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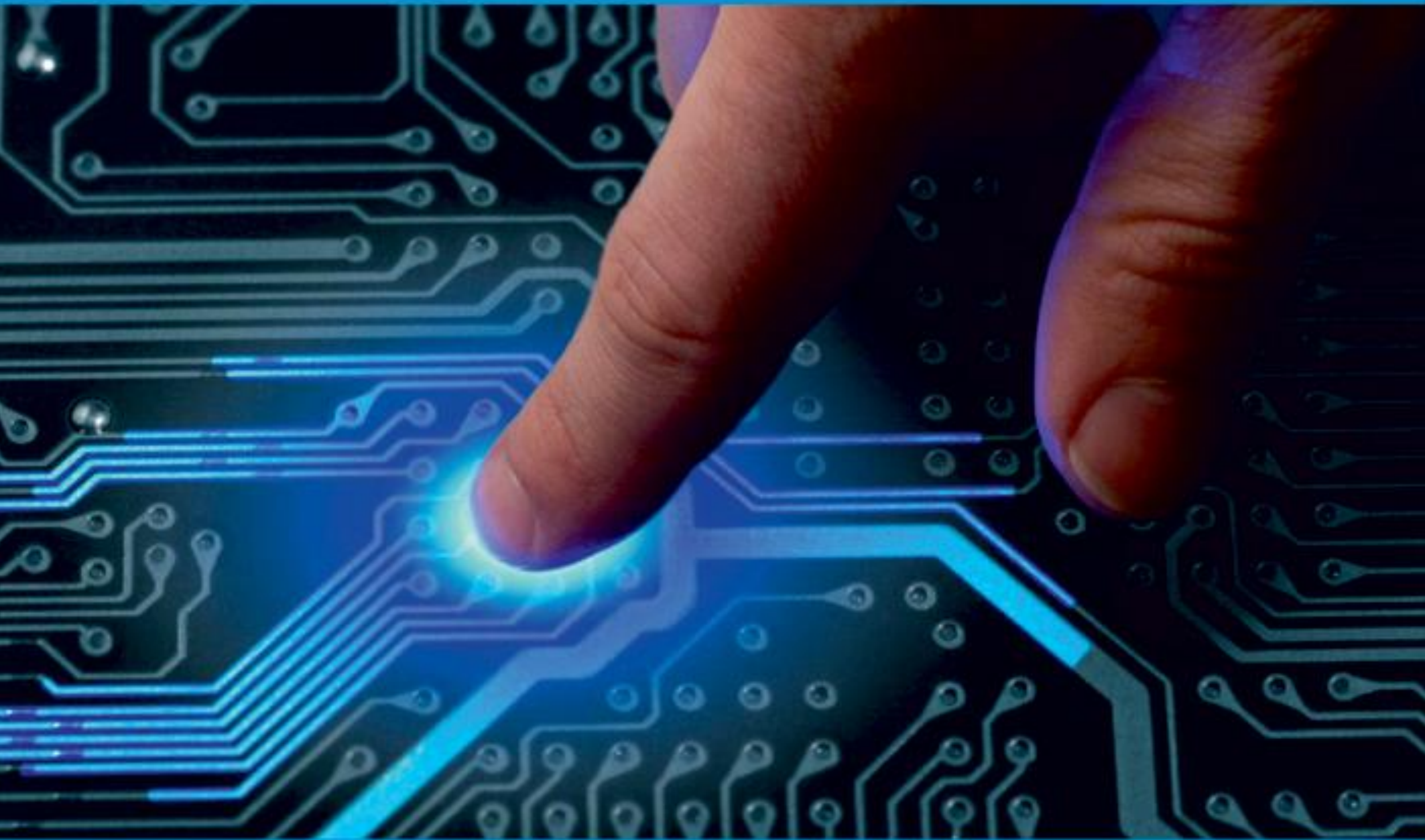

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Comparative Study of Neural Network Models for Prediction of Chaotic System

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ABSTRACT: Research into the ability to forecast the internal dynamics of chaotic systems is vital. The chaotic character of climatic systems is a major barrier to accurate climate prediction. Numerous studies have been conducted so far on the topic of numerical simulation approaches for the simulation and prediction of chaotic systems. Chaotic systems are difficult to anticipate with numerical simulation approaches due to issues like sensitivity to beginning values, error accumulation, and inappropriate parameterization of physical processes. Here, we looked into the architectures of Neural Networks. The present literature study has provided confidence in the efficacy of artificial neural networks as a powerful tool for predicting internal dynamics climatological data. Research demonstrates that ANNs have the potential for prediction of climatological analysis since they are ideally adapted to situations requiring complex nonlinear interactions.

KEYWORDS: Artificial Neural Network, Chaotic systems, Climatological data, Internal dynamics, Numerical Simulation.

I. INTRODUCTION

The term "climate" refers to the average weather conditions throughout a certain time frame, and climatology is the scientific study of climates. Meteorology is a subfield of atmospheric science that examines both the day-to-day fluctuations and the seasonal patterns that shape our planet's climate. Climatology is crucial because it is used to predict how the climate will change in the future. Because of its impact on global air circulation, which in turn affects global temperatures and precipitation, ENSO is a crucial climate phenomenon. Climate exhibits chaotic behaviour because its properties (such as wind speed, temperature, humidity, precipitation, etc.) vary throughout time. The term "butterfly effect" has come to be used to describe this climate occurrence. In chaos theory, “the butterfly effect is the sensitive dependency on beginning circumstances in which a tiny change in one state of a deterministic nonlinear system can result in significant alterations in a later state”. A seemingly insignificant rounding off of beginning condition data led to Edward Lorenz's discovery of the effect while observing runs of his weather model. He pointed out that simulations with the roughed-off starting conditions would provide different outcomes from those with the rounded ones in the weather model. The results had changed drastically due to a seemingly insignificant shift in the original conditions.

II. LITERATURE REVIEW

In past many researchers have done their work for analysis of Neural Network in context of climate data.
Classification of different methods used by them are described below.

2.1 Back-Propagation Neural Network

To train Multi-layer Perceptrons, Backpropagation is used, which is a supervised learning algorithm (Artificial Neural Networks). Using the “delta rule (or gradient descent), the Backpropagation method searches for the smallest value of the error function in weight space”. To solve the learning problem, we look for the weights that produce the smallest error function. Every BPN has three layers: input, output, and hidden. Accurate output prediction is based on the number of neurons in each layer of the network and the number of hidden layers.

The Backpropagation method used by many researchers for climatological data analysis is discussed below:
Saxena et al. have offered a literature review of the various approaches taken by scientists who have used ANN for weather prediction. The authors argued the use of an ANN instead of conventional metrological methods for weather forecasting is effective. The study details the capacities of ANN to forecast a variety of weather phenomena, including

temperature, thunderstorms, and precipitation, and draws the conclusion that key architectures like BP and MLP are well-suited to this task.

Singh et al. have suggested using a BPN model they developed to predict 45 years' worth of rainfall data for the vindhya area. The LPA (long-term average) that has been measured is 956. During the testing period, it was found that the MAD (6.09) was lower than the SD (14.37). The training and testing period correlation coefficients are 0.89 and 0.95, respectively. The model's results are accurately observed. Identification of parameters for long-term rainfall data is a good use of Back-Propagation Neural Network.

Long-range predictions of monsoon rainfall over a relatively limited area have been examined by Shrivastava et al. using the BPN model. The coordinates of Ambikapur are 23° 07′ 23″ North and 83° 11′ 39″ East. Long-range forecasting (LRF) of monsoon rainfall in this area is the focus of this model's operation in 2012. In 2012, the model predicted a value of 90 (% of LPA), with a margin of error of 2.7 (% of LPA). This experiment yields highly accurate results, suggesting BPN's potential for use in weather prediction; however, designing BPN parameters such as "learning rate, momentum factor, initial weights, neurons in the hidden layer, number of input vectors, number of hidden layers, transfer function, training cycles, etc.", necessitated near-perfect observations.

Kaur and Singh showed how neural networks can be used to investigate the coldest time of year in Chandigarh. In order to simulate a forecasting system, they employed the Multi-layer Perceptron model and trained the network with the Back-Propagation algorithm. The suggested network is trained and tested using data from the meteorological department that spans the past decade. According to the findings, using MLP and BPN, minimum temperatures can be predicted with some degree of accuracy.

According to a literature assessment published by Karmakar et al. Neural Networks are a viable tool for predicting and extrapolating climate. They concluded that Neural Networks, such as BPN and RBF, were most suitable for predicting the chaotic behaviour of climate variables like rainfall and rainfall runoff, and were also efficient enough for long-term predictions. When it comes to extrapolating average climate factors over large areas, they also discovered that Neural Networks are quite effective.

Table 1: Details of BPN method for Climatological data analysis

Author & Year	Classification Methods	Result
Saxena et al. (2013)	BPN, MLP	94.28%
Singh et al. (2016)	BPN	Better Accuracy
Shrivastava et al. (2017)	BPN	90%
Kaur and Singh (2011)	BPN, MLP	93.4%
Karmakar et al. (2016)	BPN, RBF	Better Accuracy

2.2 ARIMA Model

Autoregressive Integrated Moving Average is an abbreviation for "autoregressive" A model employed in time series analysis and econometrics. You can use the model to analyse existing data and make projections about the future of the series. It's utilised when a metric is recorded at predetermined times, such as seconds, minutes, days, weeks, or months. The ARIMA model makes forecasts about a time series by using the data from the series itself as input. It can be used to any sequence of numbers outside of a specific time period that shows regularity and is not a random sequence.
Read on for a breakdown of the ARIMA Model, a standard tool in the interpretation of climatological data used by many scientists:

The research by Shukla et al. aims to create a location-specific weather forecasting model for Pantnagar, Uttarakhand, by analysing historical data. To provide predictions for the winter season, an exponential smoothing model and a Seasonal Autoregressive Integrated Moving Average approach were used (SARIMA). The percentage of incorrect predictions and the mean square error have both been used in a comparative research. The study concluded that the SARIMA model was the best effective for forecasting monthly maximum/minimum temperatures and humidity levels on the basis of RMSE.
Based on "100 replicates on 100 generated data of the ARIMA (1,0,1) model shared by Haji et al. we compare the ARIMA model with the Fuzzy Time Series (FTS) model to determine the most effective model for forecasting time

series data. Three metrics, including Mean Absolute Percentage Error (MAPE), Root Mean Squared Error (RMSE), and Bias Statistics Criterion", were used to assess the models' performances and decide the best approach. In this case, ARIMA proved to be a reliable predictive tool.

Rainfall estimates utilising "a complex statistical model ARIMA (1,1,1) and three different kinds of Artificial Neural Network (ANNs) models, MLP, FLANN, and LPE", were presented by Nanda et al. and they discovered that weighted MVFTS and CBLSTM are effective for predicting. The ARIMA (1,1,1) model was chosen to analyse the Rainfall Estimation data since "it is the best statistical model for time series models. Multiple Artificial Neural Network (ANN) models, including Multilayer Perceptron (MLP)", Faster-Layer-Annotated Network (FLANN), and Least Squares Expansion (LPE), This is where the ARIMA model shines.

Table 2: Details of ARIMA Model for Climatological data analysis

Author & Year	Classification Methods	Result
Shukla et al. (2014)	SARIMA	Temperature, Humidity forecasting is approx 94%.
Haji et al., (2018)	ARIMA	Good Accuracy
Nanda et al. (2013)	ARIMA, MLP, FLANN, LPE	Approx 89% accuracy by ARIMA.
Pham et al. (2017)	MLP, LSSVM, NEURO FUZZY, HW, ARIMA	Better Accuracy by hybrid ARIMA- NF, ARIMA-HW compared to single model.

2.3 ANFIS Model

"Through highly interconnected processing units and information linkages, which are weighted to map the numerical inputs into an output, ANFIS is a straightforward data learning technique that use Fuzzy Logic to transform provided inputs into a desired output. The advantages of Fuzzy Logic and Neural Network, two machine learning methods, are combined in ANFIS". An ANFIS is a Fuzzy Inference System that uses Neural Network learning techniques to fine-tune the system's parameters (FIS).

The ANFIS Model used by many researchers for climatological data analysis is discussed below:
Nayaka et al. proposed an ANFIS implementation for modelling hydrologic time series, with an example application simulating the river flow of the Baitarani River in the Indian state of Orissa. To evaluate how well ANFIS and ANN models perform in comparison, a suitable ANN model is built for the same basin. As can be shown, the ANFIS model is able to maintain the time series' observable statistical features.

Moosavi et al. have analysed the accuracy of groundwater level forecasts made 1, 2, 3, and 4 months in advance using "ANN, ANFIS, Wavelet-ANN, and Wavelet ANFIS models" for two different case studies in two different sub-basins. They discovered that it's possible these models can't account for the nonlinearity and seasonality of data. Following this initial stage, the data underwent a wavelet transform, and the pre-processed data was sent into the ANN and ANFIS models in step two. The Wavelet-ANFIS hybrid model performed the best, according to the results.
As shown by Rezaeianzadeh et al. "maximum daily flow at the outlet of the Khosrow Shirin" watershed in Iran's Fars Province may be predicted using a variety of statistical methods, including ANNs, ANFISs, MLRs, and MNLRs. The RMSE and the R2 were used to assess the models' accuracy. The data demonstrates that both ANFIS and MLR are capable of producing reliable forecasts.

For modelling evaporation from meteorological data, Salih et al. offer a new method they name the "co-active neuro-fuzzy inference system (CANFIS)". Three well-established artificial intelligence (AI) models are used to verify the CANFIS model's prediction ability. According to the findings, CANFIS models provide more accurate predictions than the alternatives. By far the most accurate model for predicting evaporation given merely mean temperature and relative humidity is CANFIS, with a Nash-Sutcliffe efficiency of 0.93.

Table 3: Details of ANFIS Model for Climatological data analysis

Author & Year	Classification Methods	Result
Nayaka et al. (2009)	ANFIS	Better Accuracy
Moosavi et al. (2013)	ANFIS, Wavelet-ANN, Wavelet ANFIS	Better Accuracy by Wavelet ANFIS
Rezaeianzadeh et al. (2013)	ANFIS, MLR, MNLR	Better Accuracy by ANFIS, MLR
Salih et al. (2019)	CANFIS	Better Accuracy

2.4 Artificial Neural Network

The number of ANN nodes, often known as neurons, is essentially an engineering approximation of a biological neuron. ANN is structured in a hierarchical manner. Layers of input, hidden, and output data are used to illustrate them. There is a hidden layer in the network, and all the neurons there get their information from the neurons in the input layer. Weights and constants are determined during the training phase to indicate the relative strengths of each signal and biases. The output is a function of the transfer function applied to the sum of the inputs after they have been weighted. The activation functions can be anything from a sigmoid to a tanh.

Some important work done on Climatological data analysis using ANN is discussed below:
Kushwaha and Kumar built 8 artificial neural network models that use "daily discharge and suspended sediment concentration to forecast daily suspended sediment concentration in the Baitarani River at the Anandpur gauging station. With a sigmoid activation function and the Levenberg-Marquardt (L-M) learning algorithm", they employed multilayer feedforward back propagation neural networks. The artificial neural network-based model outperformed the sediment rating curve and the multiple linear regression in both qualitative and quantitative assessments.

Forecasts of weather conditions using ANN models have been made by Rajendra et al. Air and soil temperatures, as well as relative humidity, have been examined in relation to climate change. The availability of weather data varies throughout the year, therefore hourly and monthly estimates would be quite beneficial. Compared to the MLR, both the MLP and RBF models performed better, which is a positive sign.

Input and output parameters, data sets for training and testing, "the number of hidden layers and the number of neurons in each hidden layer, the weights, the biases, the learning rate, and the activation function are all specified are specified in the Artificial Neural Network model provided by Selvin S. and Seetha N. Measurement of accuracy is done by calculating the Mean Squared Error (MSE) between the predicted and actual output". This model's results are helpful in analysing climate patterns.

Ayodele and Precious showed that it is possible to use non-linear methods for SRP, or seasonal rainfall prediction. They determined that ANN works well at transforming input patterns into output ones. Using a number of meteorological data, including: "sea surface temperature (SST), U-wind at (surface, 700, 850, and 1000), air temperature, specific humidity, ITD, and relative humidity". The results showed an MSE of 7174, RMSE of 84.7, and MAE of 18.6. The outcome demonstrated that the proposed ANN constructed network accurately predicted seasonal rainfall totals in Ikeja with low standard deviation.

Table 4: Details of some ANN Model for Climatological data analysis

Author & Year	Classification Methods	Result
Kushwaha an Kumar (2017)	FFBPN	Better Accuracy
Rajendra et al. (2019)	RBF, MLP, MLR	91-96% Accuracy by RBF and MLP
Selvin S & Seetha N (2019)	ANN	Good Accuracy
Ayodele and Precious (2019)	ANN	94%

III. COMPARITIVE ANALYSIS

The majority of researchers who have used Neural Network techniques for forecasting various weather phenomena have used the same architectures, as was discovered after reviewing a large number of ANN architectures for prediction of the internal dynamics of chaotic systems in the context of climatology. Thus, in the review of almost twenty-one years of studies. The vast majority of weather experts agree that BPN, RBFN, ARIMA, ANFIS, and MLP are the best techniques for making accurate forecasts. In order to forecast the internal dynamics of a chaotic system, ANN can be applied to climatic data because it is dynamic and non-linear. Overall, it has been seen that while comparing other prediction techniques, such as statistical and numerical modelling, over meteorological data, Neural Network has proven to be the most appropriate technique clearly for forecasting different climatic situations. The models are graded on how well they generally perform and how accurate their results tend to be on average. Machine learning was used in this paper to conduct an in-depth analysis of neural network architecture as it relates to weather prediction. Tables 1, 2, and 3 as well as fig. 4 show that the BPN model outperformed ANN and other techniques in terms of accuracy.

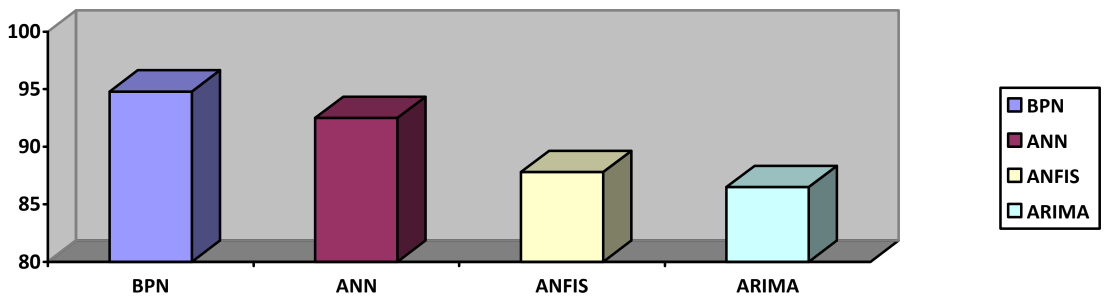

Fig 1. Comparative Analysis

IV. CONCLUSION

The strengths of ANN are the primary focus of this research. It works well enough to detect chaotic motion in any non-linear data time series. This research has advantages since it confirms that ANN is well-suited for identifying the internal dynamics of highly dynamic non-linear systems and making predictions about them. From a comprehensive analysis of Neural Network architectures in practise, we know that BPN, RBFN, ARIMA, ANFIS, and MLP are the approaches most commonly utilised by researchers, with test results deemed sufficient in the absence of any rebuttal from the scientific community. In general, it has been seen that Out of the many prediction methods available, including statistical and numerical modelling over meteorological data, Neural Networks have proven to be the most effective.

REFERENCES

[1] P. Aghelpour, B. Mohammadi, S.M. Biazar., "Long-term monthly average temperature forecasting in some climate types of Iran, using the models SARIMA, SVR, and SVR-FA," Theoretical and Applied Climatology, https://doi.org/10.1007/s00704-019-02905-w, 2015.

[2] S. Alhashimi, "Prediction of Monthly Rainfall in Kirkuk Using Artificial Neural Network and Time Series Models," Journal of Engineering and Development, vol. 18, no.1, ISSN 1813- 7822, 2014.

[3] S. Ali, M. Shahbaz, "Streamflow forecasting by modelling the rainfall–streamflow relationship using artificial neural networks," Modelling Earth Systems and Environment, Springer Nature Switzerland, 2020.

[4] R. Ata "Artificial neural networks applications in wind energy systems: a review, Renewable and Sustainable Energy Reviews 49," 534–562, 2015.

[5] S. Athiyarth, M. Paul, S. Krishnaswamy, "A Comparative Study and Analysis of Time Series Forecasting Techniques," SN Computer Science1:175 https://doi.org/10.1007/s42979-020-00180-5, 2020.

[6] A.P. Ayodele, E.E. Precious, "Seasonal Rainfall Prediction in Lagos, Nigeria Using Artificial Neural Network," Asian Journal of Research in Computer Science 3(4): 1-10, Article no. AJRCOS.50929, 2019

[7] G. Chattopadhyay, S. Chattopadhyay, R. Jain, Multivariate forecast of winter monsoon rainfall in India using SST anomaly as a predictor: Neurocomputing and statistical approaches," Journal of Atmospheric Sciences, 42, 2225-2241, 2015.

[8] S. Chattopadhyay, D. Jhajharia,, "Univariate modelling of monthly maximum temperature time series over northeast India: neural network versus Yule–Walker equation approach," Meteorological Applications Meteorol. Appl. 18: 70–82 , 2011 .

[9] C. Chen, R. Li, L. Shu, K. Aihara, L. Chen, "Predicting future dynamics from short-term time series using an Anticipated Learning Machine," National Science Review 7: 1079–1091, 2020 Doi: 10.1093/nsr/nwaa025 Advance access publication, 2020.

[10] E. Vamsidhar, K. Varma, R.Sankara, P. Ravikanth, 2010, "Prediction of Rainfall Using Backpropagation Neural Network Model", International Journal on Computer Science and Engineering, Vol. 02, No. 04, pp. 1119-1121.

[11] A.Z. Dhunny, R.H. Seebocus, Z. Allamc, M.Y. Chuttur, M. Eltahan, H. Mehta, "Flood Prediction using Artificial Neural Networks: Empirical Evidence from Mauritius as a Case Study," Knowledge Engineering and Data Science (KEDS), Vol 3, no 1, pp. 1–10, 2020.

[12] R. Lie, J.B. Eisner, A.A. Sonis, "Nonlinear Prediction, Chaos, and Noise," Bulletin American Meteorological Society,American Meteorological Society, 1992.

[13] N. Fernandez, W. Jaimes, E. Altamiranda, "Neuro-fuzzy modelling for level prediction for the navigation sector on the Magdalena River (Colombia)," Journal of Hydro informatics | 12.1 ,2010.

[14] A. Gluhovsky, E. Agee, "The Analysis of Atmospheric and Climatic Time Series," DOI: 10.1175/JAM2512.1, American Meteorological Society, 2009.

[15] A. Haji, K. Sadik, A.M. Soleh, "A Comparative Simulation Study of ARIMA and Fuzzy Time Series Model for Forecasting Time Series Data," IJSRSET, vol. 4, issue 11, Print ISSN: 2395-1990, Online ISSN: 2394-4099 Themed Section: Engineering and Technology DOI: https://doi.org/10.32628/IJSRSET1184112, 2018.

[16] G.C. Hegrel, T.R. Karl, N. Gillett, F. Zwiers, "Climate Change Detection and Attribution: Beyond Mean Temperature Signals," 5058 Journal of Climate – Special Section Volume 19, American Meteorological Society, 2006.

[17] E. Id, U. So, O. JA, A. EI, "Flood extrapolation using artificial neural network in coastal region of cross river state, Nigeria," International Journal of Environmental and Ecology Research, vol. 1, issue 1, page no. 18-24., 2019.

[18] S. Karmakar, S. Choubey, P. Mishra, "Appropriateness of Neural Networks in Climate Prediction and Interpolations: A Comprehensive Literature Review," International Journal of Applied Information Systems (IJAIS) – ISSN: 2249-0868 Foundation of Computer Science FCS, New York, USA vol. 10, no.10, 2016.

[19] A. Kaur, H. Singh, "Artificial Neural Networks in Forecasting Minimum Temperature," JECT vol. 2, issue 3, 2011.

[20] D.P. Kushwaha, D. Kumar, "Modelling suspended sediment concentration using multilayer feedforward artificial neural network at the outlet of the watershed," International Journal of Agricultural Engineering, vol. 10, issue 2, 2017.

[21] D. Kumar, S.M. Asce, A. Pandey, N. Sharma, W.A. Flugel, "Modelling Suspended Sediment Using Artificial Neural Networks and TRMM-3B42 Version 7 Rainfall Dataset," , ASCE C4014007-2 J. Hydrol. Eng, 2012.

[22] D. Kumar, K. Vaisala, S. Pattanashetty, S. Sandhya, "Comparison of Rainfall Forecasting Using Artificial Neural Network and Chaos Theory," Emerging Research in Electronics, Computer Science and Technology, Springer Nature Singapore Pvt Ltd., 2019.

[23] A. Kumar, D. Yadav, S. Pandey, "A study of ANN for air temperature prediction," Water Resource Manage, 27:1301–1321 DOI 10.1008/s11269-012-0228-2, 2016.

[24] V. Moosavi, M. Vafakhah, B. Shirmohammadi, N. Behnia, "A Wavelet-ANFIS Hybrid Model for Groundwater Level Forecasting for Different Prediction Periods," Water Resource Manage, 27:1301–1321 DOI 10.1007/s11269-012-0239-2, 2013.

[25] N. Mishra, A. Jain, "Time Series Data Analysis for Forecasting – A Literature Review," IJMER, ISSN: 2249–6645, www.ijmer.com, vol. 4, issue 7, 2014.