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RESEARCH ARTICLE

ARTIFICIAL NEURAL NETWORK-DRIVEN PREDICTION OF SOYA BEANS YIELD PRODUCE THROUGH RAIN FED SYSTEM BASED ON CLIMATIC VARIABILITY IN KANO STATE, NIGERIA

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ABSTRACT

Machine learning algorithms like artificial neural networks (ANN) are capable of providing accurate predictions of crop yields based on climatic variables. Meteorological data and Soya beans yield from 2010 to 2023 were obtained from the National Aeronautics and Space Administration (NASA) and the Kano Agricultural and Rural Development Agency (KNARDA) respectively. The ANN algorithm was used in predicting Soya beans yield based on the dataset of the climatic variables. Seven climatic variables (Rainfall, Maximum, temperature, Minimum temperature Relative humidity, Sunshine hours, Wind speed and direction) were used as input neurons for the ANN algorithm. The maximum prediction for Soya beans yield in ANN model was gotten in 6 hidden neurons. The highest prediction was obtained with an Rsquare (R_2) of 0.99 (99%) for the training and validation having an R_2 of 0.80 (80%). While the training and validation it is a perfect linear graph which shows that the actual variable is the same as the predicted variable, also the actual value and the predicted result correlate much which gives a perfect linear graph. The study indicated that the model is very reliable and statistically significant in predicting the variability of Soya beans yield. Therefore, based on the training and validation, it is a perfect linear graph which shows same values for both the actual and predicted variables. Findings from the study reveals that the ANN has the capacity of identifying patterns in historical data and can make prediction of Soya beans yield variability possible. This study therefore recommends its use in supporting the development of management practices that are best adapted to climate variability and provides an insight on how to reduce risks associated with reduction in crop yield.

Keywords: Crop yield, soyabeans, ANN, climate Variability, Prediction

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INTRODUCTION

Climatic variability refers to variation in weather and climate variables at a given location at a point of time. It brings about change in the mean values of rainfall, temperature (Maximum and Minimum), changes in the level relative humidity, sunshine hours/duration and changes in wind direction and its speed. Climatic variability became one of the contemporary issue affecting the world which takes the attention of scientists and relevant stakeholders (Francis, *et. al.,* 2014). Rain fed mode of crop production across places has already faced the consequences caused by climate change and its variability (Ray *et al*., 2020).

Dimensionally, rain-fed system is said to be sensitive to weather and climate vagaries. And significant number populations in developing nations solely depend on rain fall to produce crops (Cudjoe *et al.,* 2021). Rainfed agriculture which is mainly subsistence in nature and characterized by low output faces the impacts of Climate variability (Olayide *et al*., 2016). Rainfall and temperature are dominant variables that play a greater role toward crop yield in a farming season (Yu *et al.,* 2014). According to Siebert and Ewert, (2014) the negative effects of climatic variability on food production are very diverse and intricate. Fluctuations in rainfall and temperature are affecting rain fed crop production in most regions which has resulted to low yield (Dube & Phiri, 2013).

Kano state is the most densely populated place of northern Nigeria in which 75% of the productive age participates directly or indirectly on agricultural activities. It's believed that most of the cereals and legumes crops are cultivated in the area. The area does experience variability in climatic conditions more especially during raining season which correspond to the season where farmers depend on rain to produce legumes like Soya beans through rain fed system.

Therefore, this paper developed a predictive model for forecasting climate related Soya beans yield variability in the study area. The study was limited to Kano state, it focused is on the prediction of soya beans yield produce through rain fed system crop yield in-relation to climatic variability**.** The climatic factors concerned includes: maximum and minimum temperature, rainfall, relative humidity, sunshine hours, wind direction and wind speed.

Climatic variables determines whether or not rain fed agriculture will be feasible and the type of crops that can be successfully cultivated in a given area. In Kano state, crop production served as a major source of livelihood for most rural communities since 75% of the population practice farming which is mostly rain fed agriculture and any change in climatic variables such as rainfall, temperature, wind speed and direction, sunshine duration and humidity levels are expected to affect the potential crops yields of legumes produce under rainfed system at the end of farming season (Ndamu, *et al.,* 2014) And each of these climatic factors has the ability to separately affect the different functions of the Soya beans in the course of their growth and the final yield.

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According to Yuhan *et al*., (2024) studies on crop yield prediction in-relation to climatic variables is becoming an interesting arena that researchers in agricultural sector need to explore looking at it potentials in developing initiatives and programs that support socioeconomic wellbeing of the people. In that proper and accurate prediction of crop yield is very essential to the famers, agricultural institutions and the government for initiating policies that guides decision making and implementation.

Therefore, this paper developed a predictive model for forecasting climate related Soya beans yield variability in the study area. The study was limited to Kano state, it focused is on the prediction of soya beans yield produce through rain fed system crop yield in-relation to climatic variability**.** The climatic factors concerned includes: maximum and minimum temperature, rainfall, relative humidity, sunshine hours, wind direction and wind speed

MATERIALS AND METHODS

Description of the Study Area

The study area is located between latitude 10^0 05″ N and 12^0 45″ North of Equator and longitude $7^0$45″ E and 9^0 75″ East of Greenwich Meridian. It shares borders with Katsina State to the North-West, Jigawa State to the North-East, Bauchi State to the South-East and Kaduna State to the South-West. It has a land area of about 20,131 km². The climate of the Kano State is the tropical dry-and-wet type, classified by Koppen as Aw. There are two distinct seasons resulting from the seasonal movement of two air masses in the region. The air masses are tropical continental which is dry and the other one is called tropical maritime air mass which is wet in nature, given birth to wet and dry season.

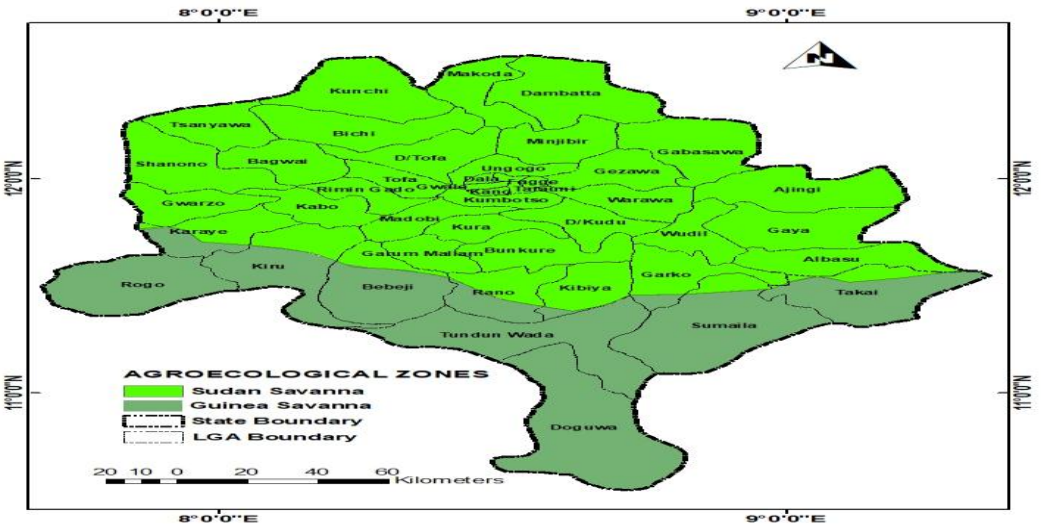

Figure 1: Kano State Showing Agro-ecological Zones.
Source: Adopted from IITA Agro-ecological Map (2004) as used in Hassan (2023).

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The wet season lasts from June to September although May is sometimes humid. The dry season extends properly from mid-October of the one calendar-year to mid-May of the next. The annual mean rainfall in the region is between 800mm and 900mm. (Olofin, 2016) variations about the annual mean value are up to ± 30 percent. More than 300mm of the rainfall is received in August alone, while the truly wet season lasts from June to September.

Data Type, Sources and Collection Procedure

The quantitative (secondary) information were generated from the historical data for climate variables (rainfall, maximum temperature, minimum temperature, relative humidity, sunshine hours, Wind speed and direction) and Soya beans yield record for 13 years were collected from National Aeronautics and Space Administration (NASA) and the Kano Agricultural and Rural Development Agency (KNARDA) respectively. Several studies utilized NASA data to analyze the status of climatic variables over time, studies like that of Udeh *et al.*, (2024) and Ishaku *et al.*, (2024), equally records of agricultural yield were used because it can provide valuable insights into trends and patterns that can be used in trend analysis and prediction of crop yield.

Mean daily data of rainfall, maximum temperature, minimum temperature, relative humidity, sunshine hours, wind speed and direction data was obtained via NASA POWER Data Access Viewer (DAV https://power.larc.nasa.gov/data-access-viewer/) where mean annual values were derived. Annual yield records (in tons) of Soya beans were collected from Kano Agricultural and Rural Development Agency (KNARDA) Kano office. These data were collected on excel spread sheet for easy computation.

Methods of Data Analysis

In this study the ANN was employed to analyze the data, the data set was divided into two, 70% of the data was used for the training and 30% of the data for validation. The essence of the training is to allow the network to understand the pattern of the data set, while validation is to validate whether the train data set has been able to predict with high level of accuracy. Artificial neural networks (ANN) is an intelligence algorithm model technique that is use to predict the impact of certain input variables (like climatic variables) on response variable or dependent variable (Example, Crop yield), ANN is widely use because it mimic the central nervous system of a human brain.

It has the ability to learn and it can be train to learn the pattern of the data set. Hence, ANN helps in predicting crop yield by learning complex and non- linear relationships between meteorological variables and crop yield data. It has the capacity of identifying patterns in historical data and makes forecast or prediction of the future yield. That is why it can handle complex relationships far better than other modeling techniques.

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PRESENTATION OF RESULTS AND DISCUSSION

Artificial neural network was applied to predict crop yield of Soya beans, where seven climatic variables that comprises of Maximum temperature, Minimum temperature, Rainfall, Relative humidity, solar radiation, Wind speed and Wind direction were used as input variables for the ANN network. Different hidden neurons were used to train the ANN network in order to understand the pattern of the data set for better prediction.

Several ANN topologies were designed to determine the best hidden layer with the maximum prediction model. The maximum prediction for Soya beans yield in ANN model was gotten in 6 hidden neurons. Therefore the highest prediction was obtained with an Rsquare (R_2) of 0.99 (99%) for the training and validation having an R_2 of 0.80 (80%) as shown in figure 2. While the training and validation it is a perfect linear graph which shows that the actual variable is the same as the predicted variable, also the actual value and the predicted result correlate much which gives a perfect linear graph presented in shown in figure 4. Equally a study conducted by Weiwei *et al.*, (2025) that modeled the soya beans yield with weather dynamics revealed an improved yield prediction.

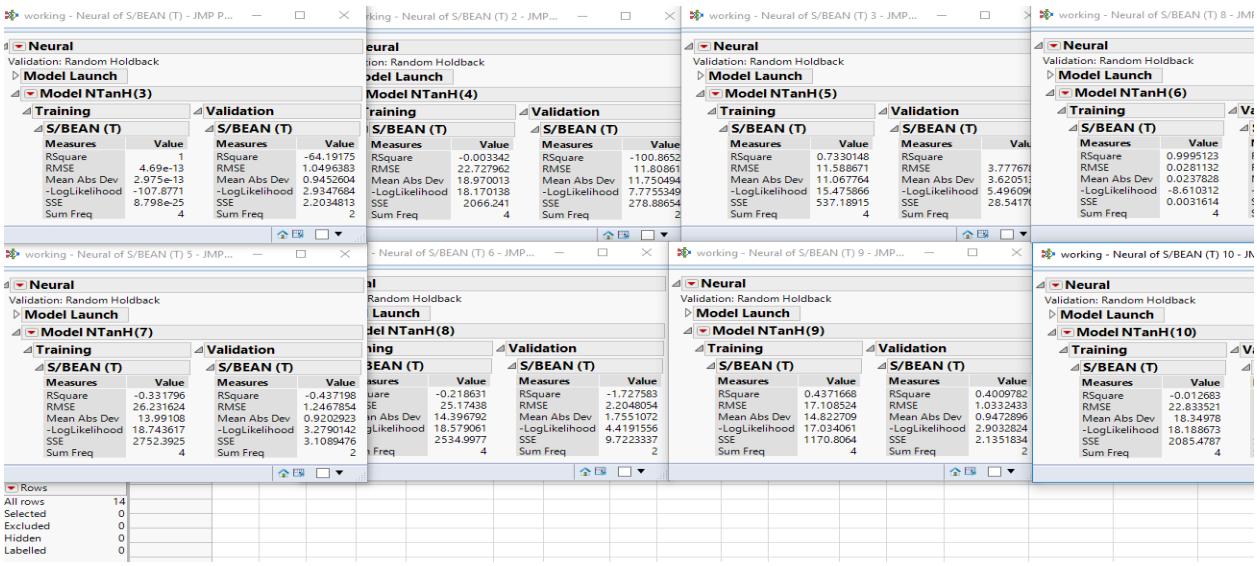

Figure 2 showing ANN training of different neurons for predicting Soya beans

Soya bean is often called "miracle crop." It is one of the global foremost providers of vegetable protein and oil. It can be grown in a wider variety of climatic conditions. Consequently, soya beans are the most widely grown oilseed in the world. Soya beans are normally regarded as warm season crop produce mainly rain-fed system of production. It requires some specific meteorological conditions to grow optimally. Some of the conditions that allow soya beans to thrive include optimum temperature at the germination stage ranging

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from 15^0 C to 30^0 C, and it can tolerate a temperature of up to 40^0C. It needs sufficient rainfall and full sunny days of between 6 to 8hours (Hassan, 2023).

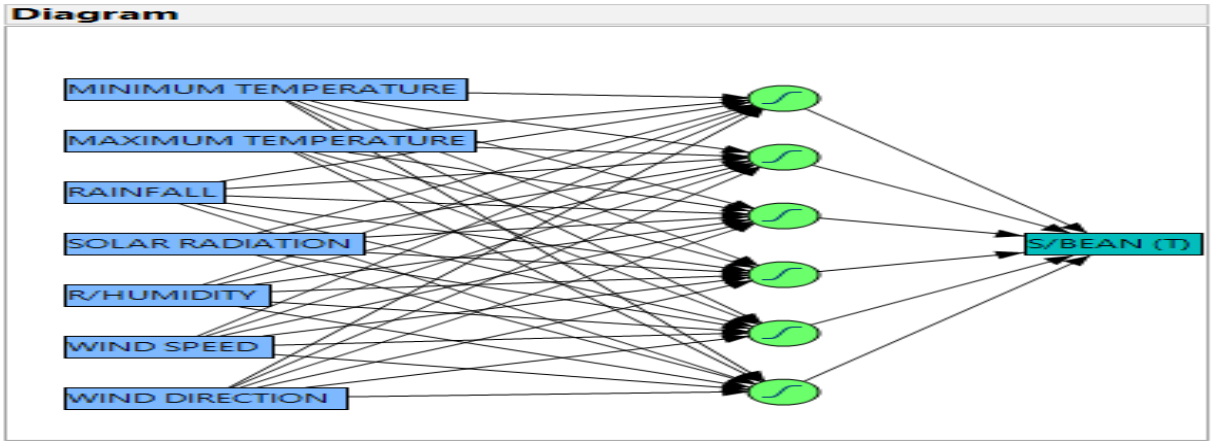

Figure 3: ANN typology showing input variables and hidden neurons for predicting Soya beans yield

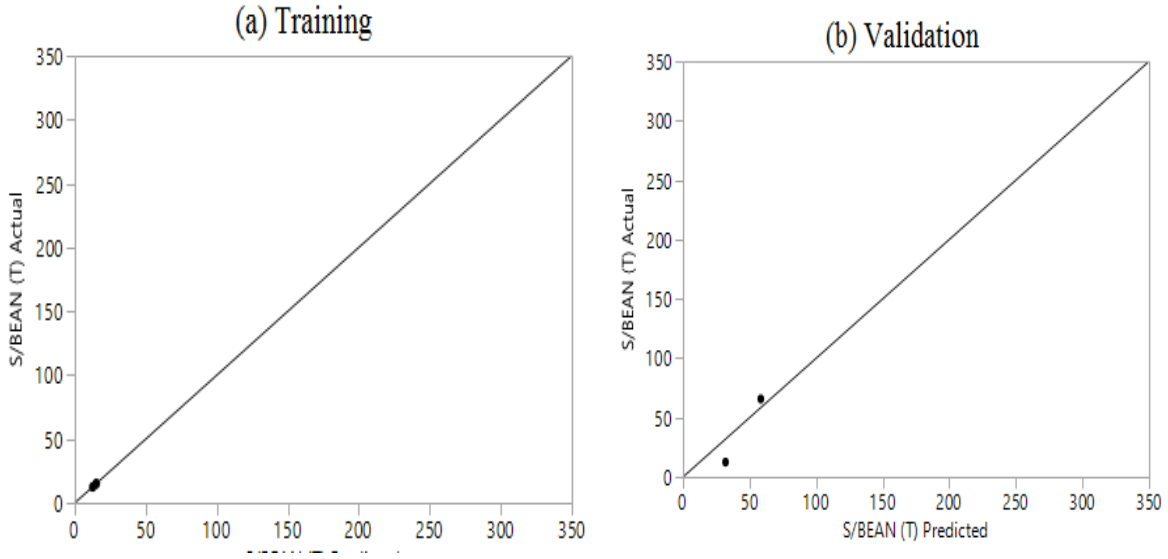

Figure 4: Showing the linear graph between the actual predicted result of soya beans (Training and Validation)

Researches has demonstrated that machine learning like artificial neural networks (ANN) can provide more accurate prediction on studying crop yield in-relation to climatic variables. Some of these studies include the work of Nirmitha *et al*., (2013) who used artificial neural networks to predict rice yield in India using climate data, the climatic variables were found to have significant impacts on rice yield. The research highlighted the importance of using advanced models for better prediction.

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Another study by John (2025) Compared five different machine learning in predicting sorghum yield including artificial neural network (ANN), the work found that artificial neural network was among the models that presented high accurate prediction supported with a better R^2 values. Also a study by Elizondo *et al.*, *(*1994) that focused on predicting the yield of soya beans using machine learning (ANN), the model clearly gives better prediction when compared to other methods. Equally a study carried out in Maharashtra India that utilized climatic data between 1998-2002 were artificial neural network was employed to predict crop yield, the model indicated the potentials of ANN model toward helping famers in making a proper decision looking at the predicted yield. It is well known fact, that crop production is influence by a number of interconnected factors and makes it difficult to explain their relationship by using conventional means (Paswan and Begum 2013).

Thus using artificial neural network (ANN) is recommended to handle complicated relations between different parameters and crop production. Many studies employed ANN in predicting agricultural crop yield example include (Dumenu, W.A & Obeng, Jian *et al*., 2016, Munkvold, 2004).

CONCLUSION AND RECOMMENDATION

The ANN model developed in the study accurately predicted the Soya beans yield with very high R-square and a resulting low root mean square error. The study indicated that the model is very reliable and statistically significant in predicting the variability of Soya beans yield. Therefore, based on the training and validation, it is a perfect linear graph which shows same values for both the actual and predicted variables. Findings from the study reveals that the ANN has the capacity of identifying patterns in historical data and can make prediction of Soya beans yield variability possible.

Therefore, the study recommends the use of ANN model in supporting the development of management practices that are best adapted to climate variability and provides an insight on how to reduce risks associated with reduction in Soya beans yield.

Competing Interest

The authors have declared that no conflicting interest exist in this study

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