Proceedings of the 14th Nigeria Association of Hydrological Sciences Conference (Okitipupa 2024) held at Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State, Nigeria, November 5 - 8, 2024

IMPACT OF RAINFALL AND TEMPERATURE TREND ON THE YIELD OF MAIZE PRODUCTION IN ONDO STATE

Titlayo O. Oladitan and Aisha Emiola

Department of Crop, Soil and Pest Management, Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State Nigeria.

Email: to.oladitan@oaustech.edu.ng.Tel:+2348060485319

ABSTRACT

Rainfall and Temperature are notable climatic variables affecting the growth and yield of maize in the rainforest environment of Ondo State, thus, a study was carried out to assess the influence of climatic variable patterns on maize yield. The study employs secondary climatic data of Ondo state from 2000 -2024 and yearly yield data of maize from Agricultural Development Programme. Daily climatic variables were summarized and analyzed using regression and correlation. The correlation analysis revealed a non-significant negative relationship between maize yield and solar radiation (r^2 = -0.119), maximum temperature (r^2 = -0.366), and rainfall (r^2 = -0.104). Conversely, minimum temperature exhibited a slight positive correlation with yield (r^2 = 0.028). The results also showed a positive correlation between solar radiation and both maximum (r^2 = 0.235) and minimum (r^2 = 0.279) temperatures, while rainfall displayed a negative correlation with these variables (r^2 = -0.271). Trend analysis indicated an upward positive trend in maize yield, despite fluctuations in temperature and rainfall. Regression analysis further demonstrated that solar radiation, temperature, and rainfall collectively explained 50.6% of the variability in maize yield (R^2 = 0.506). The most significant impact on yield was attributed to solar radiation ($\beta = 3.747$, $p < 0.01$), followed by temperature, with rising temperatures contributing to decreased yields. These findings suggest that while maize production in Ondo State is influenced by multiple agro-climatic factors, the significant role of solar radiation highlights the need for adaptive agricultural practices to mitigate the adverse effects of increasing temperatures on maize yield.

Key words: climatic variable, rainforest, maize yield, climatic pattern

INTRODUCTION

Maize (Zea mays), an important globally recognised cereal crop. It plays a significant role in the food security and agricultural economies of sub-Saharan countries in particular, Nigeria. It serves as a staple food for millions of people and a critical component of the agricultural economies of many countries, including Nigeria (Ojo, 2000). In most sub-Saharan regions, maize is a vital crop for both food security and economic development, where it is used in various forms, including flour, pap, and animal feed. The crop also provides income for farmers and contributes to the local economy through sales in markets and supply to agro-industries (FAO, 2020).

In Nigeria, maize is cultivated extensively across various agro-ecological zones. The southwest region, being a rainforest, is also a significant production area. The cultivation is primarily under rainfed agriculture practices for a good source of food and income for smallholder farmers. However, the region's climate is a major constraint limiting and reducing the production level in the southwest rainforest zone. In the southwest rainforest zone in recent decades, climatic conditions have been experiencing fluctuation due to changes in rainfall patterns, including the timing, intensity, and distribution of rainfall, along with shifts in temperature trends globally, including in Nigeria. These climatic changes have raised concerns about their potential impact on maize yields, particularly in the rainforest agroecology of Ondo State, where the significance of maize in the region cannot be overstated (Ojo, 2000).

Global climate change, marked by increasing temperatures and altered precipitation patterns, has been identified as a major threat to agricultural productivity, particularly in Africa, where agriculture is heavily dependent on climate (IPCC, 2014). The variability in rainfall and temperature can have significant implications for maize production. For instance, inadequate rainfall or prolonged dry spells during critical growth stages can lead to water stress, affecting plant development and reducing yield. On the other hand, excessive rainfall can lead to waterlogging, which can also negatively impact maize growth. Similarly, temperature extremes, whether too high or too low, can affect maize physiology, leading to reduced photosynthesis, poor grain development, and ultimately lower yields (Okoye, 2017; Lobell and Gourdji, 2012).

Given the importance of maize to the livelihood of farmers in most local governments in Ondo State, understanding the impact of rainfall and temperature trends on maize yield is critical. These understandings can guide the development of strategies to mitigate the negative effect of climate change, thereby ensuring sustainable maize production in the region.

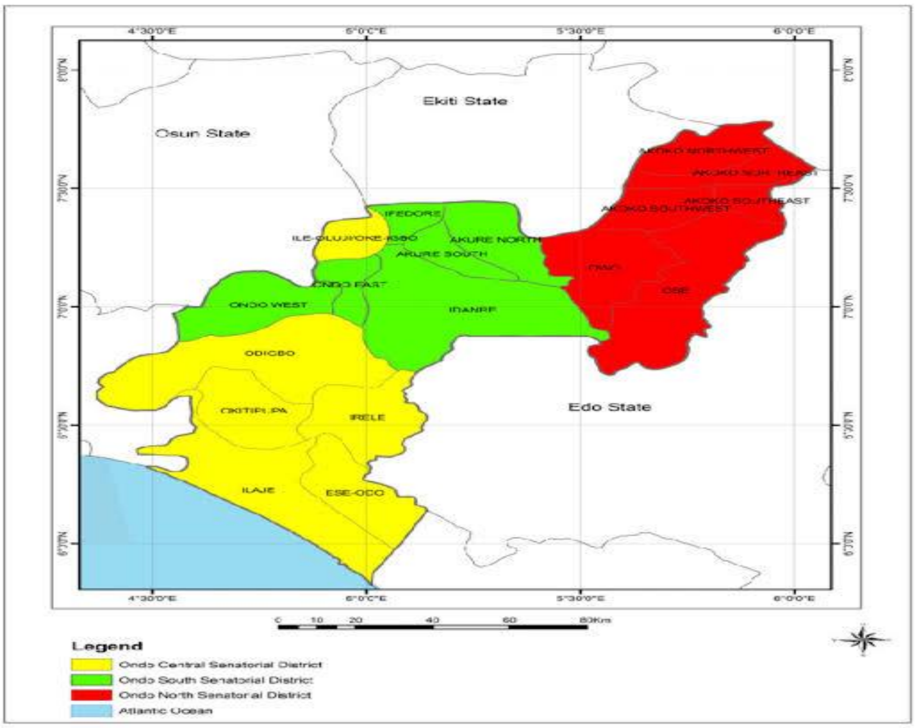
The agricultural sector in Nigeria, particularly in regions like the rainforest of Ondo State, is heavily dependent on rainfall and temperature. However, the increasing variability and unpredictability of these climatic factors due to global climate change have raised concerns about their impact on crop production. Maize, being a rain-fed crop, is particularly vulnerable to changes in rainfall patterns and temperature fluctuations (Akinseye et al., 2020).

In recent years, farmers in Ondo State have reported fluctuating maize yields, which they attribute to irregular rainfall and increasing temperatures. These climatic changes threaten the livelihoods of many farmers and the overall food security of the region. Despite the critical importance of understanding these impacts, there is limited research focusing specifically on most local governments in Ondo State. This study seeks to fill that gap by examining the relationship between rainfall, temperature trends, and maize yield in Ondo, with the aim of providing insights that can inform agricultural practices and policy decisions.

This study aims to assess the impact of rainfall and temperature trends on accumulated yield per land area of maize in Ondo State, Nigeria.

3.0 Materials and Methods

3.1 Study Area



3.1.1 Geographic Location

Ondo State is located in the southwestern part of Nigeria, lying between latitudes 5°45'N around the southern boundary (Ese-Odo) and 7°52'N around the northern boundary (Owo and Akoko) and longitudes 4°20'E and 6°05'E. It shares boundaries with Ekiti and Kogi States to the north, Osun State to the northwest, Ogun and Osun States to the west, and the Atlantic Ocean to the south. Ondo State features a mix of undulating terrain with hills and lowlands. The higher elevations in the northern part of the state and relatively flat lands in the central and southern regions provide diverse conditions for both arable staple foods and tree crops farming. The state's climate is tropical, with a distinct wet and dry season. The average annual rainfall ranges from 1,500mm in the northern parts to about 2,500mm in the southern coastal regions. Temperatures typically range from 22ºC to 32ºC, with peak temperatures typically observed in March and April, providing an optimal environment for agricultural practices.

Methodology

Meteorological data from the local weather stations within the state were collected from the Nigerian Meteorological Agency (NIMET) comprises of Rainfall (Total annual rainfall, monthly distribution, and rainfall intensity.), Temperature (maximum and minimum and mean temperatures),solar radiation and wind for a period of 24 years. Annual maize yield per hectare, planting and harvesting dates, and yield variability across different farming zones for a period of 22 years were also obtained from Agricultural Development Programme (ADP) in Ondo State.

To find out the rates of crop yields dependence on rainfall and temperature, Statistical techniques including Descriptive Statistics (Summary statistics for rainfall, temperature, and maize yield data to understand the central tendency and variability); Correlation Analysis (Pearson correlation coefficients to determine the strength and direction of the relationship between maize yield and climatic factors) and Regression Analysis (Multiple regression models to quantify the impact of rainfall and temperature on maize yield, controlling for other relevant variables) were employed to analyze the relationship between climatic variables (rainfall and temperature) and maize yield.

Trend analysis was conducted to identify long-term changes in rainfall and temperature patterns and their implications for maize production, and Time Series Analysis for the examination of temporal patterns in rainfall and temperature data to detect trends, cycles, and anomalies.

4.0 RESULTS

Summary statistics of agro-climatic variables for the period 2001 – 2024

The summary statistics of agro-climatic variables for the period 2001–2024 is presented in table 1. Solar radiation, maximum temperature, minimum temperature and rainfall ranged 2 – 530 (17.95±30.11), 26.90 – 32.43ºC (28.84±1.05 ºC), 17.63 – 29.73 ºC (25.40±41.31ºC) and 1000.64 – 2605.10mm (1792.681±399.937mm).

Correlation analysis of agro-climatic variables and maize yield

The relationship between agro-climatic variables and maize yield is presented in Table 2. Solar radiation (r^2 = -0.119),, maximum temperature (r^2= -0.366), and rainfall (r^2 = -0.104) showed a non-significant negative relationship with yield. Minimum temperature showed a positive correlation with yield (r2 =0.028).Table 3 presents the results of the correlation matrix of climatic variables. Solar radiation had a positive correlation with maximum temperature (r2 =0.235), minimum temperature (r2 =0.279) except rainfall (r2 = - 0.271) which is negative. This negative relationship pattern was observed among maximum temperature, minimum temperature, and rainfall. The overall result indicates that increases in solar radiation and temperature decrease the amount of rainfall.

Annual maize yield and agro-climatic variables

The trend analysis for maize fluctuated greatly (Figure 1), and it shows an upward positive trend, which is an increase in maize.The maximum and minimum temperature (Figure 2) show that it fluctuated with an increasing positive trend, which is an increase in maximum temperature, with the highest maximum temperature in 2001 with a value of 29.36˚C and the lowest maximum temperature of 28.39 ˚C in 2004. The highest minimum temperature was in 2022 with the value 23.39˚C and the lowest minimum temperature was 22.45 ˚C in 2002. The trend analysis of the annual mean maximum temperature remains constant every year; the annual mean minimum temperature increases 0.02 per annum. The mean temperature (Figure 3) shows that the trend line fluctuated with an increasing positive trend, which is an increase in mean temperature. And it shows an increasing upward trend, with the highest temperature in 2017 with a value of 25.49˚C and the lowest point in 2004. The annual mean temperature is increasing at 0.01 per annum.

The solar radiation (Figure 4) and rainfall (Figure 5) show that the trend line fluctuated with an increasing positive trend, which is an increase in solar radiation and rainfall. This reveals an upward trend with the highest solar radiation in 2024 with the value of 16.50 and the lowest point in 2004 with the value of 15.67. The lowest rainfall was in 2006 with a value of 1000.64 mm, while the highest point was in 2021 with a value of 16.67 mm. The annual solar radiation and rainfall increments are 0.02 and 36.07 per annum, respectively.

Influence of agro-climatic variables on maize yield

The regression analysis on the impact/influence of solar radiation, temperature, and rainfall on maize yield is presented in Table 4. The predictors (rainfall, temperature, and solar radiation) produced an r coefficient of 0.711, revealing that there is a correlation between rainfall, temperature, and solar radiation and maize yield. However, the combined effects of rainfall, temperature, and solar radiation on maize yields produced an r2 of 0.506. This signifies that rainfall, temperature and solar radiation can only explain 50.6% of maize yields, leaving the other 49.4% to soil types, farming techniques applied, and maize species used. All of which have not been used as predictors in the current study. The model is significant at F (4.611) = $p < 0.05$. This shows that maize yield in the area significantly depends on rainfall, temperature, and solar radiation. However, the effect of solar radiation (Beta 3.747; $p < 0.01$) is higher for maize yields than temperature (minimum: beta -3.756; $p < 0.01$, max: -3.213; $p<0.01$). An increase in temperature over a period of time can lead to a decrease in maize yield, while a decrease in rainfall for a long time may not have a significant impact (p=0.119) on maize yield. An increase or decrease in solar radiation will significantly impact maize yield.

Table 1: Summary Statistics of the agro-climatic variables for the period 2001–2024

Statistics						
	Minimum	Maximum	Mean	Std. Dev	Skewness	Kurtosis
Solar	2.00	530.40	17.9476	30.11103	16.996	290.229
Max.Temp	26.90	32.43	28.8454	1.04929	0.417	-0.269
Min.Temp	17.63	29.73	25.3969	41.30981	17.091	292.390
Rainfall	1000.64	2605.10	1792.681	399.937	0.102	-0.468

Table 2: Correlation coefficients between agro-climatic variables and maize yield

Parameters	Correlation coefficient
Solar radiation	-0.119
Maximum Temperature	-0.366

Minimum Temperature	0.028
Rainfall	-0.104

Table 3: Correlation matrix of agro-climatic variables

	Solar radiation	**Maximum Temperature**	**Minimum Temperature**	**Rainfall**
Solar radiation	1	0.235	0.279	-0.271
Maximum Temperature		1	0.327	-0.373
Minimum Temperature			1	-0.244
Rainfall				1

Figure 1-5 shows the trends of rainfall, temperature (Maximum Temperature, Minimum temperature and solar radiation) and yield per land area of maize in Ondo State, Nigeria fro 2000 - 2025. From the result (figure 1), between the Years 2000 - 2008, it shows yield to be on 2.0 - 2.4 (tons/hectares). Between 2008 - 2012, it shows little increase in yield to be on 2.0 - 3.0 (tons/hectares). Between 2012 - 2016, there was extensive increase in yield to be on 2.0 -6.0 (tons/hectares). This indicates that between the Years 2012 - 2016 the yield of maize increases on large land area. Between 2016 -2020, the yield showed on 2.0 - 2.5 (tons/hectares). Between 2010 -2025, 2.0 - 30 (tons/hectares) shows yield.

Maximum Temperature: Between the year 2000 - 2005 the temperature trend rose to above 29.2°C, which indicates higher increase in temperature between 2000 -2005 in Ondo State. Between 2005 - 2010, the temperature was at 29°C. Between 2010 - 2015 the temperature was between 28.8°C to 29.0°C. Between 2015 - 2020 the temperature was above 29. 2°C which indicates increase in temperature but not up to that of 2000 - 2005. Between 2020 - 2025 temperature was above 29.0°C.

Minimum Temperature: Between the years 2000 - 2005 the temperature is below 28.4°C, which indicates lower temperature between 2000 - 2005 in Ondo State. Between 2005 - 2010, the temperature is above 28.4°C. Between 2010 to 2015 the temperature is also below 28.4°C but lower to that of 2005 -2010. Between 2015 to 2020 the minimum temperature falls between 28. 6°C - 28.8°C. Between the years of 2020 - 2025 the minimum temperature falls between 28. 6°C - 28.8°C, but a bit higher than that of 2015 - 2020.

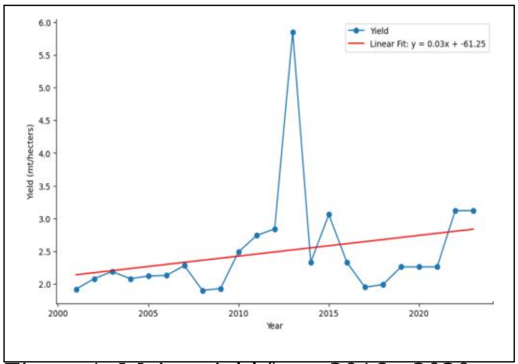
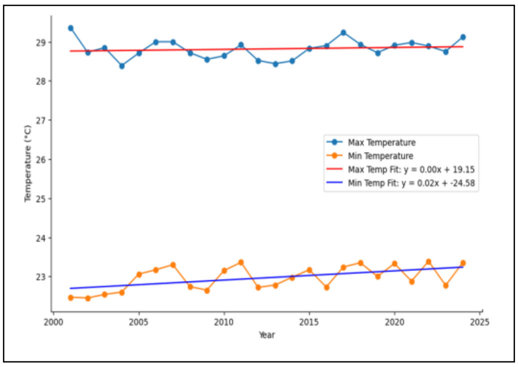


Figure 1: Maize yield from 2016 - 2020



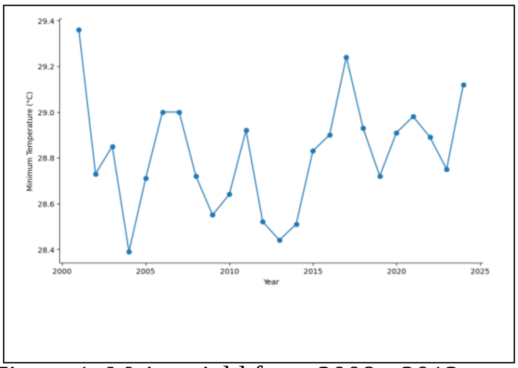


Figure 1: Maize yield from 2008 - 2012

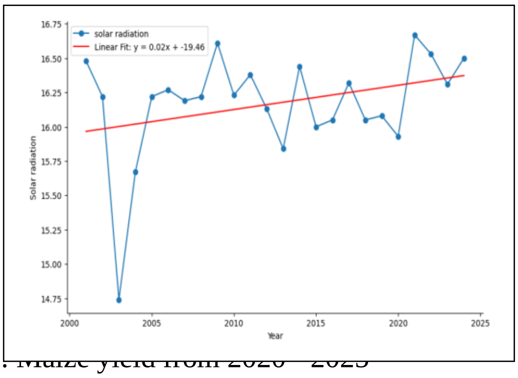
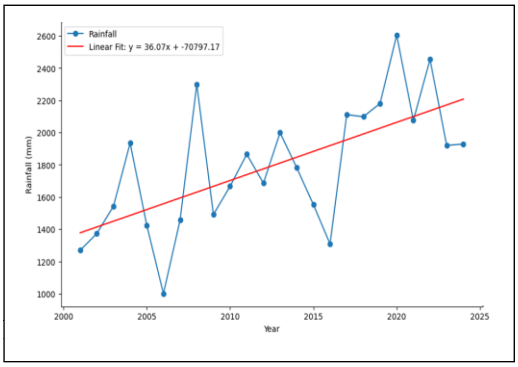


Figure 1:



Solar radiation: Between 2000 and 2005, the solar radiation is between 14.75 and 16.50. 2005 - 2010 the solar radiation is between 16.25 and 16.75. 2010 - 2015 the solar radiation is between 15.75 and 16.50. 2015 - 2020 the solar radiation is between 15.75 and 16.25. 2020–2025, the solar radiation is between 16.00 and 16.75, showing the highest solar radiation.

Based on the result (Figure 5), 2000 - 2005 shows that the amount of rainfall is between 1200mm and 2000mm. 2005 - 2010 shows 1000mm- 2400mm of rain. 2010 - 2015 shows 1200mm-2000mm of rain. 2015 - 2020 shows 1200mm- 2200mm of rain. 2020–2025 shows 1800mm–2600mm of rain. Between the years of 2020 and 2025, the amount of rain reduces from the range of 2600mm to 2000mm. Which indicates that the highest rainfall is between the years 2020 and 2025.

DISCUSSION

From the results (Figure 1-5) regarding the impact of rainfall and temperature trends on maize yield. The data were analysed to understand the relationship between the rainfall, temperature trends (minimum temperature, maximum temperature, and solar radiation), and maize yield in Ondo State, Nigeria.

In the study, the analysis of maize yield from the years 2000–2008 had shown low yield per land area; early in that same year, there was a maximum temperature; towards 2005, the temperature reduced and also the solar radiation reduced. The amount of rainfall was minimal in that same year range. Relating to the study on maize, being a rain-fed crop, is particularly vulnerable to changes in rainfall patterns and temperature fluctuations (Akinseye et al., 2020). And also those farmers in Ondo State have reported fluctuating maize yields, which they attribute to irregular rainfall and increasing temperatures. This is to show that the yield for 2000 – 2008 has been affected by the increase in temperature and irregular rainfall in Ondo State.

Between 2008 and 2012, there was a slight increase in the maize yield per land area. Observing that the temperature with those years reduces but the solar radiation increases and the amount of rainfall is fluctuating at average level in Ondo State. This shows the effect of temperature on the yield; as the temperature reduces, the yield increases. High temperatures during the grain-filling period can accelerate crop maturity, leading to smaller grains and reducing yields (Lobell and Gourdji, 2012).

Between the early years of 2012 and 2016, the yield of the maize per land area increased significantly, showing the highest maize yield per land area in Ondo State. Observing the climate condition in those years, it was shown that the temperature was minimal in the same early years of 2012–2016, but the rainfall still remained at an average level. This indicates that lower the temperature and optimal rainfall, the higher the yield of maize production. Adequate rainfall coupled with optimal temperatures promotes healthy crop growth and development. However, deviations from these conditions, such as high temperatures with insufficient rainfall, can adversely affect yield (Lobell et al., 2011).

Between the years 2016 and 2020, the maize yield per land area reduces. Within that year, the minimum temperature was below 28.8ºC, and the maximum temperature was above 29.2ºC. The solar radiation was high, and there was heavy rainfall. Changes in rainfall patterns due to climate change such as increased variability, more intense droughts, or more frequent heavy rainfall events pose significant risks to maize production, particularly in rain-fed agricultural systems. Excessive rainfall can cause waterlogging adversely affecting root development and nutrient uptake (Eze and Okoye, 2017).

Between the years of 2020 and 2024, the maize yield per land area increases to a maximum of 3.0 tons/hectare; t these same years, the temperature reduces to a minimum temperature in the range of 28.8ºC – 28.6ºC. The amount of rain during this period reduces from 2600mm below to 1800mm. adequate rainfall is essential for achieving high maize yield (Ajetomobi and Abiodun, 2010).

CONCLUSION

This study had shown the impact of rainfall and temperature trends on the yield of maize production in Ondo State.Despite the optimal temperature for maize growth, it ranges between 20ºC and 30ºC. Inadequate rainfall could lead to significant yield losses as maize is highly sensitive to water availability. Adequate rainfall and optimal temperature are the keys to achieving high maize yield production in Ondo State, Nigeria.

Recommendation

Based on the findings, it is advisable for farmers in Ondo State, Nigeria, to employ the use of weather information will help the farmers to avoid crop failure and improve yield. Farmers are to target early sowing in the region and the use of cultivars that are adaptable to the environment.

References

Akinseye, F. M., Agele, S. O., Olufayo, A. A., and Oguntunde, P. G. (2020). Maize yield responses to climatic variables and planting dates in a tropical climate. Agricultural systems, 178, 102763.

Ayoola, G.B. (2001). The Nigerian Grain Market and Industrial Utilization of Sorghum. A book of readings on Agricultural Development Policy and Administration in Nigeria. Ibadan, 249-254.

Food and Agriculture Organization (FAO). (2019). Climate Change and Food Security: Risks and Responses. Rome: FAO.

Hatfield, J. L., & Prueger, J. H. (2015). "Temperature extremes: Effect on plant growth and development." Weather and Climate Extremes, 10, 4-10.

IITA (2009). Maize, www.iita.org/cms/details/maize-project-details.aspx. Retrieved on 27th December 2013.

IPCC (2014). Climate change: impacts, adaptation and vulnerability. Cambridge university press.

IPCC, (2007). Climate change 2007: Synthesis report. Intergovernmental Panel on Climate Change, Valencia, Spain.

Lobell, D.B., & Gourdji, S.M. (2012). The influence of climate change on global crop productivity. Plant Physiology, 160(4), 1686-1697.

Nigerian Meteorological Agency (NiMet). (2022). "Climate of Ondo State: A report on climatic trends and patterns." Available at: www.nimet.gov.ng

Odekunle, T.O. (2004). Rainfall and the length of the growing season in Nigeria. Int. J. Climatology, 24. 467–479.

Ojo, S.O. (2000). Factor Productivity in Maize Production in Ondo State, Nigeria. Applied. Tropical Agriculture. 15(1), 57 – 63.

Olaniyi, O. A., & Adewale, J. G. (2012). "Maize production and supply in Nigeria: Status, prospects, and opportunities." African Journal of Agricultural Research, 7(4), 550-556.