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"Rainfall-Runoff Modeling for River Lidder Catchment" J&K, (India)

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Abstract—*The goal of this investigation was to develop rainfall-runoff model for the river Lidder that is capable of accurately modelling the relationships between rainfall and runoff in a catchment. Two types of ANN models viz. Back Propagation networks (BPN) and (RBF) were developed and tested for this data. Linear regression models were developed and then compared with the different ANN networks for determining the best suited model. For modelling the rainfall-runoff process in river Lidder, the input i.e. the precipitation was determined by taking the data from three rain gauge stations viz. Pahalgam for years 2000-2014.The runoff data was taken for Gur gauging station for the years 2000-2014.The network architecture in the back propagation network was changed by changing the number of neurons in the hidden layer. The analysis of performance of the various models was carried out by statistical analysis technique. The comparison was based on various statistical parameters like root mean square error (RMSE) and R^2. From the predicative analysis, it was found that the flow at the Gur station on any given day is dependent on previous three day flow. The developed ANN model was found performing to a good degree of accuracy compared to other models. The artificial neural networks (ANNs) performed much better than the linear regression models. Among the various ANN models developed (Back Propagation Network) with function TRANSLIM (R^2=0.994) showed better overall performance than the Function TRANSCG (R^2=0.993).From the various models then used for modelling individual hydrographs and it was seen that artificial neural networks (ANN's) proved to be superior to linear regression model.*

Introduction:-

In September 2014 the Jammu and Kashmir state and adjoining areas received heavy rainfall during last stage of monsoon in India. This triggered flooding and landslides in Kashmir region of Jammu and Kashmir. On 5 September, the Jhelum river in Srinagar was reported to be flowing at 22.40 feet (6.83 m) which was 4.40 feet (1.34 m) above the danger mark. The discharge rate in the river was recorded as 70,000 cusecs against the normal predicted discharge of 25,000 cusecs. These rivers flooded into the streets causing heavy casualties and loss of property. 50 bridges were reported to have been damaged across the state. The preliminary assessment of damages to property was estimated between INR 5000 cr to INR 6000 cr. There was a total estimated loss of 1 trillion to Kashmir division alone. By 24 September 2014, nearly 277 people had died due to the floods. This was the huge failure regarding rainfall forecasting and disposal of runoff. This instigated us to carry out our project rainfall runoff modelling on one of the tributary of river Jehlum named **lidder nallah** and to develop latest rainfall runoff model for Lidder.

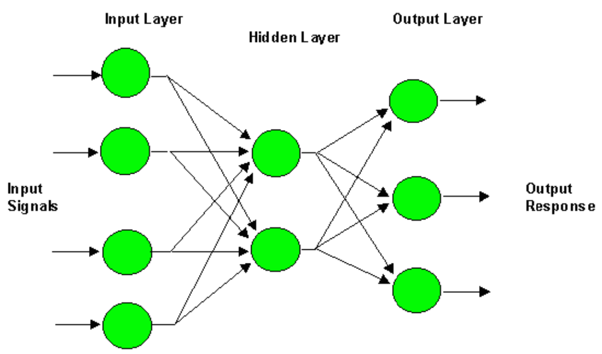
Objectives:-

The goal of this investigation was to develop rainfall-runoff model for the river Lidder catchment that is capable of accurately modelling the relationships between rainfall and runoff in a catchment. Further, this project is aimed to achieve various goals as mentioned below:-

- Development of the rainfall-runoff model for river Lidder using Linear Regression.
- Development of the Rainfall-Runoff model for river Lidder using various Artificial Neural Networks and predict the stream flow.
- Validation of Artificial Neural Network and Linear Regression models.
- Comparison between Artificial Neural Network Models and the Linear Regression model and select the best fit rainfall-runoff model in river LIDDER at the PAHALGAM Station.

Method and Approach:-

In order to predict this information, the transformation of rainfall on a catchment to runoff from it must be modelled. One approach to this modelling issue is to use empirical Rainfall-Runoff (R-R) models. Empirical models simulate catchment behaviour by parameterisation of the relations that the model extracts from sample input and output data. 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. 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. Artificial neural networks (ANNs) have analogies with biological neural networks, such as nervous systems. Two types of ANN models viz. Back Propagation networks (BPN) and (RBF) were developed and tested for this data. Linear regression models were developed and then compared with the different ANN networks for determining the best suited model.



Single Layer Neural Network

A linear regression model is also used for the development of rainfall runoff relationship.A linear regression model is a linear model that describes how y variable is related to x variable.

The general structure of the model is as given below:

$Y=\beta_o+\beta_1X_1+\beta_2X_2+\ldots$

A linear model is one that is linear in the beta coefficients, meaning that each beta coefficient simply multiplies to an x-variable. Linear regression analysis was performed using MS-Excel Data Analysis Tool Pack. The best fit is calculated for the given dataset. The regression model used for prediction was:

$$y = a_0 + a_1x_{1+\ldots}a_px_p + \varepsilon$$

Where, y is the dependent (or response) variable, x is independent (or predictor) variable and $\mathcal{E}$ is the error term.

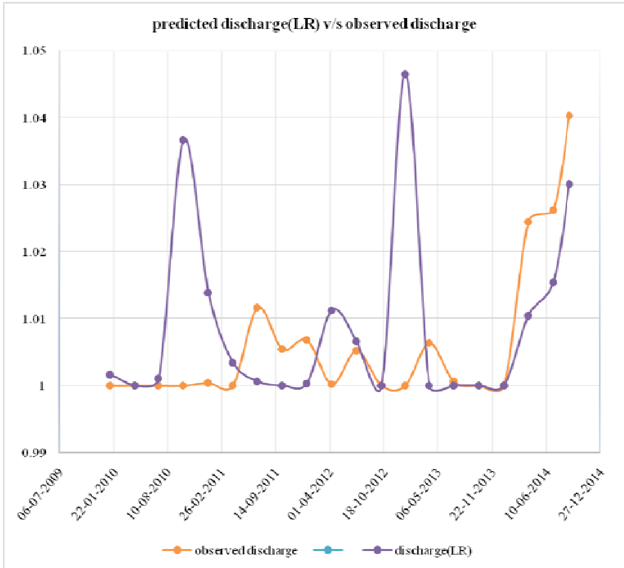
For modelling the rainfall-runoff process in river Lidder nallah ,the input i.e. the precipitation was determined by taking the data from three rain gauge stations viz. Pahalgam for years 2000-2014.The runoff data was taken for Gur gauging station for the years 2000-2014. The network architecture in the back propagation network was changed by changing the number of neurons in the hidden layer. The analysis of performance of the various models was carried out by statistical analysis technique .The comparison was based on various statistical parameters like root mean square error (RMSE) and R^2.

Results:-

From the predicative analysis, it was found that the flow at the Gur station on any given day is dependent on previous three day flow.

Results obtained from linear regression analysis:-

The LR model was first trained for the years 2000-2010 and then validated for 2010-2014.The graph shown below gives the variation of the actual discharge against the predicted discharge through linear regression:-

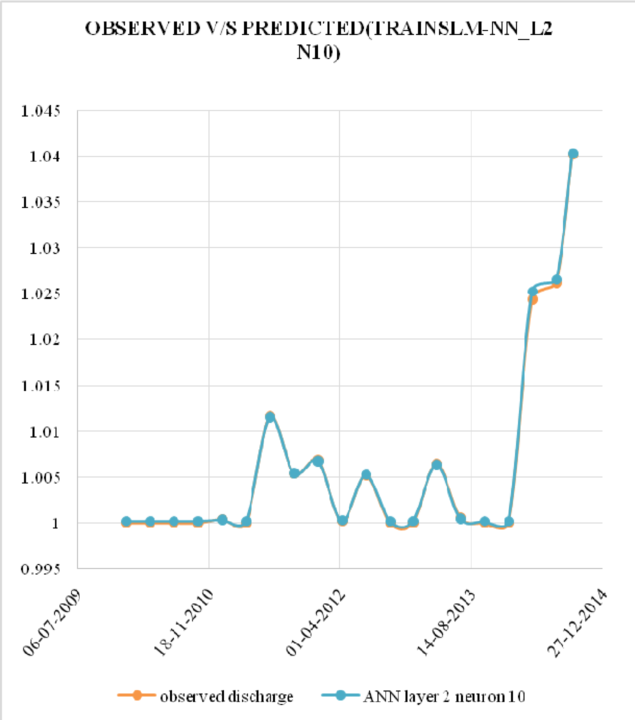


The parameters determined by the linear regression analysis are :-

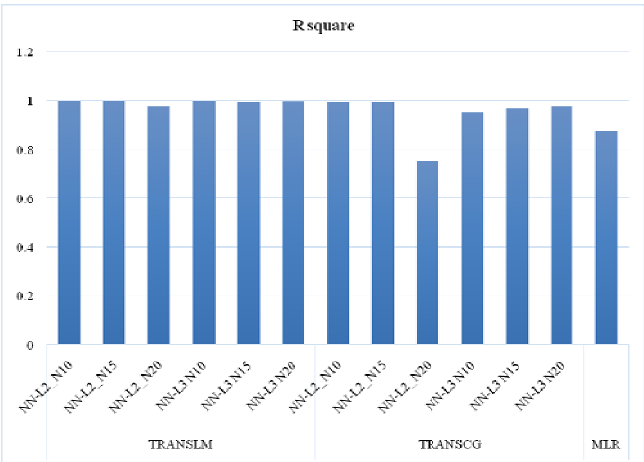
R	.92598
R^2	.857439
RMSE	.134

Results obtained from neural network analysis:-

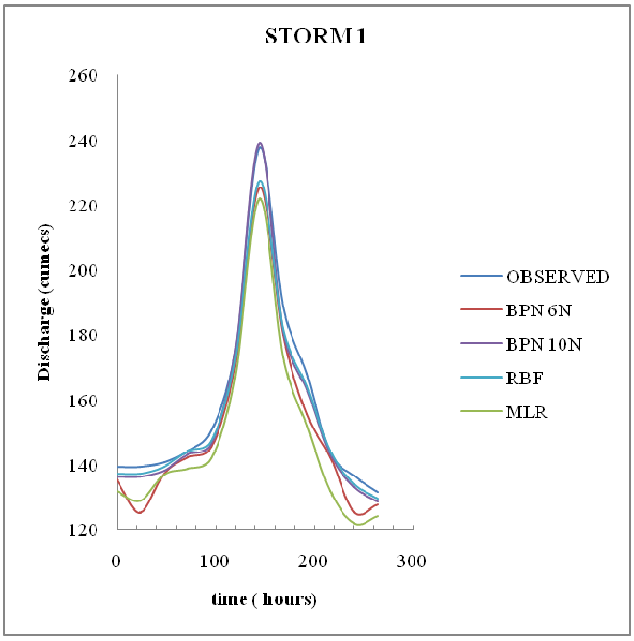
The ANN model was first trained for the years 2000-2010 and then validated for 2010-2014.Among the various functions and number of neurons used for the development of ann model, it has been seen that trainlm function with 2 layers and 10 neurons gives the most optimistic results. The graph shown below gives the variation of the actual discharge against the predicted discharge using trainlm function with 2 hidden layers and 10 neurons:-



The developed ANN model was found performing to a good degree of accuracy compared to other models. The artificial neural networks (ANNs) performed much better than the linear regression models. Among the various ANN models developed (Back Propogation Network) with function TRAINLM (R^2=0.994) showed better overall performance than the Function TRAINSCG (R^2=0.993). Coefficient of determination for various models are graphically represented as:-



The models developed were also used for the prediction of individual flood hydrographs to assess their performance. For this two individual storms were selected. These two storm were selected for two different years viz. storm 1 was selected from year 2010 and storm 2 was selected from year 2012. The input vectors were selected in the same was as in the already developed models i.e. previous five day rainfall data and previous three day flow data was provides as inputs for different models. The performance of various models is shown in the graphs below. The graphs of observed Vs predicted hydrographs for various models are shown in graphics below:-



Conclusion:-

The present study was intended to develop a rainfall-runoff model for the river Lidder catchment using black-box models which makes it possible to predict the runoff resulting from a given amount of precipitation over the catchment without the knowledge of the various features of the catchment. Two models viz. linear regression (LR) and Artificial Neural Network (ANN) were developed and validated. The performance of these models was represented by various statistical indices like RMSE and R^2. On comparing the performance of various models, artificial neural networks proved to be better in the rainfall-runoff modeling of river Lidder catchment than MLR. Among the various models developed (Back Propagation Network) with function TRAINLM (R^2=0.994) showed better overall performance than the Function TRAINSCG (R^2=0.993).

The following conclusions can be drawn from this study:

- From the predicative analysis it can be concluded that the discharge at Gur is dependent upon previous three days flow.
- The number of previous day rainfall inputs affecting the runoff was determined by hit and trial method and it was observed that the models.

- LR models showed good agreement between observed and calculated runoffs with coefficient of determination i.e. $R^2 = 0.8574$.
- BPN was optimized for two functions TRANSLM and TRANSCG having 5, 10 and 20 neurons in the two hidden layers and same for when number of layers changed to three it was found that network performed better when the function used is TRANSLM with number of layers used are 2 and number of neurons in the hidden layer were increased up-to 10. On increasing the number of neurons further, the network showed no considerable improvement in performance.
- BPN with function TRANSLM proved to be more efficient than TRANSCG as values of RMSE determined by function TRANSLM are more conservative than those calculated by TRANSCG.
- Among the various layers and neurons used in BPN with function TRANSLIM, LAYERS 2 10N (RMSE=0.000214) proved to be more efficient that BPN TRANSLIM LAYER 2 15N (RMSE=0.000367) and BPN TRANSLIM LAYER 2 20N (RMSE=0.00137).
- On the basis of AIC and BIC criteria, BPN 5N and BPN 10N were found to be more efficient than BPN 20N. Among the three BPN models, BPN 10N proved to be most efficient.
- It can be concluded that among the various rainfall runoff models used in this study radial basis function model was able to predict the stream at the Gur station more accurately than the other networks.
- For the modeling of individual hydrographs ANN's proved to be far better than LR.
- For the prediction of individual hydrographs BPN TRANSLM 10N (RMSE= 0.000214) again proves to be better than all other models developed.

Hence it can be concluded that the back propogation network (BPN) developed might be employed for Rainfall-Runoff modeling for river Lidder. It can provide a viable alternative when the hydrologic application requires that an accurate forecast of stream flow be provided using only the available input-output time series data and with relatively less conceptual understanding of the hydrologic dynamics of the basin under investigation.

Suggestions for future work:-

Some recommendations have been given for expanding the given research to multiple dimensions. These include the following:

- The present models were developed by taking the rainfall-runoff data sets spanning throughout the year. Further study can be carries out by modeling on seasonal basis.
- In present study rainfall-runoff prediction models were developed only for the Gur station. Further research can be done by predicting the runoff in river Lidder for all the other major stations.