FORECASTING THE OCCURRENCE OF DRY SPELL DURING THE GROWING SEASON IN NIGERIA: A REGRESSION MODEL APPROACH

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Abstract

This study examines the relationship between meteorological factors and dry spell occurrences during growing seasons in Nigeria. Using historical data from 2018 to 2023, we analyzed six geopolitical regions, each represented by one state. We collected and analyzed historical meteorological data (rainfall, temperature, and humidity) from the six states. Correlation analysis identified significant relationships between variables. We derived a Temperature Range variable from maximum and minimum temperatures and employed Ordinary Least Squares (OLS) regression and machine learning regression models to predict rainfall patterns. Significant correlations exist between rainfall, temperature, and humidity. Temperature Range and Relative Humidity effectively predict future rainfall patterns. Regional temperature variations were observed, with high temperatures prevailing in northern regions and low temperatures characterizing southern regions. A strong negative correlation exists between Temperature Range and annual rainfall. Furthermore, regions with lower temperature ranges exhibit higher humidity, leading to increased rainfall and reduced dry spells. Notably, machine learning regression models better OLS regression due to relaxed normality assumptions. This study enhances understanding of dry spell predictions in Nigeria's growing seasons, providing valuable insights for agricultural planning and climate resilience strategies.

Keywords: Correlation Analysis, Dry Spells, Meteorological data, Rainfall, Regression Model, Temperature

1.0 Introduction

Dry spells pose significant threats to agricultural productivity in Nigeria. Effective forecasting can mitigate these impacts. In the developed world, the occurrence of a prolonged period of little or no rainfall, commonly known as a dry spell, is typically linked to a decrease in crop yield, a deterioration of the environment, and corresponding economic setbacks. Conversely, in the

ISSN NUMBER: 1116-249X

developing world, particularly in most parts of Africa, a dry spell can pose a significant threat to the local population, manifesting in the loss of livelihoods, food insecurity, and even famine, as highlighted by Bwengye *et al*. (2023). The Ichkeul basin in Northern Tunisia experiences random dry spells during the rainy season, with the longest dry spells having a recurring interval of 127 years (Mathiouthi & Lebdi, 2022). The Indo-China Peninsula has witnessed an increasing trend in the duration of dry spells during the rainy season due to climate warming, as hotter seasons are characterized by more frequent and prolonged dry spells (Wu *et al*., 2023).

Considering Nigeria's status as a producer of various staple food crops, such as rice, corn (maize), yam, cocoyam, beans, sorghum (guinea corn), melon, and soya beans, it is evident that the occurrence of dry spells during the growing seasons would be immensely catastrophic, given that the majority of the population heavily relies on rain-fed agriculture for their sustenance and economic well-being, as explicated by Shiru *et al*. (2018) and further supported by Shiru *et al*. (2020). These dry spells, characterized by unpredictability and intensity, pose a severe threat to not only agricultural productivity but also to water resources and overall food security. Despite the growing awareness surrounding climate change and its potential consequences, there exists a noticeable gap in our understanding and capability to forecast the onset and duration of these dry spells, particularly within the agricultural context in various regions of Nigeria (Shiru *et al*., 2018, Shiru *et al*., 2020; Nnoli *et al*., 2020).

Furthermore, an increase in the quantity of annual rainfall has been observed, particularly during the months of June, July, and August, resulting in frequent incidents of inundation (Oyedepo *et al*., 2021; Abaje *et al*., 2014). The examination of trends also reveals a statistically significant upward trend in wind velocity during the period of observation. These modifications in the climate possess implications for transportation infrastructure, necessitating a reassessment of models predicated on the perceived decrease in precipitation (Osunlakin & Falola, 2022). All in all, the climate in Abeokuta has experienced alterations in temperature, humidity, rainfall patterns, and wind velocity over the past century. Climate patterns and variability in Abeokuta have been extensively examined. The examination of weather data reveals that Abeokuta undergoes a general diurnal fluctuation between the dry/harmattan season and the wet/rainy season, a pattern that is typical for Nigeria (Oyedepo *et al*., 2021). A statistical comparative analysis of meteorological parameters over a 10-year span indicates a significant decrease in vapor pressure, air temperature,

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and relative humidity, while wind speed exhibits a statistically significant upward trend (Ganiyu *et al*., 2022). Moreover, the investigation explores the impact of climate variability on biomass density in Oyo and Ogun States, revealing a gradual decline in biomass due to the continuous rise in temperature. Prediction of yearly mid-growing season first and second critical dry spells using artificial neural networks (ANN) for enhanced maize yield in nine stations in Nigeria is investigated by (Nnoli et al., 2020).

Therefore, there is an urgent need to develop a robust and context-specific regression model tailored to different regions in Nigeria. Such a model should make use of historical meteorological data, localized soil moisture dynamics, and other critical variables to enhance the accuracy of dry spell predictions during the growing season. By focusing on various regions in Nigeria, the primary objective of this research is not only to advance the scientific understanding of climate patterns in the country but also to empower local agricultural stakeholders with timely and precise information. This, in turn, will foster the adoption of sustainable practices and enhance the resilience of the agricultural sector in different regions of Nigeria. This paper is divided into five sections. Following this introduction (section 1). Section 2 describes the materials and methods used. The results are presented in sections 3, followed by a discussion in section 4. The paper concludes with a summary of key findings in section 5.

2.0 Methods

2.1 Model Evaluation

This study aims to use a reliable regression model for predicting dry spells using historical meteorological data. The objective of the regression analysis is to estimate the coefficients using the collected meteorological data. These coefficients will help understand the relationship between the meteorological variables and the occurrence of dry spells, ultimately leading to the development of a predictive model. The regression model equation could take the form:

$$Y_{ij} = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \varepsilon_{ij} \quad (2.1)$$

where,

Y is the response variable, β_0 is the intercept term, $(\beta_1, \beta_2, \beta_3)$ are the coefficients of the independent variables, (X_1, X_2, X_3) are the predictors variables and ε is the error term.

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2.1.1 Multiple Regression Model

Here, we forecast the occurrence of dry spells during the growing season, and a regression model will be developed. The regression model equation is:

$$Y(Dry\ Spell) = \beta_0 + \beta_1 Temp + \beta_2 Humd + \varepsilon \quad (2.2)$$

where,

- Y is the response variable representing the occurrence of dry spells
- β_0 is the intercept term,
- $\beta_1, \beta_2, \beta_3$ are the coefficients of the independent variables,
- Temp is the predictor variable for temperature
- Humd is the predictor variable for humidity and
- ε is the error term.

The independent variables represent the key meteorological factors that potentially influence the occurrence of dry spells. These factors will be carefully selected and analyzed to develop a context-specific regression model. The goal is to identify the most significant meteorological variables that contribute to the prediction of dry spells during the growing season in Nigeria.

2.1.2 Correlation Analysis

Correlation Analysis: Examining relationships between rainfall, temperature, and humidity which means we examine the relationships between meteorological variables, with correlation analysis. The Pearson correlation coefficient (r) will be calculated using the formula:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][\sqrt{[n\sum y^2 - (\sum y)^2]}}} \quad (2.3)$$

where,

r is the Pearson correlation coefficient, n: number of data points, $\sum xy$: sum of the product of paired scores, $\sum x$: sum of the x scores, $\sum y$: sum of the y scores, $\sum x^2$: sum of the squared x scores and $\sum y^2$: sum of the squared y scores.

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2.1.3 Data Visualization

Graphical representations, including charts, graphs, and maps, will be employed to visually convey patterns and trends in meteorological data. Visualization aids in communicating complex findings to a wider audience.

3.0 Results from Analysis of Data

Data Collection: Historical meteorological data (2018-2023) for six Nigerian states, representing six geopolitical regions. The analysis and modelling include exploratory data analysis of the data provided by the Nigerian Meteorological Agency, and correlation analysis to examining the relationship between meteorological factors and dry spells. The model forecast the occurrence of dry spells in Nigeria.

3.1 Exploratory Data Analysis

The data used for the study is inclusive the six geopolitical zones in the country (Nigeria): Enugu (South East), Oyo (South West), Rivers (South-South), Borno (North East), Kano (North West) and Abuja (North Central). The data contains the meteorological information of these states over a period of 6 years (2018 – 2023). It contains the annual minimum, maximum temperature, relative humidity and the annual rainfall in the stated states.

3.1.1 Annual Rainfall

Table 1: Statistical Summary of Annual Rainfall (2018 – 2023)

Annual Rainfall	Abuja	Borno	Kano	Enugu	Rivers	Oyo
Mean	977.3333	1126.7	774.4167	1860.818	2236.45	1925.917
Standard Deviation	122.4507	256.7003	71.39945	413.345	555.5353	248.0592
Maximum	780.7	822.6	696.2	1183.62	1580.5	1547.5
Minimum	1140.2	1444.5	876.3	2472.99	3113.1	2210.9

Table 1 shows the summary of the annual rainfall in the six states over a period of 6 years. From the result, the annual rainfall on average, is highest in Rivers which is representing the south-south region, than other states. The lowest state is Kano with an average annual rainfall of 774.4167mm.

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For further analysis, line graph and bar chart depict in Figure 1 below that shows the trend and average annual rainfall for over 6 years.

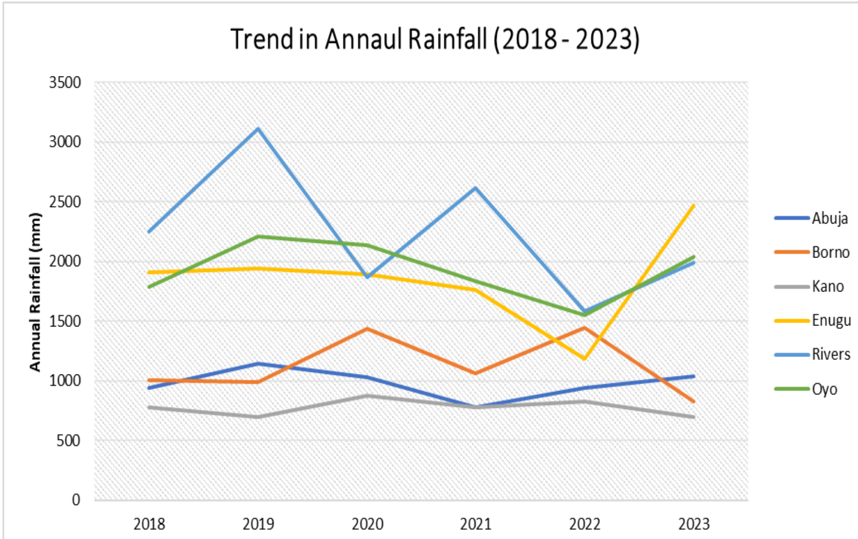

Figure 1: Line Graph showing the trend in annual rainfall (2018 – 2023)

The annual rainfall is the highest in 2019 for Rivers with a total annual rainfall of over 3000mm. For Oyo, the average rainfall is 1925.92mm with a standard deviation of 248mm. This is the highest in 2019 with a total rainfall of 2210mm. For Enugu, however, the highest is in 2023 with an average rainfall of 1860mm, and the highest is 2473mm. Hence, for the three states in the southern zone, the temperature is lowest in the year 2022 with an annual temperature of 1183mm, 1580mm and 1547mm for Enugu, Rivers and Oyo states respectively.

Also, analysis shows that northern region (Abuja) rainfall is the highest in 2019 with an annual rainfall of 1140.2mm and lowest in 2021 with a total rainfall of 780mm. Borno has highest rainfall in 2022 and lowest in 2023 with an annual rainfall of 144.5 and 822mm. Then, Kano has highest rainfall in 2020 and lowest in 2019 with an annual rainfall of 876 and 696.2mm. Also, it can be observed that rainfall pattern in Southern Nigeria is more predictable than the Northern part. In southern part, rainfall is lowest in 2022 and highest in 2019 with the exception of Enugu whose annual rainfall highest in 2023. However, northern region, has high and low of rainfall with no defined pattern.

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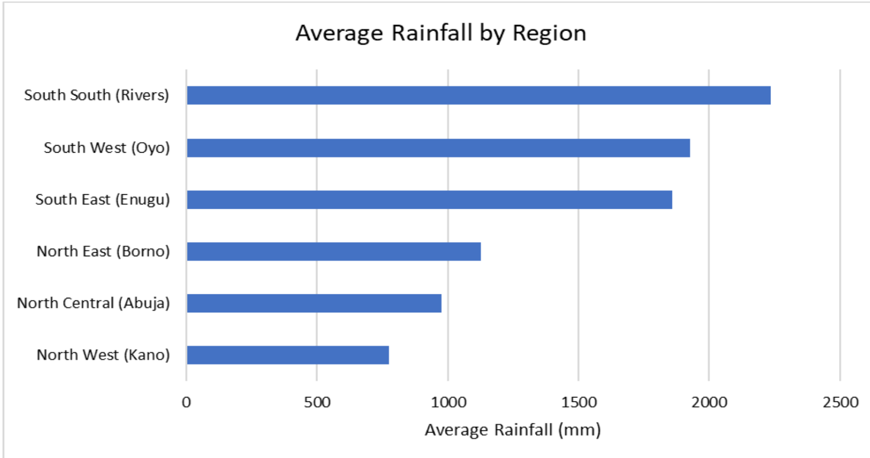

Figure 2. **Bar Chart showing the Average Rainfall by Region**

More so, the average rainfall in the past 6 years is visualized using a bar-chart as seen in Figure 2 above. The chart shows the states with the highest rainfall and those with the lowest rainfall. From the chart, the Southern region has the highest rainfall quantity with the South-South region (Rivers) at the top of the list, followed by South West (Oyo) and South East (Enugu). The northern region is at the bottom of the list with Borno (North East) at the top for the Northern states), followed by North Central (Abuja) and North West (Kano). The deductions from the analysis shows that rainfall and dry spell varies by region or location and by year. For the southern states, 2019 had the lowest rainfall amount compared to the other 6 years considered.

3.1.2 Relative Humidity (RH)

It is a meteorological term used to measure water vapour in the air compared to the total amount of vapour that can exist in the air at the current temperature. The RH is analysed for the six selected states representing the geopolitical zones in Nigeria. Table 2 below shows the statistical summary of relative humidity from 2018 to 2023.

Table 2: Statistical Summary of %Relative Humidity (2018 – 2023)

Relative Humidity	**Abuja**	**Borno**	**Kano**	**Enugu**	**Rivers**	**Oyo**
Maximum	72	51	58	79	85	81
Minimum	63	42	45	72	82	75
Mean	67	46	48	74	83	78
Standard Deviation	3.197	3.117	4.861	2.697	1.196	1.813

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In Table 2, Rivers State (South South) has highest RH of 83% with a standard deviation of 1.196. Borno State (North East) has lowest average RH of 46% and is closely followed by Kano with a RH of 48%.

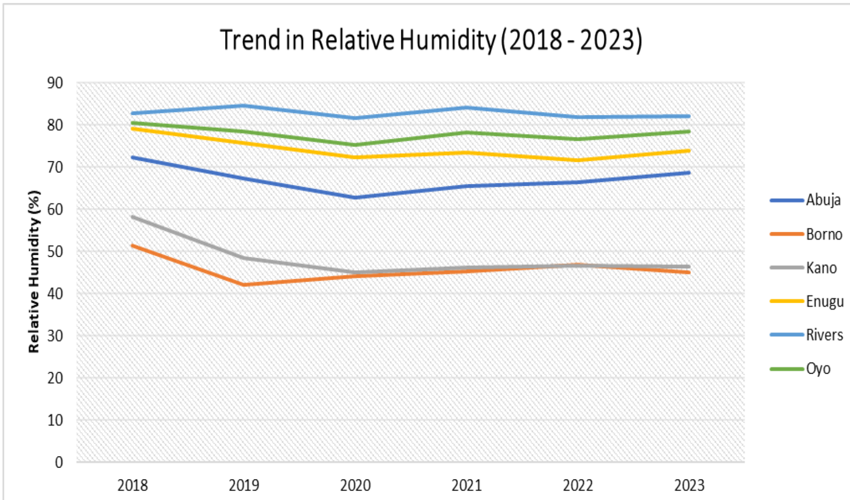

Figure 3. Line Graph showing the trend in RH (%)

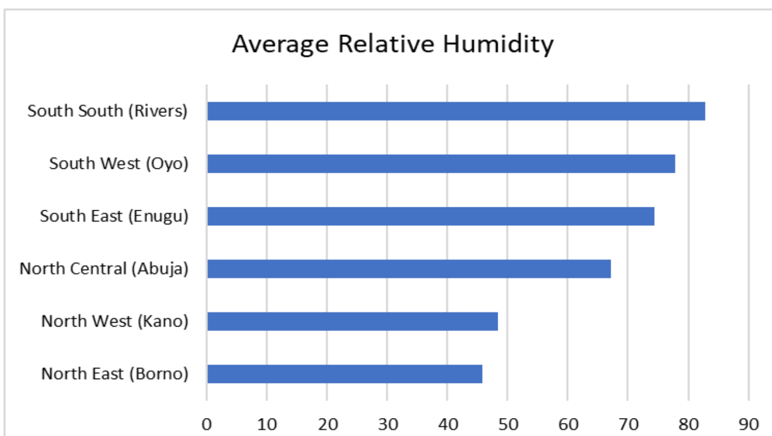

Figure 4. Bar chart showing the average RH

Furthermore, the line graph in Figure 3 exhibits the trend in RH for the six-year period. Abuja has highest RH in 2018 and lowest in 2020. In the same vein, Borno has highest in 2018 and lowest in 2019, Kano has highest in 2018 and lowest in 2020. Southern states has highest in 2018 and lowest in 2022. In Enugu, RH was high in 2019. However, in 2020, 2022 and 2023 the same RH value of 82% which is the lowest. Also, Oyo state has highest RH in 2018 and lowest in 2020. It is observed that for most of the states, the RH was high in 2018 and low in 2020.

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3.1.3 Temperature

The country has a maximum temperature of between 31^0C and 37^0C. The chart below shows the average annual maximum temperature in the six states considered.

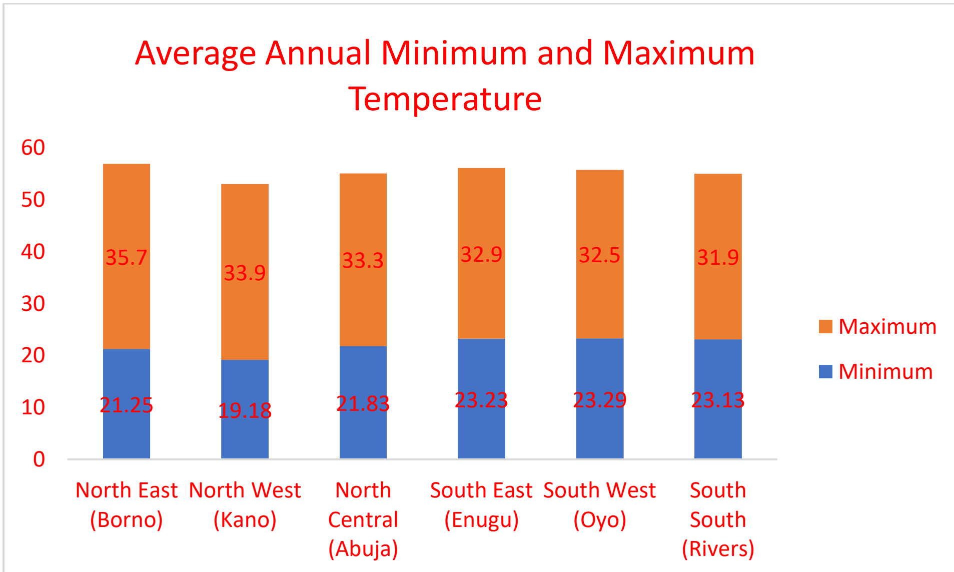

Figure 5: Bar chart showing average annual maximum and minimum temperature

The minimum temperature is on average range from 19^0C and 23^0C. Based on the bar charts in Figure 5 about the minimum and maximum temperature, it is observed that temperature range for northern region is higher than that of the southern region. The confirmation can be seen in the diagram (Figure 6) below for the distribution of temperature range by region.

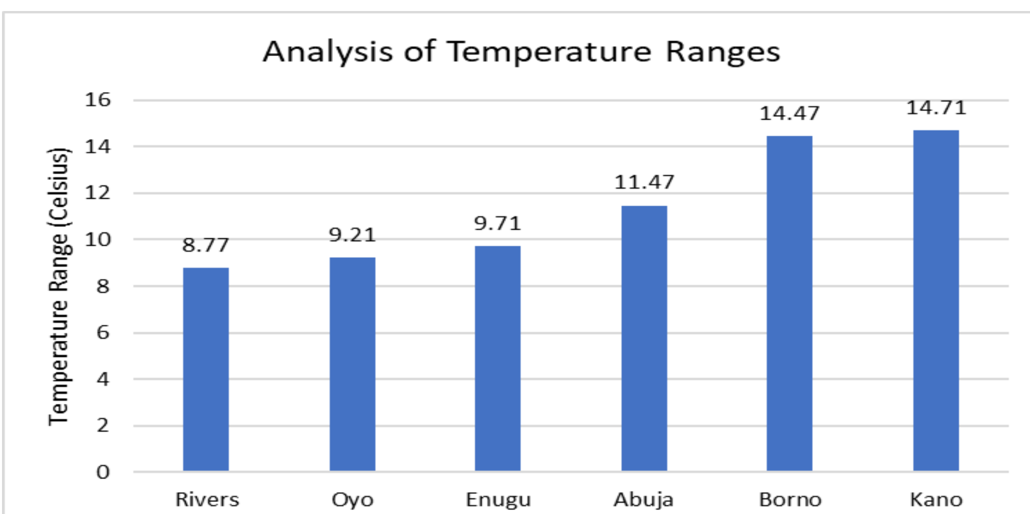

Figure 6: Analysis of average temperature ranges

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3.2 Correlation Analysis

Correlation analysis is an inferential statistical procedure used to test the relationship between variables. For this research, correlation analysis is used to test the relationship between rainfall and other meteorological variables that is relative humidity and temperature.

Table 3: Correlation Table showing the relationship between meteorological variables

Variables	Annual Rainfall	Maximum Temperature	Minimum Temperature	Temperature Range	Relative Humidity
Annual Rainfall	1.000000	-0.619898	0.757209	-0.794006	0.757643
Temperature Range	-0.794006	0.845584	-0.898056	1.000000	-0.967010
Relative Humidity	0.757643	-0.873847	0.822250	-0.967010	1.000000

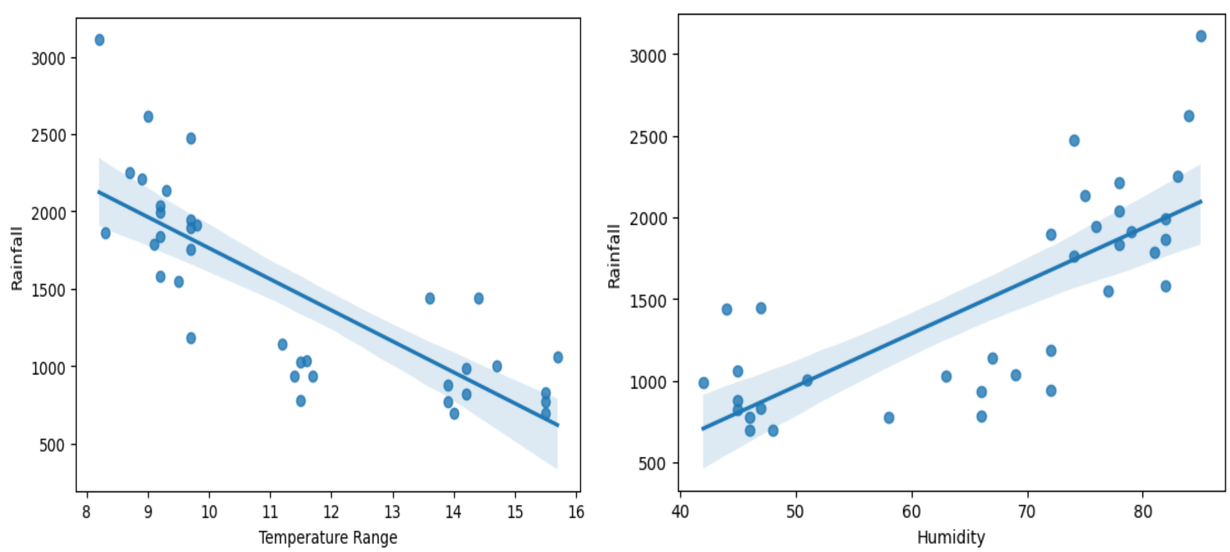

Figure 7: Relationship between temperature range and humidity with rainfall

Table 3 above shows the relationship between annual rainfall, temperature, and humidity using a correlation table. The relationship between temperature range and annual rainfall was calculated and found that there is a strong negative relationship between the two variables ($r = -0.794$).

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The first scatterplot in Figure 5 visualizes the relationship and shows there is a downward trend. An increase in temperature range is attributable to a decrease in average annual temperature. It is then obvious that regions with high-temperature ranges are generally northern regions and these areas are also known to have low annual rainfall (dry spells). Additionally, the relationship between the RH and annual rainfall is compared. In the table, it shows a strong positive relationship ($r = 0.760$) between humidity and rainfall, and the second plot in Figure 5 corroborates this claim as it shows an upward trend. This implies that regions with high humidity are prone to more rainfall quantity and less dry spells.

3.3 Multiple Regression Analysis

To predict future rainfall patterns, two major variables were considered: Temperature Range which is obtained from the difference between the maximum temperature and minimum temperature and relative humidity. These two variables are meteorological variables and the model was built to test if they are able to predict rainfall and thus dry spell in the future.

Table 4: OLS Regression Result for Coefficients

Estimates	**Coefficient**	**Std. Error**	**t-value**	**P >|t|**
Intercept	4645.538	2341.598	1.984	0.056
Temperature Range	-238.820	104.702	-2.281	0.029
Humidity	-6.678	17.667	-0.378	0.708
R-Squared	0.632			
Adj. R-Squared	0.610			
F-Statistic	28.24			
Prob (F-statistic)	6.85×10^{-8}			

The estimated β_s is

$$Dry\ Spells = 4645.538 - 238.820Temp - 6.678Humd \tag{4}$$

Equation 4 explains the relationship between temperature range and humility with rainfall. For every temperature range, dry spells decreases by -238.820 units. In addition, for every humidity, dry spells decreases by -6.678 units. The baseline dry spells is 4645.538. However, (4) indicates a negative linear relationship between the temperature range and humility with rainfall. Also, the

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model had a coefficient of determination of 0.632 which performs moderately well in prediction efficiency and an adjusted R-squared of 0.610 in Table 4.

3.4 Comparison of Models

We equally make comparison between multiple regression model and machine learning regression model, where their results show in Table 5 below.

Table 5: Ordinary Multiple and Machine Learning Regression Model

Estimate	**OLS Regression Model**	**Machine Learning**
Intercept	4645.538	4839.243
Temperature Range	-238.820	-274.301
Humidity	-6.678	-7.934
R-Squared	0.632	0.886
Adj. R-Squared	0.610	0.536
F-Statistic	28.24	66.263
-LogLik	264.610	208.480
AIC	535.230	422.960
BIC	539.980	426.960
MAE	302.980	183.780
MSE	141900.630	38610.100
RMSE	376.700	196.490

Machine learning regression model produces lower values in the estimation due to its less strict normality assumptions therefore, it performs better than the OLS multiple regression model.

4.0 Discussion

Different meteorological variables using the data obtained from the Nigerian Meteorological Center in Abuja. The analysis focused on three major variables were rainfall, temperature, and RH. From the result, it was evident that high temperatures were pertinent to the northern region as well as very low temperatures. Then, an addition variable temperature range was created which is the difference between the maximum temperature and minimum temperature. This reveal a strong negative relationship between temperature range and annual rainfall, implies that regions with

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higher temperatures are less likely to have rainfall and more likely to have dry spells. Conversely, regions with lower temperature ranges had higher humidity and more prone to have more rainfalls and little to no dry spells. The analysis also conducted a regression analysis to test if temperature range and humidity are viable in the prediction of annual rainfall. The model result showed that the regression model can significantly predict future annual rainfall and dry spells and the most important factor influencing this is temperature range with negative contributions. Therefore, analysis showed that some years are more prone to dry spells than others.

5.0 Conclusion

The effects of dry spells can be disastrous, especially in Africa where several families and communities rely on agriculture to cater their basic needs. Dry spells in these regions have been linked to loss of livelihood and famine. The major cause of dry spells is fluctuating weather patterns and climate change and it occurs when there is little to no rainfall during the growing season. To analyze and predict the future occurrence of dry spells in Nigeria, data was collected from the Nigerian Meteorological Agency and it majorly contains details about temperature (Minimum and Maximum), Relative humidity, and Rainfall in mm. For effective analysis and prediction, the data was collected over 6 years for a sample of 6 states in Nigeria, each representative of the country's six geopolitical zones. An exploratory analysis of the data showed that the states in the Northern region of Nigeria are more prone to dry spells as this region is characterized by low rainfall, low relative humidity, and high-temperature ranges. While the southern region of Nigeria stands out in terms of the total amount of rainfall and relative humidity, analysis shows that the south-south zone is less prone to dry spells. In addition to the variation in rainfall by region, analysis shows that total rainfall was lower in certain years than in others. For most of the states surveyed, annual rainfall was lower in 2019 than in the remaining five years.

To test for the relationship between meteorological variables, the Pearson correlation analysis was employed which is ideal for testing the relationship between continuous variables. The result from the correlation analysis is presented in Table 3. From the result, there is a moderate negative relationship between maximum temperature and annual rainfall, a strong positive relationship between minimum temperature and annual rainfall, and a strong positive relationship between relative humidity and annual rainfall. In addition, a new variable, temperature range was computed which is the difference between the minimum and maximum temperature. It was observed that the

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northern states had the lowest minimum temperature and the highest maximum temperature. Consequently, the northern region had a higher temperature range than the southern region. A correlation analysis of temperature range and rainfall shows that there is a strong negative relationship between the variables, implying that states with a high-temperature range tend to have a lower rainfall quantity and are more prone to dry spells. The trend in the relationship was also visualized in scatterplots as shown in Figure 7.

To predict future dry spell occurrence, total annual rainfall was selected as the dependent variable with two independent variables: Relative humidity and temperature range. The result from the Ordinary Least Square Regression can be found in Tables 4 and 5. From the result, the regression model has an R-squared of 0.632 and an adjusted R-squared value of 0.610 which performs moderately well. To test the significance of the regression model and to check if the independent variable significantly predicts the dependent variable, the model computed the *Prob (F-Statistic)* which is significantly less than 0.05, hence, we conclude that the independent variables adequately predict the dependent variable. A further analysis of the independent variable shows that temperature ranges perform significantly better than relative humidity in the prediction of annual rainfall.

Further Study

More meteorological and ecological variables can be collected to augment the current regression model. Variables such as wind pressure, wind speed, presence of natural disasters and so on might help in efficient prediction of dry spells. Furthermore, time series models such as ARIMA, SARIMA and ARMA can be used in forecasting future rainfall patterns.

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ISSN NUMBER: 1116-249X