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DEVELOPMENT OF RAINFALL-RUNOFF MODEL FOR MICRO WATERSHED OF DAL

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ABSTRACT

A micro watershed of dal i.e. Dachigam-Telbal catchment was chosen as the study site for predicting models for runoff using rainfall as single predictor. The annual records of rainfall amount and runoff were organized and analysed, which were later used as input parameter in Curve Expert 2.0 to generate prediction models. For runoff, regression analysis was done in different ways to develop model that can predict runoff by using rainfall as single input variable because it is the one hydrological parameter, which is monitored in most parts of the country. Runoff prediction model developed for the site with rainfall as single variable, displayed high promise for annual analysis with higher value of coefficient of determination i.e. R^2*=0.93,and lower standard error of estimation i.e. S=0.238 , under regression analysis. The developed models were verified for same site, predicted runoff and observed runoff was found to be in high correlation (r=0.964) with the corresponding values of runoff. Later, the best fit models were tested by predicting runoff of the years for which data was not available.*

Keywords: Catchment, Curve expert 2.0, Model, Rainfall and Runoff.

I.INTRODUCTION

A watershed is an extent or an area of land where surface runoff and snow or ice converges to a single point, usually the exit of the basin, where the water join another water-body, such as a river, lake, reservoir, estuary, wetland, sea, or ocean. The climate of Jammu and Kashmir varies greatly owing to its rugged topography. In the south around Jammu, the climate is typically monsoonal, though the region is sufficiently far west to average 40 to 50 mm (1.6 to 2 inches) of rain per month between January and March. In the hot season, Jammu city is very hot and can reach up to 40 °C (104 °F) whilst in July and August, very heavy though erratic rainfall occurs with monthly extremes of up to 650 millimeters (25.5 inches). In September, rainfall declines, and by October conditions are hot but extremely dry, with minimal rainfall and temperatures of around 29 °C (84 °F).

The estimation of runoff depends upon number of factors related to rainfall properties, geomorphologic characteristics of catchment and cover management **[1, 2]**. These parameters are not available readily like the rainfall data which is an exception. The rainfall amount can be used as a single input factor determining the volume of runoff for selected catchment (Dachigam-Telbal).

II.METHODOLOGY

The methodology included in this study incorporated several stages of data analysis for the development of runoff prediction models and testing of their strengths in the prediction of runoff rates. Prior to identification of the possible approaches and their selection for modeling of runoff rates, extensive review of relevant literature was made. In the process focus was made to those methodologies and modeling approaches which could have possible relevance to the conditions of Kashmir.

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 & Kashmir situated between 74° 8´ to 74° 9´ E longitude and 34° 5´ to 34° 6´ N latitude, at an altitude of 1583 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 Kul 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 Dal Lake works out to be 337.17 km^2 **[3]**. Dachigam is the largest catchment and drains via the Dachigam Nallah and the Telbal Nallah, the latter being the main stream flowing into Dal Lake and is the main carrier of silt load into the Lake.

Table 1 Areas of different land uses in Dal catchment

Land use class	**Area in km^2**
Bare grounds	160.97
Dense forest	52.02
Built-up/unclassified	45.44
Open Forest	34.15
Lakes/Shadows	33.49
Snow	9.25
Degraded Forest	1.85
Total	**337.17**

Source: JK LAWDA (2011)

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 meteorological data related with rainfall amount and runoff required for the current study was obtained from Division of Agronomy, Sher-e-Kashmir

University of Agricultural Sciences and Technology of Kashmir, Shalimar Campus, Srinagar and Lakes and Waterways Development Authority, Kashmir (LAWDA) respectively. The discharge data was obtained in a rough form and therefore necessitated proper processing. All the data processing and arrangements in a proper manner was done using MS EXCEL spread sheet.

Curve expert software 2.0.2 was used for predicting runoff 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.

III.RESULTS AND DISCUSSIONS

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). Several models were tried to fit the experimental data and it was found that heat capacity model was the best fit model for predicting runoff using annual data. The developed model were found to be very efficient in runoff prediction with the coefficient of determination values 0.93 for annual data, which shows that by using this model at least 94.8 percent of variation in runoff can be explained by rainfall alone. The detailed results are discussed as below:

IV.ANNUAL ANALYSIS OF DATA FOR RAINFALL-RUNOFF

The hydrological data of annual rainfall and corresponding runoff were tried to fit in heat capacity model to predict the variation in runoff based on amount of rainfall. Fig 1 illustrates five different models suggested by curve expert software for the input data. The hydrological data of annual rainfall and corresponding runoff were tried to fit in heat capacity, Farazdaghi-Harris, Steinhart-Hart, Modified power, linear regression models, to predict variation in runoff based on amount of rainfall. These models indicated 93.0, 91.0, 92.0, 90.0 and 88.6 % variability respectively, in the runoff values due to the rainfall itself. The obtained relationship between annual runoff and rainfall amount for Dachigam-Telbal Catchment is shown in Table 2. 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. However the perusal of Table 2 reveal Heat Capacity Model as best fit model for monthly analysis with R^2 value 0.93, with the use of model of this nature at least 96.8 percent of variation in runoff can be explained by rainfall alone.

The Heat Capacity Model of following form gave best fit relationship between runoff and rainfall using annual data:

$$Y = a + bx + \frac{c}{x^2}$$

(R^2= 0.93, S= 0.23)

Where;

a	=	-4.0200E+00
b	=	1.0018E-01
c	=	6.2795E+

Table 2 : Observed Relationship between Runoff and Rainfall Amount using Annual Data

Name of model	Equation	Coefficients	S	R^2	R
Heat Capacity Model	$Y = a + bx + \frac{c}{x^2}$	a= -4.0200	0.238	0.93	0.968
		b= 0.1008			
		c= 6279.5			
Steinhart-Hart-Equation	$Y = \frac{1}{(A + Bln(x) + Cln(x^3))}$	A= -1.404	0.267	0.92	0.960
		B=-0.6876			
		C= -0.0166			
Modified Power	$Y = ab^x$	a=1.822	0.255	0.90	0.952
		b=1.012			
Farazdaghi-Harris-Equation	$Y = \frac{1}{a + bx^c}$	a= -0.3452	0.273	0.91	0.958
		b= -0.00003			
		c=1.9057			
Linear Model	$Y = a + bx$	a= 0.765	0.281	0.886	0.941
		b=0.052			

Mean squared error and root mean squared error:

Table 3 shows mean squared and root mean squared error for the predicted models. Since the values of R^2 are high, while the MSE and RMSE values for different models are within permitted limit these models can be used for prediction of annual runoff using rainfall with good results.. 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. However, heat capacity model gives results much closer to the actual values. Thus heat capacity model is the best fit model

Table 3: Table of mean square error and root mean square error for developed models for annual analysis

Name of Model	MSE	RMSE
Heat Capacity Model	0.067	0.416
Steinhart-Hart Equation	0.055	0.235
Modified Power	0.067	0.259
Farrazdaghi-Harris Equation	0.040	0.202
Linear Model	0.053	0.231

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

Model Testing:

Model testing was done to test the accuracy of proposed runoff prediction model for the data set of Dachigam-Telbal Catchment. Models were tested for their accuracy by comparing observed data of annual runoff with amount of corresponding runoff predicted by developed models. Since runoff data was available only for years 2006-2011, models developed for annual analysis of rainfall-runoff were also tested for predicting the runoff corresponding to available data of rainfall for the years 1990-2011

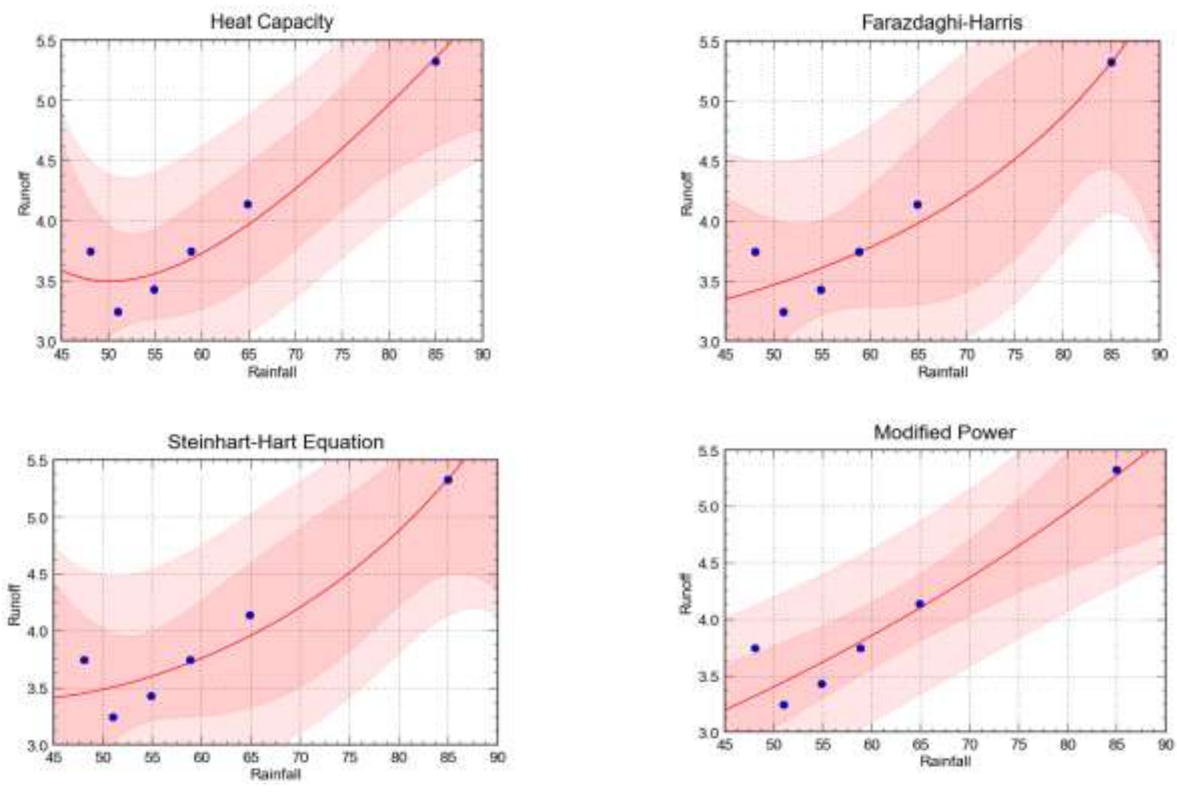
Table 4: Comparison between observed and predicted runoff for Dachigam and Telbal Catchment, 2006-2011 on annual basis

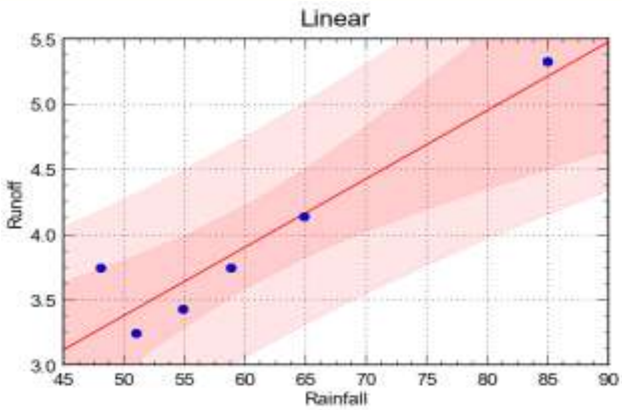
Year	Mean annual rainfall	Mean annual runoff	Predicted runoff				
			Heat capacity	Steinhart-Hart Equation	Modified power	Farrazdaghi-Harris equation	Linear model
2006	85.030	5.325	5.360	5.091	5.024	5.208	5.190
2007	48.100	3.741	3.509	3.374	3.233	3.411	3.271
2008	58.800	3.741	3.682	3.618	3.674	3.716	3.822
2009	51.000	3.241	3.499	3.422	3.348	3.483	3.423

2010	64.919	4.133	3.968	3.838	3.952	3.946	4.142
2011	54.900	3.425	3.559	3.509	3.507	3.592	3.620
Correlation coefficient			0.968	0.960	0.952	0.958	0.941

Heat Capacity Model which is the best fit model for annual runoff prediction when tested against the observed data set produced correlation coefficient of 0.968. The other proposed models also produced the correlation coefficient ranging from 0.941-0.960. The observed value correlated to a high degree with predicted value estimated, using prediction equations. This clearly illustrated suitability of the prediction equations for the estimation of runoff using rainfall as single predictor in context of the study site.

Fig.1 Annual Runoff-Rainfall relationship by using different models for hydrological period of 2006-2011





Different models developed for annual analysis were plotted in graph as shown in Figure 2.

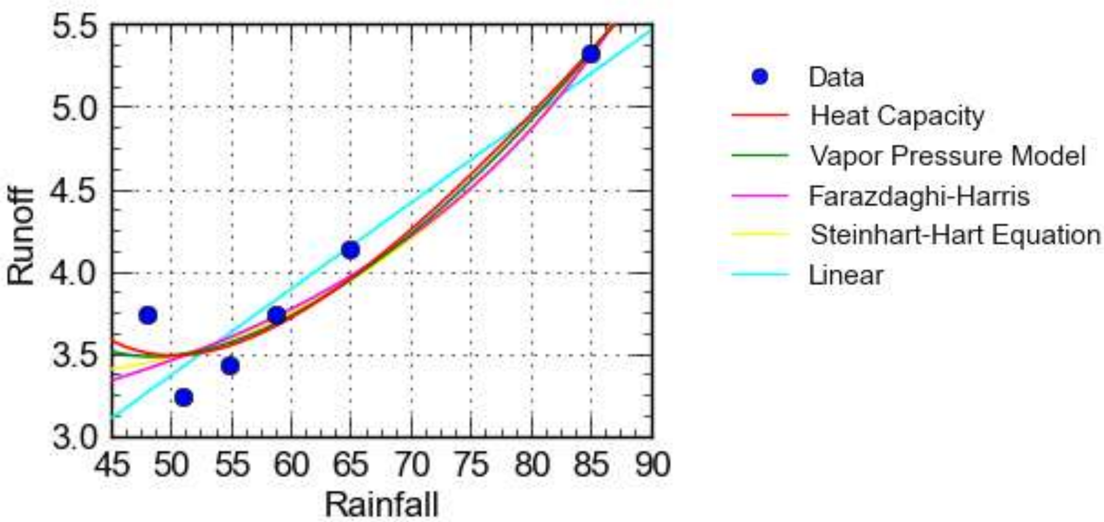


Fig. 2: Comparison between observed and predicted values of annual runoff predicted by different models

Comparison between observed and predicted values of annual runoff predicted by different models clearly indicates that there is less variation between the two. Observed amount of runoff is represented by dots and predicted amount is represented by solid lines where red line represents amount of runoff predicted by heat capacity model which is the best fit model. Amount of runoff predicted by vapor pressure, Farrazdaghi-Harris, Steinhart-Hart and linear model are represented by green, pink, yellow and blues lines respectively.

V.CONCLUSION

Regression analysis between rainfall and runoff when done showed heat capacity model gives best fit to observed runoff on annual basis with R^2 value 0.93, with the use of model of this nature at least 93 percent of variation in runoff can be explained by rainfall alone. The models developed were used to make comparison between observed and predicted values of runoff. The equations when used to predict the runoff for the study site for same period ,exhibited that predicted values are in good correlation with those observed with correlation coefficient higher than 0.97.

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