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Application of Predictive Model for Efficient Cassava (*Manihot esculenta* Crantz) Yield in the Face of Climate Variability in Enugu State, Nigeria

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Abstract

Climate variability as occasioned by conditions such as extreme rainfall and temperature, rainfall cessation, and irregular temperatures has considerable impact on crop yield and food security. This study develops a predictive model for cassava yield (Manihot esculenta Crantz) amidst climate variability in rainfed zone of Enugu State, Nigeria. This study utilized data of climate variables and tonnage of cassava yield spanning from 1971 to 2012; as well as information from a questionnaire and focus group discussion from farmers across two seasons in 2023 respectively. Regression analysis was employed to develop the predictive model equation for seasonal climate variability and cassava yield. The rainfall and temperature anomalies, decadal change in trend of cassava yield and opinion of farmers on changes in rainfall season were also computed in the study. The result shows the following relationship between cassava and all the climatic variables: $R^2 = 0.939$; $P = 0.00514$; Cassava and key climatic variables: $R^2 = 0.560$; $P = 0.007$. The result implies that seasonal rainfall, temperature, relative humidity, sunshine hours and radiation parameters are key climatic variables in cassava production. This is supported by computed rainfall and temperature anomalies which range from −478.5 to 517.8 mm as well as −1.2˚C to 2.3˚C over the years. The questionnaire and focus group identified that farmers experienced at one time or another, late onset of rain, early onset of rain or rainfall cessation over the years. The farmers are not particularly sure of rainfall and temperature characteristics at any point in time. The implication of the result of this study is that rainfall and temperature parameters determine the farming season and quantity of productivity. Hence, there is urgent need to address the situation through effective and quality weather forecasting network which will help stem food insecurity in the study area and Nigeria at large. The study made recommendations such as a comprehensive early warning system on climate variability incidence which can be communicated to local farmers by agro-meteorological extension officers, research on crops that can grow with little or no rain, planning irrigation scheme, and improving tree planting culture in the study area.

Keywords

Climate, Variability, Cassava (*Manihot esculenta* Crantz), Predictive Model, Yield

1. Introduction

Climate variability has a direct adverse influence on the quantity and quality of agricultural production. The climate of an area is highly related to the type of crop that can be cultivated and the suitable season for such crop. Temperature, rainfall, humidity and sunshine intensity are the important climatic elements that may influence crop production in the tropics. The overall predictability of these climatic elements is imperative for the short, medium and long-term planning of farm operations and productivity (Sundström, et al., 2014; IPCC, 1996; FAO, 2003, 2006; Ogbuene, 2010). The ability to predict the change in climate variability and its implication on the tonnage of cassava yield may help position developing nations such as Nigeria in their quest to achieve food security status. The prediction of climate behaviour on crop yield may help achieve efficient food production and increase yield in the face of climate variability.

Our study focuses its prediction using quantification and graph plotting of changes in tonnage of cassava yield within a period in review and pinpointing the exert climate parameter that could cause the changes. This prompts the study to develop policy implications which can be achieved through the recommendation of this work.

Moreno et al. (2021), carried out a study on cassava models for their capability to simulate storage root biomass and to categorize them into static and dynamic models. The majority are dynamic and capture within season growth dynamics. Most of the dynamic models consider environmental factors such as temperature, solar radiation, soil water and nutrient restrictions. In similar study, Anyaegbu et al. (2022), emphasized that climate change is threatening the environment, crop yield and food security. The key to ensuring a sustainable environment, crop yield increase and food security is to identify the long-term significant impact of climate change and the means of reducing the effect. This study examined the impacts of climate change on cassava yield in Nigeria.

Pushpalatha and Gangadharan, (2021) carried out a study on the influence of climate model biases in the predictions of yield and water requirement of cassava in one of the major cassava growing regions in India. Simple linear bias correction methods are used for temperature, and non-linear corrections are used for other meteorological variables.

Aim of the study: It's against this background that the present study investigated the pattern of climate variability and the consequent tonnage of crop yield in rain fed zone of Enugu State, Nigeria. The incidence of climate variability is worrisome and of enormous concern to farmers and the indigenes in the study area who practice rain-fed agriculture. The evidence of climate variability is captured by IPCC (2007) which emphasized that by 2100, parts of the Sahara will emerge as the most vulnerable to climate variability problems. This has resulted in an estimated severe agricultural loss of between 2% and 7% of GDP in the area. Western and Central Africa are also vulnerable, with impacts ranging from 2% to 4%. Northern and southern Africa (Glantz et al., 1997), however, are expected to have losses of 0.4 to 1.3% (Maharjan & Joshi, 2013; WMO, 2009; Melkonyyan et al., 2005). This scenario proved that the problem of climate variability as spelt out by excessive prolonged rainfall, flood, rainfall cessation, seasonal drought, increased soil temperature, and irregular temperature over the years may have devastating effects on crop yield and the farmers in the study area. This contributes to food insecurity which can put the livelihood of the indigenous people at risk (NIMET, 2012; IPCC, 2004; Hopkin 1999). The Food and Agriculture Organization (FAO, 2008) Report and NIMET (2009) show that climate variability may result in a shift in the present (agro) ecological zones for hundreds of kilometers horizontally, and hundreds of meters longitudinal with the hazard that some plants, especially trees and animal species cannot adjust themselves in time. This may perhaps lead to food insecurity, and ecological and environmental refugees (Beckford, & Campbell, 2013; Wu, et al., 2014). Hence, the present study examines the relationship between climate variability and tonnage of cassava yield from 1972 to 2012, intending to establish climate behaviour and its likely effects on crop yield.

Climate variability and food insecurity are critical global environmental disaster that requires prompt research action and implementation. The evidence can be seen with variation in temperature and rainfall pattern with correspondence change in tonnage of crop yield which are clarified in the present study. Recent studies indicate that an increase in daily temperature affects the period of transplanting and maturity of rice, consequently, impacting agricultural productivity and tonnage of crop yield (Challinor, 2014; FAO, 2006, 2008; Katz & Brown, 1992; Ogbuene, 2010). Climate variability over the years has caused a serious threat to food productivity and environmental disaster. This may have resulted in food insecurity and overuse of environmental resources. In combating environmental disasters and food security status; climate variability studies stand out as a fundamental measure that may be at the forefront (Zakaria & Keshav, 2014; Barnett, 2011).

Farm inputs such as fertilizer application, improved crop species, mechanization and labour appear to be very crucial in cassava production. However, the problem of irregular temperature, delayed rainfall, rainfall cessation, excessive rainfall, prolonged seasonal drought, intensive solar radiation, loss of soil moisture and increase in soil temperature may constitute serious impediments to cassava production. This is more pronounced in the study area because farmers are involved in rain-fed agriculture; hence this study is designed to predict the impact of climate variability on the tonnage of cassava yield.

The rationale for the choice of cassava: Cassava has great ease of cultivation. It can be planted in ridges, mounds or even on flat lands. The crop requires very little financial outlay and farm input. It is tolerant to other crops grown with it. The crop has the possibility of being left or "stored" in the soil for a considerable length of time provided there is no flood or fire before the farmer is ready to harvest it. Also, the extremely high and rapidly rising urban demand for garri, a major cassava food product that can be prepared into a meal in only a few minutes necessitated the choice of the crop. In addition, the increasing industrial use of cassava, especially starch and flour manufacturing, as we as high and rising market prices for cassava and its products (Igbozulike, 1986).

The study developed a predictive model for cassava yield (*Manihot esculenta* Crantz) in the face of climate variability. Hence, the policy implication of the study is food production in the face of climate variability which may be achieved through the application of the recommendations of this study.

2. Materials and Methods

Data used for the study are existing climatic data collected from the data base of Nigerian Meteorological Services, Oshodi Lagos, Enugu airport and ESUT weather observation as well as Federal Bureau of Statistics. The climate data and tonnage of cassava yield spanning from 1971 to 2012. The nature of seasonal climatic data collected are rainfall values, surface temperature, soil temperature at 5 cm, 10 cm, 30 cm, 50 cm and 100 cm depths, evaporation, relative humidity (R.H.) at 0900 GMT and 1500 GMT, Radiation, sunshine hours and cloud coverage (see **Appendix 1**, **Appendixes 3**-**8**). Questionnaire and focus group discussion was also utilized in the study. This enabled the study generate first hand information from farmers' climate and cassava yield experience. The exercise was conducted across two seasons in 2023.

The study area is Enugu State, Nigeria. The farm practice in the area is rain-fed agriculture (Ogbuene, 2010). This study developed a predictive model equation for cassava yield (*Manihot esculenta* Crantz) in the face of climate variability. The study applied regression analysis to establish the relationship between seasonal climate variability and the yield of cassava in the study area. The regression analysis was utilized to develop a predictive model equation for seasonal climate variability and cassava yield over the years. Regression analysis is good for this study because it helps to compute correlation, the strength of the relationship and predictive model equation between climate variability and crop yield. Unlike Analysis of variance that can only show the significant difference between the variables of the study. However, the regression model cannot show the exerted changes in crop yield patterns over the years. Hence, Time Series Analysis was used to plot changes in cassava yield for each decade and exert climate parameters that could cause such change. To the best of our knowledge, previous work reviewed could not bring these facts into the lime light. The rainfall and temperature anomalies were also computed and plotted. A well-structured questionnaire and focus group discussion was also employed to generate first-hand data from the active farmers on rainfall pattern and implication on crop yield in the area (NIMET, 2012; Ogbuene 2010; Intergovernmental Panel on Climate Change, 2004).

3. Results and Discussions

The result of correlation, regression model, coefficient correlation and related graph of climate variability and cassava yield are shown in the study. Multiple collinearity tests were conducted to ensure that the climate variability data were significant for the analysis. The result in **Table 1** showed the correlation values between cassava yield and seasonal climate variables studied. These seasonal climatic variables includes rainfall, surface temperature (minimum, average and mean), mean soil temperature at 5 cm, 10 cm, 50 cm, 100 cm, relative humidity and rate of evaporation over the years (Planting, growing and harvesting seasons). This enables the study to practically establish the different correlation levels between climate variables and cassava yield with a view to improving yield in the phase of climate variability.

Table 1. Cassava and seasonal climate variables correlation score.

S/N	Correlation Variables	Correlation Score
1	Cassava and Rain Planting Season PS	0.570
2	Cassava and Rain Growing Season GS	0.756
3	Cassava and Rain Harvesting Season HS	−0.239
4	Cassava and Temp Max	0.344
5	Cassava and Temp Min	0.023
6	Cassava and Temp Aver	0.520
7	Cassava and T5cm Planting Season PS	−0.112
8	Cassava and T5cm Growing Season GS	−0.029
9	Cassava and T5cm Harvesting Season HS	−0.153
10	Cassava and T10cm Planting Season PS	−0.021
11	Cassava and T10cm Growing Season GS	−0.254
12	Cassava and T10cm Harvesting Season HS	−0.108
13	Cassava and T30cm Planting Season PS	0.197

Continued

14	Cassava and T30cm Growing Season GS	0.222
15	Cassava and T100cm Planting Season PS	−0.336
16	Cassava and T100cm Growing Season GS	−0.352
17	Cassava and T100cm Harvesting Season HS	−0.352
18	Cassava and Evap Planting Season PS	−0.309
19	Cassava and Evap Growing Season GS	−0.282
20	Cassava and Evap Harvesting Season HS	−0.324
21	Cassava and RH09 Planting Season PS	0.409
22	Cassava and RH09 Growing Season GS	0.097
23	Cassava and RH1500 Planting Season PS	−0.241
24	Cassava and RH1500 Growing Season GS	−0.260
25	Cassava and RH1500 Harvesting Season HS	−0.221
26	Cassava and Sunshine Planting Season PS	0.411
27	Cassava and Sunshine Growing Season GS	−0.389
28	Cassava and Cloud Planting Season PS	0.214
29	Cassava and Cloud Growing Season GS	0.214
30	Cassava and Cloud Harvesting Season HS	−0.075
31	Cassava and Radiation Planting Season PS	0.534
32	Cassava and Radiation Growing Season GS	0.288
33	Cassava and Radiation Harvesting Season HS	0.241

The climate variables that have a high correlation with cassava yield are seasonal rainfall, radiation and temperature-related parameters. The implication is that rainfall, radiation and temperature are the key climatic variables that may highly influence cassava production in the study area. Hence, the process of improving the tonnage of cassava yield requires a comprehensive early warning system for the farmer to be acquainted with rainfall behavior which may probably help reduce loss.

In addition, the result of the regression model for climate variability and cassava yield is shown in Table 2 and Table 3 of this work. This enables the study to quantify the strength of the relationship between climate parameters and tonnage of crop yield.

Table 2. Regression model of climate variability and cassava yield.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	Df1	Df2	Sig. F Change
1	0.969(a)	0.939	0.16	11402.6	0.939	1.205	38	3	0.00514

Model 1: the result of the multiple correlation (R) value in Table 2 is 0.969. The coefficient of determination (R square) value is 0.939 with p value of 0.00514. The value of R square shows a high strength of the relationship between climate variability and cassava yield in the study area ($R^2 = 0.939$, $p = 0.00514$).

To critically examine the particular climate variable that significantly influences cassava yield; the variables with the significant score were further re-run in the SPSS regression model. Hence, the climate variables selected include: Rainfall PS, Rainfall GS, Rainfall HS, Radiation GS, Relative humidity 0900 GMT GS and HS, Sunshine PS and GS, Soil Temperature @ 30cm PS and GS and Evaporation HS (see **Appendix 1**, **Appendixes 3-9**). These climatic elements selected are the key variables that affect cassava yield more in the study area. The result of re-run multiple regression is presented in Table 3 of this study.

Table 3. Regression model of key climate variables and cassava yield.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	Df1	Df2	Sig. F Change
2	0.748	0.56	0.378	9809.968	0.56	3.076	12	29	0.007

Model 2: the result of re-run multiple correlation (R) between selected climatic variables and cassava yield is 0.748. The result showed a positive correlation between the selected variables studied.

The coefficient of determination (R square) value is 0.560 with p value of 0.007. The result indicates strong explanatory power of rainfall, solar Radiation, Sunshine hours, soil temperature @ 30 cm, Evaporation and relative humidity variables on cassava yield over the years in the study area ($R^2 = 0.560$, $p = 0.007$). The result showed that rainfall-related parameters are the key climate variables that may affect cassava yield more in the area. The p-value of 0.007 validates high level of significance between selected climate variables and cassava yield ($p = 0.007$).

The summary of the result:

Model 1: Cassava and combine climate variables: $R = 0.969$; $R^2 = 0.939$; $P = 0.00514$ over the years.

Model 2: Cassava and key climatic variables: $R = 0.748$; $R^2 = 0.560$; $P = 0.007$.

Model 2: the result of the regression emphasized that rainfall and temperature are the key climate parameter that influences cassava yield. Farmers practice rain fed agriculture and as a matter of fact rainfall determine farming season in the area and requires urgent management practice.

Predictive Model Equation for Cassava yield

The predictive model equation was developed from the multiple regressions of seasonal climate variables and cassava yield. This is derived from the coefficients of seasonal climate elements and cassava yield in **Appendix 2**. Hence, the equation is as follows:

$$y = a + b_1 + b_2 + \cdots + b_n X_n$$

The Multiple Regression Equation: $Y = a + b_1 X_1 + b_2 X_2 + \cdots + b_n X_n$.

Y—output/dependent/response variable (X_1, X_2, ..., X_n—input/independent/explanatory variables).

a—is the Y-intercept b_1, b_2, …, b_n—net regression coefficients of corresponding input variables.

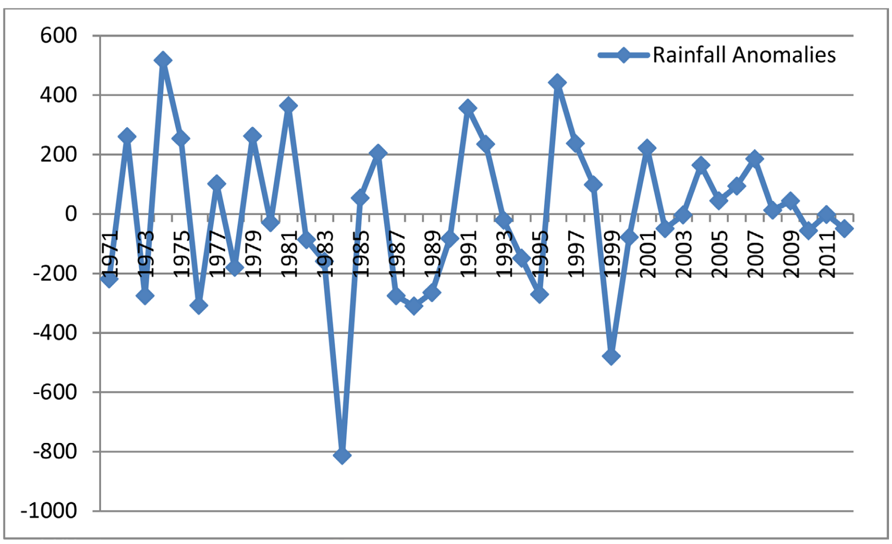
y = −264,637 + 0.237 + (−1.073) + 077 + (−4.402) + 2.636 + 5.250 + (−8.658) + 2.054 + 1.956 + (-4.831) + 0.978 + (−0.591) + 11402.6;

y = −264,637 + 0.237 − 1.073 + 077 − 4.402 + 2.636 + 5.250 − 8.658 + 2.054 + 1.956 − 4.831 + 0.978 − 0.591 + 11,402.6.

Y = 276,032.9427 (see the coefficients detail in **Appendix 2**).

The predictive model at this point emphasized that improved climate conditions will result in a correspondent increase in the tonnage of cassava yield. Hence, the predictive model emphasized that seasonal rainfall; temperature, relative humidity, sunshine hours and radiation parameters are important factors in cassava production and yield as selected by the model. Consequently, the model of the study affirms that seasonal rainfall; radiation and temperature-related parameters are the likely leading climatic variables in cassava production. This is supported by rainfall and temperature anomalies (see Figure 1 and Figure 2). The pattern of rainfall and temperature anomalies may likely affect cassava yield over the years. This is highly applicable to the study area where farmers are practising rain-fed agriculture. The predictive model also validates the result of correction in Table 1 and regression mode in Table 2 and Table 3 of this study. This result simply suggests the need to develop a coordinated system approach to climate incidents and effects as well as formulate adaptive resilience in crop production in the phase of climate variability.

Furthermore, it is important to note that since the key climate variables that



Data Source: Appendix 1.

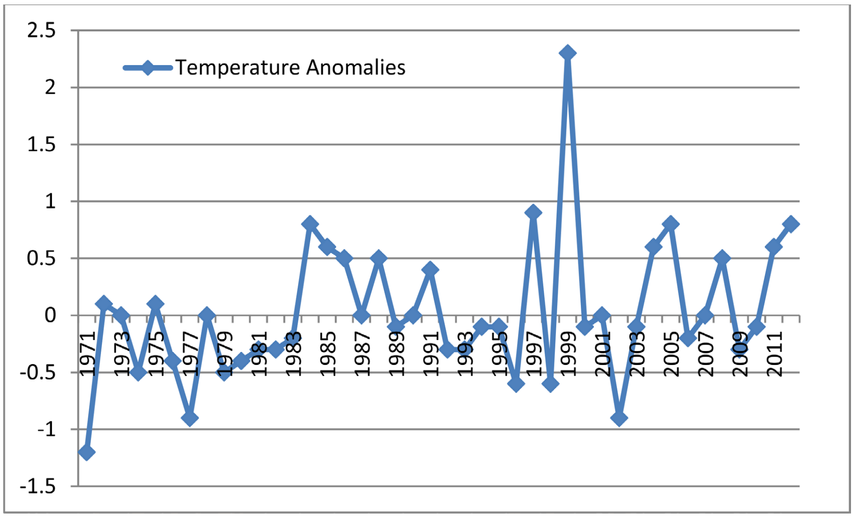
Figure 1. Trend of Rainfall Anomalies (mm).

affect cassava yield in rain-fed agricultural zones are rainfall and temperature variables, hence rainfall and temperature behaviour as well as changes in tonnage of crop yield are plotted and discussed in Figures 1-7.

Figure 1 shows rainfall anomalies in the study area. The graph is plotted with computed rainfall anomalies data in **Appendix 1**.

The rate of anomalies over the years is explained as fluctuations in rainfall values at point "0" in the graph. It records an increase and decrease values in the graph. It ranges from rainfall anomalies values of −478.5 to 517.8mm over the years. The result shows ten-year period of rainfall values closely related to mean rainfall of 1725.5 mm. The highest rainfall anomalies were recorded in 1974, 1981, 1991 and 1997 (with rainfall values of 517.8, 364.5, 356.6, and 442.4 mm). The lowest rainfall anomalies were observed in 1984 and 1999 (with values of −812.4 and −478.5 mm).

Figure 2 shows temperature anomalies in the study area. The graph is plotted with computed temperature anomalies data in **Appendix 1**.



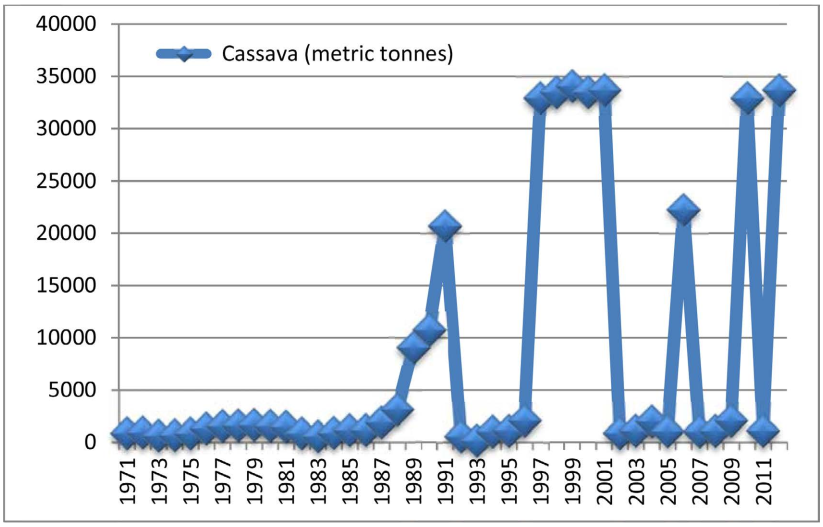
Data Source: **Appendix 1**.

Figure 2. Temperature Anomalies (˚C).

The mean annual temperature for the years is 27.6˚C while the temperature anomalies range from −1.2˚C to 2.3˚C over the years. The year 1971 records the lowest temperature anomalies and 1999 records the highest temperature anomalies. The period of 12 years out of the 42 years analysed records temperature anomalies above the mean annual temperature and 17 years records temperature below it. The analysis also indicates that 14 years records temperature anomalies closely related to the mean temperature at point "0" in the graph.

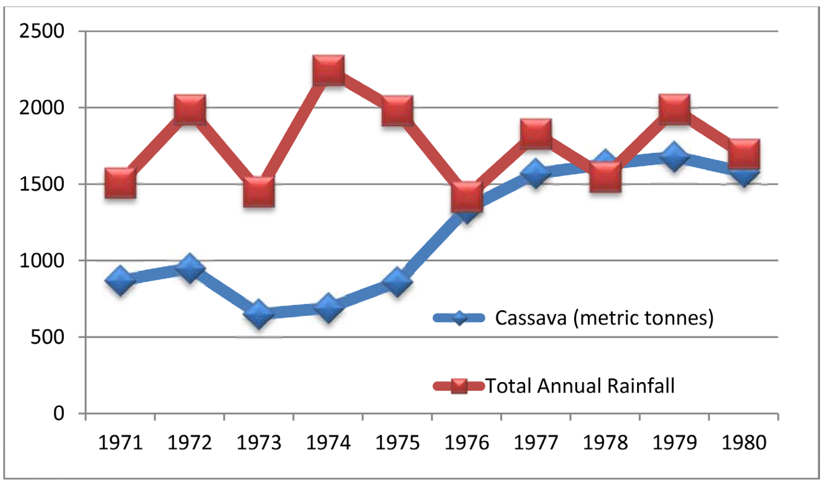
Changes in the tonnage of cassava yield from 1970 to 2012 were clearly shown in Figure 3. The time series graph is plotted with data from the tonnage of cassava yield over the years in **Appendix 1** of the study.

The time series graph in Figure 3 shows variation in the tonnage of cassava over the years. The fluctuation in tonnage of cassava yield exhibits different patterns of decrease and increase over the years. The peak tonnage of cassava yield was recorded in the year 1999 with a value of 34,094 tonnes. While lowest tonnage of cassava yield was recorded in the year 1993 with 161 tonnes. The fluctuation in the tonnage of cassava yield may be attributed to the pattern of rainfall trend over the years in the study area (see Figures 4-7).



Data Source: **Appendix 1**.

Figure 3. Time series graph of change in tonnage of crops.

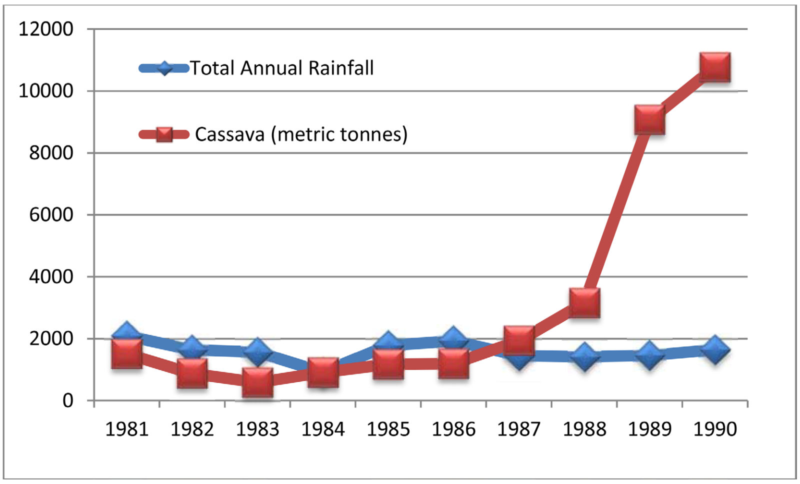


Data Source raw data: **Appendix 1**.

Figure 4. Time series graph of rainfall and cassava yield trend in decade I (1971 to 1980).

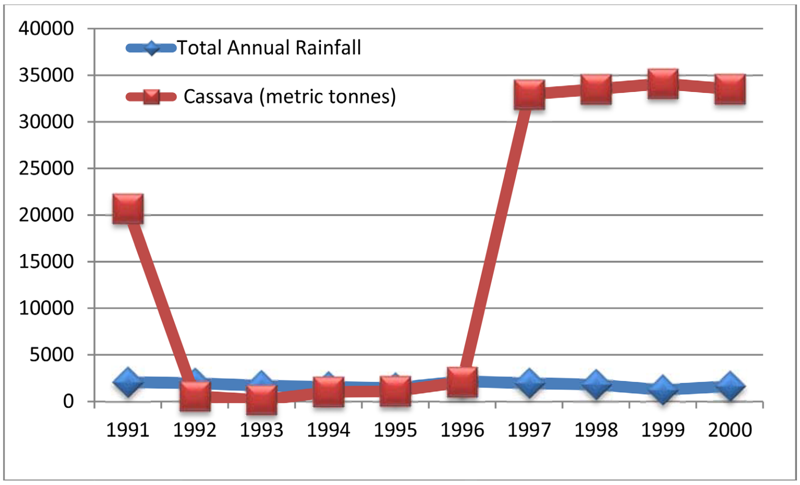
The decadal analysis of the fluctuation in rainfall and cassava yield was plotted in Figures 4-7 and is used to clarify the link between rainfall and cassava yield over the years.

The trend in decade I; showed a significant increase and decrease in rainfall pattern with a corresponding change in cassava yield. This implies that the change in rainfall may determine the crop yield behaviour from the period of 1971 to 1980.



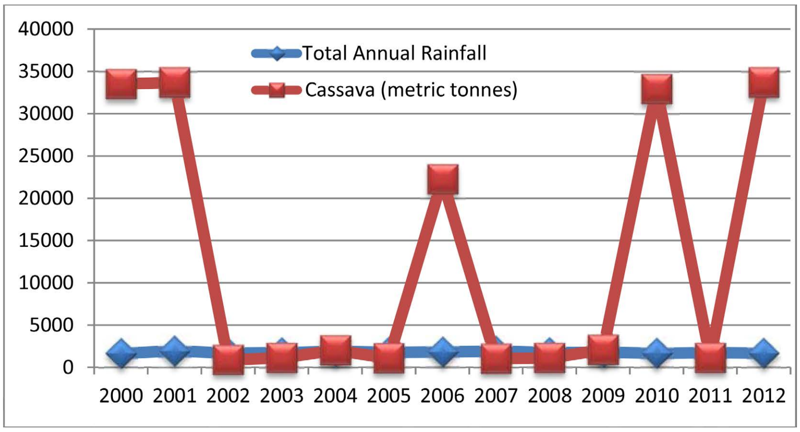
Data Source: **Appendix 1**.

Figure 5. Time series graph of rainfall and cassava yield trend in decade II (1981-1990).



Data Source: **Appendix 1**.

Figure 6. Time series graph of rainfall and cassava yield trend in decade III (1991 to 2000).



Data Source: **Appendix 1**.

Figure 7. Time series graph of rainfall and cassava yield trend in decade IV (2001-2012).

In decade II (1981-1990), there was excessive rainfall in 1981, 1982 and 1983 with corresponding low cassava yield. There is also increasing rainfall with significant increase and decrease in related crop yield values. However, there was a rapid increase in cassava yield in 1989 and 1990. This could be attributed to adequate rainfall distribution within the farming season and improved cassava species.

Decade III; which ranges from 1991 to 2000, records significant correlations between rainfall and cassava yield especially from 1992 to 1996. However, from 1997 to 2000 exhibited a serious increase in cassava yield without a corresponding increase in rainfall values. Other factors outside adequate rainfall distribution within the planting and growing seasons, such as improved cassava species may be responsible for the improvement in cassava yield in the period.

There is a significant correlation between rainfall values and cassava yield over the years in decade IV (2001-2012). The years 2001, 2006, 2010 and 2012 recorded outstanding increases in cassava yield over the period. This may be attributed to good rainfall distribution and improved cassava species within the period. Rainfall and temperature behaviour can also be predicted and plotted for sustainable farm planning and crop yield improvement.

The findings of the study showed that climate variability may have a strong positive relationship on cassava yield in the study area ($R^2 = 0.939$; $P = 0.00514$). The result indicates that climate variability especially rainfall-related parameters may have a significant effect on cassava yield. The findings are significantly related to the study of Wilcox (2006), Sundström, et al. (2014) and Salisu, (2013). Their study maintained that crop yields potentially increased with more rainfall and decreased with higher temperatures. The study also maintained that in some cases, crop yield decreased with excessive rainfall. The result of the study is related to Adejoro (2001) and Barnett, (2011). Their study emphasized that the most significant climate variability expected during the 21st century was rainfall and temperature behaviour. Hence, accurate prediction of climate variability may help in effective farm planning which may perhaps boost crop yield. This was validated by the response of the farmer during our fieldwork and the response generated through questionnaire administration and focus group discussion in the area. The farmers emphasized that rainfall amount, intensity, duration and pattern has a significant impact on their farming seasons, activities and tonnage of yield over the years (see **Figure 8**). Hence, there is an urgent need for a comprehensive early warning system to farmer in their local dialect as this will help reduce loss and maximise profit which is directly caused by change in rainfall pattern. This is in alignment with FAO (2008) estimates which emphasized that for each 1˚C rise in temperature, farm profits in Africa will drop by nearly 10%.

Figure 8 shows that the active farmers in the study area experienced more late onset and early onset of rainfall as well as rainfall cessation over the years. They hardly experienced normal rainfall patterns. The farmers practice rain-fed agriculture and may always wait for the rain to derive their farming seasons giving way to the need for urgent development of an irrigation scheme. The study strongly re-emphasized that late onset and early onset of rain as well as rainfall cessation are important factors for predictive model in efficient cassava yield and hence, prompted the recommendations of the study.

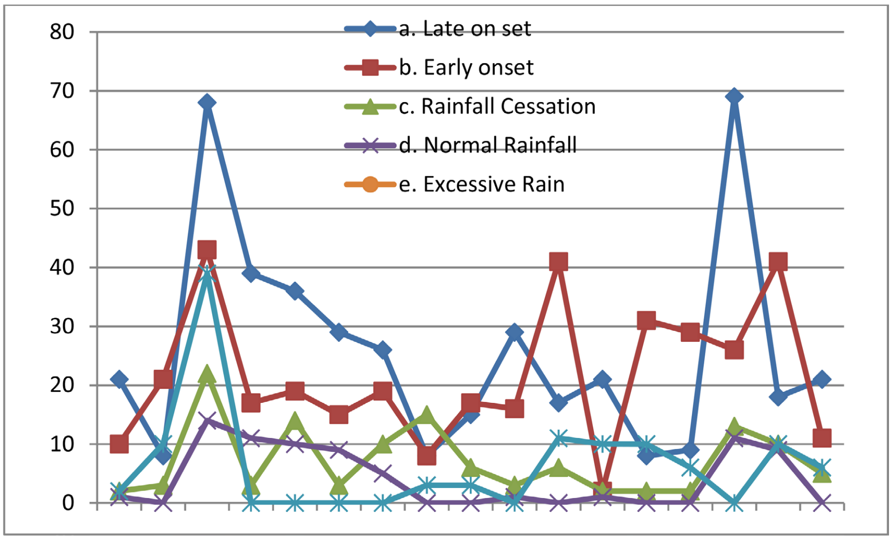


Figure 8. Perception of active farmers on change in rainfall pattern in enugu state.

4. Recommendations

The findings from the study have prompted the following recommendations

1) A comprehensive early warning system on climate variability incidence which can be translated to local farmers in their indigenous language by agro-meteorological extension officers should be developed and practiced.

2) Development of sustainable coordinated system approach on climate variability incidence, effect, adaptation and management strategies.

3) Construction of intensive and functional weather stations in accordance with WMO standards in the study area.

4) Research should focus on improved crop species that can adapt to harsh weather, and mature within the shortest time frame. The research should develop improved storage facilities.

5) Development of functional and improved irrigation scheme. Improving irrigation scheduling is an important element in effective water management and food production.

6) There is an urgent need for water conservation and improved tree-planting culture. This will help improve the hydrological cycle and atmospheric water content. This could be achieved through effective training, awareness campaigns and continuous capacity building.

7) There is an urgent need for a policy implication strategic document on climate variability-induced problems.

5. Conclusion

The predictive model in this study selected seasonal rainfall, radiation, relative humidity, sunshine, soil temperature and evaporation as important climatic variables that may influence cassava yield more. The predictive model equation for cassava yield and climatic elements is:

$$y = a + b_1 + b_2 + b_3 + b_4 + b_5 + b_6 + b_7 + b_8 + b_9 + b_{10} + b_{11} + b_{12} + E;$$

$$y = -264{,}637 + 0.237 - 1.073 + 077 - 4.402 + 2.636 + 5.250 - 8.658 + 2.054 + 1.956 - 4.831 + 0.978 - 0.591 + 11.402.6.$$

The result of rainfall and temperature anomalies, decadal change in the trend of cassava yield and the opinion of farmers on changes in rainfall season validates the predictive model developed in this study. The application of the recommendations of this study could help in food security policy making which could encourage efficient cassava production despite of climate variability incidence.

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Authors' Contributions

All the authors contributed to the conception and design of this work. Material preparation, data collection and analysis were performed by Emeka Bright Ogbuene, Obianuju Gertrude Aloh, Tonia Nkiru Nwodo, and Josiah Chukwuemeka Ogbuka. The first draft of the manuscript was written by Obianuju Gertrude Aloh, Vivian Amarachi Ozorme, Fred Emeka Achoru, and Obiageli Jacinta Okolo. All authors read and commented on the previous versions of the manuscript, as well as approved the manuscript before submission.

Data Availability

The datasets generated during, and/or analysed during this study are not publicly available due to the risk of violating the privacy of respondents/participants, who provided most of the information that makes up the study data. However, the datasets are available with the corresponding author on reasonable request.

Compliance with Ethical Standards

All relevant authorities granted their informed consent to participate in the research before the commencement of the study. Exemption from ethical precautions was granted by the Centre for Environmental Management and Control, University of Nigeria, due to the use of plants for the study. Essentially, the study was conducted according to the Nigerian University-wide ethical guidelines and review processes, as well as the internal guidelines of the Research and Ethics Directorate of the University of Nigeria and Enugu State University of Science and Technology.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix 1: Cassava Yield, Rainfall and Temperature Anomalies in the Study Area (1971-2012) (Sourced from NIMET Lagos and Enugu, 2016, 2013 and 2009; FBS, 2013)

Years	Total Annual Rainfall	Rainfall Anomalies	Mean Temperature	Temperature Anomalies	Tonnage of Cassava Yield
1971	1507.1	−218.4	26.5	−1.2	870
1972	1986.2	260.7	27.7	0.1	950
1973	1450.4	−275.1	27.6	0	650
1974	2243.3	517.8	27.1	−0.5	690
1975	1979.7	254.2	27.7	0.1	860
1976	1417.7	−307.8	27.2	−0.4	1340
1977	1827.6	102.1	26.7	−0.9	1570
1978	1545.8	−179.7	27.6	0	1630
1979	1988.1	262.6	27.1	−0.5	1680
1980	1696	−29.5	27.2	−0.4	1578
1981	2090	364.5	27.3	−0.3	1506
1982	1639	−86.5	27.3	−0.3	873
1983	1566.6	−158.9	27.2	−0.2	581
1984	913.1	−812.4	28.4	0.8	909
1985	1779.4	53.9	28.2	0.6	1174
1986	1930.6	205.1	28.1	0.5	1192
1987	1450.6	−274.9	27.6	0	1930
1988	1415.6	−309.9	28.1	0.5	3151
1989	1461	−264.5	27.5	−0.1	9066
1990	1643	−82.5	27.6	0	10768
1991	2082.1	356.6	28	0.4	20680
1992	1960.8	235.3	27.3	−0.3	567
1993	1704.7	−20.8	27.3	−0.3	161
1994	1576.9	−148.6	27.5	−0.1	1029
1995	1454.9	−270.6	27.5	−0.1	1107
1996	2167.9	442.4	27	−0.6	2087
1997	1963.1	237.6	28.5	0.9	32928
1998	1824	98.5	27	−0.6	33495
1999	1247	−478.5	29.9	2.3	34094
2000	1647.4	−78.1	27.5	−0.1	33506

Continued

2001	1947.3	221.8	27.6	0	33698
2002	1676.3	−49.2	26.7	−0.9	890
2003	1722.2	−3.3	27.5	−0.1	1120
2004	1890	164.5	28.2	0.6	2030
2005	1770.1	44.6	28.4	0.8	1080
2006	1819.6	94.1	27.2	−0.2	22240
2007	1911.2	185.7	27.6	0	1029
2008	1738.4	12.9	28.1	0.5	1107
2009	1769.7	44.2	27.3	−0.3	2087
2010	1669.5	−56	27.5	−0.1	32928
2011	1724.1	−1.4	28.2	0.6	1120
2012	1676.3	−49.2	28.4	0.8	33698

Note: Rainfall Total = 72474.3 mm; Mean Rainfall = 1725.5 mm; Mean Annual Temperature = 27.6˚C.

Appendix 2: Coefficients of Climate Elements and Cassava Yield

Coefficients

Model		unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1.000	{Constant} ·	−264637.000	1466422		−0.180	0.868	−4931448.009	4402173.352					
	RainPS	19.234	43.889	0.237	0.438	0.691	−120.441	158.909	0.170	0.245	0.063	0.070	14.319
	RainGS	−55.827	33.402	−1.073	−1.671	0.193	−162.128	50.474	0.055	−0.694	−0.239	0.050	20.111
	RainHS	18.953	103.368	0.077	0.183	0.866	−310.011	347.916	−0.239	0.105	0.026	0.117	8.538
	TempMax	−17775.700	25266.745	−1.507	−0.704	0.532	−98185.801	62634.317	0.344	−0.376	−0.101	0.004	223.770
	TempMin	10852.696	35775.155	0.348	0.303	0.781	−102999.813	124705.205	0.023	0.173	0.043	0.016	64.023
	TempAver	34939.873	48782.426	1.711	0.716	0.526	−120307.576	190187.323	0.320	0.382	0.103	0.004	278.539
	T5cmPS	−9199.600	20655.311	−0.729	−0.445	0.686	−74934.019	56534.819	−0.112	−0.249	−0.064	0.008	130.542
	T5cmGS	−14572.700	32200.820	−0.917	−0.453	0.682	−117050.059	87904.660	0.029	−0.253	−0.065	0.005	200. 170
	T5cmHS	24431.013	27877.686	1.735	0.876	0.445	−64288.226	113150.252	−0.153	0.451	0.125	0.005	191.252
	T10cmPS	4237.5&7	5608.602	−0.442	−0.756	0.505	−22086.672	13611.478	−0.021	−0.400	−0.108	0.060	16.718
	T10cmGS	−6295.312	9049.988	−0.693	−0.696	0.537	−35096.413	22505.788	−0.254	−0.373	−0.100	0.021	48.482
	T10cmHS	4480.265	3751.640	0.377	1.194	0.318	−7459.129	16419.658	−0.108	0.568	0.171	0.206	4.852
	T30cmPS	−45894.600	29123.533	−4.402	−1.576	0.213	−138578.638	46789.524	0.197	−0.673	−0.226	0.003	380.737
	T30cmGS	27917.007	12330.183	2.638	2.264	0.109	−11323.137	67157.152	0.222	0.794	0.324	0.015	66.132
	T30cmHS	11765.883	17160.094	1.189	0.686	0.542	−42845.196	66376.961	0.300	0.368	0.098	0.007	146.657
	T50cmPS	−5193.213	8140.863	−0.321	−0.638	0.569	−31101.072	20714.645	−0.192	−0.346	−0.091	0.081	12.380

Continued

T50cmGS ·	−1516.414	6813.953	−0.075	−0.223	0.838	−23253.400	20168.824	0.025	−0.127	−0.032	0.178	5.612
T50cmHS	−6531.004	5642.373	−0.438	−1.157	0.331	−24487.584	11425.516	0.194	−0.556	−0.166	0.144	6.926
T100cmPS	79101.444	97469.326	3.780	0.812	0.476	−231089.453	389292.341	−0.336	0.424	0.116	0.001	1058.114
T100cmGS	2959.047	83989.398	0.133	0.035	0.974	−264332.703	270250.797	−0.352	0.020	0.005	0.001	697.463
T100cmHS	−0.971	84634.438	−4.283	−1.148	0.334	−366467.987	172221.122	−0.352	−0.552	−0.164	0.001	679.465
EvapPS	−0.945	78072.150	−5.432	−1.210	0.313	−342912.737	154008.116	−0.309	−0.573	−0.173	0.001	983.457
EvapGS	2523.428	26237.456	0.139	0.096	0.929	−80975.868	86022.723	−0.324	0.055	0.014	0.010	101.850
EvapHS	92797.556	69506.377	5.250	1.335	0.274	−128402.757	313997.870	−0.284	0.610	0.191	0.001	754.439
RH09PS	19119.983	16238.470	7.299	1.177	0.324	−32558.075	70798.041	0.428	0.562	−0.169	0.001	1874.513
RH09GS	−22535.000	17594.928	−8.658	−1.252	0.299	−798023	34732.880	0.409	−0.586	−0.179	0.000	2331.851
RH09HS	5110.307	3353.692	2.054	1.524	0.225	−5562.637	15783.252	0.097	0.661	0.218	0.011	88.616
RH 1500PS	·12090.2	11343.677	−4.056	−1.066	0.365	−48190.893	24010.395	−0.241	−0.524	−0.153	0.001	706.475
RH 1500GS	11533.200	10173.420	4.067	1.134	0.339	−20843.182	43909.563	−0.260	0.548	0.182	0.002	627.722
RH 1500HS ·	−2813.106	3186.781	−1.037	−0.883	0.442	−12954.867	7328.655	−0.221	−0.454	−0.126	0.015	67.361
Sunshine.PS	39542.461	29423.294	1.956	1.344	0.272	−54095.591	133180.513	−0.411	0.613	0.192	0.010	103.333
SunshineGS	−97987.800	76323.638	−4.831	·1.284	0.289	−340883.648	144908.113	−0.389	−0.595	−0.184	0.001	690.825
Sunshine.HS	45965.031	67790.078	2.230	0.678	0.546	−169773.252	261703.315	−0.344	0.365	0.097	0.002	527.814
CloudPS	−4549.814	28352.764	−0.074	−0.160	0.883	−94780.962	85681.335	0.214	−0.092	−0.023	0.095	10.487
CloudHS	29932.059	27560.685	1.616	1.086	0.357	−57778.340	117642.4−58	−0.075	0.531	0.155	0.009	108.057
RadiationPS	45932.299	36161.141	0.978	1.270	0.294	−69148.589	161013.187	0.534	0.591	0.182	0.035	28.926
RadiationGS	·18591.8	13670.922	−0.591	−1.360	0.267	−82098.793	24915.158	0.288	−0.618	−0.195	0.109	9.201
RadiationHS	35311.037	38236.741	0.701	0.923	0.424	−86375.338	156997.413	0.241	0.470	0.132	0.036	28.112

SPSS Regression Analysis.

Appendix 3: Mean Soil Temperature Values at 5 cm Depth from 1971 to 2012

Years	T5PS	T5GS	T5HS
1971	29.3	29.1	29.2
1972	29.6	29.2	29.4
1973	29.5	29.4	29.3
1974	29.1	28.9	29
1975	29.7	29.5	29.6
1976	31.2	30.8	30.9
1977	29.6	29.2	29.4
1978	29.7	29.3	29.5
1979	30.1	29.8	29.9
1980	30.3	30.1	30.2

Continued

1981	29.9	29.5	29.7
1982	29.7	29.3	29.5
1983	29.9	29.7	29.4
1984	29.8	29.6	29.3
1985	30.1	29.9	29.7
1986	30.6	30.4	30.2
1987	29.4	29.3	29.1
1988	29.7	29.5	29.3
1989	29.9	29.6	29.4
1990	30.1	29.8	29.6
1991	29.7	29.5	29.2
1992	28.6	28.4	28.1
1993	29.1	28.9	28.6
1994	29.6	29.4	29.7
1995	29.4	29.3	29.1
1996	29.5	29.3	29.2
1997	29.1	28.9	28.7
1998	27.2	27.9	27.8
1999	31	30.9	30.8
2000	29.7	29.5	29.3
2001	29.4	29.2	29.1
2002	28.7	28.5	28.3
2003	27.4	27.3	27.1
2004	28.3	28.1	27.9
2005	29.1	28.9	28.7
2006	27.3	27.1	26.9
2007	29.1	29.4	28.7
2008	27.2	29.3	27.8
2009	31	29.3	30.8
2010	29.7	30.9	29.3
2011	27.4	29.5	29.1
2012	28.3	29.2	27.9

Source: NIMET Lagos and Enugu, 2013 and 2009; Author's Field work, 2013.

Appendix 4: Mean Soil Temperature Values at 10cm Depth from 1971 to 2012

Years	T10PS	T10GS	T10HS
1971	30.8	31.9	32.9
1972	31.1	32.4	33.4
1973	30.9	30.1	32.1
1974	31.2	30.8	31.2
1975	33.1	31.9	33.9
1976	32.6	31.7	33
1977	31.8	32.4	32.3
1978	30.4	32.6	32.8
1979	33.7	30.3	32.8
1980	31.1	30.4	33.6
1981	29.9	30.6	30.9
1982	32.7	30.2	30.8
1983	32.6	29.5	34.6
1984	30.6	30.3	31
1985	33.9	28.8	31.2
1986	32	28.9	32.5
1987	33.7	32.6	32.6
1988	30.1	32.4	33.3
1989	29.9	32.6	32.6
1990	30.2	30.1	32.4
1991	31.6	30.2	32
1992	30.8	32.2	33
1993	30.4	32.1	32.9
1994	31	32.1	33.1
1995	29.7	32.2	31.8
1996	30.4	28.5	32.5
1997	29.3	28.6	32.1
1998	29.5	30.3	31.6
1999	33.7	30.6	30.3
2000	30.2	28.4	`34.4
2001	31.1	28.6	33.2
2002	30.9	28.9	33.6
2003	30.2	28.6	31.2

Continued

2004	30.8	30.1	33
2005	30.1	30.2	33.6
2006	30.8	32.4	33.2
2007	30.2	30.1	32.4
2008	31.6	30.2	32
2009	29.5	30.3	31.6
2010	33.7	30.6	30.3
2011	30.2	28.6	31.2
2012	30.8	30.1	33

Source: NIMET Lagos and Enugu, 2013 and 2009; Author's Field work, 2013.

Appendix 5: Mean Soil Temperature Values at 30 cm Depth from 1970 to 2012

Years	T30PS	T30GS	T30HS
1971	27	26.9	26.7
1972	27.1	27	26.8
1973	27.5	27.3	27.1
1974	27.6	27.4	27.2
1975	27.3	27.2	27.1
1976	27.9	27.6	27.3
1977	28.1	27.8	27.6
1978	30.2	29.9	29.7
1979	29.2	29.1	28.9
1980	27.4	27.2	27.1
1981	30.3	30.1	29.9
1982	30.2	29	29.8
1983	30.2	30	29.7
1984	27.8	27.6	27.4
1985	29.6	29.4	29.2
1986	30.1	29.9	29.7
1987	29.8	29.6	29.4
1988	30.2	30	29.8
1989	30.3	30.1	29.9
1990	30.7	30.6	30.5
1991	29.8	29.6	29.5

Continued

1992	29.9	29.7	29.6
1993	27.7	27.5	27.3
1994	30.2	30.1	29.9
1995	27.9	27.6	27.5
1996	27.9	27.7	27.5
1997	27.7	27.6	27.4
1998	29.6	29.4	29.3
1999	30.3	30.1	30.2
2000	29.8	29.4	29.9
2001	30.2	30.1	30.2
2002	29.9	29.6	30.1
2003	29.8	29.6	28.1
2004	30.1	30	29.9
2005	29.9	29.7	27.5
2006	27.8	27.6	27.5
2007	27.7	27.7	27.4
2008	29.6	27.6	29.3
2009	30.3	29.4	30.2
2010	29.8	29.4	29.9
2011	30.2	30.1	27.4
2012	29.9	29.6	29.2

Source: NIMET Lagos and Enugu, 2013 and 2009; Author's Field work, 2013.

Appendix 6: Mean Soil Temperature Values at 50 cm Depth from 1970 to 2012

Years	T50PS	T50GS	T50HS
1971	31.6	28.6	31.6
1972	31.1	28.2	32.7
1973	30.4	28.3	31.9
1974	31.3	28.5	32
1975	32.6	28.9	31.3
1976	30.4	28.2	34.4
1977	30.1	28.4	32.6
1978	30.2	30	31.7
1979	30.4	29.1	34.3

Continued

1980	30.6	28.2	31
1981	30.7	28.7	31.3
1982	30.6	28.6	32.4
1983	31.9	28.7	32.6
1984	31	28.3	31.8
1985	30.3	28.4	32
1986	30.4	28.1	32.9
1987	30.6	28.3	31.4
1988	30.1	28.4	32.3
1989	30.4	28.2	32.4
1990	30	28.4	31.7
1991	29.3	28.2	31.6
1992	29.3	30.6	31.8
1993	31.3	28.2	31.3
1994	31.7	25.9	31.9
1995	32.6	28.2	32.6
1996	31.5	28.4	32.7
1997	29.2	28.2	34.4
1998	30.9	28.5	32.5
1999	30.4	28.6	32.3
2000	30.7	28.5	32.3
2001	31.2	28.4	32.1
2002	30	28.6	32.7
2003	30.4	28.2	32
2004	30.2	28.9	31.6
2005	30.3	28.3	32.6
2006	30.6	28.5	34.3
2007	30	28.4	31.7
2008	29.3	28.2	31.6
2009	30.9	28.5	32.5
2010	30.4	28.6	32.3
2011	30.4	28.2	32
2012	30.2	28.9	31.6

Source: NIMET Lagos and Enugu, 2013 and 2009; Author's Field work, 2013.

Appendix 7: Mean Soil Temperature Values at 100 cm Depth from 1970 to 2012

Years	T100PS	T100GS	T100HS
1971	30.1	30	30.2
1972	30.2	29.9	30.1
1973	30.4	30.2	30.6
1974	30.7	30.5	30.8
1975	30.8	30.4	30.6
1976	30.2	29.9	30.3
1977	30.3	30.1	30.2
1978	30.5	30.2	30.4
1979	30.9	30.6	30.8
1980	30.3	30.1	30.2
1981	30.6	30.4	30.5
1982	29.9	29.6	29.8
1983	30.3	30.1	30.2
1984	30.7	30.5	30.6
1985	30.4	30.1	30.3
1986	30.3	30.2	30.4
1987	30	29.8	30.1
1988	29.9	29.7	29.8
1989	30.6	30.2	30.5
1990	30.3	30.1	30.2
1991	30.3	30.2	30.4
1992	30.5	30.1	30.3
1993	30.4	30.2	30.5
1994	30.7	30.3	30.6
1995	30.6	30.4	30.7
1996	28.1	28	28.4
1997	30.1	29.8	30.2
1998	29.9	29.6	29.8
1999	30.6	30.2	30.5
2000	30.3	30.1	30.4
2001	30.4	30.2	30.3
2002	30.3	30	30.2
2003	30.5	30.3	30.6

Continued

2004	30.7	30.4	30.8
2005	30.6	30.3	30.5
2006	28.9	28.7	28.8
2007	30.4	30.2	30.5
2008	30.7	30.3	30.6
2009	30.6	30.4	30.7
2010	28.1	28	28.4
2011	30.1	29.8	30.2
2012	29.9	29.6	29.8

Source: NIMET Lagos and Enugu, 2013 and 2009; Author's Field work, 2013.

Appendix 8: Seasonal Mean Evaporation Values from 1970 to 2012 in the Study Area

Years	Evaporation Planting Season	Evaporation Growing Season	Evaporation Growing Season
1971	6	5.8	6.1
1972	6.2	6	6.3
1973	6.1	5.9	6.2
1974	5.9	5.6	5.9
1975	5.7	5.4	5.8
1976	5.1	4.8	5.2
1977	5.4	5.1	5.5
1978	5.8	5.2	5.9
1979	5.6	5	5.8
1980	5.7	5.1	5.9
1981	5.6	5	5.7
1982	5.6	5.1	5.8
1983	5.2	4.8	5.4
1984	6	5.4	6.2
1985	5.1	4.6	5.3
1986	5.4	4.5	5.6
1987	6	5.3	6.2
1988	6.1	5.2	6.4
1989	5.4	5	5.6
1990	4.9	4.2	4.9
1991	4.8	4.1	4.9

Continued

1992	4.7	4.2	4.8
1993	6.1	5.8	6.2
1994	5.6	5	5.7
1995	5	4.6	5
1996	4.7	4.2	4.9
1997	3.9	3.3	4
1998	3.2	3	3.4
1999	5	4.6	5.2
2000	5.6	5.1	5.8
2001	4.5	4.1	4.9
2002	4.3	4	4.5
2003	4	3.8	4.2
2004	5.4	5.1	5.6
2005	4.6	4.4	4.8
2006	4.9	4.7	5.1
2007	3.9	3.7	4.1
2008	4.1	3.9	4.3
2009	5.1	4.9	5.3
2010	5.6	5.2	5.8
2011	4.5	4.3	4.7
2012	5.4	5.1	5.6

Source: NIMET Lagos and Enugu, 2013 and 2009; Author's Field work, 2013.

Appendix 9: Relative Humidity (R.H) @ 0900 GMT from 1970 to 2012

Years	Relative Humidity (@0900GMT) Planting Season	Relative Humidity (@0900GMT) Growing Season	Relative Humidity (@0900GMT) Harvesting Season
1971	63	75	53
1972	64	76	54
1973	66	78	56
1974	60	72	50
1975	66	78	56
1976	71	83	61
1977	69	81	59
1978	60	72	50

Continued

1979	64	76	54
1980	65	79	55
1981	60	72	50
1982	59	71	49
1983	58	70	48
1984	70	82	49
1985	61	73	50
1986	59	71	51
1987	58	70	54
1988	59	71	53
1989	60	72	56
1990	61	73	52
1991	64	74	50
1992	63	75	55
1993	66	78	58
1994	62	74	61
1995	60	72	63
1996	65	77	52
1997	68	80	58
1998	71	83	48
1999	73	85	60
2000	62	74	49
2001	68	80	55
2002	58	70	45
2003	70	82	57
2004	71	83	58
2005	60	72	47
2006	66	78	53
2007	56	68	43
2008	68	80	55
2009	56	68	43
2010	68	80	55
2011	55	67	42
2012	67	79	54

Source: NIMET Lagos and Enugu, 2013 and 2009; Author's Field work, 2013.