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Econometric Trend and Impact Analysis of Rainfall and Temperature on Yam Productivity in Nigeria: 1961-2020

Chukwuemeka, O. S. and Agoh, E. C.

National Root Crops Research Institute, Umudike
Corresponding Author's email: sampchuks37@gmail.com

Abstract
Changes in concentration of atmospheric parameters will have momentous impact on crop production. The projected changes in climate variability and increase in extreme weather events may impact crop yield. This is of particular importance for yam crop (*Dioscorea spp*.), as it a desired staple food for greater population in Nigeria. The aim of this study is to examine the impact some selected climatic parameters (rainfall and temperature) on yam yield in Nigeria from 1961 to 2020 (60 years). Climatic data and yam yield data of Nigeria for this study were extracted from Climate Change Knowledge Portal on The World Bank Group and Food and Agriculture Organization of the United Nations (FAO) FAOSTAT website respectively. Autoregressive Integrated Moving Average (ARIMA) and time series analysis was done with the aid of Real Statistics Data Analysis Tool installed in Microsoft Excel 2016 as Add-Ins. The statistcal results and forcast analysis shows that yam yield in Nigeria decreased with increase in rainfall and relatively stable temperature, despite increase in the cultivated area of land. Multiple linear regression analysis also indicated that the climatic factors are not significant predictors of yam yield. Finally, the disturbing findings of projected decline in yam yield may be due to other factors, would contribute to increase food scarcity in Nigeria.

Keywords: Rainfall, Temperature, Yam, ARIMA

Introduction
Changing climate will probably change the existing farming systems (Parry *et al*., 2004; IPCC, 2007). Globally, Climate has attracted major research attention from scientists in the last 40 years due to its damaging consequences on agriculture. The projected changes in climate variability and increase in extreme weather events may impact crop yield. (Schär *et al*., 2004). According to IPCC 4th Assessment Report (IPCC, 2007), global average temperature has increased by approximately 0.74 °C in the last century and is possibly caused by anthropogenic activities that have increase greenhouse gas concentrations to unprecedented levels. IPCC, (2007) indicated that many African countries including Nigeria are likely to be severely affected by climate variation in food crop production because they are highly dependent on agricultural production that is solely practiced under hash uncontrolled climatic conditions. Agriculture is most sensitive economic sectors to climate change, because of its dependency on meteorological parameters such as temperature and rainfall. Therefore, changes in concentration of atmospheric parameters will have momentous impact on crop production (Downing, 1996; Watson *et al*., 1996). This is of particular importance for yam crop (*Dioscorea spp*.) in Nigeria. Yam is a major staple crop in Nigeria and major source of income for many subsistence farmers in rural communities. Nigeria is the largest yam producer in the world (Fig. 1 and Fig 2). Apart from cassava (*Manihot esculenta* Crantz.) and sweetpotato (*Ipomoea batatas* L. Lam.), Yam is the third most major tropical root crop in Nigeria. Relative to cassava in Africa, yam is a desired staple food, with population surge, demand will automatically escalate and the absolute production will rather increase (Srivastava *et al*., 2012). Hence, in order to meet the growing demand, there is need to do proper assessment of yam yield vulnerability to climate change and measures taken to adapt accordingly. The aim of this work is to examine the econometric trend and impact of climate change on yam yield in Nigeria from 1961 to 2020 (60 years).

Methodology
Study Area
Nigeria has approximately land area of 923,769 km^2 and lies within latitudes 4°N - 14°N and longitudes 3°E - 14°E. The country has dimensional line of about 1,450

km from north to south and 800 km from west to east. Nigeria climate is categorized by strong latitudinal zones which become progressively wet from the hinterland to coast (in the South). Nigeria has a varied climate: Monsoon climate (Am), Tropical Savanna climate, Warm semi-arid climate (BSh), Warm desert climate (BWh) (Fig. 3). Nigeria has two major seasons: wet and dry, with a wet season that rains for seven to eight months per annum. The total annual rainfall ranges from 600 mm at the extreme Northeast to about 3,800 mm at the coast (Fig. 4). Nigeria temperatures is relatively high throughout the year, with average annual maximum temperature ranges from 31°C in the South to 35°C in the North while the average annual minimum temperature ranges from 18°C in the South to 23 °C in the North (Fig. 4 and 5).

Data collection and analysis

The 60 years (1961-2020) meteorological data of rainfall and temperature (minimum and maximum) of Nigeria were extracted from Climate Change Knowledge Portal on The World Bank Group website, while yam crop yield data for same priod was extracted from Food and Agriculture Organization of the United Nations (FAO) FAOSTAT website.

Method of data analysis

The Time series analysis was performed to evaluate the existence and/or trend of a phenomenon over a designated period of time (Swanson, 2016). In this study, the trend data is a set of meteorological data and yam yield values from 1961 to 2020. The time series analysis was appropriate in this regard because it assisted to comprehend and model the data, as well as identify patterns and variations in the data. Forecasting was also excuted to determine the possible climatic and yam yield array in the future based on known past events. Finally, the Autoregressive Integrated Moving Average (ARIMA), time series analysis was done with Real Statistics Data Analysis Tool installed in Microsoft Excel 2016 as Add-Ins.

Results and Discussion

Trend of Rainfall and Temperature data for the study

Fig. 6 shows the means of Maximum (MaxT) and Miminmum (MinT) Temperature trend of climate from 1961 to 2020. The lowest MaxT and MinT Temprature was recorded in 1961 (20.17^{0}C) and 2000 (32.22^{0}C), while the highest was recorded in 2016 (21.95^{0}C) and 2013 (33.83^{0}C) respectively. Fig. 7 presents the trend of rainfall from 1961 to 2020. The highest rainfall was received in 1972 (1356.02mm), while the lowest was received in 1980 (887.75mm). The mean, sums, mode, standard deviation, kurtosis, skewness and other descritive statistives are presented in Table 1 for both the climatic parameters, land area and yam yield data. The mean land area, yam yield, rainfall, minimum and maximum temperature are 2695995.3 Ha, 100639.2 Hg/Ha, 1174.3 mm, 21.1^{0}C and 33.0^{0}C respectively. Figure 8 shows the trend of yam yield from 1961 to 2020. The yam yield showed variability over the period, while the land area mainteined a linar trend from 1961 to 1991 (30 years) and increased exponentailly from 1962 to 2020 as shown in Figure 9. While the land area was incresing, the yam yield mainteined continus decrese in trend from 2009 to 2020. This decreasing trend was reported by Verter and Becvarova (2015), where they noted that the rise in yams yield is far from been stable in Nigeria. This is partly due to the unattractiveness of farming, insecruity, and high cost of input materials. However, the larger population of people living in the rural areas are still engaged in yam cultivation because there are no other job opportunities for them apart from farming in these regions. This result revaels a big threat to food security in Nigeria, when compared to the increase in the number of people that will consume food. Using the per capita information on food production and supply, Urama and Nfor (2018) noted that the per capita value of food production in Nigeria is poor as at its 1999 value.

Forecast of climate characteristics from 2017 to 2026

The time series analysis provided a forecast of future climatic conditions. Table 2 shows the forecast of future climatic trends and yam yield in Nigeria. The mean value of maximum and mimiumum temperature was used for the analysis, while the total value of rainfall and yam yield used. The forecast extended to a period of 10 years, beginning from 2021 to 2030. The future trend of rainfall shows a slight increase from 2021 to 2030. Figures 10 and 11 shows that the minimum and maximum temperature forecast trend declined from 21.64ºC and 33.23 ºC in 2021 to 21.62ºC and 33.19 ºC in 2030 respectively. Although, in comparison to overall mean of the ten (10) years forcast of minimum and maximum temperature is 21.63 ºC and 33.21ºC respecticely, which is higher than the mean mimiumum and maximum temperture for the period of study. Figure 12 shows that the forcast of the rainfall shows an incresing trend with forcast mean of 1260.12mm, which was also higher than the mean of the 60 years under review. Figure 13 show the forcast result with a continous decline for the yam yield from 77407.70Hg/Ha in 2021 to 76162.55Hg/Ha in 2030. However, the mean of the 60 years is 100639.18Hg/Ha which is higher than 76784.63 Hg/Ha; the mean of the ten years forcast. This forcast decrease, would contribute to decline and stagnate yam yield in Nigeria as identified by Bergh *et al*. (2012). The multiple regression analysis was performed to determine the relationship between the independent variable (climatic factors; rainfall and temperature) and dependent variable (yam yield) for the period under reviwe. The aim of the multiple regression analysis was to establish the effect of the independent variables in predicting the outcome of the dependent variable during the period.

Table 3 presents the multiple regression model summary and overall fit statistics. From the result, it was observed that R^2 =0.02. This implies that the linear regression explains 2.0% of the variance in the data. The F-ratio in the ANOVA table (Table 4) tests whether the overall regression model is a good fit for the data. Table 4 shows that the independent variables performance for the forecast of the dependent variable is insignificant with F (3, 56) = 0.414, p =0.744 > .05; i.e., indicating that the regression model is not a good fit.

Table 5 shows the multiple linear regression analysis, show that the climatic factors were not significant predictor of the dependent variable with the p-value of rainfall (p = 0.83 > 0.05), minimum temperature (p = 0.41> 0.05) and maximum temperature (p= 0.30 > 0.05). During the period under review, none of the climatic parameters had statistically significant relationship with yam yield. This finding is supported by Magna *et al*. (2018), who found out that climatic variables (i.e., rainfall and temperature) have little influence on yam yield in Ghana's Krachi East District. In the study, only 10.6 % of the proportion of variation of yam yield was explained by rainfall and temperature, while 89.4 % of the yam yield as explained by the model was probably due to external factors.

Conclusion

The level of effect of climate parameters varies based on place and type of crop. Nigeria is one of the major countries that cultivate yam and is ranked the highest in yam production in the world, which made Nigeria a hotspot for yam production and this study examined the trend and the influence of climate variability on its yield. The study revealed that the trend of climate characteristics varied in Nigeria for the period under review (1961 to 2020). Trend result shows that yam yield decreased significantly in Nigeria, despite increase in the cultivated area of land. Also, yam yield forecast shows further decline in 2030. The study reveals that both minimum and maximum temperature of the area will reduce slightly by 2030, while rainfall will increase. The findings show that both rainfall and temperature will not influence the yield of yam, despite its fluctuations. This highlights the adaptability of yam to climate. The disturbing finding of projected decline in yam yield, would contribute to increase in food scarcity in Nigeria.

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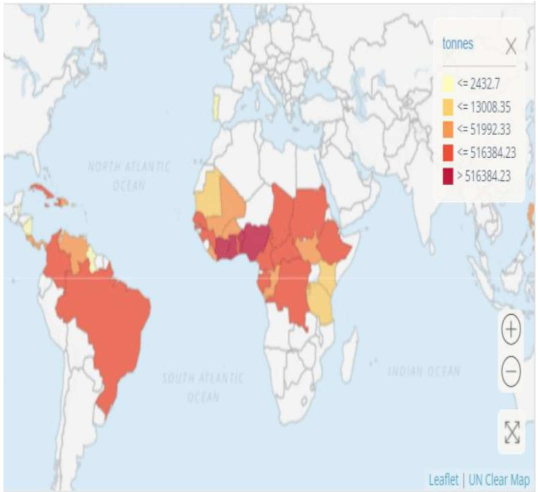


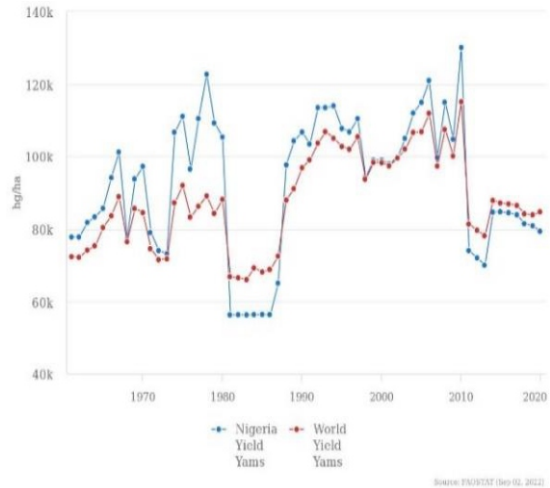


Fig 1. Global Average Yam production from 1961-2020. (Source: FAOSTAT)

Fig 2. Global Yam yield fr om 1961-2020. (Source: FAOSTAT)

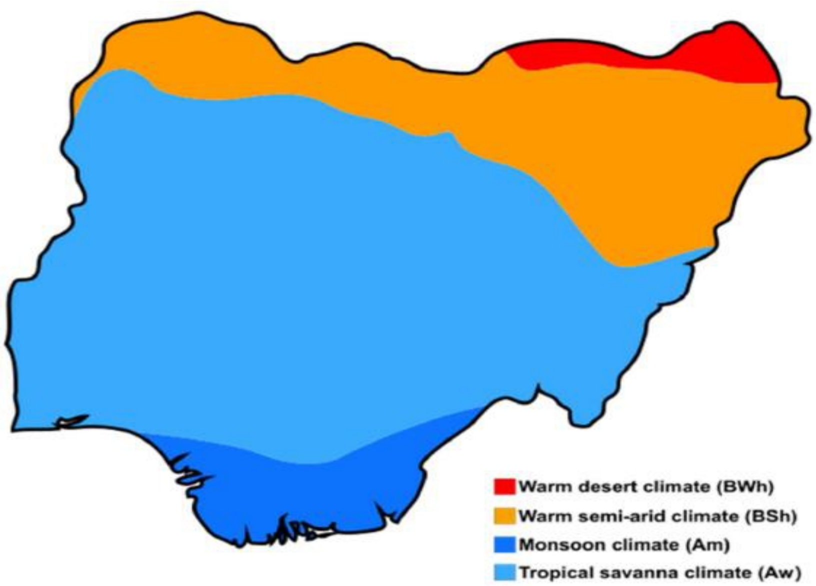
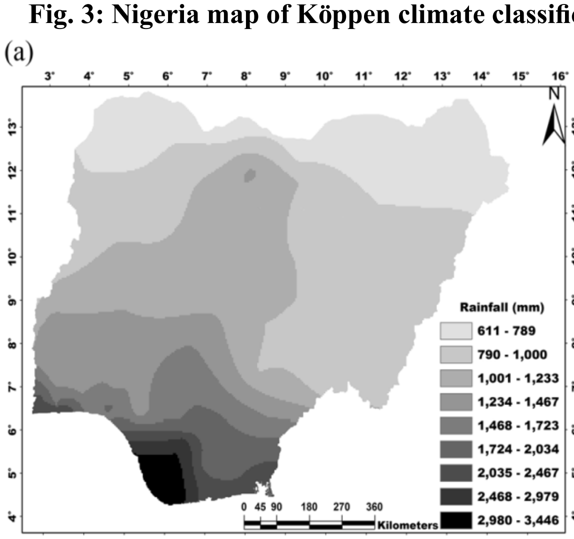


Fig. 3: Nigeria map of Köppen climate classification



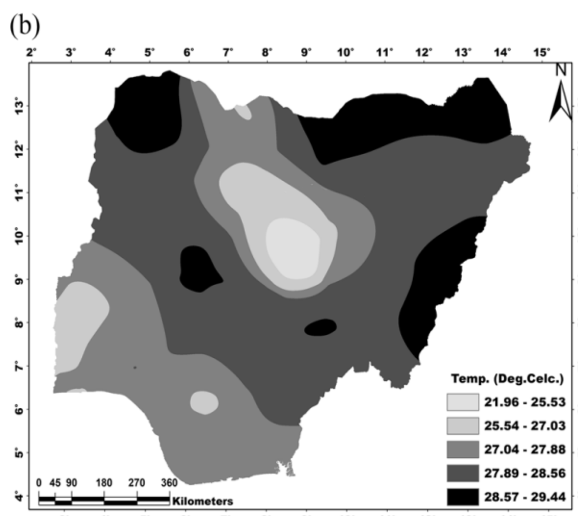


Fig 4. Historical parttern of annual rainfall from 1981–2017

Fig 5. Historical daily average temperature from 1981–2017

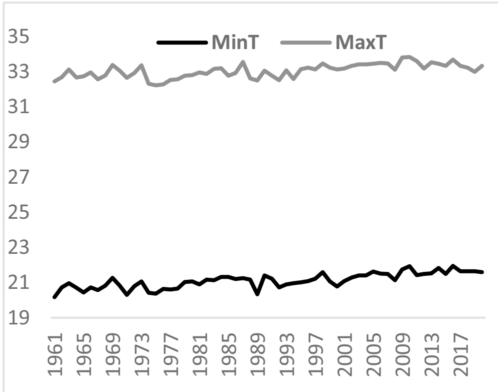


Fig. 6: MaxT and MinT Temperature Trend

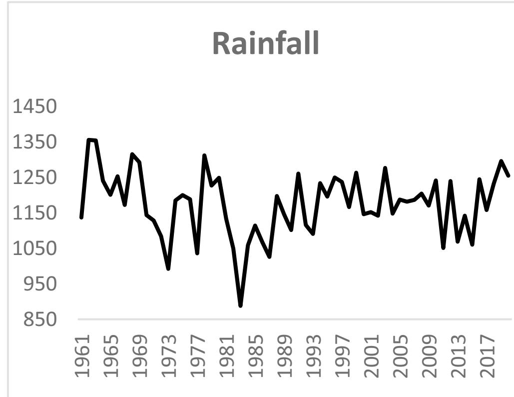


Fig. 7: Rainfall Trend