Int.J.Curr.Microbiol.App.Sci (2017) *6*(11): 3822-3826

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 11 (2017) pp. 3822-3826**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2017.611.449

Modeling of Runoff using Curve Expert for Dachigam-Telbal Catchment of Kashmir Valley, India

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Keywords

Catchment, Curve expert 2.0, Rainfall, Regression analysis, Runoff.

Article Info

Accepted:
28 September 2017
Available Online:
10 November 2017

A B S T R A C T

The study were attempted to develop prediction models for runoff using rainfall as single predictor. An outline for a complete synthetic rainfall-runoff database was developed to study catchment response to a variety of rainfall events. Dachigam-Telbal catchment was chosen as study site and records of rainfall amount and runoff were organized and analyzed. For runoff, regression analysis was done in different ways to develop model that can predict runoff by using rainfall as single variable as it is one hydrological parameter which is recorded in most parts of the country. Curve expert 2.0 was used to generate these models. The attempt to develop runoff prediction model with rainfall as single input variable, exhibited high promise for monthly analysis with higher value of coefficient of determination *i.e.* R^2=0.95, and lower standard error of estimation *i.e.* S=0.36, under regression analysis.

Introduction

Environmental problems are caused by the increasing number and intensity of floods and flash flood events, taking a high human and economic toll (Smith and Ward, 1998; Villarini *et al.*, 2010). In the pertaining period, numerous new tools and programs for flood forecasting systems and risk management plans have been developed (Chao *et al.*, 2008; Romanowicz *et al.*, 2008; Cloke and Pappenberger, 2009; Tiwari and Chatterjee, 2010; Villarini *et al.*, 2010).Runoff is the most basic and important data needed when planning water control strategies/practices, such as, waterways, storage facilities or erosion control structures (Austin, 2006). The estimation of runoff depends upon number of factors related to rainfall properties, geomorphologic characteristics of catchment and cover management (King, 2000). These parameters are not available readily and thus rainfall amount is used. The rainfall amount can be used as a single input factor determining the volume of runoff for selected catchment (Dachigam-Telbal). Among different hydrologic processes, runoff is a single important process that influences several of the soil and water management decisions and therefore runoff is often required to be measured or estimated for a given situation. The magnitude, time distribution and peak rate of runoff are important runoff properties that have important role in design, operation and management of soil and water conservation and development work.

Study area

Dachigam and Telbal catchments of Dal Lake were taken as the study area. Dal Lake is the second largest lake in the state of Jammu and Kashmir situated between 74° 8´ to 74° 9´ E longitude and 34° 5´ to 34° 6´N latitude, at an altitude of 1587 m. A perennial inflow channel, Telbal channel, enters the lake from the north and supplies about 80% of water to the lake. Towards the south-east side, an outflow channel drains the lake water into the Chount Kula tributary.

The mean depth of the lake is 1.4 m with a maximum depth up to 6 m. The length of the shore line of the lake is surrounded by high mountains on one side and by an urban area on the other side. The total catchment area of the DalLake works out to be 337.17 km^2.

From computation of runoff point of view, the Dal catchment has been divided in following sub-catchments:

Dachigam (catchment A)
Telbal (catchment B)
Lake Hillside (catchment C)
Srinagar North (catchment D)
Srinagar Centre (catchment E)
Dal Lake (catchment F)

The Dachigam and Telbal sub-catchments that constitute the major portion of Dal Lake catchment was selected for the present study. Total area of the catchment is 234.17 km^2. The data used in this study were (a) daily rainfall data for the 6 year period (2006–2011) (b) daily discharge data of the watershed at main outlet for the 6 year period (2006– 2011). The daily rainfall data were collected from AMFU-Srinagar, Division of Agronomy, SKUAST-K and daily discharge date were collected from Lakes and Waterways Development Authority, Kashmir. Curve expert software 2.0.2 was used for predicting run-off using rainfall as single variable. The software is designed with the purpose of generating high quality results and output while saving your time in the process.

Results and Discussion

The curve expert software was used for regression analysis which was performed by relating mean value of runoff as dependent variable and the amount of rainfall for respective period as independent variable.

The software has several linear, polynomials, and nonlinear inbuilt models which it tested for the supplied data, along with their rank of fitting ability. For a given set of data the first five ranked models were used to predict the runoff.

Monthly analysis data for rainfall-runoff

The hydrological data of monthly rainfall and corresponding runoff were tried to fit in different models to predict the variation in runoff based on amount of rainfall, in curve expert 2.0.2. Figure 1(a-e) illustrates the each model suggested by the software.

In order to predict the variation in runoff based on amount of rainfall, the hydrological data of monthly rainfall and corresponding runoff were tried to fit in linear regression, shifted power, rational, vapor pressure and heat capacity models. These models indicated 94.4, 94.0, 94.9, 94.7 and 94.8%variability respectively, in the runoff values due to the rainfall itself. The obtained relationship between monthly runoff and rainfall amount for Dachigam-Telbal Catchment is shown in Table 1. This table indicated models of different nature giving best fit to the observed value of runoff, ignoring the effect of other variables relating to catchment, conservation practices. However the perusal of Table 1 reveal Heat Capacity Model as best fit model for monthly analysis with R^2 value 0.95, with the use of model of this nature at least 94.8 percent of variation in runoff can be explained by rainfall alone.

Table.1 Observed relationship between runoff and rainfall amount using monthly data for Dachigam-Telbal catchment

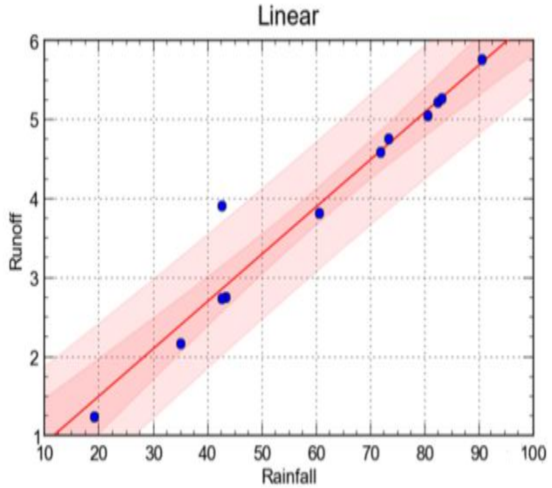
Name of model	Equation	Coefficient	S	R^2	R
Linear Regression Model	$Y = a + bx$	a=0.318	0.360	0.944	0.971
		b=0.0598			
Shifted power model	$Y = a(x - b)^c$	a=0.274	0.358	0.948	0.973
		b=8.902			
		c=0.735			
Vapor Pressure Model	$Y = \exp\left(a + \frac{b}{x} + c\ln(x)\right)$	a= -1.227	0.359	0.947	0.973
		b=-0.107			
		c= 6.821			
Heat Capacity Model	$Y = a + bx + \frac{c}{x^2}$	a=0.740	0.357	0.948	0.973
		b= -0.054			
		c= -209.4			
Rational Model	$Y = \frac{(a + bx)}{(1 + cx + dx^2)}$	a= -2.333	0.375	0.949	0.974
		b= -0.237			
		c= 0.049			
		d=-0.0002			

Table.2 Mean square error and root mean square error for developed models for monthly analysis

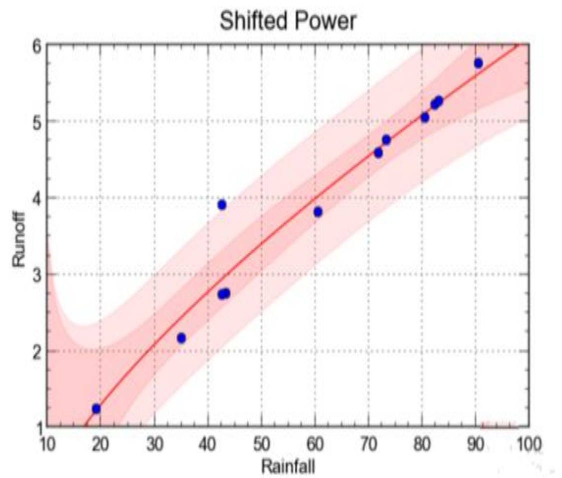
Name of model	MSE	RMSE
Linear Regression Model	0.10	0.32
Vapor Pressure Model	0.74	0.86
Shifted Power Model	0.11	0.31
Heat Capacity Model	0.12	0.30
Rational Model	0.10	0.31

MSE= mean square error, RMSE= root mean square error

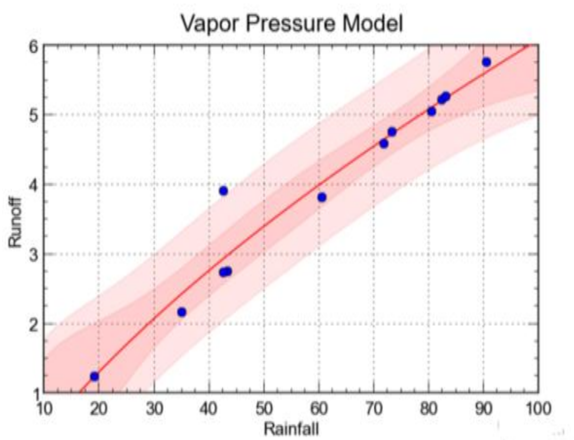
Fig.1 (a-e) Runoff-Rainfall relationship by using different models for hydrological period of 2006-2011



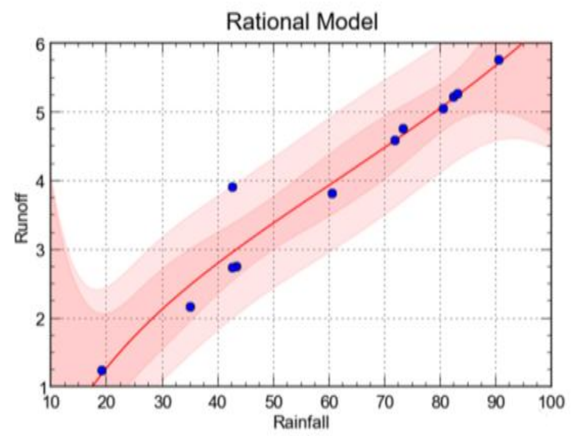
1(a) Linear Model



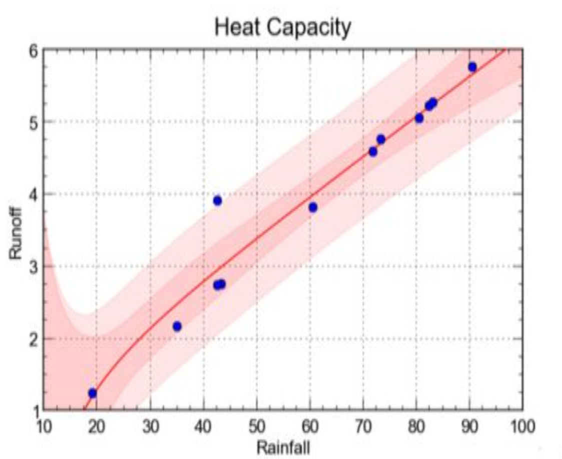
1(b) Shifted Power Model



1(c) Vapor Pressure Model



1(d) Rational Model



1(e)Heat Capacity Model

Mean squared error and root mean squared error

Mean square error and root mean square error was calculated for the models developed for predicting monthly runoff. Table 2 shows mean square error and root mean square error calculated for the models developed for monthly analysis. The values of R^2 are high, while the MSE and RMSE values for different models are within permitted limit. The heat capacity model showed highest value of R^2 and low value of MSE and RMSE and is the best among all models.

Other models also show small error values with high values of R^2. These models can also be used for prediction of monthly runoff using rainfall with good results. However, heat capacity model gives results much closer to the actual values. Regression analysis between rainfall and runoff revealed that heat capacity model gives best fit to observed runoff on monthly basis with R^2 value 0.948.

Linear regression model predicted monthly runoff volume with the coefficient of determination value of 0.944 and corresponding Standard error of estimates to be 0.360.

All the nonlinear models fitted by the software for monthly analysis gives excellent predictions of runoff with coefficient of determination value 0.944 and standard error of estimate 0.357.

Among all the linear and nonlinear models the most reliable model to predict runoff on both monthly basis was found to be the heat Capacity model based on R^2 0.948 and Standard error of estimates 0.357.By the use of model of this nature at least 94 percent of variation in runoff can be explained by rainfall alone.

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How to cite this article:

Mehlath Shah, Syed Midhat Fazil, Syed Rouhullah Ali, Yogesh Pandey, Shahzad Faisal and Iqra Mehraj. 2017. Modeling of Runoff using Curve Expert for Dachigam-Telbal Catchment of Kashmir Valley. *Int.J.Curr.Microbiol.App.Sci.* 6(11): 3822-3826.
doi: https://doi.org/10.20546/ijcmas.2017.611.449