Research Article

Climate Variability and Yam Production: Nexus and Projections

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Abstract | This study aimed to improve understanding of the nexus between climate variability and yam (*Dioscorea spp*.) production in Ikom Local Government Area of Cross River State, Nigeria. Rainfall, temperature, sunshine and relative humidity (1976-2016), as well as yam yield data (1990-2016) were considered. Results revealed that climate elements fluctuated steadily during the period with a marginal increase in yam yield. The projections from the Time Series Modeler showed that relative humidity will decrease slightly while yam yield will increase by an additional 265 metric tons in 2026. Although minimal, and not significant to the declining food production trend in Nigeria, the projected increase in yam production in the area would support the deficit in food availability. The nexus between both variables was hypothesized using the multiple linear regression analysis. The result revealed that only sunshine intensity was a significant predictor of yam yield ($p = 0.011$), whereas rain days ($p = 0.332$), rainfall volume ($p = 0.393$), temperature ($p = 0.235$) and relative humidity ($p = 0.963$) were not. This suggests that key climate variables do not significantly influence yam yield in the area, implying that non-climatic factors likely have more impact. This provides better opportunities to upscale yam production in the area and gives room for better planning by farmers and policy makers.

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Introduction

Climate is the mean atmospheric condition of a place over a long period of time say 35 years, which is dependent on the interaction between atmospheric elements, elevation above mean sea level and human factors (Srivastava *et al*., 2012; United Kingdom Environmental Change Network (UK-ECN, 2013). Climate variability denotes the variations in the mean state of climate in time scales limited seasons, yearly or a few decades, unlike in the case of climate change which persists for an extended period.

Climate variability plays a significant role in the performance of agricultural production (Adejuwon and Ogundiminegha, 2019). Important climatic elements for crop growth and yield include solar radiation, temperature and water or rainfall (Elijah *et al*., 2018). The relationship between climate variability and agricultural activities has attracted multiple interest from scholars (Jerumeh *et al*., 2018; Elijah *et al*., 2018), as a result of the dependency of agricultural activities on the climatic variability of a region. The impact of climate variability on agriculture can manifest positively or negatively, however, empirical studies have shown that the latter seems to be the case more (Adejuwon, 2004; Enete *et al*., 2011). Although, climate is not the only factor responsible for agricultural productivity, it is a salient factor to agricultural productivity (Zakari *et al*., 2014).

It is speculated that variability in climate and weather events may affect agricultural productivity and livelihoods (Srivastava *et al*., 2012), especially in the

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developing economies where farmers depend majorly on agriculture, which is climate sensitive for their living, making them vulnerable to climate change effects (Kyei-Mensah *et al*., 2019). The International Panel on Climate Change (IPPC, 2007) buttressed 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.

Crop production in Nigeria is essentially the prominent feature of agricultural activities, accounting for nearly 90 percent of agriculture's nominal GDP with livestock, forestry and fishing together comprising the remaining 10 percent (Asoko Insight, 2019). Farmers in Nigeria enormously rely on what nature provides, such as the volume of rainfall, intensity of the sun and other climate characteristics for their crop cultivation activities. For example, rain-fed agriculture is the most dominant method deployed by crop farmers who mostly grow maize, rice, cassava, yam and so on (Akov, 2017).

Yam (*Dioscorea* spp.) is one of the largely cultivated, climate sensitive food crop grown in Nigeria. It is an annual root tuber crop with at least 600 species, out of which six are socially and economically important in terms of food, cash and medicine. They are cultivated in the tropics, especially in the savannah region of West Africa (Verter and Becvarova, 2015). Nigeria ranks as the largest producer of yams in the world, contributing approximately 66% to the global production, followed by Ghana, Côte D'Ivoire, Benin, Togo, and Cameroon Food and Agricultural Organization (FAO, 2014). The tuber crop is also grown in Colombia, Brazil, Haiti, Cuba and Jamaica (FAO, 2013). Yams are mostly sold by farmers and marketers as fresh tubers (Ike and Inoni, 2006). It can as well be processed to other forms before consumption.

Yam production in Nigeria is vulnerable to the effects of climate change and variability. This manifests through its negative impacts on crop growth and yield (Elijah *et al*., 2018). Even with the fact that the yam crop thrives and produces well in Nigeria, it has depicted different growth behaviours and fluctuating yields in different years due to differences in the annual weather condition (Nwaobiala and Nwosu, 2014). The phenomenon of climate change or variability threatens food security in Nigeria where over 14 million people experience food shortages and suffer from undernutrition (Ecker and Kennedy, 2019; Urama and Nfor, 2018). The deficiency in food is highlighted by the decline in food crop production from over 34% of the GDP in 2002 to 18.6% in 2016 (Urama and Nfor, 2018).

Despite the fact that over 60% of the active population of Nigerians are farmers, studies on the influence of climate variation on agricultural production in Nigeria has received limited attention (Olah, 2019). Some studies have been conducted in other countries (Srivastava *et al*., 2012; Alemayehu and Bewket, 2016) and not as much in the tropical rainforest where subsistence farmers who may be most vulnerable to adverse changes live (Elijah *et al*., 2018).

In Nigeria, some researchers have carried out crop-specific studies that focused on yam production (Bamire and Amujoyegbe, 2005; Ike and Inoni, 2006; Zaknayiba and Tanko, 2013; Maikasuwa and Ala, 2013; Verter and Becvarova, 2015; Obidiegwu and Akpabio, 2017), while some have studied the impact of climate variability on yam production (Emaziye, 2015; Ayanlade *et al*., 2010). At the State level (Cross River State), there are only a number of studies on the effects of climate change or variability on yam production (Elijah *et al*., 2018, 2020). In Ikom Local Government Area (LGA), yam farming is predominant. The area is designated an important area for yam production in Nigeria with over 50% of the cultivated land area used for yam farming (Bassey, 2017). This makes Ikom LGA well suited for this study, especially as there are no localized studies on the relationship between climate variability and yam production at such local scale.

Whereas some studies have been identified to focus on the subject, there is still an apparent gap in the sufficiency of these studies especially in Cross River State and Ikom LGA where yam production can be upscaled to augment the food deficit in the region and Nigeria as a whole. Where the existing studies focused on climate change or variability and yam production, they barely employed quantitative climate and yam production data. Rather they relied solely on the perceptions of the farmers.

Hence, this study aimed at providing scientific substantiations to the nexus between climate variability and yam production in Ikom LGA of Cross

River State. It would do so through examining the trend of climate characteristics and yam production in the area, while forecasting future scenarios, as well as assessing the relationship between both variables. The study is timely as farmers in Cross River State cultivate their crops under rain-fed ecology and are not exempted from climatic threats. This is essential as the potential impact of climate variation includes every aspect of the four dimensions of food security, which are: food availability, accessibility, stability and utilization (Olah, 2019).

Materials and Methods

Study area

Ikom LGA is located in Cross River State, between longitudes 8.00° and 8.10°E, and latitudes 5.00° and 6.30° N. Ikom LGA is bounded in the north-east by Boki LGA, in the east by Etung LGA, in the North West by Ogoja LGA and in the south by Obubra LGA, all in Cross River State as shown in Figure 1. The LGA area is administratively located at the central senatorial zone. The study area has a land mass of about 1,961km^2. Topographically, the land is generally undulating with monotonous depressions which contain water even during the dry season (Njoku *et al*., 2017)

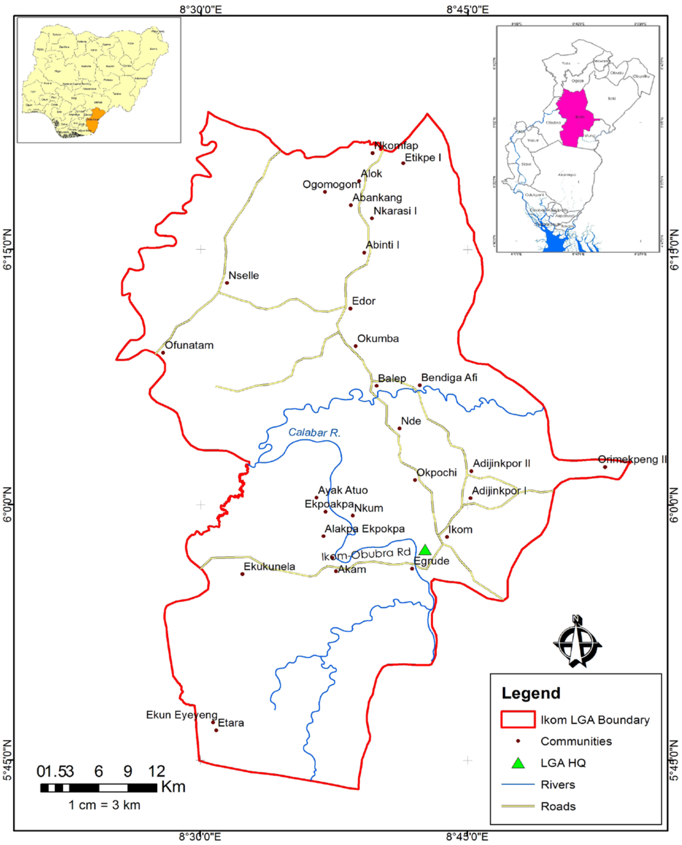

Figure 1: *Map of Ikom LGA.*

The soils in the area are derived from three major geological groups; the recent alluvial deposit, tertiary coastal plain sand and the igneous and metamorphic rocks (Onyekwere *et al*., 2015). The soils in Ikom LGA belong to three orders in the United State Department of Agriculture (USDA) soil taxonomy, namely: Inceptisols (alluvial deposits), Ultisols (soils developed over basalt materials) and Alfisols (soils derived from sandstone-shale, granite and gneiss parent materials); which correspond to Gleyic Fluvisols, Albic Luvisols and Eurtic Luvisols in the FAO/ United Nations Educational, Scientific and Cultural Organization (UNESCO) World References Base Legend (Nsor, 2011).

The climate of Ikom LGA is a typical tropical climate with distance rainy and dry seasons. The dry season stretches from November to March while the rainy season is from April to October. The mean annual rainfall is about 2900mm (Climate Data, 2019). The average maximum temperature which is observed in March is up to 30°C while the mean annual temperature is 27°C. The relative humidity is graded to be high during the rainy season with mean value of up to 60%, buttressing its location in the humid rainforest ecological region of Nigeria (Climate Data, 2019). Adopting the average population growth rate of 2.8%, the population of Ikom Local Government Area is estimated to be 353,121 National Population Commission (NPC, 2006).

Data types and sources

Data were obtained from secondary sources. This comprised of rainfall (volume and number of rain days), temperature, sunshine intensity and relative humidity data for the periods of 1976 to 2016. The 41-year period data were obtained from the Nigerian Meteorological Agency's (NIMET) station at Ikom LGA headquarters. Also, data on yam production trend from 1990 to 2016 was obtained from the Produce Office of the Ministry of Agriculture in Ikom LGA headquarters (Table 1). The yam production data is an aggregate of two major yam species (white yam *Dioscorea rotundata* and yellow yam *Dioscorea cayanensis*) produced by the farmers and recorded by the Produce Office. These data provided the bases for forecasting climate and yam production trends to the year 2026.

Data analyses techniques

This study adopted quantitative research methods, relying on the climate characteristics and yam yield data and analyses to describe, explain, predict or control variables and phenomena of interest (Gay *et al*., 2009). Statistical inference was drawn from the relationship between both variables in the area. The following quantitative analytical techniques were used to make inference from this study.

The Time series analysis is executed to assess the occurrence or trend of a phenomenon over a designated time period (Swanson, 2016). In this case, the trend data is a set of climate and yam yield values taken from 1976 to 2016 and 1990 to 2016 respectively. The time series analysis was relevant in this regard as it aided to understand and model the data, as well as identify patterns and variations in the data. Forecasting was also done to discover the possible climatic and yam yield pattern in the next years based on known past events. The Time Series Modeler was used to achieve the forecasting. The procedure estimates exponential smoothing, univariate Autoregressive Integrated Moving Average (ARIMA), and multivariate ARIMA (or transfer function models) models for time series, and produces forecasts (IBM, 2013).

Also, the multiple regression analysis was adopted to model the sensitivity of agricultural output to climate variability (Cohn *et al*., 2016). The multiple regression measured the effects of the independent variables ($x_1 - x_5$) on a single dependent variable (y). The regression model is specified as:

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_nx_n \ldots\ldots (1)$$

Where:
Y = the dependent variable (yam yield); b_1, b_2, b_3, b_4, b_5 = regression coefficients; x_1, x_2, x_3, x_4, x_5 = the independent variables (mean sunshine intensity, mean temperature, mean relative humidity, mean rainfall volume, total number of rain days); a=y intercept; e= error term.

Results and Discussion

Trend of climate characteristics of Ikom LGA from 1976 to 2016
The means and sums of the trend of climate characteristics in the study area from 1976 to 2016 are presented in Table 2. A combined trend chart is also pictured in Figure 2. Sunshine intensity showed fluctuations. The year with the highest intensity was 1983 when there was a spike to 7.8 W/m^2 from the previous and subsequent intensity average of around 5.1 W/m^2.

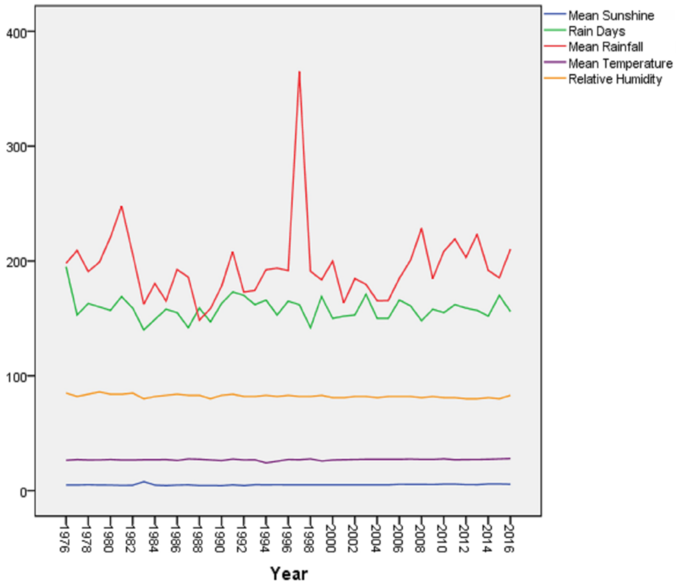

Figure 2: *Combined trend of micro-climate characteristic from 1976 to 2016.*

Ikom LGA experiences a substantial amount of rainfall with a total of 6501 rain days within the 41-year period and an average of 158 rain days per year. There was a continuous up-down trend with 1976 having more rain days than subsequent years. Also, the trend of rainfall in the area depicted variations in volume during the 41-year period. There was an increase to a total of 2974mm of rainfall in 1982, an all-time low of 1782.4mm in 1988 and an all-time high of 4381.1mm in 1997. But for these extremities, the volume of rainfall averaged of 2345.3mm for the 41-year period.

Temperature also showed variability over the period. In the first 10 years, the variation was rather stable with mean temperatures ranging from 26.5ᵒC to 27.1ᵒC. In 1986, the temperature ditched to 26.3ᵒC, then increased again in the next year. The slight fluctuations continued till 1994 when the area witnessed the highest low temperature value of 24.2ᵒC. The temperature increased again to 27.7 ᵒC in 1998 and fell to 25.59 ᵒC in the next year. Afterwards, Ikom LGA experienced a steady increase in temperature with mean values averaging at 27 ᵒC until 2016 when there was an increase to 28 ᵒC.

Relative humidity depicts a rather interesting pattern over the years. The chart (Figure 2) shows a downward trend in the humidity of the area. The area had a mean relative humidity of 85% in 1976. This reduced afterwards to 82% in the next year and increased to a record high of 86 in 1979. Afterwards, it began a gradual descent with minor fluctuations up till 2015 with a significant low of 80% in 1983, 1989 and 2015.

Forecast of climate characteristics from 2017 to 2026

The time series analysis provided a forecast of future climatic conditions. Table 3 displays the forecast of future climatic trends in the area. The mean of each variable was used for the analysis, except for rain days where the sum was used. The forecast covered a period of 10 years, beginning from 2017 to 2026. The future trend of sunshine intensity shows a slight reduction from the end year (2016). The mean sunshine intensity in 2016 was 5.57 W/m^2 and the total mean for the 41-year period of study was 5.2 W/m^2. The forecast for 2017 as shown on the table is 5.16 W/m^2, an intensity which is predicted to continue till 2026. Also, with a sum of 156 rain days in 2016 and a mean of 158 for the period, the analysis predicted an average of 159 rain days per year for coming years up till 2026.

The situation was similar for the volume of rainfall, where a similar mean of 2524 mm was predicted for the coming years. This differed significantly from the total mean from 1976 to 2016 of 2345.6 mm. Temperature forecast also showed reduction to 27.4°C in 2017 from 28°C in 2016. Although, in comparison to overall mean of the study period, there was an increment from 27°C to 27.4, which is rather high, though not as high as 2016 which had the highest recorded temperature for the 41-year period. Additionally, relative humidity predictions, unlike the other variables depicted a steady reduction from 2017 to 2026. With a mean record of 83% in 2016 and an overall mean of 82.3%, the prediction of 2017 was given as 80.7, 80.6 in 2018, 80.5 in 2019 and a progressive decline to 80% in 2026. Figure 3 displays the forecast charts of the observed and predicted scenarios.

Trend of yam production in Ikom LGA from 1990 to 2016

The quantity of yam harvested in Ikom LGA is recorded by the Produce office in the LGA headquarters (see Table 2). The descriptive statistics displayed on Table 4 shows the maximum yam yield during the 26-year period to be 2486 mt, minimum of 218 mt, sum total of 25291 mt and the mean to be 936.7 mt.

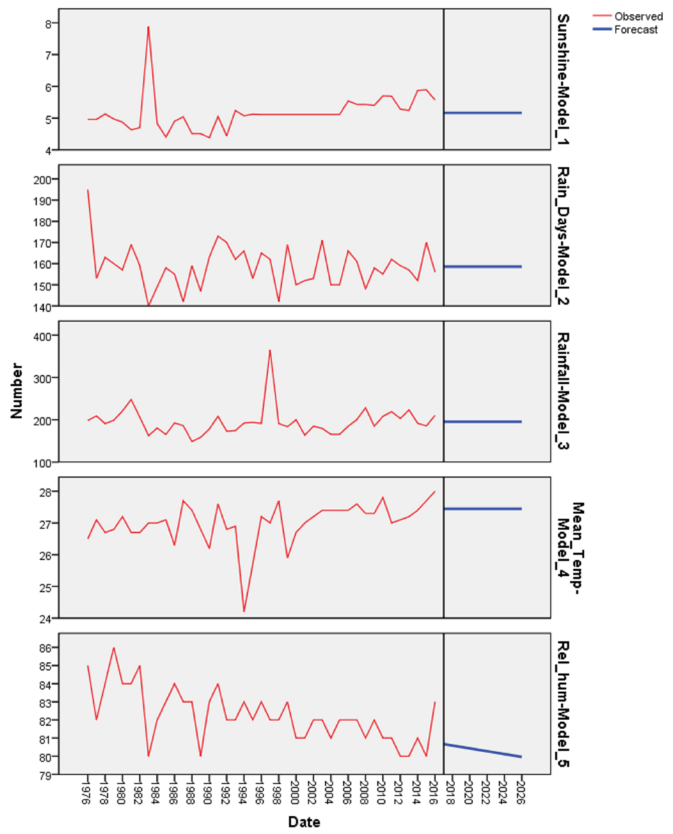

Figure 3: *Forecast charts of future climatic conditions.*

The quantity of yam produced by farmer has fluctuated over the years. For example, in 1990, the recorded yield was 611 mt. The chart (Figure 4) shows a fall in 1995 to 218 mt and a sharp continuous rise to 1225 mt in 1999. Afterwards, 2013 was another year of very poor output after which it skyrocketed to the highest output of 2486 mt in 2015 and 1319 mt in 2016.

Table 1: *Types of data used.*

S/n	Data	Unit	Period
i	Mean annual rainfall (volume)	Millimeter (mm)	1976 to 2016
ii	Mean annual temperature	Degree celsius (°C)	1976 to 2016
iii	Annual output of yam	Metric tonne (mt)	1990 to 2016
iv	Mean relative humidity per annum	%	1976 to 2016
vii	Total number of rain days per annum	Days/year	1976-2016
Viii	Mean sunshine intensity per annum	W/m^2	1976-2016

Table 2: *Trend of climate characteristics and yam yield in Ikom LGA.*

S/n	Year	Sunshine (mean)	Rain Days (sum)	Rainfall volume (mean)	Temperature (mean)	Relative Humidity (mean)	Yam yield (mt)
1	1976	4.96	195	2375.9	26.5	85	
2	1977	4.96	153	2508.9	27.1	82	
3	1978	5.13	163	2289.5	26.7	84	
4	1979	4.97	160	2387.3	26.8	86	
5	1980	4.87	157	2648.5	27.2	84	
6	1981	4.63	169	2974.1	26.7	84	
7	1982	4.7	159	2473.1	26.7	85	
8	1983	7.88	140	1949.3	27	80	
9	1984	4.83	149	2164.2	27	82	
10	1985	4.4	158	1982.1	27.1	83	
11	1986	4.9	155	2311.7	26.3	84	
12	1987	5.04	142	2231.7	27.7	83	
13	1988	4.51	159	1782.4	27.4	83	
14	1989	4.51	147	1902	26.8	80	
15	1990	4.38	163	2135.8	26.2	83	611
16	1991	5.05	173	2497	27.6	84	728
17	1992	4.44	170	2074.5	26.8	82	535
18	1993	5.24	162	2092.9	26.9	82	802
19	1994	5.07	166	2308.7	24.2	83	612
20	1995	5.12	153	2326.1	25.7	82	218
21	1996	5.11	165	2299.4	27.2	83	705
22	1997	5.11	162	4381.1	27	82	911
23	1998	5.11	142	2291.6	27.7	82	1102
24	1999	5.11	169	2203.7	25.9	83	1225
25	2000	5.11	150	2399.1	26.7	81	709
26	2001	5.11	152	1962.5	27	81	925
27	2002	5.11	153	2216.2	27.2	82	1025
28	2003	5.11	171	2154.7	27.4	82	857
29	2004	5.11	150	1984.2	27.4	81	757
30	2005	5.11	150	1985.6	27.4	82	1039
31	2006	5.54	166	2219	27.4	82	917
32	2007	5.43	161	2406.5	27.6	82	1235
33	2008	5.43	148	2740.4	27.3	81	835
34	2009	5.4	158	2215.9	27.3	82	1115
35	2010	5.7	155	2499.9	27.8	81	796
36	2011	5.69	162	2629.2	27	81	696
37	2012	5.28	159	2437.5	27.1	80	800
38	2013	5.24	157	2679.8	27.2	80	520
39	2014	5.87	152	2301.2	27.4	81	1811
40	2015	5.89	170	2224.2	27.7	80	2486
41	2016	5.57	156	2524.5	28	83	1319

In line with this trend, Verter and Becvarova (2015) opined that the increase in yams output is far from consistent in Nigeria, partly due to the unattractiveness of farming and low prices of yams in the market. However, the majority of the rural population are still engaged in farming activities because there are no other job opportunities for them apart from yam cultivation in these regions.

Table 3: *Forecast of future climatic conditions.*

Model		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Mean Sunshine-Model_1	Forecast	5.16	5.16	5.16	5.16	5.16	5.16	5.16	5.16	5.16	5.16
	UCL	6.32	6.32	6.32	6.32	6.32	6.32	6.32	6.32	6.32	6.32
	LCL	4.01	4.01	4.01	4.01	4.01	4.01	4.01	4.01	4.01	4.01
Rain Days-Model_2	Forecast	159	159	159	159	159	159	159	159	159	159
	UCL	179	179	179	179	179	179	179	179	179	179
	LCL	138	138	138	138	138	138	138	138	138	138
Mean Rainfall-Model_3	Forecast	2524	2524	2524	2524	2524	2524	2524	2524	2524	2524
	UCL	260.5	260.5	260.5	260.5	260.5	260.5	260.5	260.5	260.5	260.5
	LCL	143.3	143.3	143.3	143.3	143.3	143.3	143.3	143.3	143.3	143.3
Mean Temperature-Model_4	Forecast	27.4	27.4	27.4	27.4	27.4	27.4	27.4	27.4	27.4	27.4
	UCL	28.8	28.8	28.8	28.8	28.8	28.9	28.9	28.9	28.9	28.9
	LCL	26.1	26.1	26.1	26.1	26.1	26.0	26.0	26.0	26.0	26.0
Relative Humidity-Model_5	Forecast	80.7	80.6	80.5	80.4	80.4	80.3	80.2	80.1	80.0	80.0
	UCL	83.1	83.0	82.9	82.8	82.8	82.7	82.6	82.6	82.5	82.4
	LCL	78.3	78.2	78.1	78.0	77.9	77.9	77.8	77.7	77.6	77.5

For each model, forecasts start after the last non-missing in the range of the requested estimation period, and end at the last period for which non-missing values of all the predictors are available or at the end date of the requested forecast period, whichever is earlier.

Table 4: *Descriptive statistics for trend of yam production (1990 to 2016).*

	N	Minimum	Maximum	Sum	Mean	Std. Deviation
Yam Production (mt)	27	218	2486	25291	936.70	435.768
Valid N (listwise)	27					

Table 5: *Forecast for yam production (2017 to 2026).*

Model		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Yam Production-Model_1	Forecast	1319	1349	1378	1407	1437	1466	1496	1525	1554	1584
	UCL	2094	2124	2153	2183	2212	2242	2271	2300	2330	2359
	LCL	544	573	603	632	661	691	720	750	779	808

Even more, although the above information indicated that there had been some level of increase in the production of yam in the area, it may not capture the real situation. In a similar study that showed an increase in crop (cereal, maize, cassava and yam) production in Nigeria, Urama and Nfor (2018) noted that the increase is not significant when compared to the increase in the number of people that will consume the food. Using the per capita information on food production and supply, the authors revealed that the per capita value of food production in Nigeria is poor and currently at its 1999 value.

Forecast of yam production from 2017 to 2026

The forecast for yam yield from 2017 to 2026 is tabulated and pictured in Table 5 and Figure 5. The analysis predicts improvements in yam production in the next 10 years. The prediction for 2017 remained at 1319 mt, same as the previous year, but increased to 1349 mt in 2018. The analysis predicted a continuous increase in yam production with 1407 mt in 2020, 1466 mt in 2022 till as much as 1584 mt in 2026. This predicted increase, although minimal would contribute to the declining and stagnant yam yield at country level as identified by Bergh*et al.* (2012).

Climate variability and yam production in Ikom LGA from 1990 to 2016

The multiple regression analysis was used to explore the relationship between the climate variables and yam production in the area. The purpose for this analysis was to ascertain the effect of the independent variables (mean sunshine intensity, mean temperature, mean relative humidity, number of rain days and mean rainfall volume) in predicting the outcome of the dependent variable (yam yield) during the period. Table 2 is the variable description used for the analysis. It shows the data for the climate variables and yam output for the period.

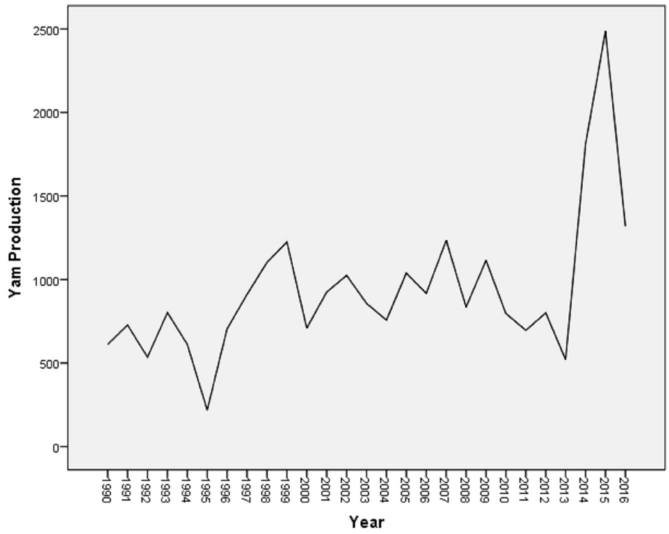

Figure 4: *Trend of yam production from 1990 to 2016.*

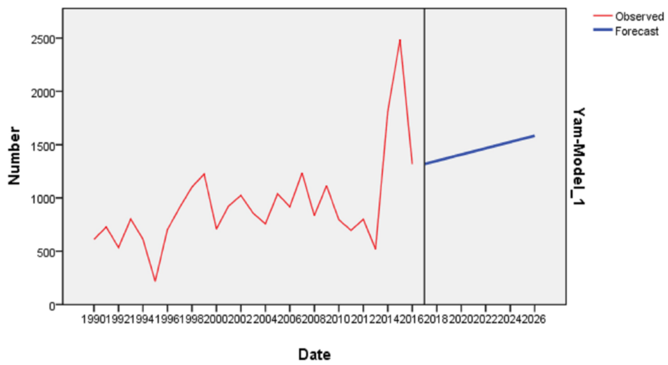

Figure 5: *Forecast for yam production (1990 to 2026).*

The multiple regression model summary and overall fit statistics is presented in Table 6. We find that the R^2 = *.437*. This means that the linear regression explains 43.7% of the variance in the data. The F-ratio in the ANOVA table (Table 7) tests whether the overall regression model is a good fit for the data. The table shows that the independent variables significantly predict the dependent variable, F (5, 21) = 3.262, p = .025 < .05; i.e., the regression model is a good fit of the data.

The next table (Table 8) shows the multiple regression coefficients and significance levels. In our multiple linear regression analysis, we find that only sunshine intensity is a significant predictor of the dependent variable (p= .011<.05), whereas rain days (.332>.05), rainfall volume (.393>.05), temperature (.235>.05) and relative humidity (.963 > .05) were not significant. During the period examined in Ikom LGA, only sunshine intensity showed to have statistically significant relationship with yam production. Rain days, rainfall volume, temperature and relative humidity were not significant predictors.

Table 6: *Model summary.*

Model	R	R square	Adjusted R square	Std. error of the estimate	Durbin watson
1	.661[a]	.437	.303	363.760	1.459
Model Summary[b]					
a. Predictors: (Constant), Relative Humidity, Mean Rainfall, Mean Temperature, Rain Days, Mean Sunshine					
b. Dependent Variable: Yam Production					

Table 7: *ANOVA.*

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	2158472.128	5	431694.426	3.262	.025[b]
	Residual	2778755.502	21	132321.691		
	Total	4937227.630	26			
ANOVA[a]						
a. Dependent Variable: Yam Production						
b. Predictors: (Constant), Relative Humidity, Mean Rainfall, Mean Temperature, Rain Days, Mean Sunshine						

We can also see that sunshine intensity has the highest impact (beta= .551) than rain days (beta= .0176), rainfall volume (beta= -0.144), temperature (beta= .224) which has the 2nd highest impact and relative humidity (beta= .009). These are comparisons of the standardized coefficients. The information on Table 8 also allows us to check for multicollinearity in our multiple linear regression model. Tolerance should be > 0.1 and VIF = 1 for all variables. A VIF > 5 indicates high correlation and may be problematic. The output from the analysis shows there was moderate multicollinearity in the model with the VIF values ranging from 1.0 to 1.4. The output shows that the VIF for the independent variables are less than 1.5, which indicates some correlation, but not enough to be overly concerned about.

On the one hand, exposure to the extreme heat of the sun has been noted to increase tissue damage in yams (Azeteh *et al*., 2019). This supports the finding of this study that sunshine intensity is a significant predictor of yam production in Ikom LGA and is corroborated

Table 8: *Coefficients.*

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.	95.0 percent confidence interval for B		Correlations			Collinearity statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero order	Partial	Part	Tolerance	VIF
1	(Constant)	-7539.9	7661.8		-0.98	0.336	-23473	8393.72					
	Mean sunshine	688.15	245.623	0.551	2.802	0.011	177.348	1198.95	.598	.522	.459	.694	1.441
	Rain days	9.458	9.53	0.176	0.992	0.332	-10.361	29.276	.052	.212	.162	.849	1.178
	Mean rainfall	-1.674	1.918	-0.144	-0.87	0.393	-5.662	2.314	-.059	-.187	-.14	.982	1.018
	Mean temperature	124.796	102.002	0.224	1.223	0.235	-87.328	336.921	.412	.258	.200	.799	1.252
	Relative humidity	3.965	83.771	0.009	0.047	0.963	-170.25	178.177	-.226	.010	.008	.707	1.414

Coefficients[a]

a. Dependent Variable: Yam Production

by the study of Adewuyi *et al*. (2015) at Oyo State, Nigeria, that sunshine hour significantly affects yam yield. It also corroborates with the result of Uger (2017) that temperature (sunshine) correlates with preponderate effect on yam production in Benue State, an effect which manifests through destruction of yam seedlings which adversely affects its production.

On the other hand, Cohn *et al*. (2016) revealed that although hot and wet conditions were largely associated with gains or losses in crop yields, a focus on these alone, and not other factors that influence crop production may create bias in the assessments of the vulnerability of agriculture to climate change. Based on the deduction that rainfall, temperature and relative humidity do not significantly influence yam yield in Ikom LGA from 1990 to 2016, Adejuwon and Ogundiminegha (2019) were of the position that non-climatic factors have a greater influence on crop yield than climatic factors in the Humid Forest Agro-Ecological Zone of Nigeria. This is supported by a similar study/ ecological zone where Magna *et al*. (2018) 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.

In the same vein, although not specific to yam, Obiefuna and Njar (2018) revealed that 1 % of the total variation in crop production in Ogoja LGA which neighbors Ikom LGA is explained by variations in temperature and rainfall, thus deducing that there is no relationship between climate change and agricultural production in the area. It was thus recommended that crop yield should be regressed with other factors such as soil fertility, fertilizer application, irrigation, specie of crop etc. The qualitative study by Elijah *et al*. (2018) also suggests that climate change has no significant effect on the production of certain root crops, such as yam in Cross River State. The foregoing implies that the climate of the study area is largely suited for the production of yam. This is unlike the northern parts of Nigeria where studies in the Savanna Uger (2017) in Benue State, Zakari *et al*. (2014) in Abuja; Yahaya *et al*. (2014) in Niger State and Srivastava *et al*. (2012) in the savanna zone of West Africa, which revealed a positive significant relationship between climate variables (rainfall and temperature) and yam yield.

Conclusions and Recommendations

The fact that climate variability influences the productivity of crops has been highlighted in previous studies. However, the level of effect has shown to vary based on place and type of crop. Yam is a commonly cultivated food crop in Ikom LGA of Cross River State, which is a hotspot for yam production in Nigeria and this study examined the influence of climate variability on its production. The study revealed that the trend of climate characteristics varied in the area during the period (1976 to 2016). The forecast of future climate scenario shows that only the relative humidity of the area will reduce slightly by 2026. On the other hand, yam production slightly increased, although with fluctuations over the years. It was also predicted that yam yield would increase minimally by an additional 265 mt by the year 2026. The trend of yield and projected increase, although marginal would contribute to reduce food scarcity in the area. The findings also show that sunshine intensity and not rainfall, temperature and relative humidity influences the yield of yam in the area. This highlights the adaptability of yam to the climate of the area and its ability to thrive without significant climate impacts. It also suggests the likelihood that other factors have more influence on the productivity of yam in Ikom LGA. These findings would give better direction to the government through her agencies (e.g. Ministry of Agriculture), Civil Society Organizations and farmers in their policy formulation and activities.

Further recommendations are suggested thus:
- The forecast of climatic attributes in this study should be considered for context-specific climate risk mitigation with regard to yam production by relevant government agencies such as the Ministry of Agriculture and the Ministry of Climate Change and Forestry in Cross River State.
- Due to the established variations and fluctuations in climatic conditions in the area, measures should be taken through local evidence-based based technology to forestall uncertainties that can deter yam production through providing improved yam breeds that can withstand climate fluctuation shocks.
- Specific findings from this study can guide farmers' decisions on the best farming methods to practice. For example, since sunshine intensity showed to have significant influence on yam production, green houses should be introduced for nursing yam seedlings to control their germination in their budding stages when they are most vulnerable.
- Because of the potential impacts of climate variability on yam production, there is need for continued sensitization and preparedness for climate variability impacts by relevant agencies, especially on sustainable agricultural practices that would improve currently marginal yam yield with regards to current and future climate/ yam yield nexus in Ikom LGA.
- The inference of climate-suitability of Ikom LGA for yam production which implies reduced adaptation costs compared to unfavorable climatic zones should be leveraged upon by yam farmers and the Ministry of Agriculture to upscale yam yield in the area. This would support in strengthening food security in Cross River State and Nigeria at large.
- Also, although the study is local to Ikom LGA, similar studies can be replicated in other yam producing LGAs of Cross River State and beyond while the findings can be borrowed for decision making in neighboring ecological zones.

Novelty Statement

This study is targeted at highlighting the nexus between climate variability and yam (*Dioscorea* spp.) production in a yam production hotspot of Nigeria. The novel hypothesis from the analyses is that contrary to general assumptions, key climate variables (rainfall, temperature and relative humidity) do not significantly influence yam yield in the area. Rather, only sunshine intensity showed to have significant influence, while highlighting the possible influence of non-climatic factors. This knowledge gives room for better planning by farmers and targeted policy formulation by the government and other stakeholders.

Author's Contribution

Grace Okongor: Conducted the research. All authors read and approved the final manuscript.
Chukwudi Gbadebo Njoku: Assisted with data analyses and reporting. All authors read and approved the final manuscript.
Pauline Essoka: Assisted with reviewing the work. All authors read and approved the final manuscript.
Joel Efiong: Assisted with developing the methods and also reviewed the work. All authors read and approved the final manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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