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RAINFALL SIMULATION USING CO-ACTIVE NEURO FUZZY INFERENCE SYSTEM (CANFIS) AND MULTI LINEAR REGRESSION METHOD (MLR)

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Abstract - *Rainfall prediction is one of the most important and challenging task in the modern world. In this study, we attempted to forecast the daily rainfall on the basis of Co-active neuro-fuzzy inference system (CANFIS) and Multi Linear Regression (MLR) techniques. Fifteen CANFIS models and MLR were selected based on the performance evaluation indices during testing period. CANFIS models were found to be much closer to the observed values of rainfall as compared to MLR.*

Key Words*: *Rainfall Simulation, CANFIS, MLR

1. INTRODUCTION

The rainfall forecast information is an essential requirement to support water resources management especially when it is related to climate change .An accurate long-term rainfall prediction is necessary for water resources management, food production and maintaining flood risks. The important factors of a hydrological model are precipitation, infiltration, stream flow, interception, evaporation, transpiration, variability in time and space. The main purpose of this paper is to compare and analyze the performance of the CANFIS and MLR to see their applicability in rainfall forecasting.

2. LITERATURE REVIEW

Otair and Salameh (2016) presented the enhanced version of delta-bar-delta (EVDBD) through applying the Delta-Bar-Delta on Optical Backpropagation (OBP) to adapt its weights rather than standard Backpropagation (BP). The feasibility of the proposed algorithm is shown through experiments on a three training problems: Xor, encoder, and optical character recognition with different architectures. A comparative study has been done to solve these problems by using different algorithms, and the performance of the EVDBD is shown.

Sachan and Kumar (2017) proposed and compared one conjunction model combining wavelet-neuro-fuzzy for runoff forecast with simple neuro-fuzzy inference system. The inflow series to the conjunction model has been decomposed by wavelet transform. The performance of the conjunction model under the changed inflow parameters has been compared with the simple model. The results show that both the model performed well, however, increase in complexity of a model does not necessarily increase the performance of the model.

Kisi et al. (2017) utilized four heuristic approaches, multi-layer perceptron neural network (MLPNN), co-active neuro-fuzzy inference system (CANFIS), radial basis neural network (RBNN) and self-organizing map neural network (SOMNN) to estimate monthly pan-evaporation (EPm) at two locations, Pantnagar and Ranichauri, in the foothills of Indian central Himalayas.

Malik et al. (2018) used Co-active Neuro Fuzzy Inference System (CANFIS) and Multi-layer Perceptron Neural Network approaches for daily rainfall-runoff modeling in the hilly Naula Watershed of Ramganga River in Uttarakhand. The daily rainfall and runoff data from June 1, 2000 to October 31, 2004 were used for training and testing of applied models. Gamma Test was also used for determining best combinations of input variables for each model. The simulated values of runoff from CANFIS and MLPNN models were compared with the observed ones with respect to root mean squared error (RMSE), Nash-Sutcliffe efficiency (CE), Pearson correlation coefficient (PCC).The study provides conclusive evidence that the CANFIS shows better accuracy than the MLPNN model.

3. MATERIALS AND METHOD

The area selected for study is Gadarwara Narsinghpur district in the state of Madhya Pradesh, India, located at 22.92°N 78.78°E. The daily data of rainfall for monsoon season June 2005 to September 2014 were used. Total data of monsoon season for 10 years were divided into two sets: (i) training data set consisting of first 8 years data from 1 June 2005 to 31 September 2012; and (ii) testing data set consisting of remaining 2 years data from 1 June 2013 to 31September2014.

In this study, the soft computing technique based on ANN, Co-active neuro fuzzy interface system (CANFIS) and

Multi Linear Regression (MLR) has been developed for simulating the total rainfall in Gadarwara (M.P). The methodology of developing the CANFIS models along with training and testing of developed models, the Neuro Solution 5.0 software and Microsoft Excel were used in analysis and the performance evaluation indices for developed models.

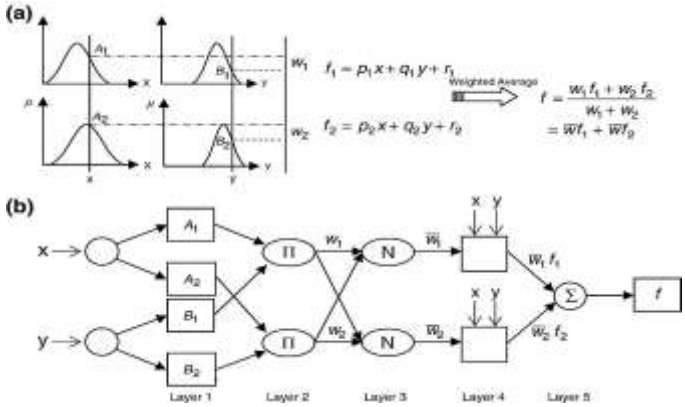

Fig. 3.1 A basic overview of CANFIS structure.

In this study, membership functions (Gaussian) is used. Choosing the number of membership functions for each input reflects the complexity of CANFIS model for selecting parameters. In each application, a different number of membership functions were tried, and the best one that gives the minimum errors was selected.

Model No.	Input-Output Variables
CANFIS-1	Rt = f (T_{min})
CANFIS-2	Rt = f (T_{max})
CANFIS-3	Rt = f (W_s)
CANFIS-4	Rt= f (R_s)
CANFIS-5	Rt= f (T_{min}, T_{max})
CANFIS-6	Rt= f (T_{min}, W_s)
CANFIS-7	Rt= f (T_{min}, R_s)
CANFIS-8	Rt= f (T_{max}, W_s)
CANFIS-9	Rt= f (T_{max}, R_s)
CANFIS-10	Rt= f (W_s, R_s)
CANFIS-11	Rt= f (T_{min}, T_{max}, W_s)
CANFIS-12	Rt= f (T_{min}, T_{max}, R_s)
CANFIS-13	Rt= f (T_{min}, W_s, R_s)
CANFIS-14	Rt= f (T_{max}, W_S, R_s)
CANFIS-15	Rt= f (T_{min}, T_{max} , W_s , R_s)

Table 3.1-Input-output combination for CANFIS models for rainfall simulation at Gadarwara city of M.P

The daily data of rainfall and meteorological data (temperature, solar radiation, wind speed) on daily basis were split into two sets: a training data set from 2005 to 2012 and a testing data set from 2013 to 2014 for Gadarwara city. The input pairs in the training data set were applied to the network of a selected architecture and training was performed using CANFIS.

The model attempts to reproduce the outcome based on the learning or training on data input information. In ANN model of the biological neurons, there are three basic components such as:

I. **Synapses**: The synapses of the neuron are modeled as weights which represent the strength of the connectivity between an input and a neuron.
II. **Adder**: This activity is referred to as linear combination which sums up all the inputs modified by their respective weights and is the actual activity within the neuron cell.
III. **Activation function**: The activation function controls the amplitude of the output of the neuron.

Multiple Linear Regression(MLR)

Multiple Linear Regression(MLR) is simply extended form of Simple regression in which two or more variables are independent variables are used and can be expressed as **(Kumar and Malik, 2015)**:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots\ldots \beta_p X_p$$

Where,

Y = Dependent variable;
α = Constant or intercept;
β1 = Slope (Beta coefficient) for X1;
X1 =First independent variable that is explaining the variance in Y;
β2 = Slope (Beta coefficient) for X2;
X2 = Second independent variable that is explaining the variance in Y;
p= Number of independent variables;
βp= Slope coefficient for Xp;
Xp= pth independent variable explaining the variance in Y.

4. RESULTS AND DISCUSSION

The performances of models were evaluated qualitatively and quantitatively by visual observation and various statistical and hydrological indices viz. mean square error (MSE), correlation coefficient (r) and coefficient of efficiency (CE). The model having higher values of correlation coefficient and coefficient of efficiency and low value of mean square error is consider as the best fit model.

4.1 Rainfall modeling using CANFIS

CANFIS models (Table 3.1) were used to simulate rainfall as output based on various input combinations of minimum and maximum temperature, wind speed and solar radiation. CANFIS model Nos. 4, 2, 3,6, were selected for further analysis and comparison based on the statistical indices, such as mean squared error (MSE), coefficient of efficiency (CE) and correlation coefficient (r). The values of statistical indices for the selected CANFIS models during testing are presented in Tables 4.1 respectively.

Table 4.1 Statistical indices for selected CANFIS models during testing phase for GADARWARA.

Model No.	MF per input	Testing			
		MSE	CE	r	R^2
CANFIS-4	Gauss-6	0.0064	0.5793	0.9224	0.8509
CANFIS-2	Gauss-2	0.0072	0.5237	0.9156	0.8385
CANFIS-3	Gauss-2	0.0077	0.4911	0.8395	0.7048
CANFIS-6	Gauss-6	0.0086	0.4321	0.8167	0.6670
CANFIS-7	Gauss-2	0.0077	0.4890	0.8651	0.7485

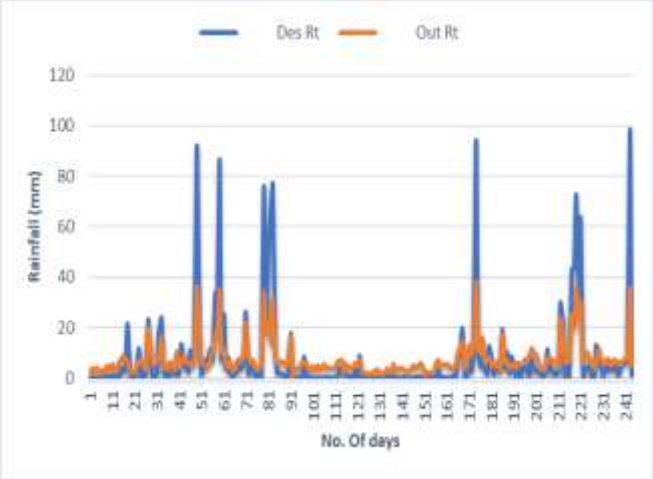

Fig 4.1 Comparison of observed and predicted rainfall by CANFIS-4, Gauss-6 during the validation period

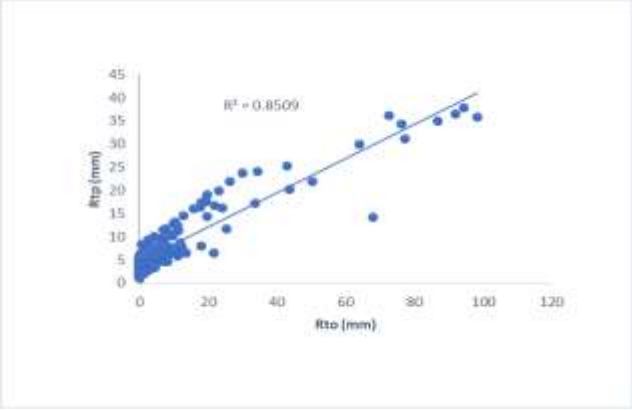

Fig 4.2 Correlation between observed and predicted rainfall by CANFIS- 4, Gauss-6 during the validation period4.2

Rainfall modeling using MLR

Universal processes of forecasting rainfall amount involve Data collection, data preprocessing and data selection, Reduction of explanatory predictor, building model using regression and at the last validity check.

Table 4.2 Statistical indices for selected MLR models during testing phase for GADARWARA.

Model No.	Testing			
	MSE	CE	r	R2
MLR-12	202.1568	0.2515	0.5012	0.2515
MLR-13	203.8248	0.2450	0.4950	0.2450
MLR-14	205.1342	0.2401	0.4900	0.2401
MLR-9	205.6508	0.2382	0.4881	0.2382
MLR-4	205.8523	0.2375	0.4873	0.2375

4. CONCLUSION

In this study, we attempted to forecast the daily rainfall on the basis of Co-active neuro-fuzzy inference system (CANFIS) and Multi Linear Regression (MLR) techniques. On the basis of lower values of MSE (0.0056) and higher CE (0.5793) and r (0.9224) in the testing phase, the CANFIS 4 model were found to be the best performing model. The predicted rainfall using CANFIS models were found to be much closer to the observed values of rainfall as compared to MLR.

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