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Forecasting of Rain Fall in Mirzapur District, Uttar Pradesh, India Using Feed-Forward Artificial Neural Network

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ABSTRACT: *Rain fall is a major component of ecosystem and important role in hydrological cycle. It is recharged ground naturally. Rain fall percolate through pores of space of soil and enhance groundwater availability result in increasing level of groundwater. A feed-forward neural network model has been developed and trained with Levenberg Marquardt Back Propagation Algorithm for forecasting of rain fall in Mirzapur district, Uttar Pradesh, India. Monthly temperature (average, diurnal, maximum and minimum), evaporation (Potential and Reference crop), relative humidity, cloud cover and frequency (ground frost and wet day) have been chosen for inputs and rain fall for targets. The good results of the artificial neural network (ANN) model is depend upon the high correlation between actual and predicted value of rain fall. The regression coefficient (R^2) was calculated for efficiency and accuracy of developed model. For best fitting of developed model, the predicted trend followed the observed trend closely (regression coefficient (R^2) = 0.9858) and other statistics parameters of artificial neural network (ANN) of model were calculated such as mean, standard deviation (S.D.), and error mean, error standard deviation (error S.D.) and standard deviation ratio (S.D. ratio).*

KEYWORDS: *Artificial neural network (ANN), Rain fall, Back propagation feed-forward, Forecasting, Mirzapur*

I. INTRODUCTION

Rain fall process is essentially random in nature. It is important role in hydrological cycle. Due to rain fall natural recharge take place and it follows rising of groundwater level. Rainfall forecasting is one of the most difficult and important processes of the hydrologic cycle. This is largely related to the variability it displays over a wide range of scales both in time and space [1].

Flash flooding, being a product of intense rainfall, is a life-threatening phenomenon. Developing a rainfall forecasting and flood warning system for typical catchments is not considered a simple task. Both internal and external characteristics of rainfall field depend on many factors including: pressure, temperature, wind speed and its direction, meteorological characteristics of the catchments and so on. Although a physically-based approach for rainfall forecasting has several advantages, given the short time scale, the small catchments area, and the massive costs associated with collecting the required meteorological data, it is not a feasible alternative in most cases because it involves many variables which are interconnected in a very complicated way [2]. Artificial neural network (ANN) has been widely used on pattern/speech recognition and image/signal processing in a variety of fields [3].

II. LOCATION & GEOGRAPHICAL OF THE STUDY AREA

The study area extended over Mirzapur district and is the part of south-east Uttar Pradesh, shown in Fig.1. It is bounded in north by Sant Ravidas Nagar district, in south by Sonbhadra district & Rewa District of Madhya Pradesh, in east by Chandauli district, in West by Allahabad district and in north-west by Varanasi. It situated between latitudes 24^0 20’ 24’’ to 25^0 09’ 36’’ north and longitudes 82^0 30’ 00’’ to 83^0 06’ 36’’ east and total area approximately 4522 sq. kms. It has an average elevation of 80 metres (265 feet).

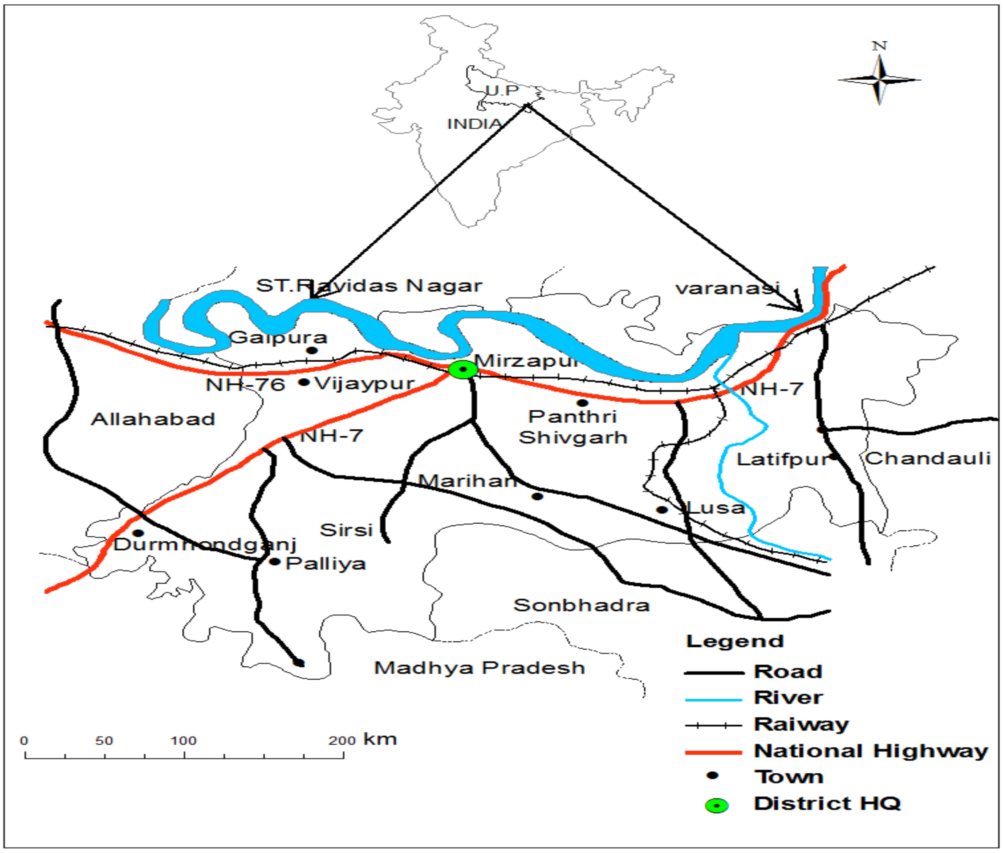


Fig. 1: Map of the study area

III. ARTIFICIAL NEURAL NETWORK (ANN)

Artificial neural networks (ANNs) started about 47 years ago, when the theory of perceptron was presented by Rosenblatt (1962). During the mid-1960s, the interest in the artificial neural network (ANN) decreased, because of the limitations of the theory of perceptron [4]. Since new ANN paradigms have overcome some of these limitations, the artificial neural network (ANN) has emerged again as an active research area within computer science, engineering, physics and geophysics [5].In recent years, Artificial neural networks (ANNs) have become extremely popular for prediction and forecasting in a number of areas, including finance, power generation, medicine, water resources and environmental science [1].The Artificial neural network (ANN) is computational tool based on the biological nervous systems. Artificial neural network (ANN) is composed of three essentials: neurons, architecture and learning paradigm. Neurons are fundamental elements of a network and are interconnected in a definite rule to form architecture through network weights. The learning paradigm refers to the method that the network weights are adjusted [6].

IV. FEED-FORWARD NEURAL NETWORK (FNN)

The Feed-forward neural networks have been applied successfully in many different problems since the advent of the error backpropagation learning algorithm. This network architecture and the corresponding learning algorithm can be viewed as a generalization of the popular least-mean-square (LMS) algorithm [7-8].

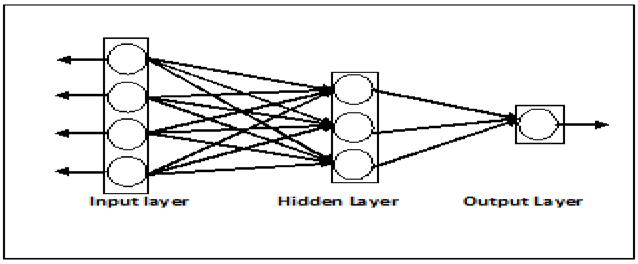


Fig. 2: Architecture of the Artificial Neural Network (ANN) model

A multilayer perceptron network consists of an input layer, one or more hidden layers of computation nodes, and an output layer. Figure 2 shows a typical feed-forward network with one hidden layer consisting of three nodes, four input neurons and one output. The input signal propagates through the network in a forward direction, layer by layer. Their main advantage is that they are easy to handle, and can approximate any input/output map, as established by Hornik et al. (1989). The key disadvantages are that they train slowly, and require lots of training data (typically three times more training samples than network weights) [8].

V. TRAINING AND TESTING WITH LEVENBERG-MARQUARDT BACK PROPAGATION ALGORITHM (LMB)

The Levenberg–Marquardt method is a modification of the classic Newton algorithm for finding an optimum solution to a minimization problem. It uses an approximation to the Hessian matrix in the following Newton-like weight update

$$x_{k+1} = x_k - [J^T J + \mu I]^{-1} J^T e \qquad (1)$$

where x the weights of neural network, J the Jacobian matrix of the performance criteria to be minimized, μ a scalar that controls the learning process and e the residual error vector.

When the scalar μ is zero, Eq. (1) is just the Newton's method, using the approximate Hessian matrix. When μ is large, Eq. (1) becomes gradient descent with a small step size. Newton's method is faster and more accurate near an error minimum, so the aim is to shift towards Newton's method as quickly as possible [8].

Here, seven years (1995-2002) monthly rain fall data have been used for targets data and other metrological parameters such as monthly temperature (average, diurnal, maximum and minimum), evaporation (Potential and Reference crop), relative humidity, cloud cover and frequency (ground frost and wet day) have been used for inputs data.

VI. Statistics of Artificial Neural Network ANN Model

The regression coefficient (R^2) was measured for efficiency and accuracy of developed model and calculated by

$$R^2 = 1 - \frac{\sum (y_i - \bar{y}_i)^2}{\sum y_i^2 - \frac{\sum \bar{y}_i^2}{n}} \qquad (2)$$

where R^2 is regression coefficient

y_i is the observed data

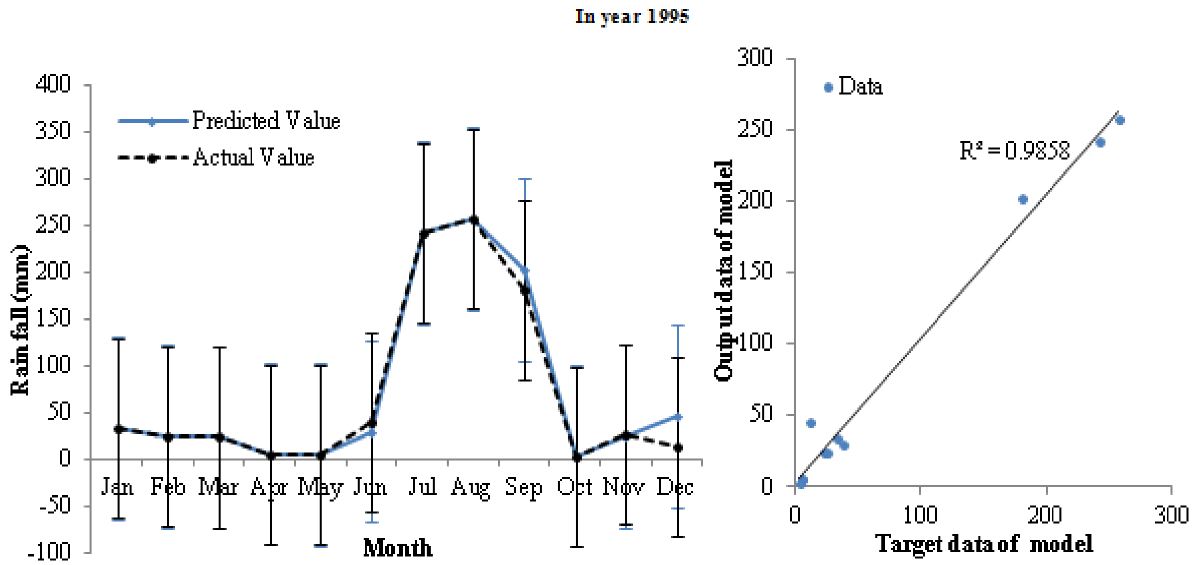
$\bar{y}_i$ is the calculated data

n is the number of observations.

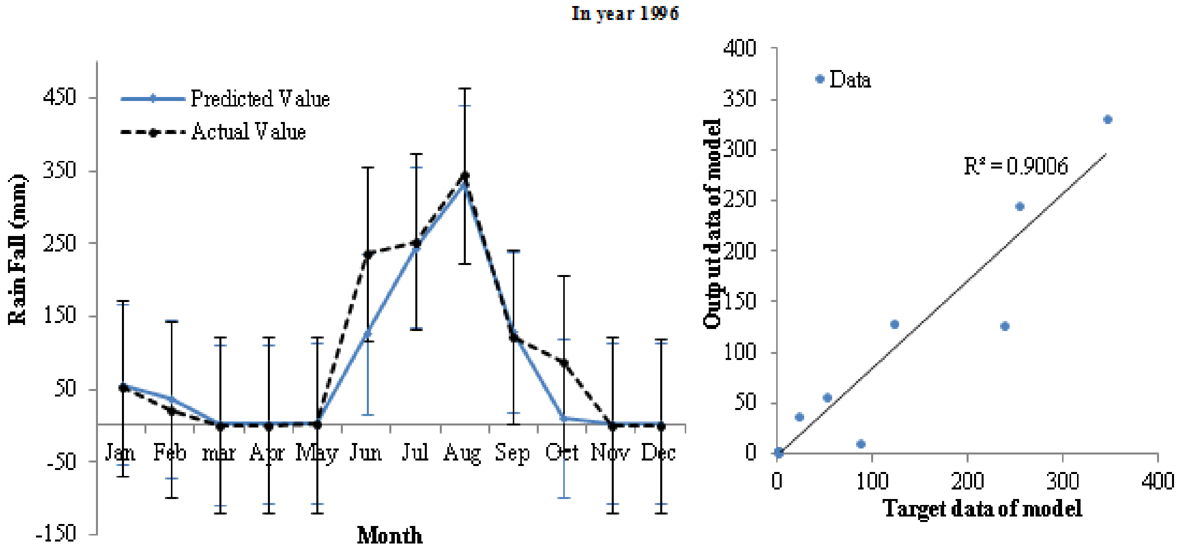
Regression analysis is utilized to measure the degree of correlation between the actual output and the network output. Regression coefficient (R^2) of 1 gives an indication of a perfect model while an (R^2) of 0 indicates a very bad model. A perfect prediction will have a regression coefficient of 1.0. A correlation of 1.0 does not necessarily indicate a perfect prediction (only a prediction which is perfectly linearly correlated with the actual outputs), although in practice the regression coefficient is a good indicator of performance. Other statistics parameters of Artificial Neural Network (ANN) of model were calculated such as mean, standard deviation (S.D.), and error mean, error standard deviation (error S.D.) and standard deviation ratio (S.D. ratio) shown in table 1 [9].

VII. RESULTS AND DISCUSSION

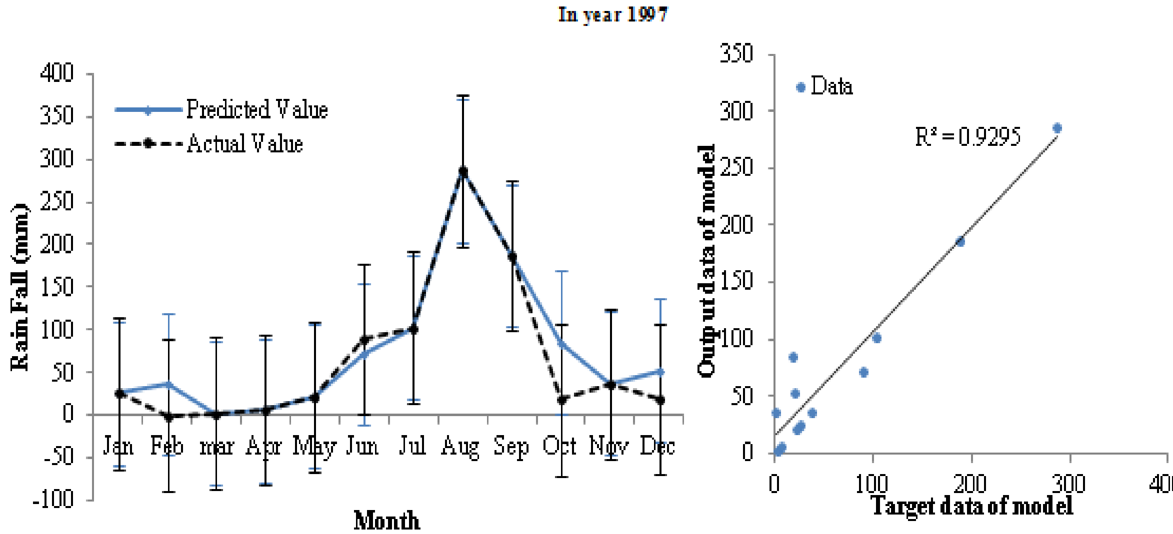
Deciding the number of neurons in the hidden layers is a very important part of deciding overall neural network architecture. There are many rule-of-thumb methods for determining the correct number of neurons to use in the hidden layers, such as (1) The number of hidden neurons should be between the size of the input layer and the size of the output layer (2) The number of hidden neurons should be 2/3 the size of the input layer, plus the size of the output layer (3) The number of hidden neurons should be less than twice the size of the input layer[10].


In year 1995
Predicted Value
Actual Value
Rain fall (mm)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Data
R² = 0.9858
Output data of model
Target data of model

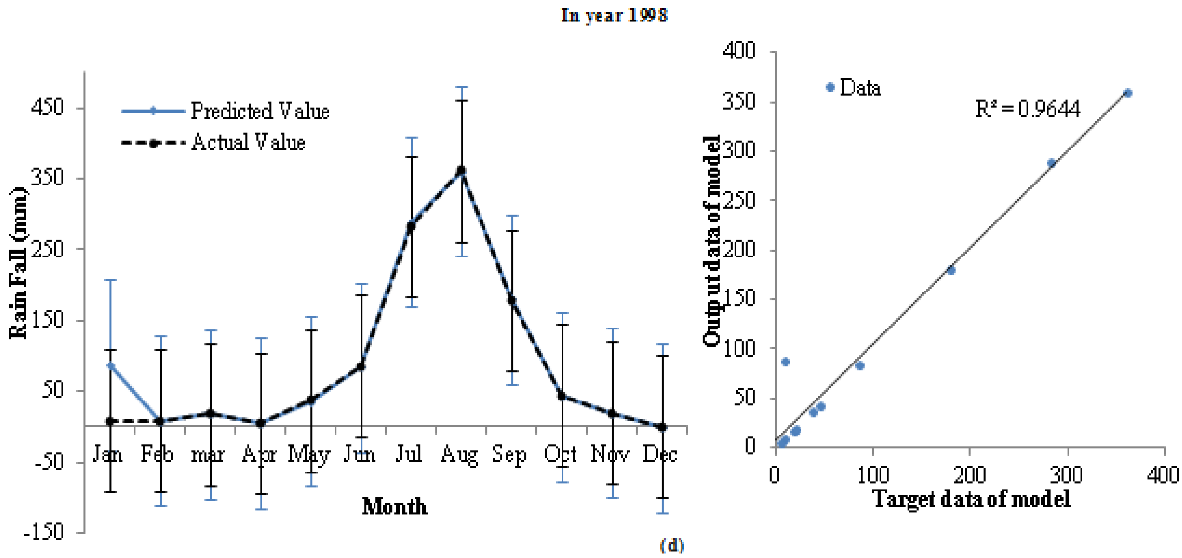
(a)


In year 1996
Predicted Value
Actual Value
Rain Fall (mm)
Jan Feb mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Data
R² = 0.9006
Output data of model
Target data of model

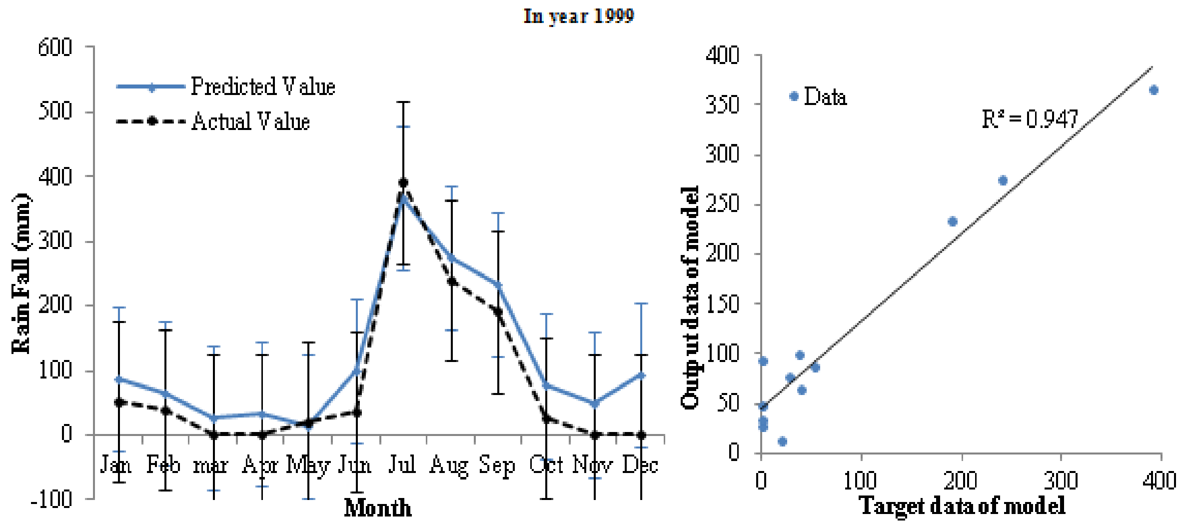
(b)


In year 1997
Predicted Value
Actual Value
Rain Fall (mm)
Jan Feb mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Data
R² = 0.9295
Output data of model
Target data of model

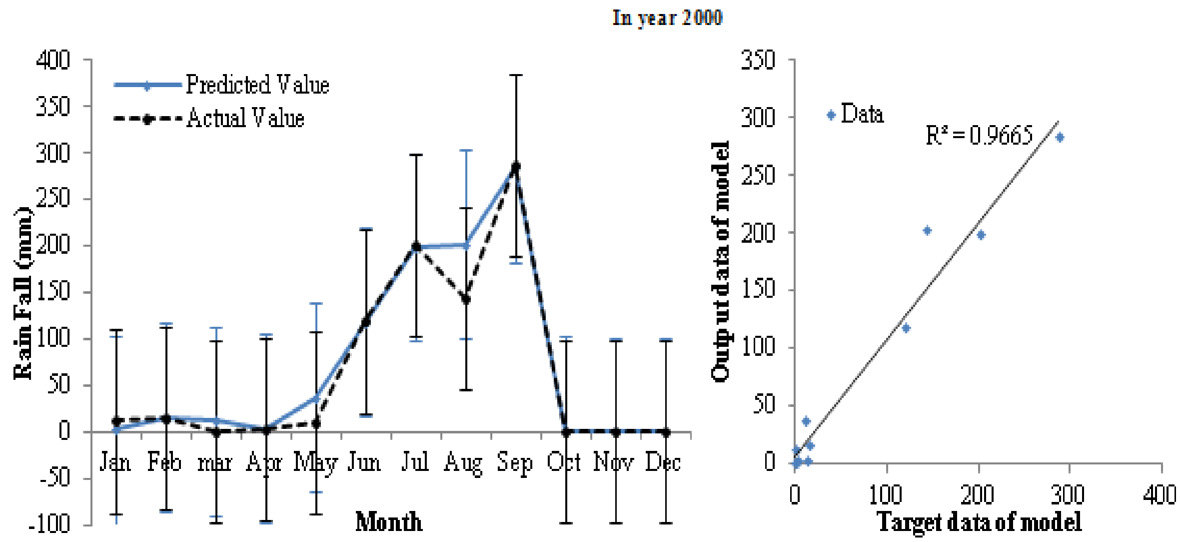
(c)


In year 1998
Predicted Value
Actual Value
Rain Fall (mm)
Month
Jan Feb mar Apr May Jun Jul Aug Sep Oct Nov Dec
Data
R² = 0.9644
Output data of model
Target data of model

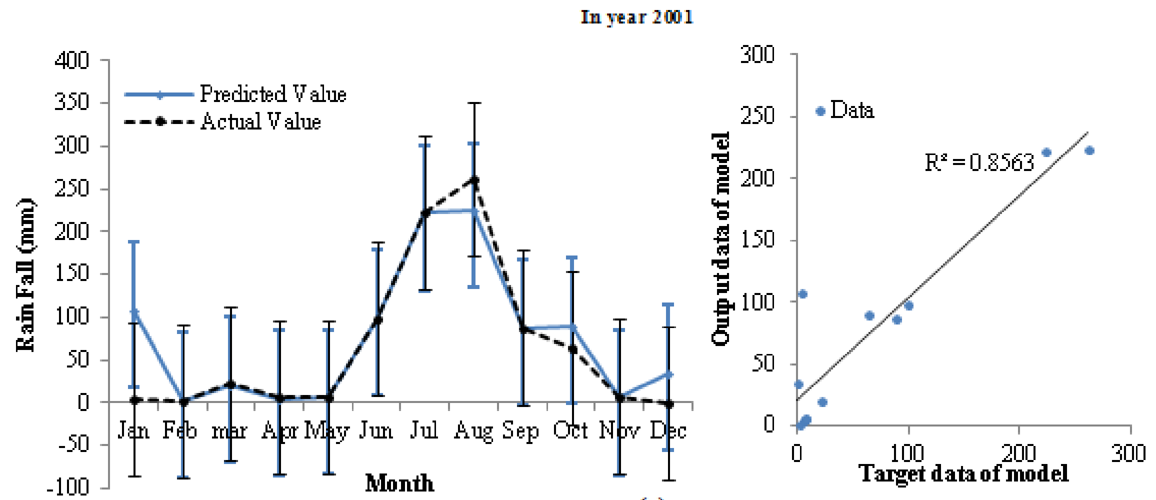
(d)


In year 1999
Predicted Value
Actual Value
Rain Fall (mm)
Month
Jan Feb mar Apr May Jun Jul Aug Sep Oct Nov Dec
Data
R² = 0.947
Output data of model
Target data of model

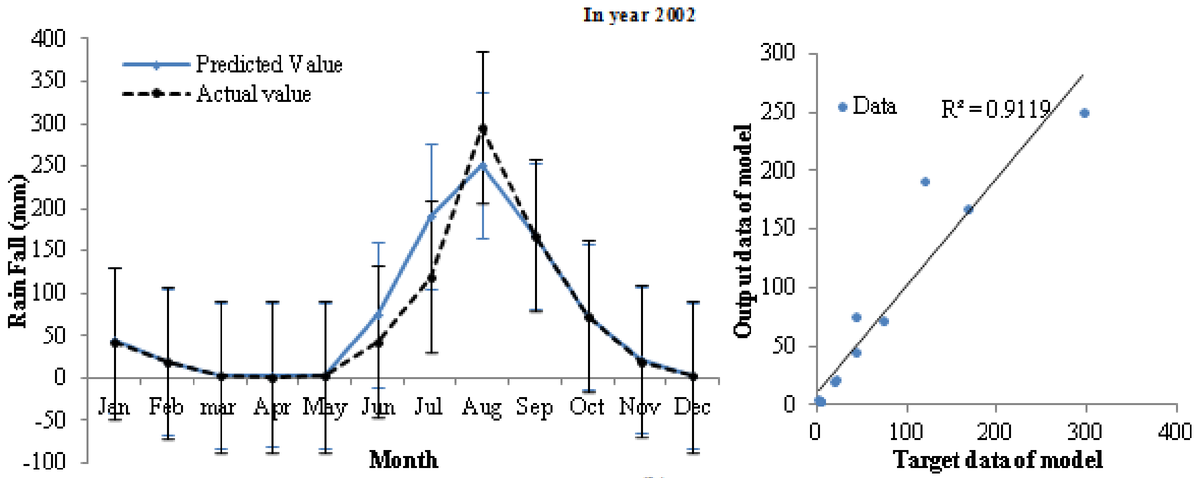
(e)


In year 2000
Predicted Value
Actual Value
Rain Fall (mm)
Month
Jan Feb mar Apr May Jun Jul Aug Sep Oct Nov Dec
Data
R² = 0.9665
Output data of model
Target data of model

(f)



(g)



(h)

Fig. 3a-h Trend of the model corresponds to the regression analysis of the model

Here, ten input layer such as temperature (average, diurnal, maximum and minimum), evaporation (Potential and Reference crop), relative humidity, cloud cover and frequency (ground frost and wet day) and one output layer such as rain fall have been chosen . So, according to thumb rule the number of hidden neurons should be less than twenty. Regression coefficient (R^2) have been calculated from Eq.2 and varies from 0.8563 to 0.9858.

Fig. 3a: This figure presented a comparison of predicted rain fall using artificial neural network (ANN) and the observed rain fall with the standard deviation and shows very high correlation between the observed and predicted values of rain fall. The regression coefficient (R^2) between the predicted and observed output values of the artificial neural network (ANN) model is 0.9858. The high value of regression coefficient (R^2) showed that the predicted trend of rain fall (model trend) using the artificial neural network (ANN) model followed the observed trend of rain fall and in between very good agreement which indicates, artificial neural network (ANN) model are helpful and applicable for prediction.

Fig. 3b: The number of hidden layer is 9 and the value of regression coefficient (R^2) is approximately 0.9006. It is closely to one. The model trend followed 75% to the observed trend shown in Fig. 3b and other statistics parameters has been calculated and shown in table 1.

Fig. 3c: The value of regression coefficient (R^2) is approximately 0.9295. The model trend followed 67% to the observed trend shown in Fig. 3c.

Fig. 3d: The number of hidden layer is 8 and the value of regression coefficient (R^2) is approximately 0.9644. It is closely to one. The model trend followed 90% to the observed trend shown in Fig. 3d and in between very good agreement.

Fig. 3e: The model trend followed only 34% to the observed trend shown in Fig. 3e and the predicted trend of rain fall (model trend) using the artificial neural network (ANN) model was not followed properly to the observed trend of rain fall and no good agreement in between.

Fig. 3f: The number of hidden layer is 9 and the value of regression coefficient (R^2) is approximately 0.9665. It is closely to one but the model trend followed only 67% to the observed trend shown in Fig. 3f.

Fig. 3g: The number of hidden layer is 9 and the value of regression coefficient (R^2) is approximately 0.8563. The model trend followed 67% to the observed trend shown in Fig. 3g and other statistics parameters shown in table 1.

Fig. 3 h: The model trend followed 75% to the observed trend shown in Fig. 3h. The number of hidden layer is 13 and the value of regression coefficient (R^2) is approximately 0.9119. It is closely to one and the predicted trend of rain fall (model trend) using the artificial neural network (ANN) model followed the observed trend of rain fall and in between very good agreement which indicates, artificial neural network (ANN) model are helpful and applicable for prediction.

Table 1: Network parameters, Regression coefficient (R^2) and other statistics parameters for the ANN model

Year	Hidden Neuron Layers	Learning rate (η)	Regression coefficient (R^2)	Mean	Standard Deviation	Error Mean	Error Standard Deviation	Standard Deviation Ratio
1995	10	1.00E-09	0.9858	74.457	97.422	3.599	1.497	0.0153
1996	9	1.00E-08	0.9006	79.298	109.652	14.208	10.845	0.0989
1997	12	1.00E-08	0.9295	76.560	83.604	9.909	4.854	0.0580
1998	8	1.00E-08	0.9644	93.992	119.910	6.555	1.351	0.0112
1999	11	1.00E-08	0.9470	118.390	112.010	34.967	12.651	0.1129
2000	9	1.00E-08	0.9665	75.286	101.435	9.180	2.937	0.0289
2001	9	1.00E-09	0.8563	75.596	79.986	10.318	10.109	0.1263
2002	13	1.00E-08	0.9119	72.571	85.313	6.565	3.983	0.0466

VIII. ACKNOWLEDGEMENT

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