It is reported that there is a normal practice of pumping water from the river for providing irrigation to surrounding agricultural fields.

The present study has been carried out at National Institute of Hydrology (NIH), Regional Centre, Bhopal, India. Thus data collected by NIH from various State and Central agencies was used in the study for analysis. The daily rainfall data collected from Indian Meteorology Department (IMD), Pune and State Water Data Centre, Water Resources Department, Govt. of Madhya Pradesh, Bhopal, India was used in the study. The meteorological data of Indore observatory collected from IMD, Pune like relative humidity, wind speed, sunshine hours, mean and maximum temperature etc. was used in the study. Shipra River for the period from 1996 to 2006 was used in the study for calibration and validation of rainfall runoff model. This data was collected by NIH, Regional Centre, Bhopal from Chambal Division, Central Water Commission, Jaipur. Both the model was developed to carry out rainfall-runoff modeling in Shipra river basin at Ujjain G/d site having catchment area 2102 Km^2 using daily rainfall data of five rain gauge stations namely Indore, Ujjain, Dewas, Mhow and Sanwer to apply in the model. As present study has been carried out as a part of NIH, Regional Centre, Bhopal in India. Shipra river basin as well as location of stations for which the present study has been carried out is shown in Figure 1. The GPS coordinates and elevation of study area is shown in Table 1. 0.5 per cent mineral matter. The mineral matter reported to be present in fair amount of calcium, phosphorus, iron, potassium, sodium and iodine.

Table 1: Geographical location of Study Area

Stations	Latitude	Longitude	Elevation
Indore	22.7196° N	75.8577° E	550 m
Ujjain	23.1823900° N	75.7764300° E	494 m
Dewas	22.9623° N	76.0508° E	535 m
Mhow	22.5524° N	75.7565° E	556 m
Sanwer	22.976303°N	75.827553° E	32000 m

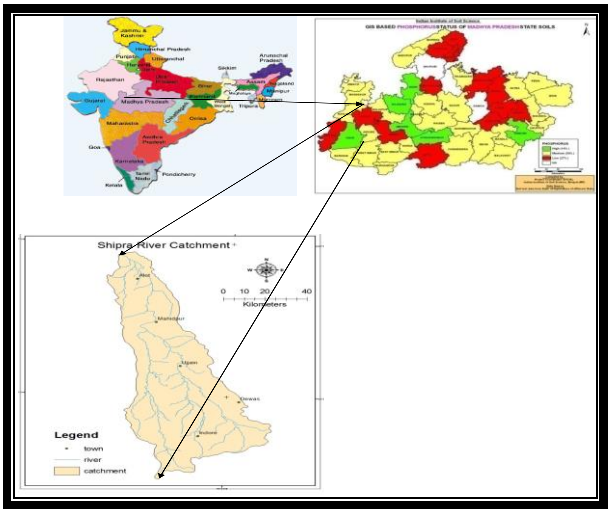

Fig 1: Index map of Shipra river basin

SCS-CN Method

Soil Conservation Service Curve Number (SCS-CN) method developed by Soil Conservation Services (SCS) of USA, 1969 is a simple, predictable and stable conceptual method for estimation of direct runoff depth based on storm rainfall depth. It relies on only one parameter, CN. In this method, runoff depth is a function of total rainfall depth and an abstraction parameter referred to as runoff curve number or simply curve number and is usually represented by CN (Mishra and Singh, 2003) [13]. Pandey and Sahu (2002) [17] pointed out that the land use/land cover is an important parameter input of the SCS-CN model. Currently, it is a well established method, having been widely accepted for use in USA and many other countries.

The SCS-CN method is based on the water balance equation and two fundamental hypotheses. The first hypothesis equates the ratio of the amount of direct runoff (Q) to maximum potential runoff (P-I_a) is equal to the ratio of the actual infiltration (F) to the potential maximum retention (S). The second hypothesis relates the initial abstraction (I_a) is some fraction of the potential maximum retention (S). Thus, the SCS-CN method consisted of the following equations (Subramanya K, 1994) [20].

The SCS-CN model calculates direct runoff depth (Q) using the following equation:

$$Q = \frac{(P-I_a)^2}{(P-I_a)+S} \text{ for} P > Ia \qquad \text{(Eq.1)}$$

Where, P= total precipitation (mm), Ia = initial abstraction (mm), and S= potential maximum retention (mm).

Q=0, for$P \leq I_a$.

The initial abstraction is related to S by the equation:

$$Ia = \lambda S \qquad \text{(Eq.2)}$$

Where, λ is an initial abstraction ratio. The values of λ vary in the range of 0.1 and 0.3. The value of λ has been developed for black soil region for Indian conditions as 0.3 for AMC-I and 0.1 for AMC-II & III (Hand book of Hydrology, Mini. of Agriculture, 1972). On the basis of extensive measurements in small size catchments (US Soil Conservation Service, 1985) adopted λ=0.2 as a standard value. In practice, the Curve Number (CN) is used to compute S in mm as,

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

Soils

As per National Engineering Handbook (NEH) developed by USDA (1986) soils are classified in four Groups A, B, C and D based upon the infiltration and other characteristics. The description of each of the hydrologic soil groups is given in Table 2.

Table 2. Hydrological soil groups

Hydrological Soil Group	Soil textures	Runoff potential	Water transmission	Final infiltration
Group A	Deep, well drained sands and gravels	Low	High rate	>7.5
Group B	Moderately deep, well drained with Moderate	Moderate	Moderate rate	3.8–7.5
Group C	Clay loams, shallow sandy loam, soils with moderate to fine textures	Moderate	Moderate rate	1.3–3.8
Group D	Clay soils that swell significantly when wet	High	Low rate	<1.3

Antecedent Moisture Condition (AMC)

AMC indicates the moisture content of soil at the beginning of the rainfall event. The AMC is an attempt to account for the variation in curve number in an area under consideration from time to time. Three levels of AMC were documented by SCS AMC I, AMC II & AMC III. The limits of these three AMC classes are based on rainfall magnitude of previous five days and season (dormant season and growing season). AMC for determination of curve number is given in Table 3.

Table 3: Antecedent moisture conditions (AMC) for determining the values 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

Land use

For determination of composite curve number (CN), soil type and land use information is essential. To obtain the spatial information of soil type and land cover, the output of a case study carried out by Mishra A (2014) [14] on Shipra basin was referred and applied as an input in present study. The said study was carried out for assessment of surface water yield using SWAT hydrological model where author prepared soil map and land use maps using remote sensing data and GIS software. The same information was used in the present study for estimation of CN as required in SCS model. The study concluded that major soil type observed in Shipra basin was clay and land type was mainly irrigated agricultural land.

As the soil in Shipra basin is mainly of clay type, all soils in the Shipra basin belong to soil group D. Once the hydrologic soil group has been determined, the curve number of the site is determined by land use and hydrologic condition to the soil group.

Computation of average curve number

Theissen polygons are established for each identified raingauge station. For each theissen cell, area weighted CN (AMC II) and also CN (AMC I) and CN (AMC III) were determined.

CN for AMC I is calculated as:

$$CN_I = CN_{II}/(2.281 - 0.01281 CN_{II}) \text{ (Eq.4)}$$

CN for AMC III is calculated as:

$$CN_{III} = CN_{II}/(0.427 - 0.00573 CN_{II}) \text{ (Eq.5)}$$

SCS- CN for hydrologic soil cover complex under AMC II condition for the study area is given in Table 4. Jena *et al.*, (2012) [10] used area weighted composite curve number for various conditions of land use and hydrologic soil conditions are computed as follows:

$$CN=(CN_1 \times A_1)+ (CN_2 \times A_2)+ \ldots\ldots (CN_n \times A_n)/A \text{ (Eq.6)}$$

Where A_1, A_2, A_3, …., represent areas of polygon having CN values CN_1, CN_2, CN_3,….., CN_n respectively and A is the total area.

Table 4: Weighted curve number (AMC II) for the study area

Type of Cultivated Land	Hydrologic condition	Hydrologic Soil Group	Curve Number	% Area	% Area* CN	Weighted CN
Contoured	Good	D	86	40	34.40	
Bunded	Good	D	79	40	31.60	82.6
Bunded	Poor	D	83	20	16.60	

NAM Model

MIKE11 NAM is a rainfall-runoff model that is part of the MIKE 11 module developed by Danish Hydraulic Institute (DHI), Denmark. MIKE 11 software is meant for simulation of flows, water quality and sediment transport in river, irrigation systems, channels and other water bodies. The NAM (Nedbor Afstromnings Model) is deterministic, lumped and conceptual rainfall-runoff model that operates by continuously accounting for the moisture content in three different and mutually interrelated storages that represent overland flow, interflow and base flow (DHI, 2003) [3]. The physical processes involved for runoff simulation in the model are shown in Figure 2. It treats each sub-catchment as one unit, therefore the parameters and variables are considered for representing average values for the entire sub-catchments. The result is a continuous time series of the runoff from the catchment throughout the modeling period. Thus, the MIKE11 NAM model provides both peak and base flow conditions that accounts for antecedent soil moisture conditions over the modeled time period.

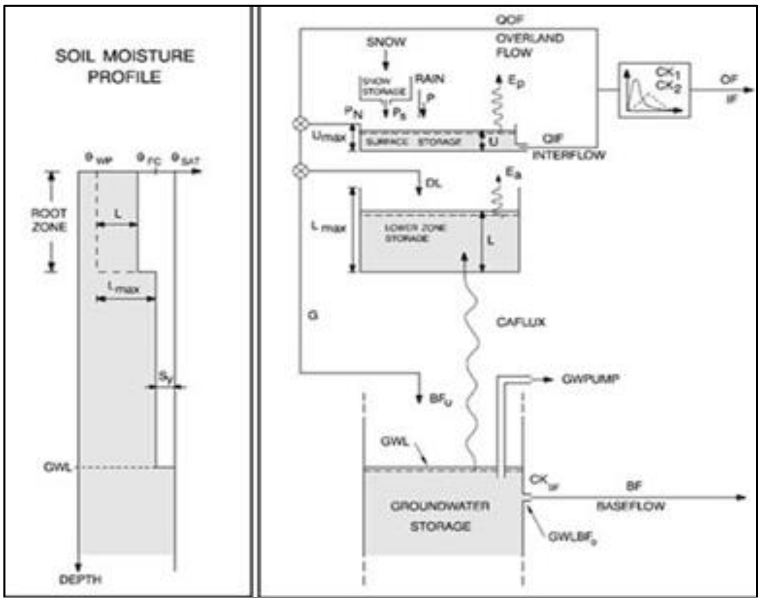

Fig 2: Processes of NAM Model

NAM is prepared with 9 parameters, representing surface zone, root zone and ground water storage. Description of the parameters and their effects is presented in Table 5.

Table 5: Different parameters of the NAM model

Parameter	Unit	Description	Effects
U_{max}	Mm	Maximum water content in surface storage	Overland flow, infiltration, evapotranspiration, interflow
L_{max}	Mm	Maximum water content in lower zone/root storage	Overland flow, infiltration, evapotranspiration, base flow
C_{QOF}		Overland flow coefficient	Volume of overland flow and infiltration
C_{KIF}	Hrs	Interflow drainage constant	Drainage of surface storage as interflow
T_{OF}		Overland flow threshold	Soil moisture demand that must be satisfied for overland flow to occur
T_{IF}		Interflow threshold	Soil moisture demand that must be satisfied for interflow to occur
TG		Groundwater recharge threshold	Soil moisture demand that must be satisfied for groundwater recharge to occur
C_{K1}	Hrs	Timing constant for overland flow	Routing overland flow along catchment slopes and channels
C_{K2}	Hrs	Timing constant for interflow	Routing interflow along catchment slopes
C_{KBF}	Hrs	Timing constant for base flow	Routing recharge through linear groundwater recharge

Model Calibration

Calibration is a process of standardizing predicted values, using deviations from observed values for a particular area to derive correction factors that can be applied to generate predicted values that are consistent with the observed values. MIKE 11 NAM model was set up with the input information and the models were calibrated for six years period from 1996 to 2001. During calibration, the default model parameters were kept same and model was run in auto-calibration mode. The model output simulation results during calibration were checked for coefficient of determination (R^2) value and graphically analyzed for degree of agreement between simulated and observed runoff. The model parameters were again adjusted one by one using trial and error method to obtain the set of best fit model parameters which could simulate runoff with high degree of agreement with observed runoff in term of timings, peaks and total volume.

Model Validation

Model validation means judging the performance of the calibrated model over the portion of historical records which have not been used for the calibration. MIKE 11 NAM model thus calibrated and then validated for the remaining period of five years from 2002 to 2006. During validation the set of model parameters obtained during the calibration was used and model was run without auto-calibration mode to simulate runoff. The statistics of the simulated results were analyzed and output of the model was checked to compare the simulated and observed runoff to verify the capability of calibrated model to simulate the runoff.

Accuracy Criteria

Accuracy of the model can be examined on the basis of coefficient of determination (R^2), Efficiency Index (EI) and Root Mean Square Error (RMSE). The use of the coefficient of determination is to test the goodness of fit of the model and to assess how well a model explains and predicts future outcomes. It is expressed as a value between zero and one. The coefficient of determination (R^2) of the model was calculated by using the following equation:

$$R^2 = \frac{\sum_{i=1}^{n}(q_o - \bar{q}_o)(q_s - \bar{q}_s)}{\sqrt{[\sum_{i=1}^{n}(q_o - \bar{q}_o)^2][\sum_{i=1}^{n}(q_s - \bar{q}_s)^2]}} \quad \text{(Eq.7)}$$

Where, q_o = observed flow, $\overline{q}_o$ = mean value of observed flow, q_s = simulated flow and n = number of data points.

The reliability of the model was evaluated on the basis of Efficiency Index (*EI*) as described by the Nash and Sutcliffe. EI depends upon the error present in the model like missing data or inconsistency in the data and it is directly proportional to errors present in the input information of the model. The value of efficiency index lies between 0 to 1. The efficiency index equal to 1 indicates the best performance of the model. The efficiency index was calculated by using the following relationship:

$$EI = \frac{[\sum_{i=1}^{n}(q_o - \bar{q}_o)^2 - \sum_{i=1}^{n}(q_o - q_s)^2]}{\sum_{i=1}^{n}(q_o - \bar{q}_o)^2} \quad \text{(Eq.8)}$$

Where, q_o= observed flow, $\overline{q}_o$= mean value of observed flow, q_s= simulated flow and n = number of data points.

Root Mean Square Error (RMSE) was used by Fleming (1975) [6] was another technique applied to assess the reliability of MIKE11. This technique can be taken to be a measure of absolute error between the observed and simulated discharges. It is defined by

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(qo - qs)^2} \quad \text{(Eq.9)}$$

Where, q_o= observed flow, q_s= simulated flow and n = number of data points.

Results and Discussion

Both the model was developed to carry out rainfall-runoff modeling in Shipra river basin at Ujjain G/d site having catchment area 2102 Km^2 using daily rainfall data of five rain gauge stations whose weights play a main role in calculating the rainfall weights to apply in the model. The Theissen polygon of study area was prepared in Arc GIS tool by considering five rain gauge stations namely Indore, Ujjain, Dewas, Sanwer and Mhow. It is shown in following Figure 3 and Figure 4. Among five rain gauge stations, Indore and Ujjain are the most influencing station covering maximum area. The weights of rain gauge stations are given in Table 6.

Fig 3: Catchment area of Ujjain up to G/D site

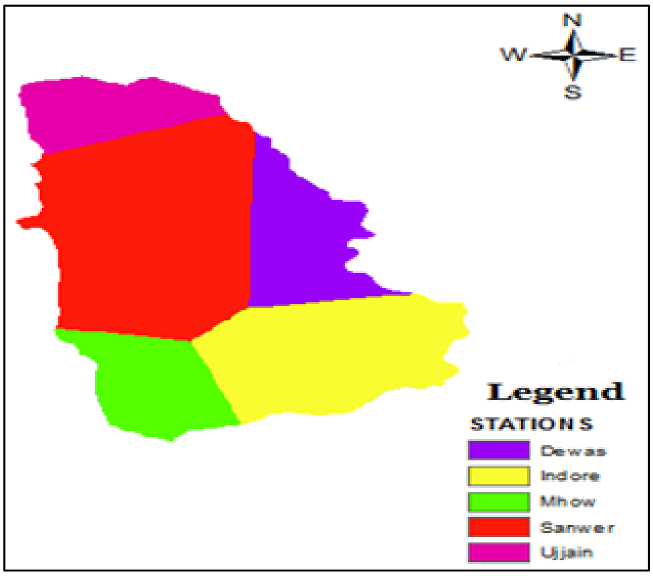

Fig 4: Theissen Map

Table 6: Thiessen weights for raingauge stations

Station	Raingauge Station	Weights
1	Ujjain	0.12
2	Indore	0.31
3	Dewas	0.23
4	Sanwer	0.25
5	Mhow	0.90

Before starting the model development, the reliability of rainfall data was tested by plotting the annual rainfall against the annual runoff as shown in Figure 5. The correlation coefficient was obtained as 0.781, showing good correlation between rainfall and observed runoff. A straight line graph thus obtained, shown the linear relation between rainfall and observed runoff and concluded that the data was consistent to be used further in rainfall-runoff modeling.

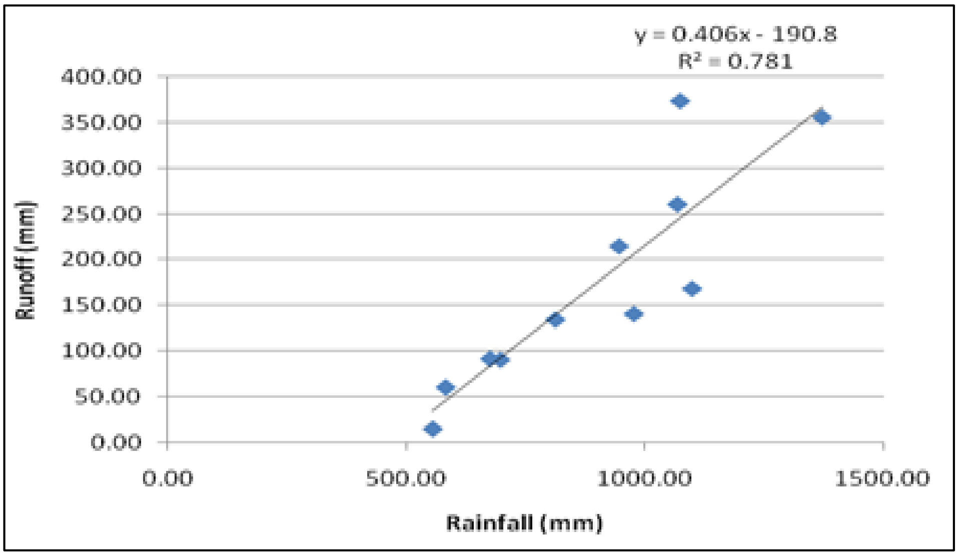

Fig 5: Linear relation between rainfall and runoff for the 1996 to 2006

SCS-CN model

The SCS-CN model was a setup to carry out rainfall-runoff modeling in Shipra river basin at Ujjain G/d site having catchment area 2102 km^2.In the SCS-CN model, the daily rainfall values were used as inputs to compute daily runoff. For various curve numbers, the runoff estimated for different AMC conditions. The individual composite curve number was computed for all study area for AMC II condition. Using equation (5) the daily runoff depth were computed. From the equation (1) daily runoff, monthly and annual values can be derived. The runoff depths are computed for each rainfall event for the years 1996-2006 is shown in Table 7 and the relationship between rainfall-runoff is shown in Figure 6.

Table 7: Runoff Values (1996-2006)

Year	Rainfall (mm)	Estimated Runoff (mm)
1996	1075.19	319.4697
1997	1069.53	215.3062
1998	946.98	165.9087
1999	985.12	160.6527
2000	556.34	63.68513
2001	583.59	116.436
2002	736.41	124.5204
2003	1100.32	247.4099
2004	813.48	174.2698
2005	676.33	220.3154
2006	1372.99	442.932

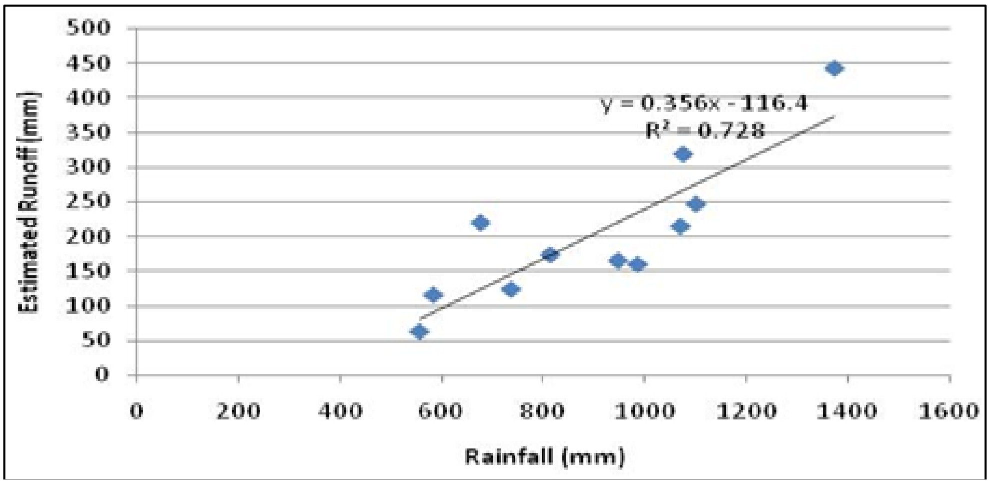

Fig 6: Rainfall-Runoff relationship for the year 1996 to 2006

NAM model

MIKE 11 NAM was setup to carry out rainfall-runoff modeling in Shipra river basin at Ujjain G/d site having catchment area 2102 km^2. The NAM models were calibrated for six years period from 1996 to 2001 and then validated for the remaining period of five years from 2002 to 2006. Figure 7 shows the comparison between observed discharge and simulated discharge during the calibration of NAM model. The typical example of graphical results for the years 1998 by NAM model is shown in Figure 8. Figure 9 and Figure 10 shows the comparison of simulation results of SCS-CN and NAM model with the observed value for calibration and validation period respectively.

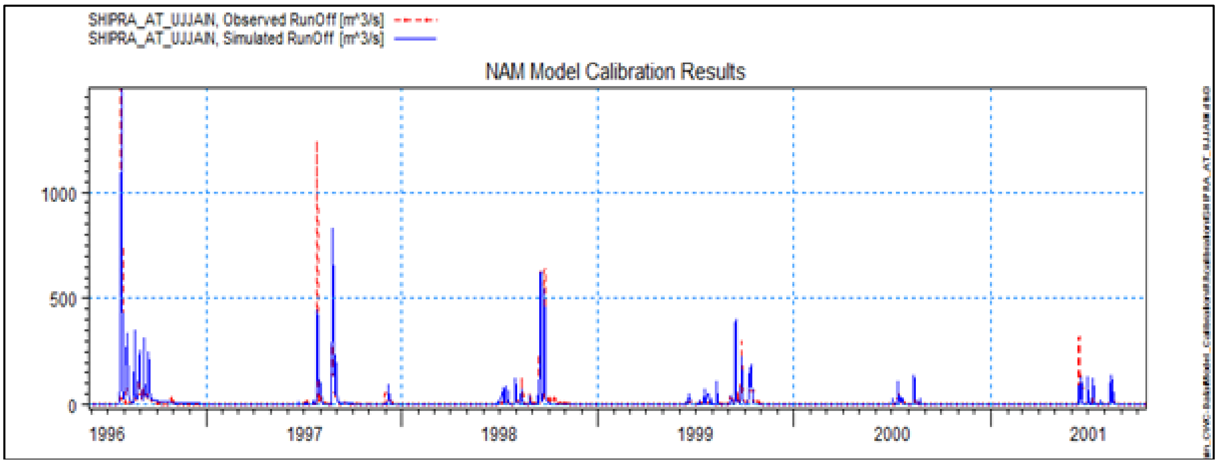

Fig 7: Comparison between observed and simulated discharge for calibration period.

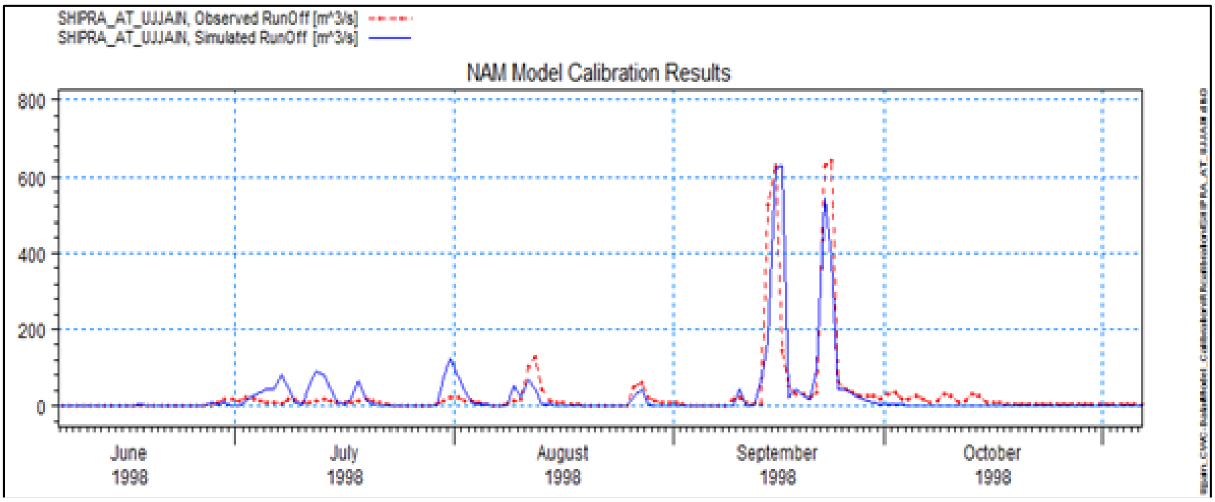

Fig 8: Comparison between observed and simulated discharge for calibration for 1998

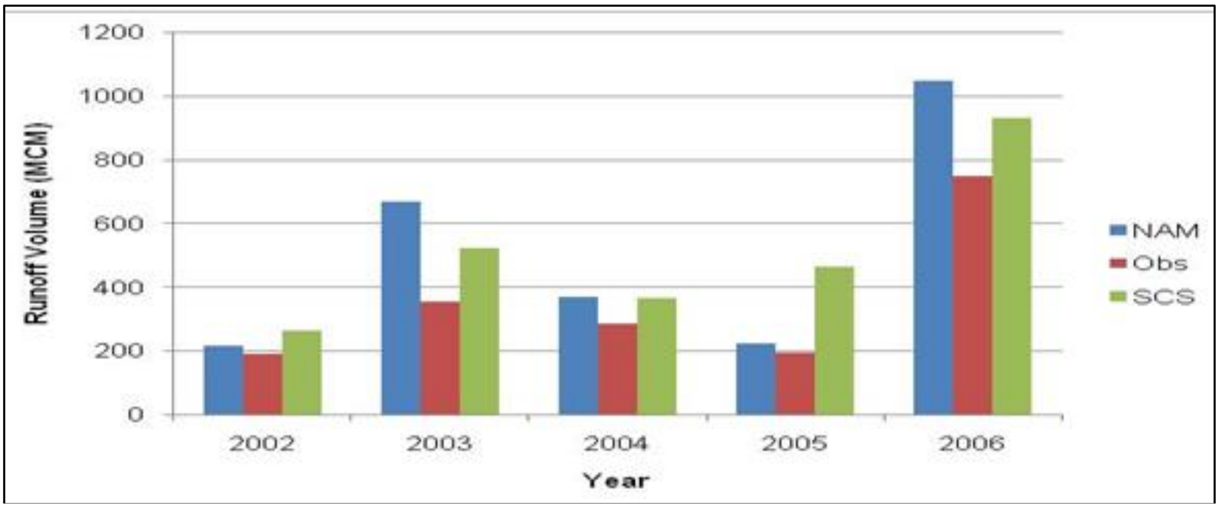

Fig 9: Comparative bar chart of simulation results of SCS-CN and NAM model with observed value for the calibration period.

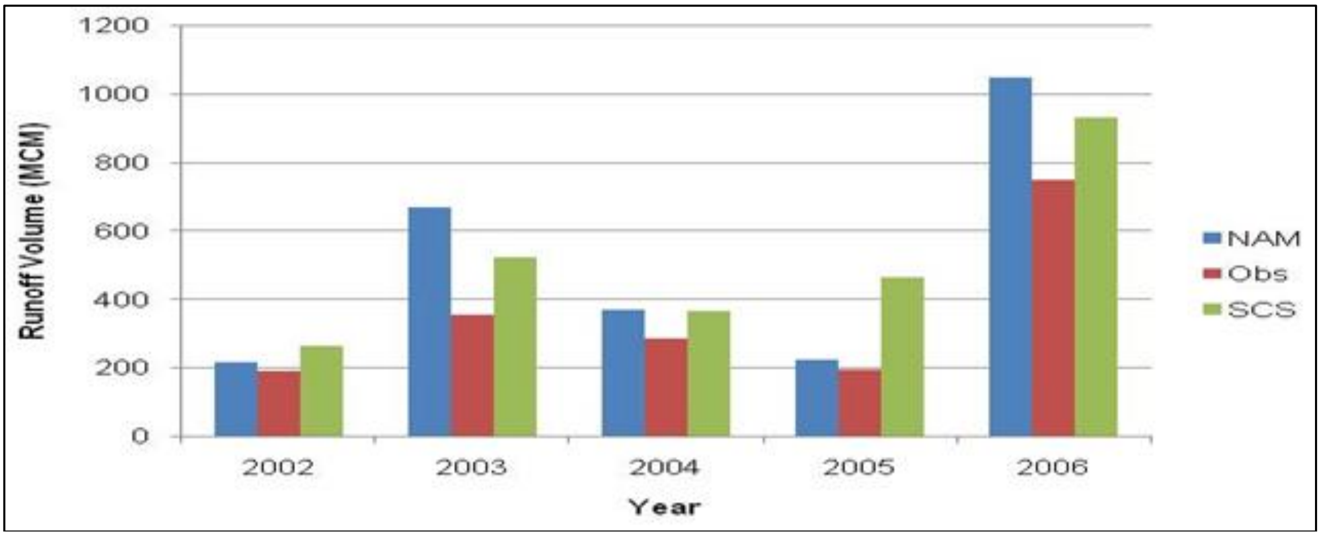

Fig 10: Comparative bar chart of simulation results of SCS-CN and NAM model with observed value for the validation period.

Accuracy Criteria

Comparison of models is important to evaluate which model is best suitable for particular basin. Most efficient model gives us better result and help in the efficient planning and management of water resources. Cheap, efficient and less time consuming, simple, highly trusted and does not require hydrologist suggestion in best chosen for the proper distribution and management of water resource planning and development. Comparison of models helps us to take better decision which model to choose.

Table 8: Comparision of SCS-CN with NAM rainfall runoff model for calibration period

	SCS-CN model	NAM model
Coefficient of determination (R^2)	0.616	0.720
Coefficient of correlation (r)	0.78	0.76
Nash Sutcliff Efficiency (%)	72%	76%
Root Mean Square Error	83.09	68.26

Table 9: Comparision of SCS-CN model with NAM rainfall runoff model for validation period

	SCS-CN model	NAM model
Coefficient of determination (R^2)	0.440	0.502
Coefficient of correlation (r)	0.66	0.84
Nash Sutcliff Efficiency (%)	53%	85%
Root Mean Square Error	130.6	64.4

Table 10: Comparision of SCS-CN model with NAM rainfall runoff model for total period

	SCS-CN model	NAM model
Coefficient of determination (R^2)	0.506	0.678
Coefficient of correlation (r)	0.47	0.690
Nash Sutcliff Efficiency (%)	0.79	0.806
Root Mean Square Error	107.32	66.59

The performance of SCS-CN and NAM model was evaluated based on Accuracy criteria such as coefficient of determination (R^2), Coefficient of correlation (r), Nash Sutcliff Efficiency and Root Mean Square Error. The SCS-CN showed Nash-Sutcliffe efficiency is 72% and 53%, coefficient of determination R^2 values 0.616 and 0.44, coefficient of correlation is 0.78 and 0.66 and Root Mean Square Error is 83.09 and 130.06 from the period of calibration and validation respectively in Table 8 and Table 9 which were satisfactorily close to the observed values. The NAM model showed Nash-Sutcliffe efficiency is 76% and 85%, coefficient of determination R^2 value is 0.72 and 0.502, coefficient of correlation is 0.76 and 0.84 and Root Mean Square Error is 68.26 and 64.4 from the period of calibration and validation respectively in Table 8 and Table 9 which were found closer to the observed values in comparison to the SCS-CN model. Table 10 also showing values for total period for SCS-CN and Nam Model.

Conclusion

In this study the runoff is estimated to Shipra River Catchment of Madhya Pradesh, India by two models namely SCS-CN and NAM model and compared. The NAM model recommended by Danish Hydraulic Institute of Denmark gives lesser runoff which is professional engineering software. But the SCS-CN method developed by Soil Conservation Services (SCS) of USA, for calculating runoff for ungauged catchments gives more runoff than NAM model even by considering all the parameters which influences runoff namely soil type, land use pattern and antecedent soil moisture conditions. SCS-CN is covering a large area i.e. the estimated discharge value coming out to be much higher than the observed value, so for designing purpose it is not economical rather safer. The estimated or the simulated discharge from the SCS-CN and NAM model was compared with the observed discharge to test their performance in Shipra basin. The models were also evaluated on the basis of performance criteria such a Coefficient of Determination (R^2), Coefficient of correlation (r), Efficiency Index (EI), Root Mean Square of Error (RMSE). The SCS-CN model shows Efficiency Index 72% for calibration and 53% for validation and coefficient of determination R^2 value 0.616 for calibration and 0.440 for validation which were satisfactorily close to the observed values. The NAM model showed Efficiency Index 76% for calibration and 85% for validation and coefficient of determination R^2 value 0.720 for calibration and 0.502 for validation which were found closer to the observed values in comparison to SCS-CN model. From this study it is inferred the NAM model suits more to this study area than the SCS-CN model to calculate runoff to ungauged catchments.

Reference

1. Arcelus EA. Coupling two hydrological models to compute runoff in ungauged basins. Project Report, National Directorate of Hydrography, Ministry of Transport and Public Works of Uruguay, 2001.
2. Chander S, Prasad RK. Water Resource Systems. Jain Brothers, New Delhi, 2014.
3. Danish hydraulic institute. MIKE BASIN: Rainfall-runoff modeling reference manual. DHI, Denmark, 2003.
4. Das G. Hydrology and Soil Conservation Engineering, PHI Learning Private Limited, New Delhi, 2012, 80-83.
5. Das SN, Tripathi MP, Shrivastava PK. Hydrological Modeling of a Small Watershed Using Satellite Data and GIS Technique, Journal of the Indian Society of Remote Sensing. 2004; 32:145-157.
6. Fleming G. Computer simulation techniques in hydrology. New York: Elsevier, 1975, 18-53.
7. Galkate R, Jaiswal RK, Thomas T, Nayak TR. Rainfall Runoff Model using NAM Model. International Conference on Sustainability and Management Strategy (ICSMS-2014), Institute of Management and Technology, Nagpur, 2014, 21-22.
8. Green WH, Ampt GA. Studies on soil physics. The flow of air and water through soils. Journal of Agriculture Science. 1911; 4:1-24.
9. Kumar Rastogi. Determination of direct runoff from a small agricultural watershed. Journal of Agricultural Engineering. 1989; 26:223-228.
10. Jena SK, Tiwari KN, Pandey A, Mishra SK. RS and Geographical Information System-Based Evaluation of Distributed and Composite Curve Number Techniques. Journal of Hydrologic Engineering, ASCE. 2012; 17:1278-1286.
11. Maidment DR. Handbook of Hydrology. 1st Edition, New York: McGraw Hill Publication, 1993.
12. Mcpherson MB. Some notes on the rational method of storm drain design. Tech. Memo. No. 6 ASCE, Water Resources Research Program, Harvard University, Cambridge, MA, 1969.
13. Mishra SK, Singh VP. Another look at SCS-CN method. Journal of Hydrology Engineering. American Society of Civil Engineering. 2003; 4:257-264.
14. Mishra A. Case Study of the Shipra Basin. Assessment of Surface Water Yield using SWAT Hydrological model. INRM Consultants, New Delhi, 2014.
15. Ministry of Agriculture, Govt. of India, Handbook of Hydrology, New Delhi, 1972.
16. NASH JE. Determination of runoff from rainfall. Institute of Civil Engineering, 1958; 10:163-184.
17. Pandey A, Sahu AK. Generation of curve number using remote sensing and Geographic Information System. http://www.GISdevelopment.net. 2002.
18. Pathak P, Swaify SA, Murty VVN, Sudi R. Runoff model for small semi-arid watersheds. 21st Annual Convocation of Indian Society of Agricultural Engineering, Indian Agriculture Research Institute, New Delhi, 1984.
19. Shamsudin S, Hashim N. Rainfall-Runoff simulation using MIKE 11 NAM. Journal of Civil Engineering. 2002; 2:1-13.
20. Subramanya K. Engineering Hydrology, Tata McGraw-Hill, Education, 1994.
21. US Soil Conservation Service, National Engineering Handbook Section 4 - Hydrology, Washington DC, 1985.
22. USDA Soil Conservation Service Urban hydrology for small watersheds. Technical Release 55, U.S. Department of Agriculture, Washington, DC, 1986.