Int.J.Curr.Microbiol.App.Sci (2018) *7*(5): 2850-2856

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 7 Number 05 (2018)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2018.705.331

Simulation-Optimization Modelling of Rainwater Harvesting from Karso Watershed of Damoder Catchment

Mahesh Prasad Tripathi[1*], Sandeep Kumar Pandey[2*] and C. John Wesley[3]

[1]CAE, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, India
[2]Department of Soil and Water Engineering, PAU Ludhina-141004, Punjab, India
[3]Department of Soil Water Land Engineering and Management, SHIATS, Allahabad, U.P, India

**Corresponding author*

Keywords

Auto-regressive time series model, Forecast, Mean square, Stochastic process

Article Info

Accepted:
20 April 2018
Available Online:
10 May 2018

A B S T R A C T

An evaluation was conducted to develop a stochastic time series model, capable of prediction of rainfall and runoff in Karso watershed. The Karso Watershed selected for hydrological studies is one of the sub watershed of the Damoder dam catchment of upper Damodar Valley, comprising a cover the area of 27.41 km^2. The hydrologic sequences data of watershed collected from Soil Conservation Deptt., Damodar Valley Corporation, Hazaribagh, Jharkhand State were analysed. The watershed be capable of be divided into three main landscapes. The first one is the southern part which is highly undulating and rolling uplands, which drains from south to north which is parallel to the Hazaribag – Patna National Highway. The second is gently undulating and rolling uplands, that are dissected by narrow valley and depressions. The third is valley lands, which drains from south to north which is parallel to the Hazaribagh–Patna national highway. In this area sheet wash, rill erosion, shallow and medium gullies are prominent. The hilly area lies near the village Kundwa, Daurwa, Rola etc. The main objective of the study was to develop an autoregressive time series model for annual rainfall, runoff and sediment yield. The underlying stochastic process of annual rainfall, runoff and sediment yield is characterized by autoregressive time series model. The autoregressive time series (AR) model is applied to simulate water demand and supply year by year for each basin or aggregated basin used in impact water. The model assumes that non-agricultural water demand, including municipal and industrial water demand and committed flow for in stream uses, is satisfied as the first priority, followed by livestock water demand. The effective water supply for irrigation is the residual claimant, simulated by allowing a deficit between water supply and demand. This research is based upon identification and parameter estimation of model and evaluation of performance and adequacy of the model by statistical parameters and several other measures such as mean forecast error, mean absolute error, mean relative error, mean square error, root mean square error and integral square error. The assessment among the measured and predicted rainfall and runoff by AR(1) model clearly shows that the developed model can be used capably for the future prediction of rainfall and runoff in Karso watershed.

Introduction

The rainfall and runoff relationship is one of the most difficult hydrologic occurrences to understand due to the incredible spatial and temporal variability of watershed characteristics and precipitation patterns and the number of variables involved in the modelling of the physical processes. The whole physical process in the hydrologic cycle is mathematically formulated in conceptual models that are composed of a large number of parameters. Flood inference is one of the major aspects of hydrologic intend and is considered as the first step in planning for flood protection method. The primary goal of hydrologic modelling is to represent the response of a flow system to spatially and temporally changing inputs and conditions as well as to provide a forecast of the future performances of hydrological systems. Many rainfall-runoff prediction models have been developed and basin out flow simulation continues to be at the forefront of the research community. A proper understanding and modelling of the rainfall-runoff relationships at watershed scales is important for water management studies, safe yield computations and plan of flood control structures. In current year's computer based rainfall-runoff models have become a useful tool for water resources management, flood forecasting and control, and environmental concerns. An ideal rainfall-runoff model would identify completely the properties and processes that happen in all the applicable components of a watershed.

The term 'precipitation' denotes all forms of the water that reach the earth form the atmosphere, and runoff means the draining or flowing off of precipitation from a catchment area through a surface channel after satisfying all surface and subsurface losses Dubayah and Lerrenmaier (1997). Most of the rain water is lost as surface runoff through seasonal ephemeral stream because of slow and continuous removal of soil water erosion is mostly insidious in nature. It results not only in physical degradation of soil but also carries away nutrients to the tune of 106.5 kg/ha/year in the area Morgan *et al.,* (1984). The Soil Conservation Services (SCS) method has been used by many researchers to determine the relationship between rainfall and run-off (Jain *et al.,* 1996).

Rainfall, Runoff and Sediment yield modeling is an essential area of hydrological studies and is one in which research is dynamically carried out. Method for coupling stochastic models of hydrological process applying two different time scales so that the time series generated by different models be consistent. (Koutosoyiannis 2001) particularly conceptual models, which attempt to represent the physical process which occurs on the catchments and mathematical models, which only considered the mathematical association between rainfall and runoff without allowing for the physical process. The principal aim of time series analysis to express the history of moments in time of some variable at a particular site. A comprehensive review on time series analysis technique used in climatology and hydrology. It was suggested to use more important powerful test for stationary and trend detection in time series (Machiwal and Jha 2006).

Materials and Methods

Study area

The selected area for study is Karso watershed lies between latitude 24° 12' 30" N to 24° 17' 30" N and longitude 85° 25' E to 85° 27' 30" E in SOI toposheet No. 72H/7/SE and 72H/8/NE of scale 1:25000 and is a part of North Chhotanagpur plateau (Fig. 1). The watershed is in Tilaiya catchment of Damodar river valley in Hazaribag district of Jharkhand, eastern part of India. Including Karso there are about 16 villages in this watershed. The main river is Kolhuwatari Nadi is a 6th order stream joining with Mohaghat Nadi just beyond the outlet and then flowing down to river Barakar as Nadhadwa Nadi or Barhi Nadi. The entire watershed lies in the catchment of Tilaiya reservoir. The area varies from almost flatland to steep hills. The range of elevation varies from 385 to 655 m above the mean sea level.

Forecasting from estimated autoregressive time series model

The model is based on a watershed; Autoregressive time series model generates projections of water demand and water supply based on changes in water supply infrastructure and water allocation and management policy. The model is designed to simulate water demand and supply year by year (up to 14 years) for each basin or aggregated basin used in impact water. The model assumes that non-agricultural water demand, including municipal and industrial water demand and committed flow for in stream uses, is satisfied as the first priority, followed by livestock water demand. The effective water supply for irrigation is the residual claimant, simulated by allowing a deficit between water supply and demand. The model is applied for a monthly water balance within one year, and is run through a series of years by solving individual years in sequence and connecting the outputs from year to year. The ending storage of one year is taken as the initial storage of the next, with assumed initial water storage for the base year. For those basins with large storage capacity, inter year flow regulation will be active. The time series of climate parameters is derived from 14-year historic records for the period 1981–1995. In addition to a basic scenario that overlays the single historic time series over the 1981–1995 projection period, a number of alternative scenarios of hydrologic time series are generated by changing the sequence of the yearly historic records. These scenarios are used in model to generate alternative scenarios of water availability for irrigation. The model is run for individual basins but with inter basin and international flows simulated.

Evaluation of water resources and demand/use

Above a proper water distribution system, which is considered to coordinate frequent water uses from a single water sources system such as a watershed, the design of water rights conditions can become very significant as a way of control the diversity of uses. The design of these reciprocally impacting use conditions requires the assessment of the water sources as a whole and the evaluation of the impacts of all water users on the water body.

Irrigation water demand

Irrigation water insists is assessed as crop water requirement based on hydrologic and agronomic kind. Net crop water demand (NCWD) is a basin in a year is calculated based on an observed crop water condition function (Doorenbos and Pruit, 1979):

$$NCWD = \sum_{cp}\sum_{ct} kc^{cp,ct} \cdot ET_0^{ct} \cdot A^{cp} = \sum_{cp}\sum_{ct} ETM^{ct,cp} \cdot A^{cp} \quad (1)$$

In which cp is the index of crops, ct is the index of crop enlargement stages, ET0 is the reference evapotranspiration [L], kc is the crop coefficient, and A is the crop area. Part or all of crop water demand can be satisfied by effective rainfall (PE), which is the rainfall infiltrated into the root zone and available for crop use. Effective rainfall for crop growth can be increased through rainfall harvesting technology. Then net irrigation water demand (NIRWD), with consideration of effective rainfall use and salt leaching requirement, is:

$$NIRWD = \sum_{cp}\sum_{st}\left(kc^{cp,st} \cdot ET_0^{st} - PE^{cp,st}\right) \cdot AI^{cp} \cdot (1 + LR) \quad (2)$$

In which AI is the irrigated area. LR is the salt leaching factor, which is characterized by soil salinity and irrigation water salinity. Total irrigation water demand represented in water depletion (IRWD) is calculated as:

$$IRWD = NIRWD / BE \quad (3)$$

In which *BE* is defined as basin effectiveness. The concept of basin efficiency was discussed, and various definitions were provided by Molden, Sakthivadivel, and Habib (2001). The basin efficiency used in this study measures the ratio of beneficial water depletion (crop evapotranspiration and salt leaching) to the total irrigation water depletion at the river basin scale. Basin efficiency in the base year (1995) is calculated as the ratio of the net irrigation water demand (NIRWD, Equation 2) to the total irrigation water exhaustion estimated from records. Basin efficiency in future years is assumed to increase at a prescribed rate in a basin, depending on water infrastructure investment and water management improvement in the basin. The projection of irrigation water demand depends on the changes of irrigated area and cropping patterns, water use efficiency, and rainfall harvest technology. Global climate change can also affect future irrigation water demand through temperature and precipitation change, but is not considered in the current modelling framework.

Auto-correlation function

The auto-correlation function r_k of the variable Y_t is obtained, Y_{t+k} and taking expectation term by term. The relationship proposed by Kottegoda and Horder, (1980) for the computation of auto-correlation function of lag K was used which is expressed as:

$$r_k = \frac{\sum_{t=1}^{N-K}(Y_t - \overline{Y})(Y_{t+k} - \overline{Y})}{\sum_{t=1}^{N}(Y_t - \overline{Y})^2} \quad (4)$$

Where,

r_k = Auto-correlation function of time series Y_t at lag k

Y_t = Rainfall and runoff (measured data)

$\overline{Y}$ = Mean of time series Y_t

k = Lag of K time unit

N = Total number of discrete values of time series Y_t

The auto-correlation or serial correlation is a graphical relationship of auto-correlation function r_k with lag k. The auto-correlogram was used for identifying the order of the model for given time series as well as for comparing the sample correlogram with model correlogram. For an independent time series the population correlogram is equal to zero for $K \neq 1$. However, sample of independent time series due to sampling variability have r_k fluctuating around zero but they are not necessarily equal to zero.

Therefore probability limits for the correlogram of an independent series is determined. The following equation was used to determine the 95 per cent probability levels Anderson, (1942).

$$r_k\,(95\%) = \frac{-1 \pm 1.96\sqrt{N-K-1}}{N-K} \quad (5)$$

Where, N = Sample size

Mean forecast error

Mean forecast error was calculated to evaluate the performance of auto regressive models fitted to time series of rainfall, runoff. The mean forecast error (MFE) was computed for the annual rainfall and runoff by the following equation.

$$\text{MFE} = \frac{\sum_{i=1}^{n} \chi_c(t) - \sum_{i=1}^{n} \chi_0(t)}{\eta} \qquad (6)$$

where,

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

Goodness of fit of auto-regressive (AR) models

The goodness of fit tests of AR models fitted to annual hydrologic series were accomplished by testing whether the residuals of a dependence model for correlation and whether the order of the fitted model is adequate compared with the order of the dependence model and whether the main statistical characteristics of measured series one preserved. The following tests were performed to test the goodness of fit of autoregressive (AR) models.

Results and Discussion

The observations recorded at the progressive stages of the experiment were analysed statistically significant. The results of the experiments are presented under the following sections. The Autoregressive time series model calculates effective irrigation water supply in each basin by crop and by period (NIWi, t), over a 30-year time horizon. The results from the model are then incorporated into impact for simulating food production, demand, and trade. The autoregressive models up to order 2 were tried in this study. The parameters of AR models up to order 2 were determined through equation (Fig. 2 and Table 1).

Table.1 Evaluation of regeneration performance with statistical errors

Sl. No.	Statistical error	Autoregressive (AR 1) model		
		Rainfall (mm)	**Runoff (mm)**	**Sediment yield (tons/ha)**
1	Mean Forecast Error	44.34	431.57	66.71
2	Mean Absolute Error	-44.34	-431.57	-66.71
3	Mean Relative Error	25559.95	24212.0	57856.74
4	Mean Square Error	159.87	1556.04	240.53
5	Root mean square Error	5.05	260.501	109.64
6	Integral Square Error	-0.58	-12.46	14.18

Fig.1 Location of Karso watershed

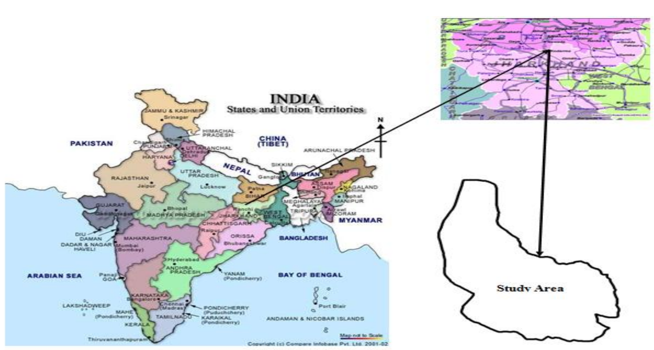
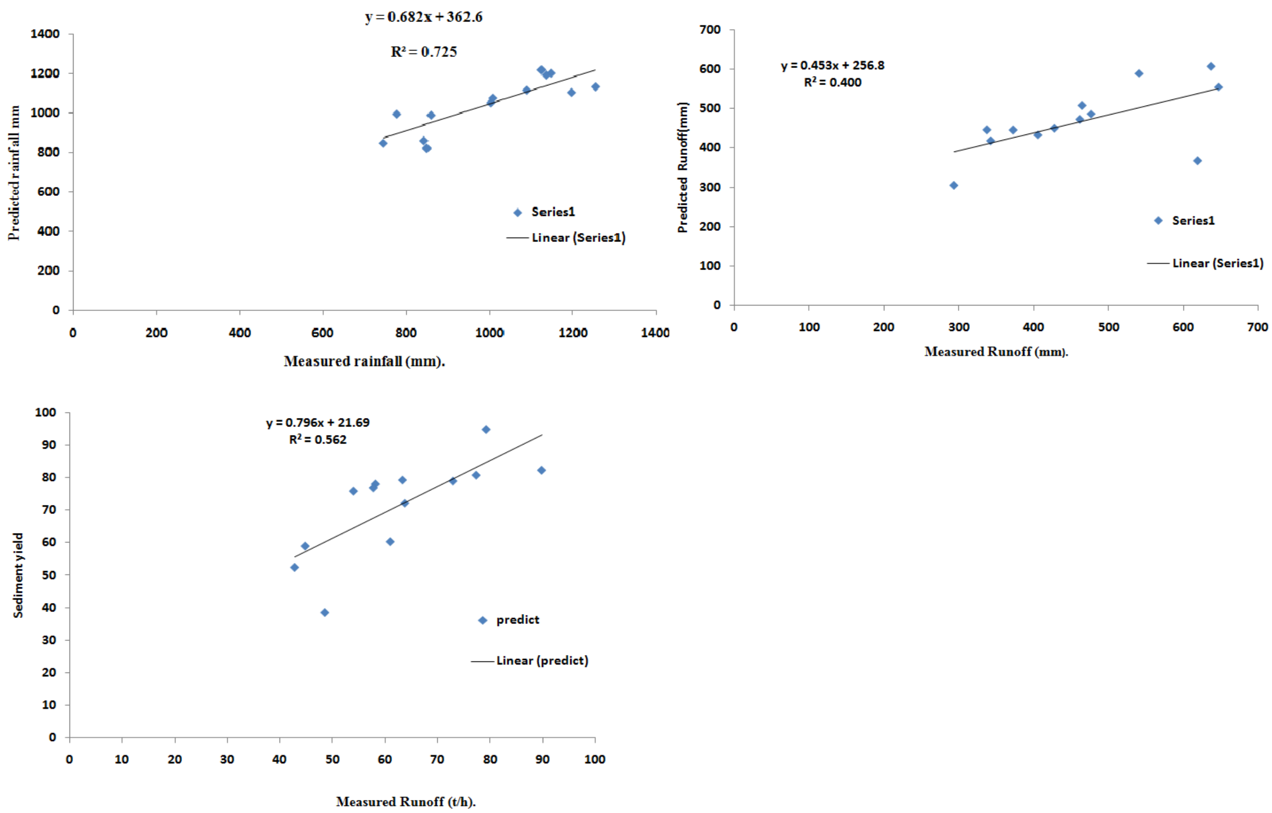


Fig.2 shows the comparison between measured and predicted annual Rainfall (mm), Runoff and Sediment yield(t/h) of Karso watershed of Damodar catchment. The value of R^2 is 0.725 for observed rainfall and 0.400 for predicted runoff and 0.562 for the sediment yield



In conclusion, the aim of this modelling implement is to develop a tool for strategy analysis in local and global water resources development and management. As stated, many policy-related water variables are involved in this modelling structure including potential irrigated area and cropping patterns, Autoregressive time series model for both surface and groundwater, water use efficiency, water storage and inter basin transfer facility, rainfall harvest technology (that is, to increase of use rainfall for crops), distribution of water to agricultural and non-agricultural uses, and dedicated in stream flow needs. During scrupulous, water supply in irrigated agriculture is included with irrigation infrastructure, which permits the opinion of the impact of savings on growth of potential crop area and step up of irrigation systems.

References

Doorenbos, J., and A. H. Kassam. 1979. Crop yield vs. water. FAO Irrigation and Drainage Paper No. 33. Rome: Food and Agriculture Organization of the United Nations.

Dubayah, R and D. Lerrenmaier, (1997). Combing Remote Sensing and Hydrological Modeling for Applied Water and Energy Balance Studies,NASA EOS Interdisciplinary Working Group Meeting, San Diego, CA. Jain SK, Das KK, Singh R (1996) GIS for estimation of direct runoff potential. JIndian Water Resour Soc 2(1):42–4

Koutosoyiann, D., (2001):" Coupling stochastic models of different time scales". Water Resources Research, 37(2):379-391.

Kottegoda N.T, Horder M.A, (1980) Daily flow model rainfall occurs using pulse and transfer function. J. Hydrology, 47: 215-234.

Morgan, R.P.C., Morgan, D.D.V., and Finney, H.J., 1984. A predictive model for the assessment of soil erosion risk, J. Agric. Engg. Res. vol. 30, pp. 245-253.

Molden, D., R. Sakthivadivel, and Z. Habib. 2001. Basin-level use and productivity of water: Examples from South

Asia. Research Report 49. Colombo, Sri Lanka: International Water Management Institute.

Machiwal,D. and Jha, M.K.(2006). "Time series analysis for water resources planning and management". Journal of Hydrology and Hydro mechanics, Vol. 54(3), pp: 237-257.

How to cite this article:

Mahesh Prasad Tripathi, Sandeep Kumar Pandey and John Wesley, C. 2018. Simulation-Optimization Modelling of Rainwater Harvesting from Karso Watershed of Damoder Catchment. *Int.J.Curr.Microbiol.App.Sci.* 7(05): 2850-2856.
doi: https://doi.org/10.20546/ijcmas.2018.705.331