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APPLICATION OF ARTIFICIAL NEURAL NETWORKS (ANNS) FOR FORECASTING RAINFALL IN ILORIN KWARA STATE, NIGERIA.

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ABSTARACT

Rainfall is one of the most complex and difficult elements of the hydrological cycle to understand and model due to the tremendous range of variation over a wide range of scales both in space and time. The complexity of the atmospheric processes that generate rainfall makes quantitative forecasting of rainfall an extremely difficult task. The Artificial Neural Networks (ANNs) is an emerging computationally powerful technique with very high degree accuracy and widely used as forecasting models in many areas such as engineering, social, finance, economic, stock and foreign exchange problems. The Artificial Neural Networks (ANN) approach has several advantages due to its robustness and flexibility over conventional methods or semi-empirical models require known input data set with few prior assumptions. In this research, we attempt to study the application of artificial neural networks for forecasting rainfall using some dependent weather variables such as temperature, rainfall, wind speed and sunshine hour in Ilorin metropolis Kwara state, Nigeria. The research work adopted some key climatic data ranging from monthly Maximum and Minimum Air Temperature, Relative Humidity, Wind Speed and total monthly Rainfall from June to October, all for the period of 19 years (1999-2018) over the study area (Ilorin Metropolis). The first part of the methodology to carry out this research was the collection of rainfall data (from the Nigerian Meteorological Agency) which serves as the fundamental input for statistical computations. The second aspect was the data processing then followed by the presentation of relevant outputs. From the monthly rainfall data, computation of mean rainfall and percentage mean rainfall for the period under study was carried out.

Decadal charts were plotted to ascertain the maximum mean rainfall for each decade and the degree of variation in the amount of fluctuation in rainfall recorded over the period. Developing an artificial neural network (ANN) as a reliable rainfall forecast essentially involve a nonlinear modeling approach that provides a fairly accurate universal approximation to any function. Its approximation power comes from the parallel processing of the information from the data. ANN is a non-statistical data forecasting tool which is contained in any version of "MATLAB tool box . The reliability of the artificial neural network is determined in the results of its prediction when compared to the observed data obtained from meteorological stations. This is done both visually (using plotted graphs) and statistical measurements such as root-mean-square error (RMSE), mean square error (MSE), Mean Absolute Percent Error (MAPE) and the coefficient of correlation (CORR) to test the degree of error and examine the model performance. The research has established that with the availability of relevant and necessary weather parameters serving as inputs, the Artificial Neural Network (ANN) rainfall forecast has the capability to forecast accurate rainfall amount over a given a location. The findings from the study showed that the trend and pattern of rainfall movement with respect to its amount and time is such that the rainfall amount either ascends gradually or fluctuates. It was discovered that much of the amount of rainfall in all the years under study is received in the month of June, July, August and September which are largely variant and characterized with fluctuations. Generally, a decreasing trend in rainfall is observed within the first three years of the first decade, with the highest amount of rainfall experienced in the first year of the decade totaled up to 1539.3mm. Also a significant increase in the rainfall amount for the last year of the first decade was observed resulting in an upward trend with values close to what was experienced at the beginning of the decade. The trend in rainfall for the second decade is a little similar to the previous decade with respect to the first, second, eight, ninth and tenth year. However, the eighth year of this decade is most significant as it recorded the highest value of 2552.6mm compared to the previous years in the decade. The highest mean annual rainfall experienced in the first decade was 128.3mm and 212.7mm in the second decade which also correspond to the highest value within the period under study. It was recommended that meteorological stations should be established to cushion the effect and challenge of sparse meteorological data

and further reduce the representativeness of a system which can also have significant effect on the results of subsequent analysis. Government should support and encourage private organizations to key into establishment of more automatic weather stations.

Keywords: *Application, Artificial Neural Networks (ANNS), Forecasting, Rainfall, Ilorin Kwara State.*

INTRODUCTION

Rainfall is one of the most complex and difficult elements of the hydrological cycle to understand and model due to the tremendous range of variation over a wide range of scales both in space and time. The complexity of the atmospheric processes that generate rainfall makes quantitative forecasting of rainfall an extremely difficult task. The Artificial Neural Networks (ANNs) is an emerging computationally powerful technique with very high degree accuracy and widely used as forecasting models in many areas such as engineering, social, finance, economic, stock and foreign exchange problems. The Artificial Neural Networks (ANN) approach has several advantages due to its robustness and flexibility over conventional methods or semi-empirical models require known input data set with few prior assumptions. In this research, we attempt to study the application of artificial neural networks for forecasting rainfall using some dependent weather variables such as temperature, rainfall, wind speed and sunshine hour in Ilorin metropolis Kwara state, Nigeria. Past geographical survey has established that most theoretical analysis for rainfall prediction characteristics in Nigeria has been based on assumption. This is done with the view of rainfall normally in its distributive pattern, especially for an annual series. On the basis of these rainfall attributes, a thorough statistical analysis of rainfall distribution over the study area will not only be imperative but useful to the agricultural, social, commercial and industrial sectors of the economy of the study area but at the same time be a stepping stone to sustainable development of the entire country. Thus, it is imperative therefore to find out if this condition is practically obtainable in Ilorin considering the fact that agricultural practice in Kwara is also rain fed. Also, not just for no other thing to study, but because of the importance of such knowledge for all planning schemes for which rainfall is widely used. Further to this is the fact that such assumption about rainfall condition in the area may have serious and delicate implications on agricultural production. In agricultural production especially in the tropics, rainfall is without doubt a critical climatic factor. It is known fact that one of the two major limiting factors to agricultural production next to soil fertility is nothing but insignificant water supply (Oladipo, 1993). Rainfall is the main source of soil moisture in any given environment. Thus an assessment of its distribution be it monthly, weekly, and especially daily distribution) is therefore of great importance in agricultural planning. In Nigeria, the dominant feature of rainfall is its seasonal character. Hence water supply for agricultural practices is highly dependent on precipitation. Moreover in areas where the climate is greatly influenced by drought and desertification, the condition of precipitation in relation to yield, the rate of evapo-transpiration and soil moisture content may help promote or hinder crop production.

Aim and Objectives

The aim of this research work is to apply Artificial Neural Networks (ANNs) to forecast rainfall in Ilorin, Kwara State. Nigeria, the specific objectives include;

i. To examine the rainfall trend and distribution in the study area (1998-2018)
ii. To develop a reliable rainfall forecast for the period under study using ANNs.
iii. To examine the reliability of the developed rainfall forecast over the study area.

Study Area Description

Kwara is located within the north central geopolitical zone. The state capital is Ilorin located at Longitude 4 º 20'E and 4 º 35'E and Latitude 8º 30'N and 8 º 36'N. It has an approximate area of about 468sqKm. Ilorin shares southern and eastern boundaries with Ifelodun LGA, while it shares northern boundary with Moro LGA and western boundary with Asa LGA. It is about 300km away from Lagos and 500km away from Abuja the Federal Capital of Nigeria (FCT). Ilorin metropolis is made up of parts of the three local government areas namely, Ilorin west, Ilorin south and Ilorin East. (Tunde *et.al.*, 2013).

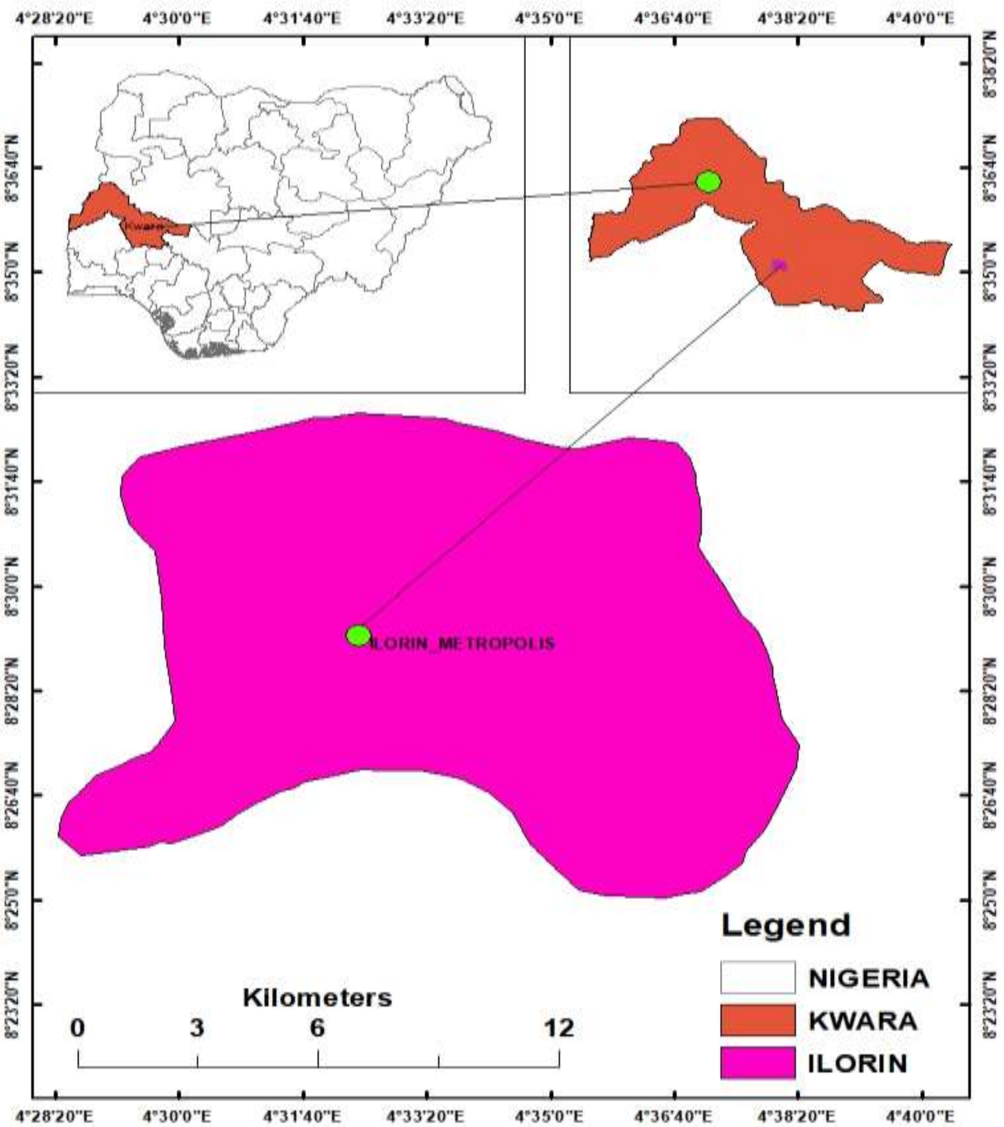

Figure 1: Map of the study area.

MATERIALS AND METHOD

Data Types and Sources

This research work adopted some key climatic data ranging from monthly Maximum and Minimum Air Temperature, Relative Humidity, Wind Speed and total monthly Rainfall from June to October, all for the period of 19 years (1999-2018) over the study area (Ilorin Metropolis). The datasets will be acquired from the Nigerian Meteorological Agency (NIMET).

Characteristics of the Data Sets

The characteristics of all the climatic dataset used in the study are summarized on Table below.

Table 1 : Characteristics of Datasets for the study

S/N	Data type	Acquisition date	Format	Source
1	Monthly Rainfall	1999 - 2018	Text	NIMET
2	Maximum /Minimum Air Temperature	1999 - 2018	Text	NIMET
3	Relative Humidity	1999 - 2018	Text	NIMET
4	Wind Speed	1999 - 2018	Text	NIMET
5	Sunshine	1999 - 2018	Text	NIMET

Method of Data Collection;

Before beginning the network design process, you first collect and prepare sample data. It is generally difficult to incorporate prior knowledge into a neural network, therefore the network can only be as accurate as the data that are used to train the network. It is important that the data cover the range of inputs for which the network will be used. Multilayer networks can be trained to generalize well within the range of inputs for which they have been trained. However, they do not have the ability to accurately extrapolate beyond this range, so it is important that the training data span the full range of the input space. After the data have been collected, there are two steps that need to be performed before the data are used to train the network: the data need to be preprocessed, and they need to be divided into subsets.

Result and Discussion

This study has established that with the availability of relevant and necessary weather parameters serving as inputs, the Artificial Neural Network (ANN) rainfall forecast has the capability to forecast accurate rainfall amount over a given a location. The results from this study will no doubt provide information that will aid the agriculture, water resource and other related sectors of the economy.

The study utilizes key meteorological data (rainfall, minimum and maximum temperature data, sunshine, relative humidity and wind speed) to examine the rainfall trend over Ilorin, develop a reliable rainfall forecast using ANNs and examine the reliability of the developed rainfall forecast over the study area.

To address the first objective, the monthly rainfall distribution in Ilorin from 1999 to 2018 were gotten from the Nigerian Meteorological Agency Abuja (NIMET) and were converted into charts to show the trend and pattern of rainfall movement with respect to its amount and time. From the monthly rainfall data collected, total rainfall for each year, mean rainfall and percentage mean rainfall were calculated for the period under study. The data was further used to plot a decadal chart to ascertain the maximum mean rainfall for each decade.

Table 2: Total and mean monthly rainfall from 1999 to 2018.

Year	Annual Total Rainfall (mm)	Monthly Mean (mm)	% Mean
1999	1539.3	128.3	5.5
2000	993.3	82.8	3.6
2001	697.7	58.1	2.5
2002	957.1	71.8	3.1
2003	1286.7	107.2	4.6
2004	1327.1	110.6	4.7
2005	1317.1	109.8	4.7
2006	1303.8	108.7	4.7
2007	1292.2	107.7	4.6
2008	1401.4	116.8	5
2009	1343.1	111.9	4.8
2010	924.3	77	3.3
2011	1086.5	90.5	3.9
2012	1071.1	89.9	3.9
2013	1275.5	105.9	4.5
2014	2296.5	191.3	8.2

2015	1701.1	141.8	6.1
2016	2552.6	212.7	9.1
2017	1483	123.6	5.3
2018	2195	182.9	7.9
		Total: 2329.3	

Source: Author's Data Analysis 2020

Considering the results on the decadal level,
The table shows the trend in rainfall with the minimum rainfall increasing gradually from 697.7mm in the first decade to 924.3mm in the second decade. On the other hand the maximum rainfall was not steady as it fluctuates from 1539.3mm in the first decade which later increased drastically to 2552.6mm in the second decade. The result shows slight similarity in the pattern and trend of rainfall for the first two years and last three years in both decades. As seen from table 2, a decreasing trend in rainfall is observed within the first three years of the first decade, with the highest amount of rainfall experienced in the first year of the decade totaling up to 1539.3mm. The value dropped to 993.3mm and 697.7mm for the second and third year respectively. The fourth year however experienced slight increase in rainfall amount of up to 957.1(mm). This increasing trend continues for the fifth and sixth year before almost maintain a uniform pattern for the seventh, eighth and ninth year with just slight difference in the quantity of rainfall received for the years. The pattern and trend in rainfall for the second decade is a little similar to the previous decade with respect to the first, second, eight, ninth and tenth year. The eighth year of this decade is very significant as it recorded the highest value of 2552.6mm compared to the previous years in the decade. It was also observed that this decade shows some degree of difference in the fifth, sixth and seventh year when compared to the previous decades as its rainfall trend was characterized with upward and downward fluctuations against the previous decade where almost uniform trend was observed for the fifth, sixth and seventh year respectively.

Figure 2: Annual Rainfall Trend of Ilorin for 20 years (1999-2018).
Source: Author's Data Analysis 2020

Standardized Precipitation Index (SPI)

In other to further understand and confirm the distribution and trend of rainfall in the entire study area under the period of study, standardized precipitation index (SPI) analysis were carried out so as to understand the sensitivity of the SPI to actual rainfall / rainfall deviation and the behavior in wet and normal years.

Table 3: Anomaly and Standardized precipitation Index (SPI) from 1999 to 2018

Year	Annual Total Rainfall (mm)	Rainfall Anomaly	SPI
1999	1539.3	137.08	+0.3
2000	993.3	-408.92	-0.89
2001	697.7	-704.52	-1.53
2002	957.1	-445.12	-0.97
2003	1286.7	-115.52	-0.25
2004	1327.1	-75.12	-0.16
2005	1317.1	-85.12	-0.19
2006	1303.8	-98.42	-0.21
2007	1292.2	-110.02	-0.24
2008	1401.4	-0.82	-0.00
2009	1343.1	-59.12	-0.13
2010	924.3	-477.92	-1.04
2011	1086.5	-315.72	-0.69

2012	1071.1	-331.12	-0.72
2013	1275.5	-126.72	-0.28
2014	2296.5	894.28	+1.94
2015	1701.1	298.88	+0.65
2016	2552.6	1150.38	+2.5
2017	1483	80.78	+0.18
2018	2195	792.78	+1.72

Source: Author's Computation 2020

In developing a reliable rainfall forecast using the ANN, the relevant sample data were first collected. Owing to the fact that it is generally difficult to incorporate prior knowledge into a neural network and that networks can only be as accurate as the data that are used to train them, it is therefore important that the data covers the range of inputs for which the network will be used. To create the neural network, the network creation function was used. Using the "feedforwardnet" command, a simple, two-layer feedforward network is created. After the neural network was created, it was then configured. The configuration step consists of examining input and target data, setting the network's input and output sizes to match the data, and choosing settings for processing inputs and outputs that will enable best network performance. The network configuration was then followed by network training before proceeding to validating the network.

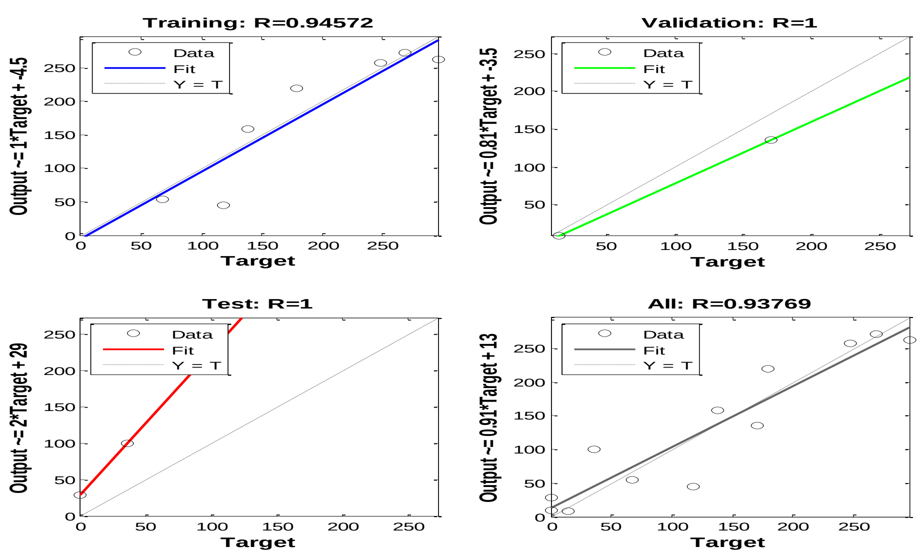

Figure 3: Showing Regression Graph for 1999

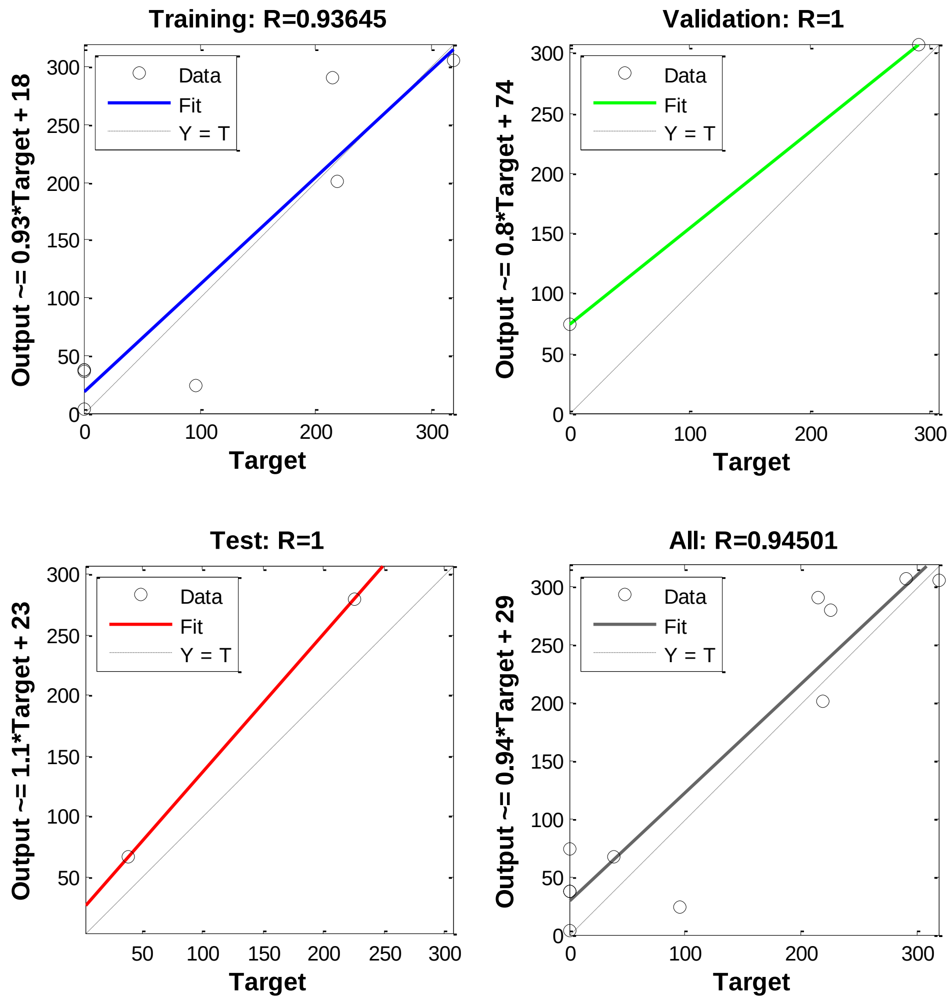

Figure 4: showing regression table for200

In line with the investigation of the forecast, results showed that the difference between actual rainfall and predicted rainfall is minimal and acceptable which therefore means that the ANN forecast can predict the amount of rainfall thus giving it some degree of reliability.

The result obtained in this study compared with other researches such as Fallah-Ghalhary., *et al* (2009) and Mekanik., *et al* (2011) showed that ANN techniques are efficient in the rainfall forecast and they can successfully predict amount of rainfall.

Generally, a decreasing trend in rainfall is observed within the first three years of the first decade, with the highest amount of rainfall experienced in the first year of the decade totaled up to 1539.3mm. Also a significant increase in the rainfall amount for the last year of the first decade was observed resulting in an upward trend with values close to what was experienced at the beginning of the decade. The trend in rainfall for the second decade is a little similar to the previous decade with respect to the first, second, eight, ninth and tenth year. However, the eighth year of this decade is most significant as it recorded the highest value of 2552.6mm compared to the previous years in the decade .The highest mean annual rainfall experienced in the first decade was 128.3mm and 212.7mm in the second decade which also correspond to the highest value within the period under study.
Finally, in determining the reliability of the Artificial Neural Network, the results of its prediction were compared to the observed data obtained from meteorological stations. This is done both visually (using plotted graphs) and statistical measurements such as root-mean-square error (RMSE), mean square error (MSE) and regression analysis to test the degree of error and examine the performance. The findings from the study showed that the trend and pattern of rainfall movement with respect to its amount and time is such that the rainfall amount either ascends gradually or fluctuates. It was discovered that much of the amount of rainfall in all the years under study is received in the month of June, July, August and September which are largely variant and characterized with fluctuations.

Recommendations

The result of this study has shown that the Artificial Neural Network (ANN) is capable of forecasting complex non-linear problems and therefore has the ability to predict accurate rainfall amount. Based on the outcome of this study, the following recommendations should be considered;

i. More meteorological stations should be established to cushion the effect and challenge of sparse meteorological data and further reduce the representativeness of a system which can also have significant effect on the results of subsequent analysis
ii. Government should support and encourage private organizations to key into establishment of more automatic weather stations

iii. More funding and grants should be made available to interested individual and research institutions to embark on relevant research that will translate into better economic and social development.

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