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Monsoon Rainfall Forecasting by ANN Model in Ranchi, Jharkhand

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ABSTRACT

In this research paper, ANN model is utilized to forecast the monsoon rainfall using the monthly rainfall of January, February, March, April and May. Three different ANN models are deployed based on different transfer function. It is observed that the accuracy level of forecasting is affected by the transfer function. The Accuracy of forecasting is evaluated using the rainfall data for three years viz. 2021 to 2023 and is observed that the better accuracy is provided by the ANN model with Scaled Conjugate Gradient transfer function. It is also observed that the correlation coefficient of the testing phase is more important than training and validation phase. SCG ANN model has the highest correlation coefficient in testing phase. SCG model has an accuracy level of 88.80% for monsoon rainfall forecasting.

KEYWORDS: ANN model, Rainfall Forecasting, Monsoon Rainfall, Ranchi

1. INTRODUCTION

Rainfall is one of the main climatic variables which highly impacts the livelihood of human and biodiversity of environment. The majority of the fresh water on Earth is deposited by rainfall, which is a key element of the water cycle. It supplies water for crop irrigation and hydroelectric power facilities, as well as ideal circumstances for a variety of ecosystems. Extreme rainfall that falls in a short period of time can seriously harm the economy and occasionally even result in disastrous floods. Drought is caused by prolonged periods of insufficient rainfall. This may have an impact on developing nations' economic progress. Because of its impact on human existence, water resources, and water usage, rainfall estimation is crucial. It is exceedingly difficult to estimate rainfall because is influenced by regional and geographical differences and peculiarities. Some researchers are forecasting rainfall using time series analysis such as interpolation method, ARIMA model, SARIMA model, Exponential smoothing method, etc. and found a satisfactory level of accuracy [1-2]. Researchers have employed a variety of approaches to analyze time series data, and among these approaches—such as focused time delay neural networks, generalized regression, the Pearson coefficient technique, fuzzy inference systems, and others—Neural Network (NN) performance is acknowledged as the best choice. The Generalized Regression Neural Network was used in the development of the model [3], and it was compared with the Back Propagation Neural Network-based model. An accurate annual rainfall prediction was produced by the Generalized Regression Neural Network, which also produced a straightforward and stable structure. When the regression approach and the Pearson Coefficient Technique [4] were compared, it was discovered that the anticipated values for time series data analysis were lower than the computed value. In addition to the previously mentioned methods, the Fuzzy Inference System [5] was found to be a reliable substitute for precise prediction.

One widely accepted technique for visualizing complex, dynamic, nonlinear frameworks is the use of artificial neural networks (ANN). An artificial neural network (ANN) can be used to construct a suitable model in situations when the physical process relationship is unclear or the occasion's characteristics are unclear. Although the neural network necessitates historical data about the framework, it reduces the model's dependency on this historical data. This eliminates the need for a complete explanation of the precise real-world relationship type that the model seeks to address.

A multilayer neural network's architecture might contain several layers, each of which corresponds to a group of parallel processing units, also known as nodes [Figure 1]. Although a multilayer ANN can have several hidden layers, just one hidden layer is necessary for problem prediction. The network's ability to identify and record appropriate patterns in the data as well as perform composite non-linear mapping between the input and output variables is made possible by the hidden layer nodes. Transmitting external inputs to the hidden layer neurons is a crucial function of the input layer of nodes.

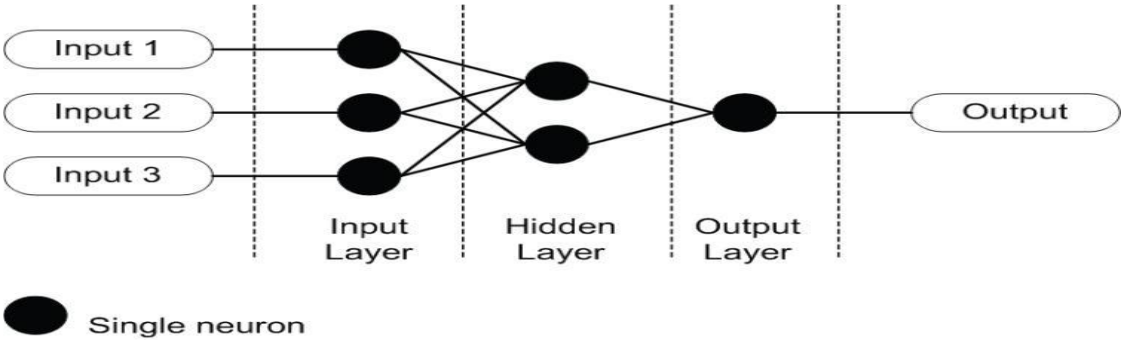


Figure 1: A simple three-layer neuron network

An ANN is an adaptive system that, in its learning phase, modifies its structure in response to information flowing through the network, either internal or external. In a neural network, neurons are interconnected, and each neuron's output feeds into the next until the desired end output is obtained. When the network is shown an example of a set of input data with known results or output, it learns. The weighting factors are then changed (either by a programmed algorithm or by a human), and these connection weights store the information needed to move the final result closer to the known result [6]. The ANN approach has been widely employed for rainfall and other hydrologic time series prediction [7-10]. Nevertheless, the inability to deploy any of the existing ANN models in the field arises from the fact that the relationship between input and output takes the form of connecting weights, which field engineers now find challenging to extract and comprehend.

In this research paper, monthly rainfall of January, February March, April and May are used to forecast monsoon rainfall using ANN technique. Three ANN models are deployed based upon transfer function and best accuracy yielding model is identified. The findings of the study can be very important to the farmers and various policy maker agencies as they can early predict the monsoon rainfall; and according to that, better agricultural and water management plans can be prepared.

2. STUDY AREA

Ranchi is the capitol of state Jharkhand of India which is situated on the Chota Nagpur plateau of the eastern India. Ranchi is surrounded by hilly terrain with dense forests. The region falls under subtropical climate zone but because of its forest surrounding, the weather is pleasant throughout the year. However, in recent years climate change has affected its weather pattern and the unique convectional summer rain which Ranchi used to get frequently have decreased nowadays. The average annual rainfall of Ranchi is around 1300mm of which about 80% rain is received in south-west monsoon season from month June to September [11].

3. METHODOLOGY

The rainfall data for the period 1975-2023 is used for the analysis of study. The rainfall data from 1975 to 2020 are used to train the models and rainfall data for the period 2021-23 is used to find the accuracy of models. The daily rainfall data for the said period is obtained from the website of National Centre For Environmental Information (https://www.ncdc.noaa.gov/cdo-web/datatools/findstation). Monsoon rainfall is calculated from daily rainfall data. Monsoon season kicks in mid-June and remains until mid-September and hence rainfall in months from June to September is considered as monsoon rainfall. The monthly rainfall of January, February, March and May are used to forecast the monsoon rainfall in that year. After training the ANN model, monsoon rainfall for period 2021-23 are evaluated and by comparing these values with the actual monsoon rainfall in those year, accuracy of ANN models are evaluated.

A. *ANN Model*

The ANN model was trained using back-propagation algorithm network with simple structure, five nodes in the input layer, single hidden layer with ten nodes and one node in the output layer [Figure 2]. Input to the model is the monthly rainfall data of January, February, March, April and May while the output is rainfall in monsoon season

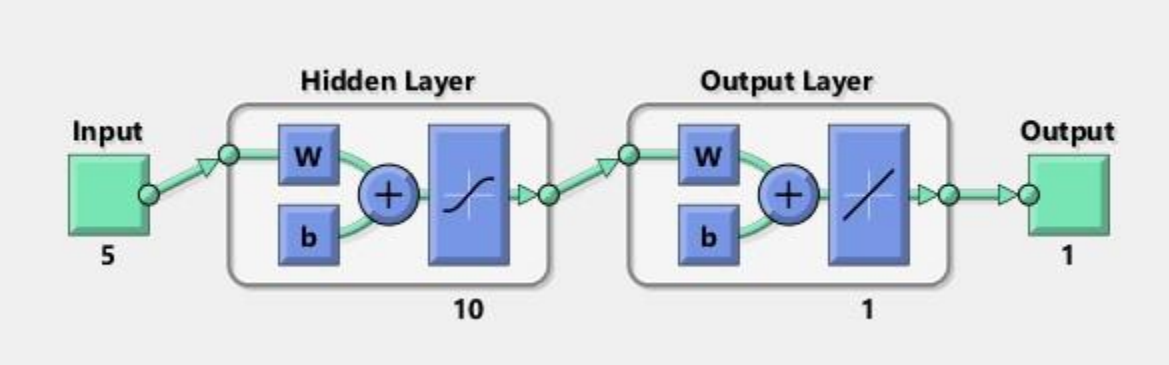


Figure 2: Layers of ANN model with nodes

Three different ANN models are deployed on the basis of transfer function [Figure 3]. Three considered models are LM model (transfer function is Levenberg-Marquardt function), BR model (transfer function is Bayesian Regularization function) and SCG model (transfer function is Scaled Conjugate Gradient function). After training and testing of these models, the correlation coefficients (R value) are calculated for training period, validation period and testing period respectively. The training of models is done using 70% of the samples; and the validation and testing are done using 15% samples each. That is, 32 samples are used for training, 7 samples are used for validation and 7 samples are used for testing.

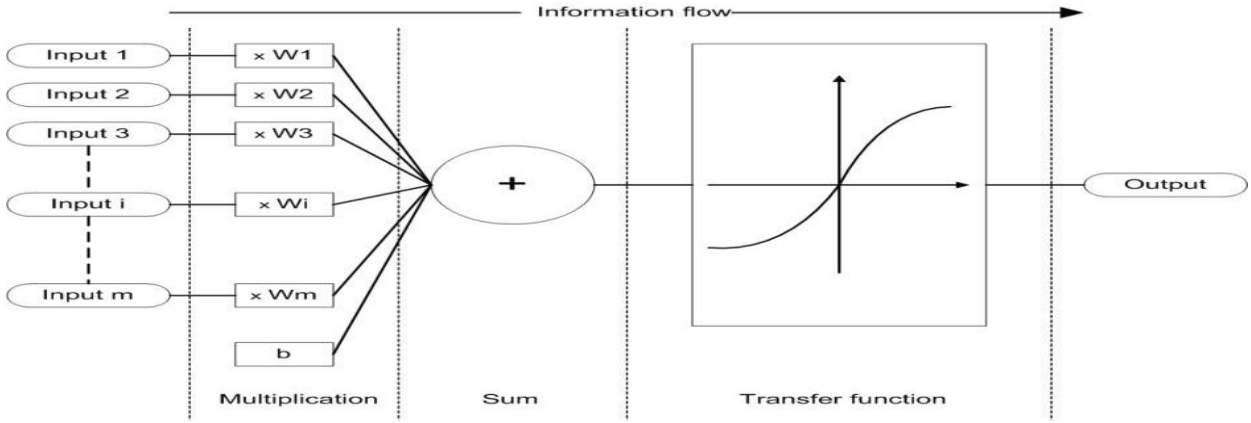


Figure 3: Working principle of ANN model with transfer function

B. *Coefficient of correlation:*

The degree of linear relationship between the observed and the predicted values is indicated by the coefficient of correlation (R). It shows the extent to which the trends in the actual observed values and the expected values coincide. The range of the value is 0 to 1. The correlation coefficient rises as the actual and anticipated values become more similar. Therefore, a greater correlation coefficient indicates a better outcome.

Let x_i be the 'n' input value and $\bar{x_i}$ be its mean value. Let y_i be the forecasted value and $\bar{y_i}$ be its mean then the correlation coefficient (R) can be calculated as follows:

$$R = \frac{\sum_{i=1}^{n}(x_i - \bar{x_i})(y_i - \bar{y_i})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x_i})^2}\ \sqrt{\sum_{i=1}^{n}(y_i - \bar{y_i})^2}}$$

4. RESULTS

ANN models are firstly trained using rainfall data for period 1975-2020 and the value of correlation coefficients are evaluated [Table 1]. Overall, LM model provide higher value of correlation coefficient compare to that of BR and SCG models. While in testing phase, SCG model (0.525) provides better correlation coefficient than LM model (0.449) and BR model (0.287). The figure of correlation coefficients is deployed in Figure 5. Based on these trained models, monsoon rainfall for year 2021, 2022 and 2023 are forecasted by providing monthly rainfall of January, February, March, April and May of these years [Table 2]. The actual monsoon rainfall and predicted rainfall for year 2021 to 2023 is deployed in Figure 4. The relative error % are then calculated for these years by comparing the predicted values to the observed values [Table 3]. SCG model provides better forecasting for year 2021 and 2023; while LM model provides better forecasting for 2022. BR model provides very poor accuracy for year 2021 while for year 2022 and 2023, accuracy level is satisfactory. The overall accuracy for forecasting of LM, BR and SCG models are calculated and are respectively 72.339%, 57.222%, 88.804% [

Table 4]. The best accuracy among these models is provided by SCG model which also have the highest testing correlation coefficient.

Table 1: Correlation Coefficients of ANN Models

Model	Correlation Coefficient (R-value)			
	Training	Validation	Testing	Overall
LM	0.609	0.468	0.449	0.546
BR	0.562	NA	0.287	0.519
SCG	0.353	0.395	0.525	0.342

Table 2: Actual and Forecasted Rainfall by ANN Models

Year	Actual Rain	LM Forecasts	BR Forecasts	SCG Forecasts
2021	1114.044	1889.200	2150.700	1121.300
2022	1052.322	923.188	882.728	717.195
2023	737.616	729.269	596.264	729.570

Table 3: Error% in Forecasting of Monsoon Rainfall

Year	Error %		
	LM	BR	SCG
2021	69.580	93.053	0.651
2022	12.271	16.116	31.846
2023	1.132	19.163	1.091

Table 4: Accuracy% of ANN models

Year	Accuracy %		
	LM	BR	SCG
2021	30.420	6.947	99.349
2022	87.729	83.884	68.154
2023	98.868	80.837	98.909
Overall	72.339	57.222	88.804

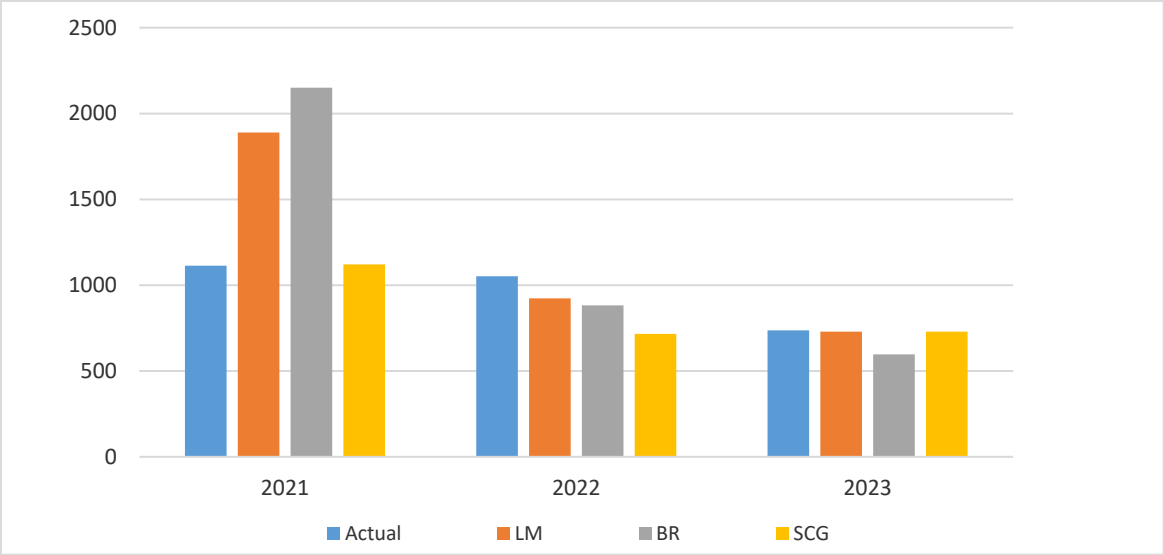
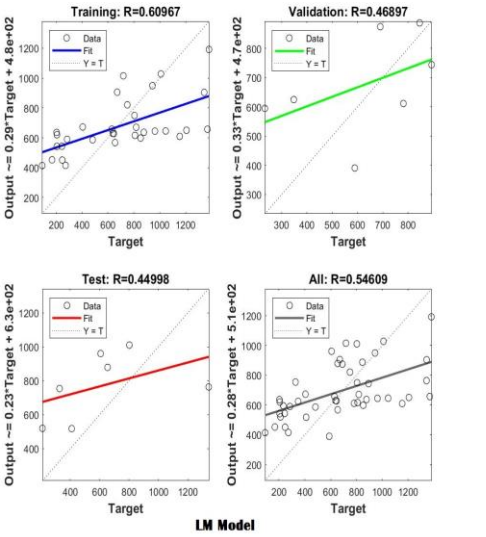
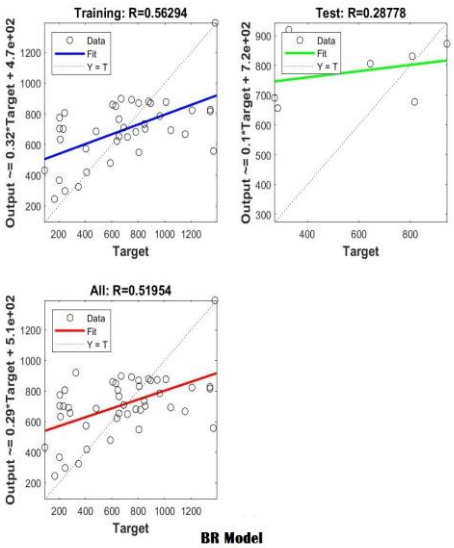


Figure 4: Graph of actual and forecasted rainfall by ANN models





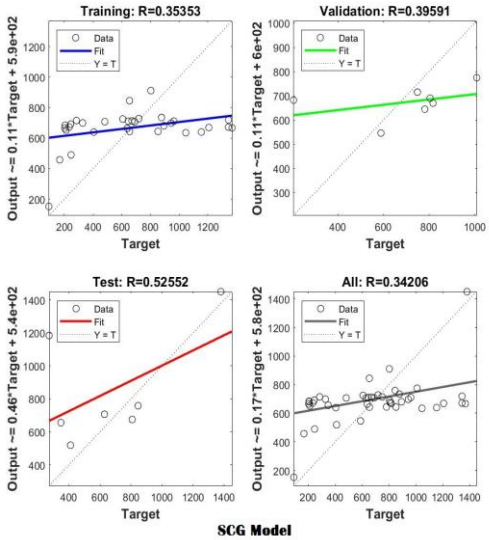


Figure 5: R values of LM, BR and SCG models

5. CONCLUSION

The monsoon rainfall forecasting by ANN model shows a promising accuracy level. However, it is observed that the transfer function affects the accuracy level. The ANN model with Scaled Conjugate Gradient transfer function (88.80%) yields better forecasts than ANN models with Levenberg-Marquardt transfer function (72.33%) and Bayesian Regularization transfer function (57.22%). It is also observed that the correlation coefficient of testing phase is more important than training and validation phase. The correlation coefficient of SCG model is the highest and so its accuracy level.

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