RAINFALL-RUNOFF MODELING USING ARTIFICIAL NEURAL NETWORK TECHNIQUE

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Abstract - *Artificial neural networks (ANNs) are among the most sophisticated empirical models available and have proven to be especially good in modelling complex systems. Their ability to extract relations between inputs and outputs of a process, without the physics being explicitly provided to them, theoretically suits the problem of relating rainfall to runoff well, since it is a highly nonlinear and complex problem. The goal of this investigation was to develop rainfall-runoff models for the river Jhelum catchment that are capable of accurately modelling the relationships between rainfall and runoff in a catchment. It is for this reason that ANN technique was tested as R-R models on a data set from the upper Jhelum catchment in Jammu and Kashmir, India. Two types of ANN models viz. Back Propagation networks (BPN) and Radial Basis function (RBF) were developed and tested for this data and later their performance was checked by different statistical parameters like coefficient of determination R^2 and root mean squared error (RMSE).*

***Key Words*: Back Propagation network, Radial Basis function network, Modeling, Artificial neural network.**

1. INTRODUCTION

Hydrologic engineering design and management purposes require information about runoff from a hydrologic catchment. In order to predict this information, the transformation of rainfall on a catchment to runoff from it must be modeled. One approach to this modeling issue is to use empirical Rainfall-Runoff (R-R) models. Empirical models simulate catchment behaviour by parameterization of the relations that the model extracts from sample input and output data. Artificial Neural Networks (ANNs) are models that use dense interconnection of simple computational elements, known as neurons, in combination with so-called training algorithms to make their structure (and therefore their response) adapt to information that is presented to them. ANNs have analogies with biological neural networks, such as nervous systems. ANNs are among the most sophisticated empirical models available and have proven to be especially good in modeling complex systems. Their ability to extract relations between inputs and outputs of a process, without the physics being explicitly provided to them, theoretically suits the problem of relating rainfall to runoff well, since it is a highly nonlinear and complex problem. The goal of this investigation was to prove that ANN models are capable of accurately modeling the relationships between rainfall and runoff in a catchment. An existing software tool in the Matlab environment was selected for design and testing of ANNs on the data set. A special algorithm (the back propagation algorithm) was programmed and incorporated in this tool. This algorithm was expected to ease the trial-and-error efforts for finding an optimal network structure. The ANN type that was used in this investigation is the so-called static multilayer feed forward network. The main conclusion that can be drawn from this investigation is that ANNs are indeed capable of modeling R-R relationships. In the present study Multiple Linear Regression technique was employed on the normalized data using MS Excel. The analysis of variance was done and R^2, root mean squared error (RMSE) were computed. The MLR model was validated by plotting the predicted discharge v/s actual discharge curve for years 2010-2013 (about 20% data).

2. STUDY AREA

The present study was carried out in the upper Jhelum catchment. The study area spatially lies between 33° 21′ 54″ N to 34° 27′ 52″ N latitude and 74° 24′ 08″ E to 75° 35′ 36″ E longitude with a total area of 8600.78 sq.kms (Figure.1). It covers almost all the physiographic divisions of the Kashmir Valley and is drained by the most important tributaries of river Jhelum. Srinagar city which is the largest urban centre in the valley is settled on both the sides of Jhelum River and is experiencing a fast spatial growth. Physical features of contrasting nature can be observed in the study area that ranges from fertile valley floor to snow-clad mountains and from glacial barren lands to lush green forests.

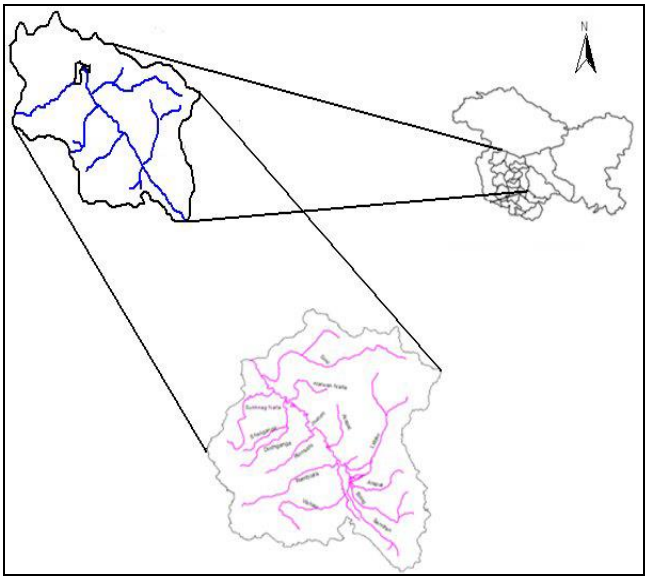

Fig -1: Location map of study area

3. DATA

The discharge data at Padshahibagh gauging station from 1991-2013 was obtained from the irrigation and flood control department, Kashmir and the precipitation data was procured from the Indian meteorological department (IMD) and National climate data centre (NCDC). The data sets for the years 2001-2009 were used for development/calibrating/training the models and these models were validated for various data sets achieved for 2010-2013.

4. ARTIFICIAL NEURAL NETWORK (ANN)

Artificial Neural Networks (ANNs) are networks of simple computational elements that are able to adapt to an information environment. This adaptation is realised by adjustment of the internal network connections through applying a certain algorithm. Thus, ANNs are able to uncover and approximate relationships that are contained in the data that is presented to the network. ANN applications are becoming more and more popular since the resurgence of these techniques in the last part of the 1980's. Since the early 1990's, ANNs have been successfully used in hydrology related areas, one of which is Rainfall-Runoff (R-R) modelling [after Govindaraju, 2000]. The application of ANNs as an alternative modelling tool in this field, however, is still in its nascent stages. The reason for modelling the relation between precipitation on a catchment and the runoff from it is that runoff information is needed for hydrologic engineering design and management purposes [Govindaraju, 2000]. However, as Tokar and Johnson [1999] state, the relationship between rainfall and runoff is one of the most complex hydrologic phenomena to comprehend. This is due to the tremendous spatial and temporal variability of watershed characteristics and precipitation patterns, and the number of variables involved in the modelling of the physical processes. The network is able to intelligently change its internal parameters, so that the target output signal is approximated. This way the relationships between the input and output variable are parameterised in the model structure and the ANN can make an output prediction based on new input. ANNs have proven to be especially good in modelling complex and non-linear systems. Other important merits of these techniques are the short development time of ANN models, their flexibility and the fact that no great expertise in a certain field is needed in order to be able to apply ANN techniques in this field. The present study is under taken develop rainfall-runoff model in river Jhelum. Artificial Neural Network Techniques will be used to develop the rainfall runoff models, to predict the runoff discharges at Padshahi Bagh station. A predictive analysis is used to determine the predictors which influence the runoff. After the model development the runoff at the Padshahi-Bagh station could then be predicted. Neural Network Tool Box of MATLAB was used to develop Artificial Neural Network Models for Rainfall-Runoff modeling in River Jhelum. Various types of neural networks Viz. BPN and RBF were developed . The BPN was optimized for the number of neurons in the hidden layer by changing the number of neurons in the hidden layer. AIC and BIC criteria was employed on various BPN models which led to the selection of two BPN networks with 6 and 10 neurons in the hidden layer. These networks are represented as BPN 6N and BPN 10N in this study respectively. The predicted vs. actual discharges were developed curves were drawn for all the neural network models and there by models were validated for about 20% of the data. Various statistical indices like R^2 and RMSE were computed for comparing these models. Based on these statistical indices, the artificial neural networks proved to be better than MLR. Among various ANN models, RBF with RMSE=0.046 and R^2=0.937 emerged to be the best suited model for the prediction. The models developed were then used to developed two individual hydrographs and all the models predicted flood hydrograph to a good extent but RBF networks with RMSE=0.016 and R^2=0.976 again proved to be quite impressive as per the overall performance .

5. RESULTS AND DISCUSSIONS

The number of neurons in the hidden layer is a very complicated task in finalizing the network architecture. This can be done by trial and error analysis. We have to finalize the number of hidden layers and the number of neurons in the hidden layers. The hidden layers in the network were fixed to one. Hence we start with one neuron in the hidden layer and increase it every time after training the network. The observed Vs predicted runoffs for various number of neurons in the hidden layer is shown in figure 6.10 to 6.13. Results of BPN network with 6 neurons in the hidden layer and BPN network with 10 neurons in the hidden layer are shown in Figure 4 and Table 1.After carrying out regression and validating the data the value of R^2 and RMSE for different parameters were calculated as shown in table 1 and table 2:

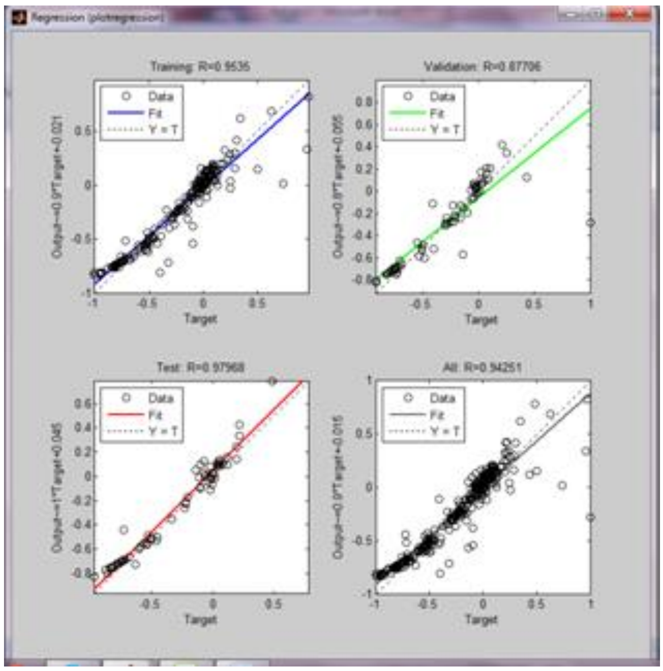

Fig -2: Dialogue box showing the training performance of RBF network.

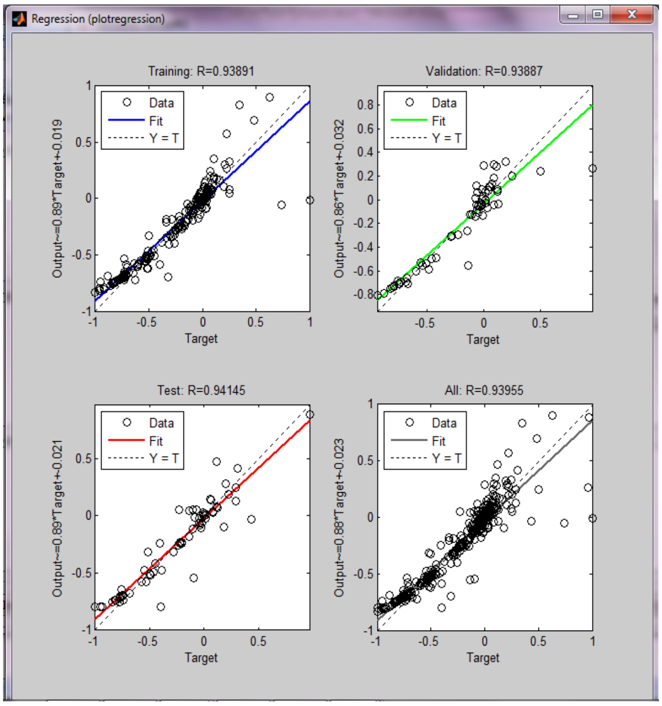

Fig -3: Dialogue box showing training performance of BPN network.

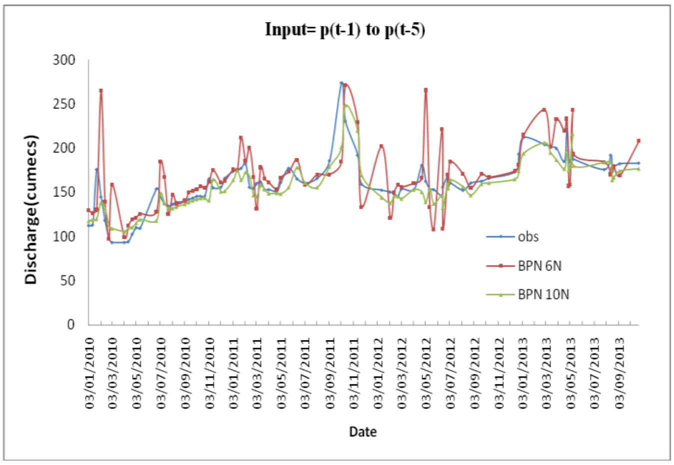

Fig -4: Observed vs. predicted discharge, P(t-1) to P(t-5) for BPN network.

NETWORK	INPUTS	RMSE	R-SQUARE
Back propagation network 6 neurons.	P(t-1)	0.521	0.776
	P(t-1)...P(t-5)	0.245	0.856
Back propagation network 10 neurons.	P(t-1)	0.342	0.814
	P(t-1)...P(t-5)	0.132	0.891

Table -1: Goodness of fit for the effect of no. of previous day input rainfall parameters.

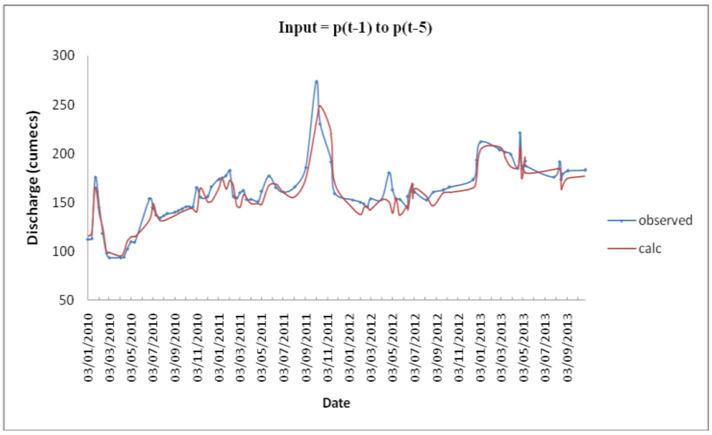

Fig -5: Observed vs. predicted discharge, P(t-1) to P(t-5) for RBF network.

Table -2: Statistical indices of RBF model for various inputs.

NETWORK	INPUTS	RMSE	R-SQUARE
RBF	P(t-1)	0.097	0.912
	P(t-1)...P(t-5)	0.046	0.937

The statistical analysis shows that the performance of this network increases as the number rainfall inputs increase from one to five i.e. from p(t-1) to p(t-1)....p(t-5).

3. CONCLUSIONS

From the values of R^2 and RMSE it was observed that radial basis function networks (RBF) were able to predict the runoff more accurately than Back propagation networks (BPN). BPN network performed better when the numbers of neurons in the hidden layer were increased upto 10. On increasing the number of neurons further, the network showed no considerable improvement in performance. The radial function model (RBF) gave better results compared to BPN networks with RMSE = 0.046 and was able to predict the stream at the Padshahi-Bagh station more accurately than the other networks.

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