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Research Article

DEVELOPMENT OF SCS-CN METHOD AND AUTOREGRESSIVE TIME SERIES MODEL FOR THE ESTIMATION OF RUNOFF OF UPPER SEWANI WATERSHED OF DAMODAR CATCHMENT, JHARKHAND, INDIA

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Abstract- The present experiment was conducted the prime objective, to generate and estimate the curve number for runoff and also to develop autoregressive (AR), for the prediction of rainfall, from the study area and estimate the parameters of runoff. Autoregressive (AR) models of orders 0, 1 and 2 were tried for annual stream flow series. Parameters were estimated by the general recursive formula process by Kottegoda. The adequacy of models and goodness of fit were tested by Box-Pierce Portmanteau test, Akaike Information Criterion (AIC) and by comparison of historical and predicted correlogram. The AIC value for AR (1) model (141.855) was lying between AR (0) (142.764) and AR (2) (152.749) which is satisfying the selection criteria. The mean forecast error was also very less. On the basis of the statistical test, Akaike Information Criterion, AIC the AR (1) model with estimate model parameters, estimated for the best future predictions in Upper Sewani watershed. This is graphical representation between historical and generated correlogram, where in runoff there was a very close agreement. The performance comparison of both the models was made with the coefficient of determination (R^2) which was 0.988 in case of SCS- Curve Number and 0.946 in case of Autoregressive Time Series Model. On further comparison it shows that autoregressive is giving much better results than the Curve Number method, so it can be more trust worthy.

Keywords- Curve Number Method, Time Series Model, Rainfall-Runoff Akaike Information Criterion

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Introduction

Water is vital to life for every organism present in this world. In the agricultural country like India water play a key role in economic growth and development in all activities. Growing population, rapid urbanization and increasing industrial and agricultural growth has increased the pressure on water resources. At the same time, climatic changes are beginning to affect the events like rainfall and will probably lead to even higher temperatures and lower rainfall in tropical areas. Rainfall and runoff are highly non-linear and complex. One of the important problem in hydrology deals with interpreting a past record of hydrologic events in terms of future probabilities of occurrence. Rainfall and runoff modelling is of particular relevance for engineering applications of water as well as in flood disaster management. Heavy rainfall results in land degradation and low rainfall cause the reduction of soil's nativity and productivity. It has been estimated that about 113.3 mha of land is subjected to soil erosion due to water and about 533.4 m tones of soil is being detached annually due to various reason's in India [6]. Meteorological data are frequently needed while estimating the long term effects of proposed man-made hydrologic changes. Such assessments are often hydrologic processes which use weather data as the input. The meteorological variables required for most of the hydrologic models include precipitation. It is necessary to have a sufficiently long historic data to achieve a functional mathematical rule. It's record which consist of short-term data are not suitable for proper planning and arrangement processes are also available for a location of interest. In such circumstances, it becomes compulsory to have deterministic as well as stochastic component. Most hydrologic system have both deterministic as well as stochastic component [22]. Stochastic time series model such as Autoregressive (AR) [14,16,10] moving average (MA) and Autoregressive moving average (ARMA) [9] are widely used to predict annual runoff. Identification generally depends on the characteristics of overall water resources system, characteristics of time series and the models input [13]. A developed Auto regressive model is suitable for a certain range and applicable for particular zone of climate [12]. Multivariate autoregressive and univariate autoregressive (AR) methods are applied to regional scale rainfall runoff modeling [15]. Curve Number Method and stochastic time series models, such as Autoregressive, Autoregressive Moving average are widely used to developed and generate the annual Rainfall and Runoff [1]. Keeping this in view an attempt has been made to develop an autoregressive time series model for prediction of annual rainfall and runoff of Upper Sewani watershed, which is situated in Damodar Catchment Jharkhand.

Materials and Methods

In present study, SCS-Curve Number Method and Autoregressive Time Series Model was developed to predict the annual runoff of Upper Sewani watershed.

Generation of Curve Number

Curve Number is estimated by following mathematical equations-

$$\frac{F}{S} = \frac{Q}{P - I_a} \quad [1]$$

F= actual retention
S= Potential maximum retention (mm)
Q= accumulated runoff depth (mm)
P= accumulated rainfall depth (mm)
I_a= initial abstraction (mm)
After runoff has started, all additional rainfall becomes either runoff or actual retention.[13].

$$F = P - I_a - Q \quad [2]$$

Combining (1) and (2)-

$$Q = \frac{(P-I_a)^2}{(P-I_a-S)} \quad [3]$$

The following average relationship was found-

$$I_a = 0.2 \quad [4]$$

Combining equations 3 and 4 yields,

$$Q = \frac{(P-0.2S)^2}{(P+0.8S} \quad [5]$$

Equation (3) is the rainfall-runoff relationship used in the Curve Number method. It allows the runoff depth to be estimated from rainfall depth, given the value of the potential maximum retention S [4]. This potential maximum retention mainly represents infiltration occurring after runoff has started. This relationship is-

$$CN = \frac{25400}{254+S} \quad [6]$$

Stochastic Time Series Model

A stochastic process is the “mathematical abstraction of an empirical method that’s governed by probabilistic laws” [18].
A simple time series model could be developed by single probability distribution function **f(X: Θ)** with parameters **Θ = (Θ_1, $\Theta_{2\ldots}$)** valid for all positions **t = 1, 2….N** and without any dependence distinction **X_1, X_2,………X_n.**
A time series model with dependence structure can be formed as:

$$\varepsilon_t = \phi\, \varepsilon_{t-1} + \eta_t \quad [7]$$

Where η_t is an Independent series with mean zero and variance (1- ϕ_1), ε_t is dependent series and ϕ is the parameter of the model. Time series modelling can be organized in five stages, i.e. Selection of model type, identification of model composition, identification of model form, estimation of model parameters and testing goodness of fit for validation of the model.

Autoregressive (AR) Model

The p^{th} order autoregressive model AR (p), is estimated by following eq -

$$Y_t = \overline{Y} + \sum_{j=1}^{p} \Phi_j (Y_{t-j} - \overline{Y}) + \varepsilon_t \quad [8]$$

Where, Y_t is the time dependent series (variable), ε_t is the time dependent series which is independent of Y_t and is normally distributed with mean of annual flow and rainfall data and Φ_1, Φ_2, ……..Φ_p are the Auto-regressive parameter
The parameters Φ_1, Φ_2,.... Φ_p were estimated by[17] solving the p system of following linear equations-

$$r_k = \Phi_1 r_{k-1} + \Phi_2 r_{k-2} + \ldots\ldots + \Phi_p r_{k-p} \quad K>0 \quad [9]$$

or

$$r_k = \sum_{j=1}^{p} \Phi_j r_{k-j} \quad K>0$$

Where, r_1, r_2 were computed from equation [9].

Estimation of Autoregressive Parameter

For estimation of the model, parameter method of maximum likelihood will be used [8].

$$AR(1): \Phi_1 = \frac{D_{1,2}}{D_{2,2}} \quad [10]$$

$$AR(2): \Phi_1 = \frac{D_{1,2}D_{3,3} - D_{1,3}D_{2,3}}{D_{2,2}D_{3,3} - D_{2,3^2}} \quad [11]$$

$$\Phi_2 = \frac{D_{1,3}D_{2,2} - D_{1,2}D_{2,3}}{D_{2,2}D_{3,3} - D_{2,3^2}} \quad [12]$$

Auto-Correlation Function

Autocorrelation function (rk) of lag k was estimated as proposed by [7].

$$r_k(95\%) = \frac{-1 \pm 1.96\sqrt{N-K-1}}{N-K} \quad [13]$$

Partial Auto-correlation Function

The PC_{kk} was calculated the 95% probability limit to identify both the type and order of the model [23].

$$PC_{k,k}(95\%) = \frac{1.96}{\sqrt{N}} \quad [14]$$

Statistical Characteristics-

(a) Mean Forecast Error

Mean forecast error was calculated to evaluate the performance of auto regressive models fitted to time series of rainfall, runoff [11].

$$MFE = \frac{\sum_{i=1}^{n} \chi_c(t) - \sum_{i=1}^{n} \chi_0(t)}{\eta} \quad [15]$$

Where,
$\chi_c(t)$ = Computed rainfall and runoff value
$\chi_0(t)$ = Observed rainfall and runoff value
η = Number of observations

(b) Mean Absolute Error-

$$MAE = \frac{\sum_{i=1}^{n} |\chi_c(t) - \chi_0(t)|}{\eta} \quad [16]$$

(c) Mean Relative Error -

$$\text{MRE} = \frac{\dfrac{\sum_{i=1}^{n}|\chi_c(t)-\chi_0(t)|}{\chi_0(t)}}{\eta} \qquad [17]$$

(d) Mean square error-

$$\text{MRE} = \frac{\dfrac{\sum_{i=1}^{n}|\chi_c(t)-\chi_0(t)|}{\chi_0(t)}}{\eta} \qquad [18]$$

(e) Root Mean Square Error-

$$\text{RMSE} = \left[\frac{\sum_{i=1}^{n}[\chi_c(t)-\chi_0(t)]^2}{\eta}\right]^{1/2} \qquad [19]$$

(f) Integral Square Error-

It was estimated by following equation proposed by [5].

$$\text{ISE} = \frac{\sqrt{\sum_{i=1}^{n}[\chi_c(t)-\chi_0(t)]^2}}{\sum_{i=1}^{n}\chi_0(t)} \qquad [20]$$

Test Goodness of Fit of Autoregressive Model

The following tests were performed to test the goodness of fit of autoregressive models.

(a)Box-Pierce Portmonteau lack of fit test-

$$Q = N \sum_{k=1}^{L} r_k^{\,2} \qquad [21]$$

Where,
N = Number of observations
rk = Serial correlation or autocorrelation of series Yt
The statistic Q follows χ 2 distribution with r = K-p degree of compared with tabulated values of χ 2. [8].

(b) Akaike Information Criterion

The Akaike Information Criterion [2] was used for checking whether the order of the fitted model is adequate compared with the order of dependence model. Akaike Information Criterion for AR (p) models was computed using the following equation-

$$\text{AIC (P)} = \text{N 1n}\left(\hat{\sigma}_{\varepsilon}^{2}\right)+2(P) \qquad [22]$$

Where,
N = Number of observations
σ ε 2 ∧ = Residual variance
A comparison was made between the AIC (p) and the AIC (p-1) and AIC (p+1). If the AIC (p) is less than both AIC (p-1) and AIC (p+1), then the AR (p) model is best otherwise, the model which gives minimum AIC value was the one to be selected model.

Results and Discussion

Generation of Curve Number using observed Rainfall and Runoff data

The retention parameter S was determined on the basis of observed rainfall and runoff. The equation is depicted below-

$$S = 5\{P+2Q-(4Q^2+5PQ)^{1/2}\}$$

Where P, Q and S is in mm.

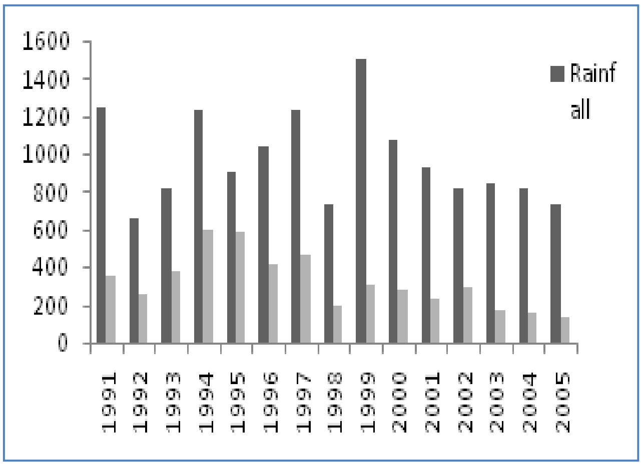

Fig-1 Generation of Curve Number using observed Rainfall and Runoff
Estimation of Curve Number

Using the USDA Soil Conservation Services Curve Number method was estimated from rainfall, runoff and potential maximum retention values S. It reveals that the Curve Number for different condition i.e. CN I, CN II and CN III, higher the valued of curve Number causes less potential maximum retention and less value of Curve Number causes high potential maximum retention.

Average value of Curve Number (CN II)

It indicates the slope of watershed varies from 1 to 5%, it is evident that it belongs to land use capability class III and class IV. Relationship plotted between CN I and CN II, the closeness of the data points to the line of perfect fit indicates a satisfactory model performance and shows that some data are underestimated because of heavy rainfall.

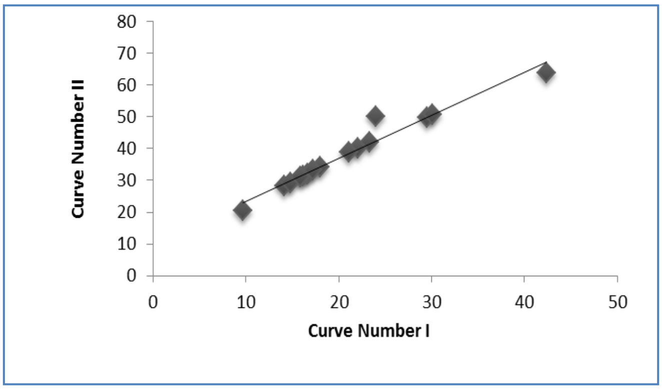

Fig-2 Average value of CN I and CNII

Estimation of Initial Abstraction

Initial abstraction depends upon infiltration and surface storage, which occur over the watershed runoff. The relation between Ia and S was developed by means of rainfall and runoff data from experimental small watershed [12].

$$I_a = 0.2S$$

Where, S is in mm.

Development of Statistical Model

A regression model developed between observed runoff and estimated runoff.

$$Y= 0.988X$$

R2 = 0.98

Where,
X= estimated runoff
Y = observed runoff
This model exhibited strong linear relationship between observed runoff and estimated runoff [Fig-3].

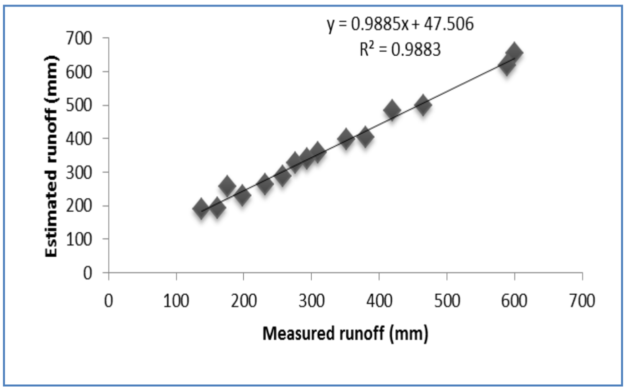

Fig-3 Comparison between measured and predicted annual rainfall

Stochastic Time Series Model

Model Identification

The annual series Y_t for runoff was displayed through the autoregressive model. The various steps elaborate in are identification, estimation of parameters and verification of the model type, order and parameters. The auto-correlogram is a plot of autocorrelation function against lag K and partial autocorrelation is a plot of partial autocorrelation function against lag K.

Models of AR Family

In this study the autoregressive models were tried order second. The parameters of AR models up to order second were determined through equation [8].

AR (p) models for prediction of annual Runoff:

AR (1): $Y_t = 322.13 + 0.602285\,(Y_{t-1} - 381.99) + \varepsilon_t$

Box Pierce Portmonteau Test for AR Model

The Box-Pierce Portmonteau lack of fit test to check the adequacy of autoregressive model both for AR (0), AR (1) and AR (2) models were estimated. The results revealed that all three models, *viz.* AR (0), AR (1) and AR (2) were charitable worthy fit and were suitable

Table-1 *Statistical constraints of autoregressive (AR) model for annual runoff for Upper Sewani watershed.*

Model	AR parameters	White Noise variance(σ^2_ε)	AIC	Value Portemonteaue Test (Q)	Degree of freedom up to 5 lags	Table value of χ^2 at 5% level of significance
AR(0)	-	109.09	142.73	29.736	5	11.07
AR(1)	Φ_1=0.655	99.104	141.85	22.634	4	9.48
AR(2)	Φ_1=0.602	162.653				
	Φ_2 = 0.056		152.74	16.218	3	7.81

Table-2 *Statistical features of Measured and Predicted annual stream flow for Runoff*

S. No.	Statistical Characteristics	Measured Runoff	Predicted Runoff
1.	Mean	294.17026	323.59941
2.	Standard Deviation	145.07381	137.76609
3.	Skewness	0.7303254	0.5467997

Table-3 *Evaluation of regeneration performance with statistical errors.*

S.No	Statistical error	Autoregressive AR (1) model
		Runoff
1.	Mean forest error	25.748436
2.	Mean absolute error	25.74844
3.	Mean Relative error	-1.312935
4.	Man Square error	9944.7236
5.	Root Mean square error	99.723265
6.	Integral Square error	0.0796836

Akaike Information Criterion Test for AR Models

In order to choose the better model, Akaike Information Criterion for all three models was computed. The computed values of AIC for runoff are given in [Table-1]. It is clear from the table that AIC value of AR(1) in all three cases are lying in between AR(2) model and AR(0) model therefore it was considered appropriate model for further prediction of runoff.

Comparison of the measured and selected Model Correlogram

The correlogram of Measured and Predicted series for runoff was developed by plotting autocorrelation functions against lag K. The autocorrelation functions r_k (k) of the fitted AR (1) model is calculated with the help of SPSS software. The graphical representation of the data displays a closer agreement between measured correlogram and predicted correlogram of runoff for selected model. So the developed model for runoff can be exploited for the prediction of upcoming

Statistical Characteristics of Data

The measured and predicted data was calculated by mean, standard deviation and skewness and it's evaluate the fitting of the model in moment preservation [Table-2]. The results of the skewness of predicted data by AR (1) model and measured data is lying between -1 to +1 [Fig-3] and therefore AR (1) model give the superior results of mean and skewness.

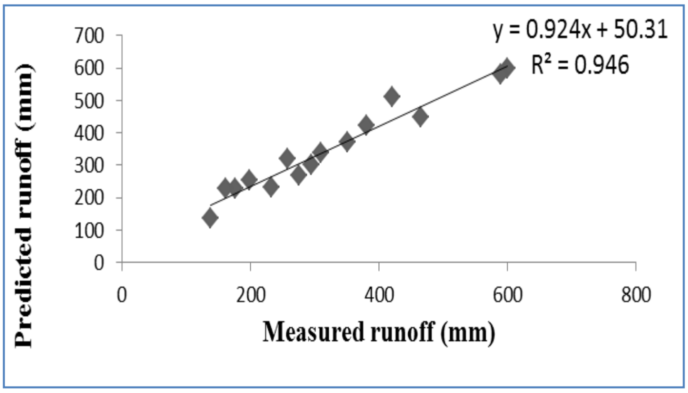

Fig-4 Comparison between measured and predicted annual Runoff

Performance of AR (1) Model for Runoff

The statistical features such as MFE, MAE, MRE, MSE, RMSE and ISE were also used to test the adequacy of the model for upcoming prediction with higher degree of correlation to previous measured explanations [Table-3]. The different types of errors in rainfall and runoff of the generation of AR (1) model are calculated.

The data of the table visibly represents that prediction AR (1) model is giving the best results. Since all the errors are very less. It indicates that AR (1) model can used for prediction in upper Sewani watershed. The co-relation between the predicted and measured values are runoff (R^2 = 0.946). The graphical representation of data shows the strong co-relation between measured and predicted values.

Comparison of the two Models

From the graph, it is clearly visible that, the result obtained by SCS-CN is showing in fig much more deviation by Autoregressive Time Series Model. SCS Method is not only showing the peak among three and there is rather showing the deepest valley too, which is compensated by the force coming peak. One more important result visible from the graph is that AR is giving much more better results or it can be concluded that Autoregressive Time Series Model is much more trust worthy than SCS-CN.

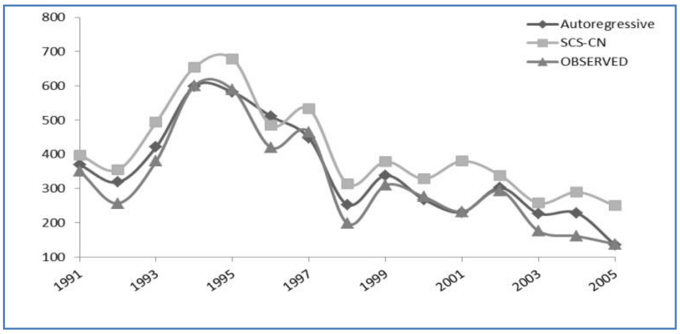

Fig-5 Comparison of the Autoregressive time series and SCS-CN Models

Conclusion

On the basis of the estimated errors, statistical characteristics and correlation between both the observed and predicted values, it was concluded that the proposed autoregressive model used to predict the annual rainfall and runoff in Autoregressive (AR) models of orders 0, 1 and 2 were tried for annual stream flow series and different parameters were estimated. The AIC value for AR (1) model (141.85) was lying between AR (0) (142.76) and AR (2) (152.74) which is satisfying the selection criteria. This is also validated by Graphical representation between historical and generated correlogram, where in runoff there was a very close agreement. The performance comparison of both the models was made with the coefficient of determination (R^2) which was 0.988 in case of SCS- Curve Number and 0.946 in case of Autoregressive Time Series Model. On further comparison it displays that autoregressive is giving much better results than the Curve Number method, so it can be more trust worthy.

Conflict of Interest: None declared.

References

[1] Adamwoski K. (1971) *Journal of Hydrology,* 14, pp- 43-52.
[2] Akaike H. (1974) A new look at the statistical model identification on IEEE transaction on automatic control" AS-19. pp-716-723.
[3] Baig M., Afzal Ali, Mallikarjuna P. and Reddy TV Krishna (2008) *Journal of Hydrolic Engineering,* 14, 2008.
[4] Mishra SK, Jain M K and Singh V P (2004) *Water Resource Management,* 18(6), 567-589.
[5] Singh S., Raghuwanshi S. and Wallendcr W.S. (1991) *Water Resources Research*, 22(3), 315-320.
[6] Jain M.K., Mishra S.K., Suresh Babu P., Venugopal K. and Singh V.P. (2006) *Journal of Hydrologic Engineering*.
[7] Anderson R.L. (1942) *Statistics,* 13(1), 1-13.
[8] Box G.E.P. and Jenkins G. (1970) Time series Analysis, Forecasting and control. First Ed. Holden – Day Inc., San Francisco.
[9] Carlson R.F. (1970) *Water Resource Research,* 64,1070-1078.
[10] Matalas N.C. (1967) *J Water Resource Res,* 3, pp-937-945.
[11] Raghuwanshi S. and Wallender W.S. (2000) *Agricultural Engg. Journal,* 9 (1), 1-16.
[12] Rai E. and Sherring A. (2007) *J Agric Eng.,* 44(4), pp :38-42
[13] Salas J.D. and Smith R.A. (1980b) Uncertainties in hydrologic time series analysis. Paper presented at the ASCE spring Meeting, Portland, Oregon, Preprint, 80-158..
[14] Thomas H.A. and Fiering M.B. (1962) Mathematical synthesis of streamflow sequences for the analysis of river basins by simulations. In Design of Water Resource Systems, pp: 459-493, Cambridge, *Massachussetts, Harvard University Press.*
[15] *Tomasz (2006) J Hydrology,* 21, pp: 746- 761.
[16] Yevjevich V.M. (1963) Fluctuations of wet and dry years. Part I .Research data assembly and mathematical models. Hydrology Paper-1, Colorado State University, Fort Collins, Colorado.
[17] Yule G.V. (1927) On a method of investigating periodicities in disturbed series with special reference to Wolfer's sunspot number. Phil. Tran. A 226:267.
[18] Doob J. L. (1953) Stochastic Processes. Wiley.
[19] USDA, SCS (1964) United States Department of Agriculture, Soil Conservation Services.
[20] Ling L. and Yusop Z. (2014) A micro focus with macro impact: Exploration of initial abstraction coefficient ratio (λ) in (CN) methodology, IOP Conference Series Earth and Environmental Science, 18(1) pp-1-5.
[21] Sherman L.K. (1949) The Unit Hydrograph Method in Physics of the Earth, O. E. Meinzer, Ed. New York: Dover Publication Inc., 514–525
[22] Patil J.P. (2008) *Water Resources Management,* 22(9), pp 1221-1239.
[23] Durbin J. (1960) *Review of International Statistical Institute,* 28, 23-33.
[24] Kottegoda N.T., Horder M.A. (1980) *Journal of Hydrology,* 47, 215-234.