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Evaluation of modified CN methods for watershed runoff estimation using a GIS-based interface

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Accurate surface runoff estimation techniques suitable for ungauged watersheds are relevant to areas such as India where hydrologic gauging stations are not widely available. The natural resources conservation services curve number (NRCS-CN) method is one of the most widely used methods for quick and accurate estimation of surface runoff from ungauged watersheds. In this study, an interface in geographic information system (GIS) was developed using the in-built macro-programming language Visual Basic for Applications (VBA) of the ArcGIS® tool to estimate the surface runoff by adopting the NRCS-CN technique and its three modifications. The developed interface, or interface for surface runoff estimation using curve number techniques (ISRE-CN), was validated using the recorded data for the periods from 1993 to 2001 of a gauged watershed, Banha, in the Upper Damodar Valley, Jharkhand, India. The observed runoff depths for different rainfall events in this study watershed were compared with the predicted values of NRCS-CN methods and its three modifications using statistical significance tests. It was found that using all the rainfall data for different antecedent moisture conditions (AMCs), the modified CN I performed the best ($R^2 = 0.92$; $E = 0.89$), followed by the modified CN III method ($R^2 = 0.88$; $E = 0.87$), while the modified CN II ($R^2 = 0.42$; $E = 0.36$) failed to predict accurately the surface runoff from the Banha watershed. Moreover, under AMC-based conditions, the modified CN I method also performed the best ($R^2 = 0.95$; $E = 0.95$) for the AMC II condition, while the modified CN II performed the worst under all the AMC conditions. Overall, it was observed that the application of the modified CN I method in the ungauged watersheds that are hydrologically similar to the Banha watershed would result in an accurate surface runoff estimation.

1. Introduction

India has a geographical area of about 328.6 Mha, with the average annual rainfall varying from as low as 100 mm in the west to as high as 11,000 mm in the northeast. Of the $4\times10^{12}\,m^3$ average annual precipitation over India, the utilisable surface and groundwater resources have been estimated as $6.9\times10^{11}\,m^3$ 1 and $6.9\times10^{11}\,m^3$, respectively, due to topographical, geologic, hydrologic and economic constraints (Sharda and Juyal, 2006). Also the land and water availability per capita is decreasing daily. With a projected annual population growth of 1.8% and per capita water availability in most parts of India touching the water stress level ($<1700\,m^3$/person/year), it is a challenging task for the agricultural scientists in India to sustain the required level of grain production. In the coming decades, the population

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Nomenclature

A	area, m^2
E	model efficiency parameter
F_c	cumulative infiltration, mm
F_d	dynamic infiltration component (mm)
F_s	static infiltration component (mm)
I_a	Initial abstraction (mm)
o_i	ith observed value
$\bar{o}$	mean of observed values
P	rainfall, mm
p_i	ith predicted value
Q	runoff, mm
R^2	coefficient of determination
S	potential maximum retention, mm
t_p	time of ponding, min
α	Hortonian constant
λ	dimensionless constant

growth, surface water pollution and climate change together may produce a drastic decline in fresh water supply. With the above factors in mind, the quantification and conservation of surface water resources is required to ensure sustainability. Estimation of surface runoff is essential to assess the potential water yield of a watershed, to plan water conservation measures including the recharging of the ground water zones and the reduction of the sedimentation and flooding hazards downstream. Also it is an essential prerequisite of integrated watershed management (IWM). In India, accurate information on runoff is scarce and only available in a few selected sites. Thus, there is an urgent need to generate information on basin runoff and sediment yield for the acceleration of the watershed development and management programmes (Zade et al., 2005). Also, most of the agricultural watersheds in India are ungauged, having no past records of the rainfall–runoff processes (Sarangi et al., 2005). This has led to the development of techniques for estimating surface runoff from ungauged basins (Chattopadhyay and Choudhury, 2006). Of the several methods for runoff estimation from ungauged watersheds, the soil conservation service curve number (SCS-CN) (renamed as natural resources conservation services curve number (NRCS-CN), USDA 1994) method along with its derivatives has been widely applied to ungauged watershed systems and has proved to be a rapid and accurate estimator of surface runoff (Mishra et al., 2003). The watershed hydrologic responses that lead to the generation of surface runoff are governed by the interaction of precipitation with the topographic, land use and soil physical properties of the land surface. Therefore, the use of a geographic information system (GIS) is preferred over the traditional techniques such as quantify surface runoff by storing and analysing the factors responsible for runoff. The estimation process becomes more efficient, interactive and less cumbersome when the GIS is used for storing, interpreting and displaying the data required in CN-based runoff estimation techniques.

Since its inception, the NRCS-CN method has been widely accepted by scientists, hydrologists, water resources planners, agriculturists, foresters and engineers for estimation of surface runoff. Mishra and Singh (2002) modified this method for long-term hydrology simulations by incorporating an evapotranspiration component, modifying the initial abstraction estimation techniques and extending it for computation of infiltration and runoff rates. Bhuyan et al. (2001) used the modified curve number (CN) technique for predicting surface runoff by adjusting the CNs based on the estimated AMC ratios. It was shown that the CN approach could be used for accurate prediction of runoff depths from storm events over ungauged watersheds. Bhuyan et al. (2003) studied event-based watershed scale antecedent moisture condition (AMC) values to adjust field-scale CNs, and to identify the hydrological parameters that provide the best estimate of AMC. The AMC condition of the watershed refers to the 5 days preceding rainfall, in which conditions I, II and III denote the low, medium and high runoff potentials, respectively. Bhuyan et al. (2003) revealed that the agricultural non-point source pollution model (AGNPS) overestimated the runoff depth when using a CN based in an AMC II condition. Thus, the universal assumption to apply AMC II conditions under typical watershed conditions was observed to be invalid for many experimental watersheds. Pandey and Sahu (2002) estimated the runoff from the Karso watershed situated in the Damodar Barakar catchment of the Hazaribagh district, Jharkhand, India. The NRCS-CN estimation techniques were applied to estimate the runoff from daily storm events and these were validated using the measured runoff from a few selected events during the monsoon period of 1993. The maximum and minimum deviations between the observed and predicted runoff depths were observed to be 28.33% and 3.27%, respectively. Tripathi et al. (2003) verified a calibrated soil and water assessment tool (SWAT) model for a small watershed, Nagwan, which is located in upper Damoder Valley Corporation (DVC) in the Hazaribagh District of Bihar, India. This model was used for identifying and prioritising critical sub-watersheds and developing an effective management plan. The SWAT predicts surface runoff for daily rainfall by using the NRCS-CN method. The study confirmed that the SWAT model could accurately simulate runoff particularly from small agricultural watersheds. Geetha et al. (2005) studied the applicability of the modified NRCS-CN concept to identify the dominant runoff generation process in watersheds. The pronounced modifications were the incorporation of seasonal variation of CN and variations in the daily storages using evaporation and transpiration estimates. In the model formulation, the runoff resulting from the original NRCS-CN application was used for computing the direct runoff hydrograph (DRH) at the outlet of the catchments. Mishra et al. (2005) studied the field applicability of the NRCS-CN-based Mishra–Singh general model (Mishra and Singh, 1999) and its variants. This model and its eight variants were evaluated using a large set of rainfall–runoff events. Pandey et al. (2005) modelled an agricultural watershed using remote sensing (RS), a GIS and the Arc View SWAT 2000

(AVSWAT2000) model. The model was tested on a daily, monthly and seasonal basis and applied to the Banikdih agricultural watershed located in Jharkhand, West Bengal State, India. The model calculates surface runoff by applying an improved NRCS-CN approach. It was shown that the model could satisfactorily predict the daily, monthly and seasonal surface runoff. Sahu et al. (2005) modified the initial abstraction expression in the existing NRCS-CN method. The modification incorporated the effect of storm duration and the antecedent 5-day rainfall into the abstraction parameter. Their study revealed that the CN was very sensitive to AMC as well as the effect of rainfall duration on runoff depths.

Shrestha (2003) developed a distributed hydrological model using RS and GIS tools to assess the changes in runoff value due to land-use change over the Kathmandu Valley basin, Nepal. A spatially distributed model with NRCS-CN was developed to assess the surface runoff variability due to alternate land-use scenarios. De et al. (2005) developed a computer interface, designated as an erosion database interface (EDI), which processed the surface hydrology output from the database of the water erosion prediction project (WEPP) model, providing a geo-referenced estimate of runoff depth. Martin et al. (2005) reviewed two distinctive and independently developed technologies using GIS and predictive water resource models. They provided a state-of-the-art critical review of current trends in interfacing GIS with predictive water resource models. Emphasis was placed on discussing the limitations to efficient interfacing and potential future directions, including recommendations for overcoming recent challenges.

GIS and RS tools have been extensively used by the researchers to estimate the watershed hydrological responses. The use of these advanced tools, along with process-based hydrologic models and empirical approaches, has made the surface runoff estimation more accurate and less cumbersome. In this study, an effort was made to compare the performance of three modified CN methods with the original NRCS-CN method using a developed interface in ArcGIS® for watershed runoff estimation for a gauged watershed to ascertain its applicability over ungauged watersheds.

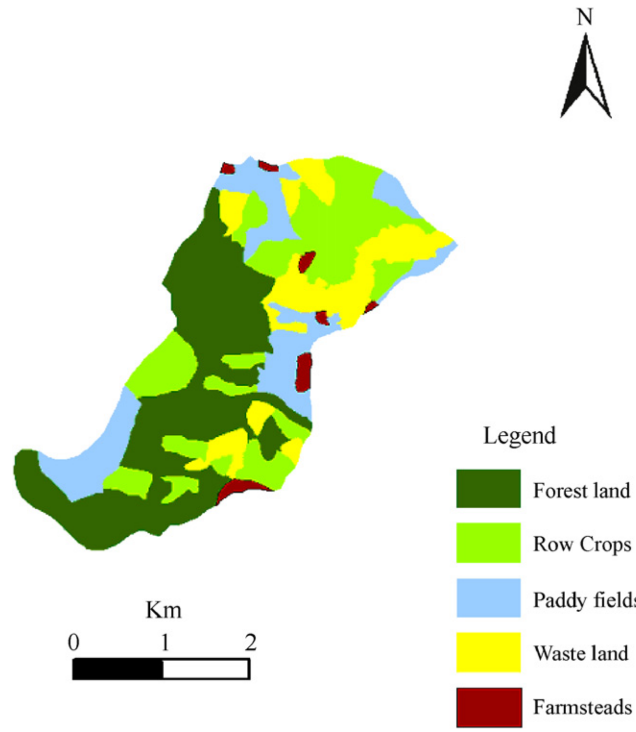

Fig. 1 – Landuse map of the Banha, India watershed for use in CN techniques for surface runoff estimation.

2. Material and methods

2.1. *Study area and data acquisition*

The study watershed Banha was located in the Chotanagpur plateau of Jharkhand state, India, and covers an area of 1751 ha. It drains into the river Damodar and its tributaries the Barakar and the Konar. It is located between 24°13′50″ and 24°17′00″ North latitude and 85°12′2″ and 85°16′5″ East longitude. The climate of the study area is tropical sub-humid having three well-defined seasons viz. summer, rainy and winter. The average annual rainfall of the region is 1202 mm. Its soils vary from red and brown sandy loam to clay type. The surface layer is 70–110 mm thick, dark brown in colour with a varying texture of sandy loam to clay loam having a moderate to medium sun-angular blocky structure. The soils are most susceptible to erosion due to a fine texture and contribute in transportation of silt to the reservoir and are severely eroded with a network of gullies spread in an intricate manner. The topography is undulating with slopes varying from 1% to 5%.

To develop the interface for CN-based runoff estimation, the data relating to event-based rainfall depths, runoff rate, soil type, land use and land cover from Banha watershed were acquired. The data required for this study were obtained from the gauging station located at the outlet of the watershed, which was equipped with a stage level recorder and a rain gauge. The rainfall and runoff data used in this study related to the period from 1993 to 2001. The land-use map acquired from DVC authorities was converted to a GIS feature class-based thematic digital format using the ArcGIS® tool (Fig. 1). The entire basin was classified in terms of areas having row crops, paddy fields, forested land, waste land and farmsteads. According to the soil survey report of the Banha watershed, 38.34% of the total area is under forest while the net cropped land is 44.06% (Table 1). The CN values for these different land uses were estimated from the standard CN tables. The infiltration rate curve (Reddy, 1993; Sarangi and Bhattacharya, 1999) was used to classify the hydrologic soil groups of the watershed and for use in the modified CN II and modified CN III equations. The parameters of the Hortonian equation, such as the initial infiltration rate, basic infiltration rate, time to attain the basic rate and the recession constant, were obtained from the infiltration curves. The soils of the study watershed were grouped under different hydrologic groups according to the infiltration rate values. The land use, soil type and hydrologic soil group maps in ArcGIS® format were generated and projected to a polyconic projection system using ArcGIS® projection utility (Sarangi et al., 2004).

These digitised GIS feature classes of land use and hydrologic soil group were used as the input data for the interface to estimate CN values. The information used for selection of CN values is shown in Table 2.

To compare the performance of the CN methods with the observed data from a gauged watershed, the recorded data at the watershed outlet were analysed to obtain the DRHs by using straight-line base-flow separation techniques (Chow et al., 1988). Further, the areas under the DRHs were estimated using standard procedures and divided by the watershed area to obtain the runoff depths for the different rainfall events. The observed runoff depths were then used for comparison with the CN-based predictions.

2.2. Interface in GIS for runoff estimation

The interface for surface runoff estimation using curve number techniques (ISRE-CN) was written in Visual Basic for Applications (VBA) programming language, which is the built-in macro programming language for ArcGIS®. The programming syntax is based on the "arc-objects" library protocol of the ArcGIS® tool. The developed interface performs different activities such as extraction of the values of fields and records in the attribute table of the feature class, acquisition of the user input information for CN estimation, estimation of the surface runoff by using four different CN techniques and finally storing the results in a designated folder of the computing system.

2.3. CN methods used in the interface

To date, researchers have reported eight modifications of the original NRCS-CN approaches (Mishra and Singh, 2003). Considering the application of the modified CN methods under different topographic, hydrologic soil group and land-use conditions, and their contrasting characteristics relating to initial abstraction and antecedent moisture conditions, three modified CN methods were selected for inclusion in the interface as well as the original NRCS-CN formulae. The methods are briefed in the following subsections.

Table 1 – Land-use information of the Banha, India, watershed

Type	Area (ha)	% Area
Cropped land	771.42	44.06
Forest land	671.41	38.34
Waste Land	268.32	15.32
Farmsteads	39.85	2.28
Total	1751	100

2.3.1. NRCS-CN method

The NRCS-CN method is based on the water balance equation and two fundamental hypotheses (SCS, 1956). The first hypothesis equates the ratio of the amount of direct surface runoff Q to the total rainfall P (or maximum potential surface runoff) with the ratio of the amount of infiltration F_c to the amount of the potential maximum retention S. The second hypothesis relates the initial abstraction I_a to the potential maximum retention. Thus, the NRCS-CN method consisted of the following equations:

(a) Water balance equation:

$$P = I_a + F_c + Q \quad (1)$$

(b) Proportional equality hypothesis:

$$\frac{Q}{P - I_a} = \frac{F_c}{S} \quad (2)$$

(c) I_a–S hypothesis:

$$I_a = \lambda S \quad (3)$$

where P is the total rainfall; I_a the initial abstraction; F_c the cumulative infiltration F_c excluding I_a; Q the direct runoff; S the potential maximum retention or infiltration; and λ the regional parameter dependent on geologic and climatic factors ($0.1 \leqslant \lambda \leqslant 0.3$). The relation between I_a and S was developed by analysing the rainfall and runoff data from experimental small watersheds (SCS, USDA, 1956) and is expressed as $I_a = 0.2S$. Combining the water balance equation and proportional equality hypothesis, the NRCS-CN method is represented as:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \quad (4)$$

The potential maximum retention storage S of watershed is related to a CN, which is a function of land use, land

Table 2 – Information used for selection of the curve number (CN) value

Land use	Hydrological soil group	Treatment or practice	Hydrological cover condition
Row crops	C	Straight row	Poor
Paddy fields	C	Straight row	Poor
Forest land	B	NC[a]	Fair
Farmsteads	D	NC	NC
Wasteland	B	NC	NC

[a] NC—not classified.

treatments, soil type and antecedent moisture condition of watershed. The CN is dimensionless and its value varies from 0 to 100. The S-value in mm can be obtained from CN by using the relationship:

$$S = \frac{25400}{CN} - 254 \quad (5)$$

2.3.2. *Modified CN method (CN I)*

The modified CN I method is based on the concept of zero initial abstraction ($I_a = 0$), i.e. immediate ponding for calculating the runoff depth Q from a given rainfall depth P. Using this concept in the original NRCS-CN proportionality hypothesis (i.e. Eq. (2)), the resulting equation for surface runoff estimation was obtained:

$$Q = \frac{P^2}{S + P} \quad (6)$$

The two extremely dry and wet scenarios, which may produce runoff, were not considered in the original NRCS-CN method due to its concept of runoff occurring only after fulfilling the initial abstraction I_a requirements. Therefore, this modified CN method was considered in this study to account for the conditions prevailing in watershed systems under high-intensity rainfall events.

2.3.3. *Modified CN method (CN II)*

In this modification of the CN method, the initial abstraction I_a was modified by associating a non-dimensional parameter λ with the potential maximum retention S, which is represented as $I_a = \lambda S$. The parameter λ depends on the time of ponding t_p and Horton's constant α and are associated as: $\lambda = \alpha t_p$. In contrast with the hypothesis of the original NRCS-CN method, which assumes the time of ponding to be zero, this modification considered the time of ponding from the beginning of rainfall to the initiation of the runoff process. Under these modifications, the equation for estimation of surface runoff using the modified CN II was:

$$Q = \frac{(P - \lambda S)^2}{P - S(\lambda - 1)} \quad (7)$$

2.3.4. *Modified CN method (CN III)*

In this modification, the cumulative infiltration F_c parameter used in the original NRCS-CN method was divided into basic and dynamic components during the rainfall–runoff processes. The modified CN III method highlighted the basic infiltration component during the rainfall–runoff processes, whereas the original NRCS-CN method did not consider this parameter directly. However, in the hypothesis of the NRCS-CN method, the actual infiltration (F_c–I_a) was considered without any specific attention both basic and dynamic infiltration components in the runoff generation process. Therefore, the modified CN III method could provide meaningful and accurate predictions of runoff for longer duration rainfall events, in which the basic infiltration component is more predominant. Therefore, in the original NRCS-CN hypothesis, by substituting the components of F_s and F_d against appropriate parameters of Eq. (2), the final expression of surface runoff depth was

$$Q = \frac{(P - F_s)^2}{(P - F_s + S)} \quad (8)$$

2.4. *Validation of interface-predicted results*

The calculated runoff depths were compared with the observed runoff depth values recorded at the watershed outlet for different rainfall events under three variable AMC conditions. This was achieved by using two standard statistical significance estimators, namely, the model efficiency factor E and the coefficient of determination R^2. The expression for model efficiency E (James and Burgess, 1982; Sarangi and Bhattacharya, 2005) is given as

$$E = 1 - \frac{\sum_{i=1}^{n}(p_i - o_i)^2}{\sum_{i=1}^{n}(o_i - \bar{o})^2} \quad (9)$$

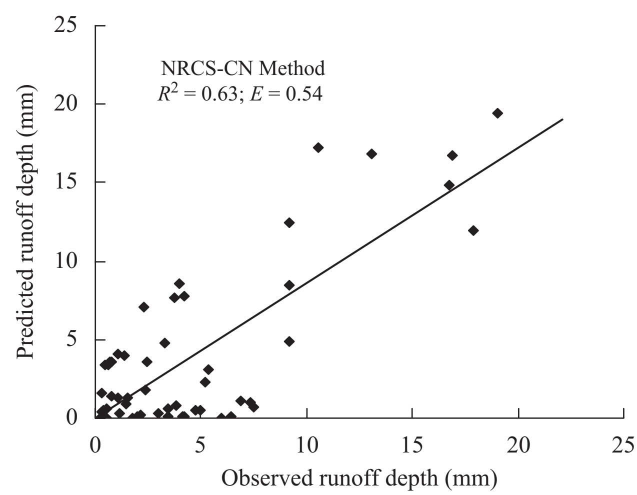

Fig. 2 – The 1:1 line for the original NRCS-CN method using all the AMC conditions for 52 rainfall events.

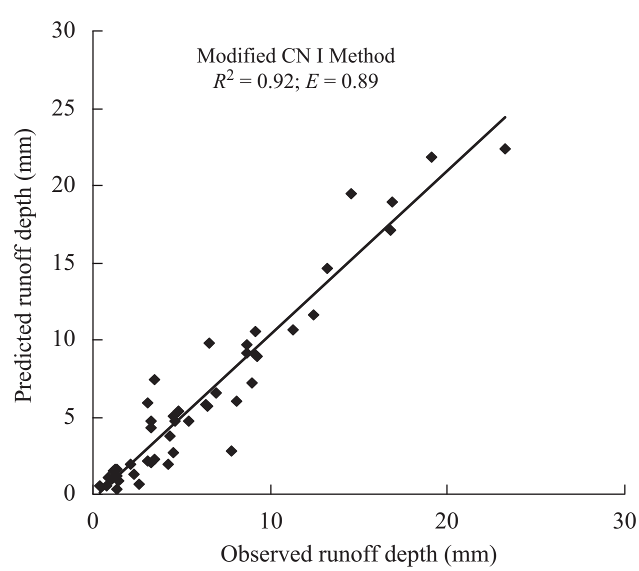

Fig. 3 – The 1:1 line for the modified CN I method using all the AMC conditions for 52 rainfall events.

where, N is the total number of observations; o_i the ith observed value; $\bar{o}$ the mean of observed values; and p_i the ith predicted value. The R^2 was estimated from the fitted trend line (1:1 line) between the observed and model predicted values and the model efficiency (E) was estimated for all the 52 validation sets using Eq. (9).

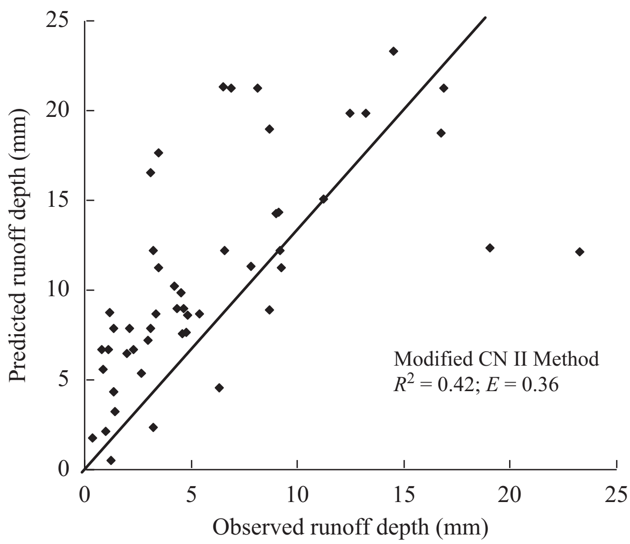

Fig. 4 – The 1:1 line for the modified CN II method using all the AMC conditions for 52 rainfall events.

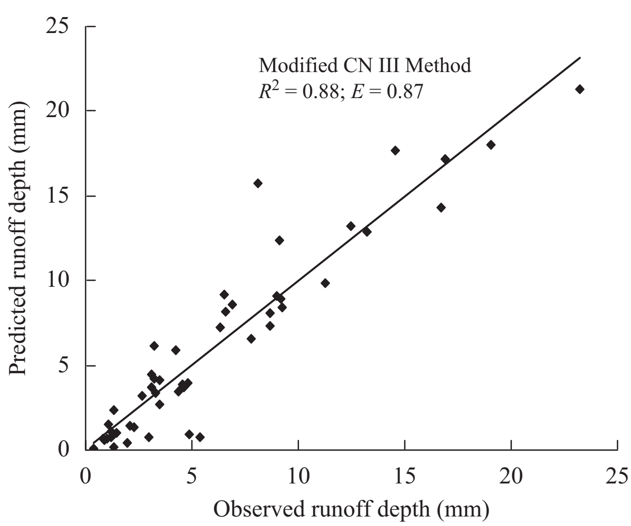

Fig. 5 – The 1:1 line for the modified CN III method using all the AMC conditions for 52 rainfall events.

3. Results and discussion

The developed ISRE-CN interface was operated using the acquired data of the study watershed and the output generated from the interface in terms of the runoff depth was compared with the recorded data from the study watershed.

3.1. *Validation of the interface-generated runoff depths for all AMC conditions*

The interface was operated for the 52 rainfall events by inputting the AMC conditions and rainfall depths required by the interface. The outputs of all these events, i.e. the runoff depths for different CN methods, were tabulated in an Excel™ spreadsheet to estimate the statistical parameters R^2 and E and the predicted and the observed values plotted.

It was shown (Figs. 2–5) that the coefficient of determination (R^2) values ranged from a minimum of 0.42 to a maximum of 0.92 and the statistical parameter model efficiency (E) ranged from a minimum of 0.36 to a maximum of 0.89. The minimum R^2 and E ($R^2 = 0.42$; $E = 0.36$) occurred for the modified CN II method whereas the maximum R^2 and E ($R^2 = 0.92$; $E = 0.89$) occurred with the modified CN I method using the same set of rainfall depth and other input parameters in all the CN methods.

Based on the estimated statistical parameter values, it was observed that the modified CN I performed best for the Banha watershed followed by modified CN III, original NRCS-CN and the modified CN II method. The reason for the poor prediction by the modified CN II method could be attributed to the infiltration parameters used in the modified CN II method, which were for a single soil type representing the lumped watershed behaviour. The variability in soil type and the corresponding changes in the infiltration rates for each soil-type polygon were not considered in the modified CN II method due to a lack of spatially distributed infiltration records. Also, from the hydrologic soil group map, it was observed that the watershed area under group B was the largest (53.66% of total watershed area), which could result in

Table 3 – Coefficient of determination (R^2) and model efficiency (E) of different CN methods under grouped and individual AMC conditions

AMC condition	NRCS-CN		CN-I		CN-II		CN-III	
	R^2	E	R^2	E	R^2	E	R^2	E
Grouped AMCs	0.63	0.54	0.92	0.89	0.42	0.36	0.88	0.87
AMC-I	0.75	0.82	0.87	0.81	0.56	0.45	0.79	0.93
AMC-II	0.86	0.84	0.95	0.95	0.26	0.17	0.89	0.82
AMC-III	0.89	0.82	0.93	0.84	0.52	0.34	0.82	0.54

a higher infiltration rate and reduced runoff. However, this behaviour, as observed from ground truth information, was not reflected in the predictions by the modified CN II method.

The predictability of surface runoff by the original NRCS-CN method ($R^2 = 0.63$; $E = 0.54$), which has been widely accepted for surface runoff estimation, was found to be lower than that of the modified CN I ($R^2 = 0.92$; $E = 0.89$) and CN III ($R^2 = 0.88$; $E = 0.87$) methods. The compiled prediction scenarios of this analysis are presented in Table 3. The comparatively better predictions from the modified CN I and CN III methods could be attributed to the fact that the modified CN I is based on the

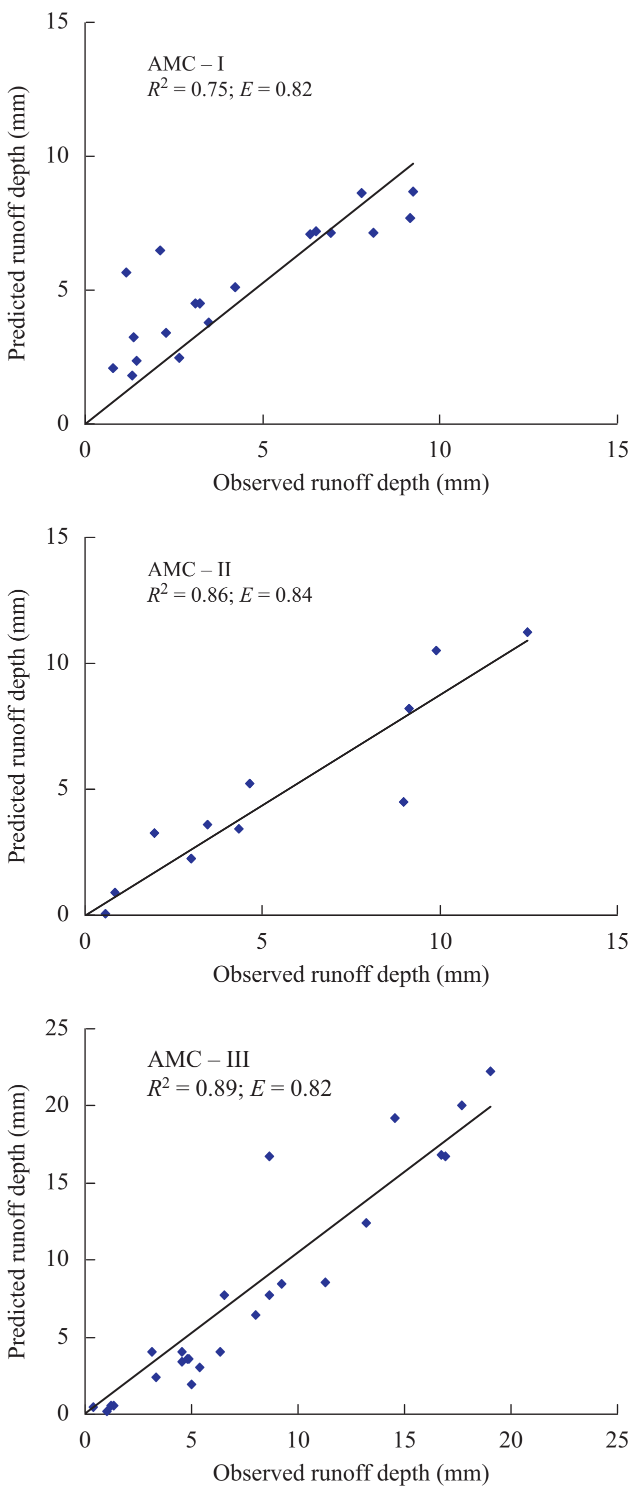

Fig. 6 – The 1:1 line for different AMC conditions using NRCS-CN method.

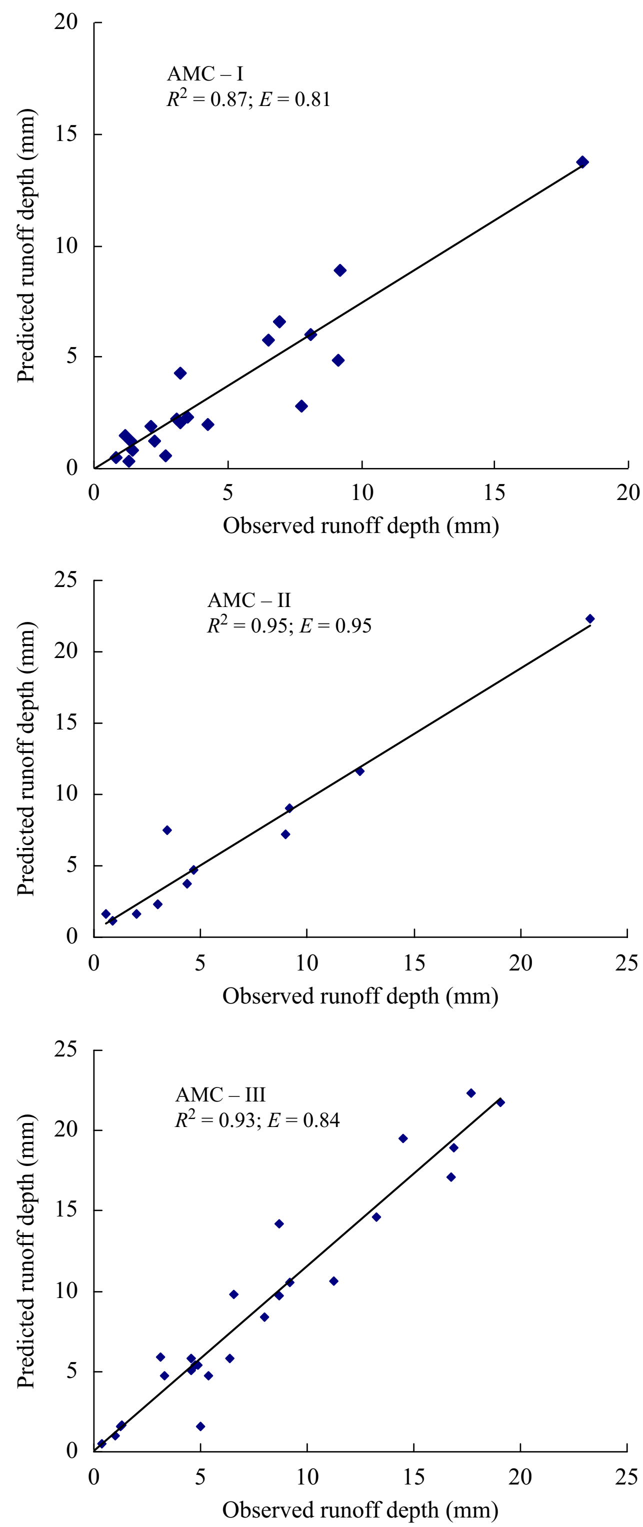

Fig. 7 – The 1:1 line for different AMC conditions using modified CN I method.

concept of a fully saturated soil condition, and the CN III method considered the basic infiltration component to be the initial abstraction parameter during rainfall. In this context, use of the interface could automate the process and minimise the time required for estimation of runoff using different methods.

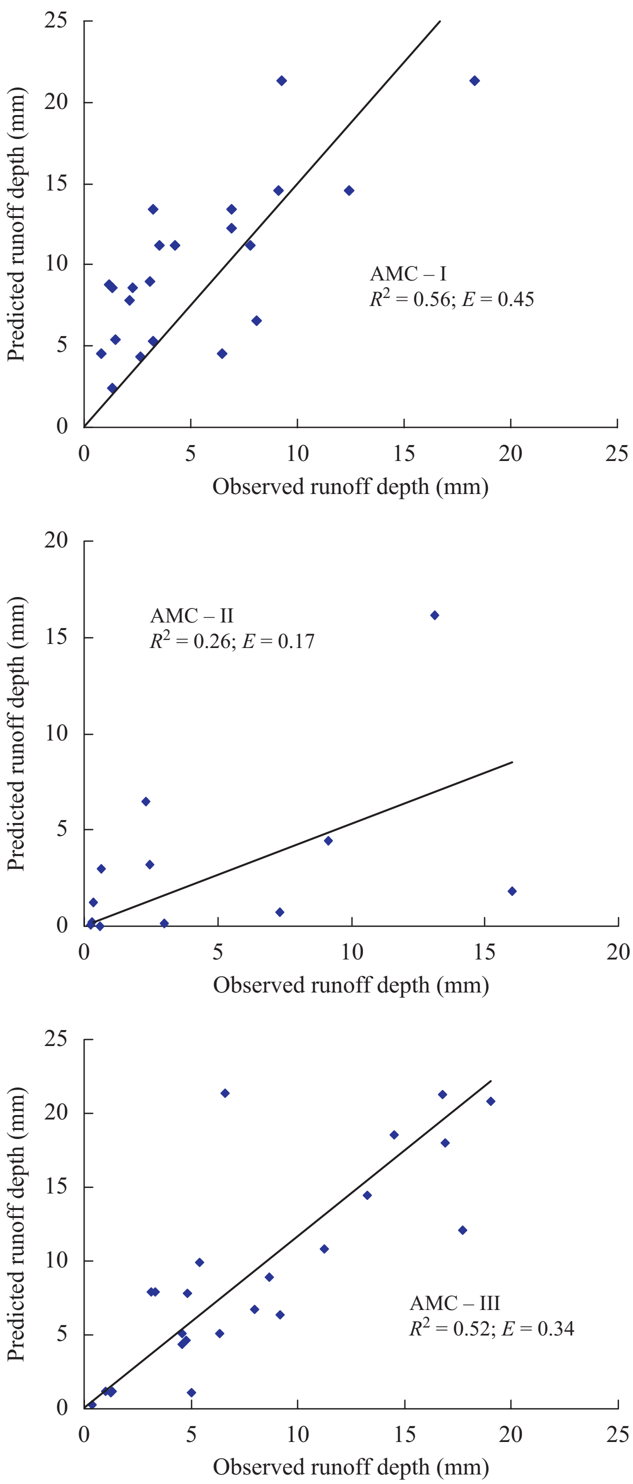

Fig. 8 – The 1:1 line for different AMC conditions using modified CN II method.

3.2. *Validation of the interface-generated runoff depths for AMC I, AMC II and AMC III conditions*

In addition to considering all the events for predicting runoff using all the CN methods, the AMC-based criterion was also analysed to investigate the selection of a specific modified CN

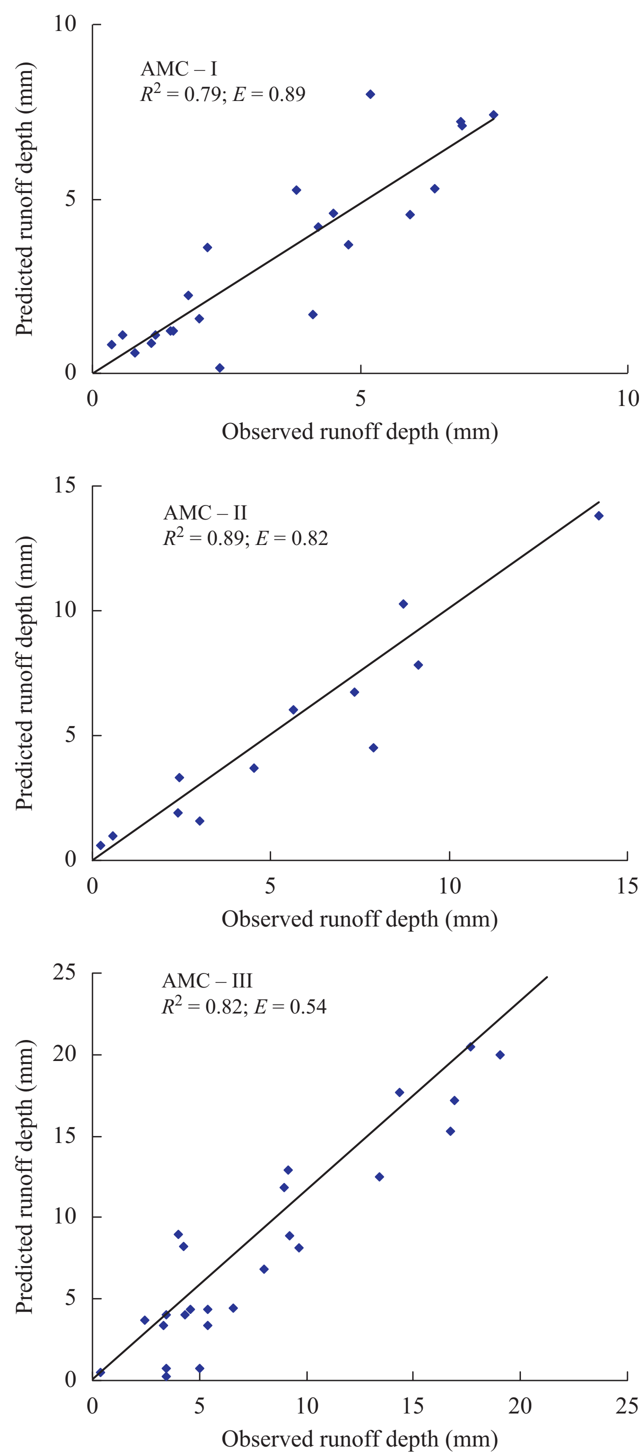

Fig. 9 – The 1:1 line for different AMC conditions using modified CN III method.

method with respect to the AMC condition. The selected rainfall events were grouped under different AMC conditions based on preceding 5-day rainfall. From the selected 52 events, 21 events were under AMC I; 12 events were under AMC II; and the remaining 19 events were under the AMC III condition. The interface was operated for these AMC conditions using the original and modified CN methods and the resulting output values were tabulated in an Excel spreadsheet to estimate the statistical parameters R^2 and E and to plot the predicted and the observed runoff values.

It can be seen from Figs. 6–9 that the AMC-based predictions yielded better accuracy with higher values of statistical parameters R^2 and E for AMC I condition using all the CN methods. The modified CN I method was the best ($R^2 = 0.87$; $E = 0.81$), followed by the modified CN III ($R^2 = 0.79$; $E = 0.93$) and NRCS-CN method ($R^2 = 0.75$; $E = 0.82$). The modified CN II was the poorest predictor of runoff ($R^2 = 0.56$; $E = 0.45$). Similarly, for the AMC II condition, the modified CN I method was the best ($R^2 = 0.95$; $E = 0.95$), followed by modified CN III ($R^2 = 0.89$; $E = 0.82$) and NRCS-CN method ($R^2 = 0.86$; $E = 0.84$), while modified CN II was again the poorest ($R^2 = 0.26$; $E = 0.17$). Finally, under the AMC III condition, the modified CN I method had the best fit ($R^2 = 0.93$; $E = 0.84$), followed by NRCS-CN ($R^2 = 0.89$; $E = 0.82$), and the modified CN III method ($R^2 = 0.82$; $E = 0.54$), with modified CN II being the poorest ($R^2 = 0.52$; $E = 0.34$).

All the above statistical parameter values were also compiled and presented in Table 3 to provide easy comparison of the performance of CN-based methods under three different AMC situations. Overall, the modified CN I method performed the best under all three AMC situations, whereas the modified CN III performed better for AMC I and AMC II conditions. The original NRCS-CN performed satisfactorily for all the AMC conditions with a marginal difference of R^2 and E values (R^2 ranged from 0.89 to 0.75 and E ranged from 0.82 to 0.84).

4. Conclusions

In this study, a developed Interface in ArcGIS® for surface runoff estimation using curve number techniques (ISRE-CN) was used to estimate the surface runoff by adopting one of the most widely used NRCS-CN techniques and its three derivatives. This study grouped together the two most desirable components, i.e. the prediction of surface runoff from ungauged watersheds and use of the advanced GIS interface development ability of ArcGIS® tool to predict the surface runoff. The developed interface performed a series of activities starting from storing of the GIS feature class attribute tables to the estimation of surface runoff depths using four different CN techniques. The results corroborated the finding that the NRCS-CN-based surface runoff predictions are very sensitive to the antecedent moisture conditions (AMC) of watershed systems. This necessitates further modification of the CN-based methods to include more limiting scenarios and any realistic indices to account for the antecedent moisture conditions prevailing in the watershed during and before the rainfall event. The developed interface needs to be tested under different watershed conditions to ascertain the predictability of the modified CN techniques for runoff estimation from ungauged watersheds.

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