



IMPACTS OF CLIMATE CHANGE ON THE YIELD OF SOME SELECTED ROOT CROPS IN ENUGU STATE, SOUTH EASTERN NIGERIA

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ABSTRACT

Climate change variability has posed a huge threat on the yield of root crops in South-Eastern Nigeria. Studies were carried out to assess the effect of climate change on some selected root crops in Enugu State. Climatic and root crop yield data were collected for Twenty years (20years) each from Nigerian Meteorological Agency (NIMET), Abuja, and Agricultural Development Programme (ADP) under the Ministry of Agriculture, Enugu State respectively. Data collected were statistically analyzed using ANOVA. The ANOVA result shows that significant difference ($p < 0.05$) were observed in annual temperature and mean values of annual rainfall and minimum temperature. Crop yields of cocoyam, yam and cassava were also significantly different at $p < 0.05$. The highest mean annual rainfall was observed in 2006, annual temperature was also significant at $p < 0.05$ in 2015. Most significant values ($P < 0.05$) for Cocoyam yield was recorded in 2016. The regression of combined climatic factors and crop yields from 2001 to 2020 showed that coefficient of determination (R^2) recorded for cocoyam and yam yield as 0.59 and 0.34 respectively, cassava recorded a very poor correlation of 0.09. The multiple correlation coefficient (R) shows that there was high correlation ($R = 0.769$) between cocoyam yield and climatic factors, and a moderate correlation ($R = 0.584$) for yam yield and climatic factors. Single correlation between climatic factors and crop yield showed that moderate correlations were recorded for cocoyam yield and mean annual sunshine hour ($R = 0.441$) and cocoyam yield with annual temperature (0.450). it is recommended to use up to 30 years crop yield data for future studies.

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1.0 Introduction

Climate change is one of the most serious environmental threats facing mankind worldwide. It affects agriculture in several ways, including its direct impact on food production. Climate change, which is attributable to the natural climate cycle and human activities, has adversely affected agricultural productivity in Africa (Ziervogel et al., 2006). In Nigeria, agriculture is the main source of food and employer of labour, employing about 60-70 per cent of the population (Mayong et al., 2005). It is a significant sector of the economy and the source of raw materials used in the processing industries as well as a source of foreign exchange earnings for the country (Mohammed-Lawal and Atte, 2006).

There are a number of challenges which have militated against self-sufficient food production and agricultural development in Nigeria, despite its huge agricultural potentials and opportunities (FAO et al., 2019). Unsteady temperature and rainfall pattern could be due to effects of climatic change in the area and according to Arnell, (1992) climatic variability could result in changes in rainfall distribution. The study further shows that change in climatic factors have significant effect

on agricultural productivity. FAO (2004) estimated 25% loss of cereals, 37% loss of root and tubers and 53% loss of fruits in developing world as a result of factors ranging from weather conditions, production practices to harvesting, handling to processing. It is projected that crop yield in Africa may fall by 10-20% by 2050 or even up to 50% due to climate change (FAO, 2006).

Given the above statistics, climate change has indeed become a global issue. It is very likely that climate change problem can aggravate conditions that can slow the pace of progress along sustainable development pathways. Addressing sustainable development challenges in agricultural sector is, therefore, of paramount importance to Nigeria especially in southeast where agriculture is largely rain-fed.

Root crop farming system which is cassava and yam-based (Dixon *et al.*, 2001) is one of the food and agricultural systems that is under threat by climate change despite its importance in Nigeria's food basket especially in the derived savannah ecological zone. For example, food products from cassava followed closely by yams are the predominant food crops consumed by both urban and rural households in southeast zone and which also serve as major sources of income; in fact, when compared to other arable crops, cassava ranks topmost as regards potential to generate cash income for farmers (Nweke *et al.*, 1997).

In Nigeria, Agboola and Ojeleye (2007), examined the impact of climate change in Ibadan Nigeria. The study adopted both primary and secondary sources of data. For the secondary source of data, time series data covering 30 years were collected on climatic variables and the analysis was done with bivariate Chi-square and ANOVA supported by graphical illustrations. The study revealed that farmers have experienced reduced crop yield on food crop production due to reduction in rainfall and relative humidity as well as increase temperature.

Eragha *et al* (2014) in their study found that temperature had a significantly negative influence on crop yield, while rainfall was found to have a significantly positive effect on crop yield. The technique of analysis was done with the Error Correction technique. The data coverage was 1970-2009. The study used variables like crop output, temperature and rainfall as well as carbon emission. Similarly, carbon emission was found to have a significantly negative impact on crop production in Nigeria. This paper is targeted at examining the impact of climate change on the yield of some selected root crops production in Enugu State.

2. Materials and Methods

2.1. Study Area Description

Enugu State is located on the Northwestern fringe of southeastern Nigeria between latitudes 6°30'N and 7°10'N and longitudes 6°35'E and 7°30'E, 200 meters above sea level. Figure 1 shows the map of Enugu State. The estimated population of Enugu State is about 4,1671 million people (NPC, 2007). The land area is approximately 16,727 square km. The soil type is mostly hydromorphic, which is heavy and composed of silt and clay

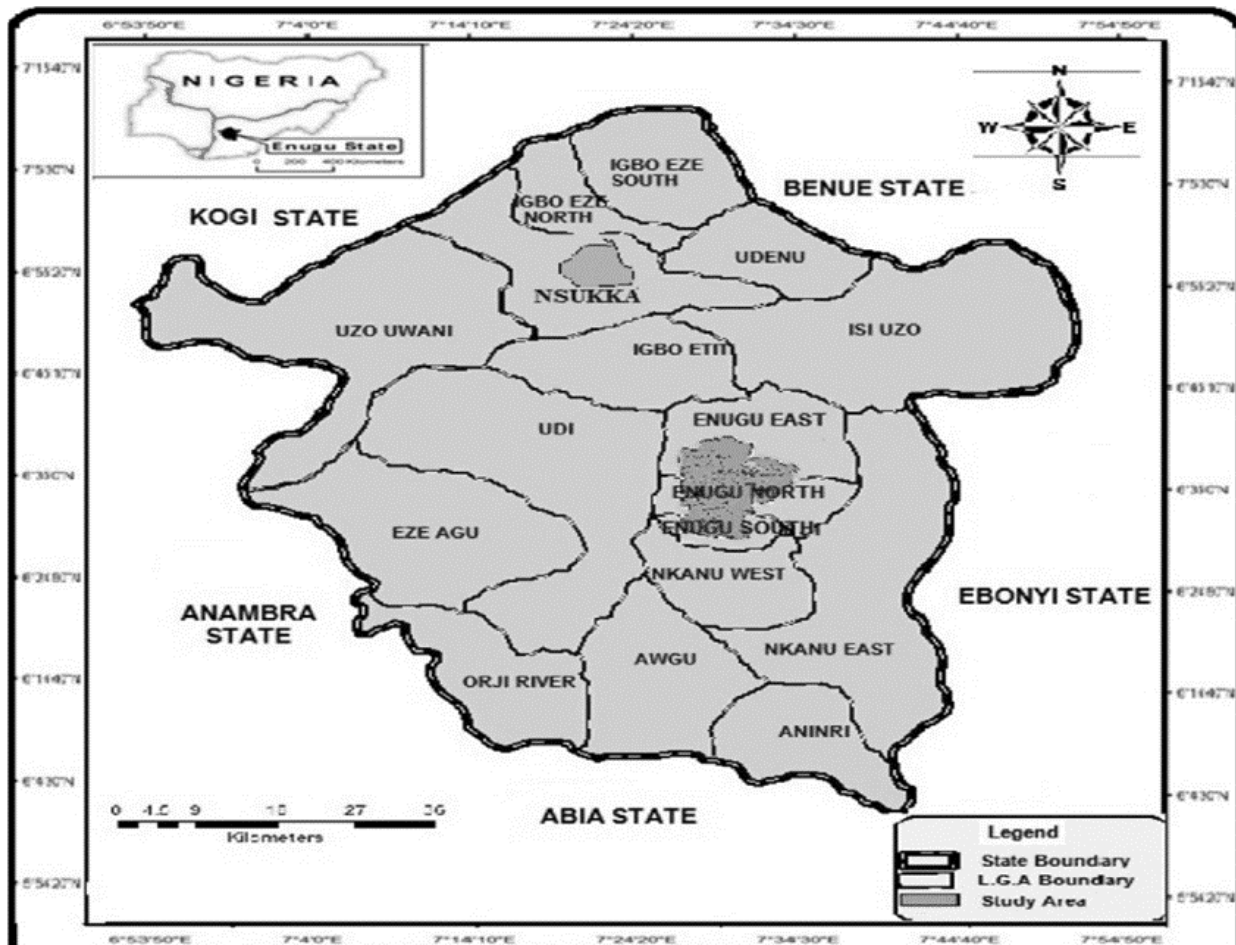


Figure 1: Map of Enugu State

2.2 Methodology

2.2.1 Data Collection

Data on temperature, rainfall volume, relative humidity and sunshine duration ranging from 2000 to 2020 were collected from Nigerian Meteorological Agency, Abuja (NIMET). The data for crop yield were sourced from Agricultural Development Programme, Enugu State.

2.2.2 Data Analysis

The data was subjected to statistical analysis using the Genstat statistical package. Regression and Correlation analysis were conducted to establish a relationship between the climatic data and the yield of some selected root crops in Enugu State.

3. Results and Discussion

3.1. Effect of Climatic Factors on Some Vegetable Crops Yield

Table I shows the effect of climatic factors (mean annual rainfall, sunshine hour, average minimum temperature and annual range of temperature) on crop yields (cassava, yam and cocoyam) from 2001 to 2020.

The results in Table I shows that significant differences ($p < 0.05$) were observed in mean values of the climatic data (annual rainfall, minimum temperature and annual temperature) and on crop yield (cassava, yam and cocoyam yield) from 2001 to 2020. The highest rainfall amount was

observed in 2006, while the least was in 2001. Average minimum temperature recorded most significant values in the year 2016 and 2017.

Table I: Mean Annual Variability of Selected Climatic Factors and Cassava, Yam and Cocoyam Outputs

Year	Rainfall (mm)	Sunshine	Max. Temp. (°C)	Min. Temp. (°C)	Temp. Range (°C)	Cassava (kg/ha)	Yam (kg/ha)	Cocoyam (kg/ha)
2001	139.77 ⁱ	5.31	32.44	22.53 ^{bcd}	9.91 ^{abc}	11.13 ^{cde}	11.04 ^d	5.55 ^c
2002	143.39 ^{gh}	5.48	32.64	22.94 ^{bcd}	9.70 ^{abc}	11.26 ^{bcd}	11.13 ^d	5.55 ^c
2003	157.58 ^f	5.28	32.95	23.23 ^{bcd}	9.72 ^{abc}	11.28 ^{bcd}	11.22 ^{cd}	5.73 ^c
2004	149.18 ^g	5.16	32.20	22.56 ^{bcd}	9.64 ^{abc}	10.67 ^{def}	11.34 ^{cd}	5.72 ^c
2005	141.45 ^{ij}	5.52	32.70	22.29 ^{bcd}	10.41 ^{ab}	12.15 ^{bcd}	11.36 ^{cd}	5.62 ^c
2006	201.22 ^a	5.31	32.04	22.29 ^{bcd}	9.75 ^{abc}	12.36 ^{bcd}	11.46 ^{cd}	5.19 ^c
2007	159.27 ^{ef}	5.38	32.09	23.17 ^{bcd}	8.94 ^{bc}	12.36 ^{bcd}	11.52 ^{cd}	6.09 ^c
2008	147.38 ^{gh}	5.75	32.71	22.18 ^{bcd}	10.53 ^{ab}	13.11 ^b	11.76 ^{abc}	6.29 ^c
2009	147.48 ^{gh}	5.28	32.54	23.28 ^{bc}	9.25 ^{abc}	13.07 ^b	11.85 ^{abc}	6.36 ^c
2010	140.58 ^{ij}	5.81	32.77	23.97 ^b	8.20 ^{cd}	13.07 ^b	26.37 ^a	9.48 ^{ab}
2011	144.11 ^{hi}	5.40	32.20	22.15 ^{bcd}	10.05 ^{abc}	12.77 ^{bc}	26.48 ^a	9.44 ^b
2012	178.14 ^b	5.47	32.19	21.90 ^{cd}	10.05 ^{abc}	12.77 ^{bc}	28.45 ^a	9.60 ^{ab}
2013	161.76 ^{ef}	5.54	32.04	21.25 ^d	10.81 ^{ab}	18.78 ^a	13.14 ^{ab}	5.67 ^c
2014	160.55 ^{ef}	5.58	32.07	21.25 ^d	10.75 ^{ab}	1.25 ^g	13.66 ^b	5.38 ^c
2015	167.41 ^d	5.61	32.23	21.64 ^{cd}	11.09 ^a	1.22 ^g	13.47 ^b	5.65 ^c
2016	159.03 ^{ef}	5.56	32.53	32.53 ^a	0.00 ^e	9.41 ^{ef}	12.02 ^{abc}	11.32 ^a
2017	172.61 ^c	5.55	33.08	33.08 ^a	0.00 ^e	9.43 ^{ef}	11.86 ^{abc}	9.55 ^{ab}
2018	159.21 ^{ef}	5.55	32.58	22.79 ^{bcd}	9.79 ^{abc}	9.43 ^{ef}	11.93 ^{abc}	9.55 ^{ab}
2019	162.08 ^e	5.56	32.88	23.19 ^{bcd}	9.69 ^{abc}	9.25 ^f	12.25 ^{abc}	9.06 ^b
2020	157.73 ^f	5.40	30.13	23.26 ^{bcd}	6.74 ^d	9.07 ^f	12.58 ^{abc}	8.59 ^b
SEM	1.90	0.11	0.13	0.42	0.41	0.51	0.69	0.28

^{abcdeghij} Means within the rows with different superscripts differ significantly (P<0.05); SEM- Standard Error of the Mean

3.2. Relationship between Climatic Factors and the yield of Some Root Crops

Table 2 shows the regression and correlation of combined climatic factors and yields from 2001 through 2020. The regression equations were significant for predicting Yam yield and cocoyam yield but not significant for predicting cassava yield. This result was supported by the better coefficient of determination (R²) recorded for cocoyam yield (59.10%) and yam output (34.10%) and the poor R² recorded for cassava yield prediction (9.70%). The coefficient of determination measures the reliability of the regression equation and as such, the prediction of cocoyam yield with combined climatic factors was most reliable whereas, the prediction of cassava yield with climatic factors was least reliable. The multiple correlation coefficient(R) shows that there was high and strong positive association(R-0.769) between cocoyam yield and climatic factors. In other words, an increase or decrease in cocoyam output was associated with an increase or decrease in the amount of climate factors. Very moderate positive correlation (R-0.584) was also recorded for yam yield and climatic factors implying that an increase in the values of the climatic factors. This result is in agreement with the work of Chikezie *et al.* 2015. The result of this work concurred with the findings of Ishaya, *et al.* (2014) which observed that tuber crops such as yam

and Cassava and Sweet Potatoes may not be negatively impacted by climate variability. A poor association was recorded between cassava yield and climate factors (R=0.311). The poor association implies that the yield of the cassava crop was not really strongly dependent on the amount of the climatic factors.

Table 2: Regression and Correlation of Combined Climate Factors on Crop Yields from year 2001 through 2020

Regression Equations	A	R ² %	SEM	R	SIG
1. Cassava output = -32.514-0.016(MAR)+2.191(MAS)+3.580(MAMXT)-2.574(MAMNT)-2.442(ATR)	-32.51	9.70	3.89	0.311	NS
2. Yam Output = -47.968+0.027(MAR)+11.804(MAS)+10.641(MAMXT)-10.952(MAMNT)-10.602(ATR)	-47.97	34.10	4.52	0.584	***
3. Cocoyam Output = 4.849+0.003(MAR)+3.705(MAS)+1.999(MAMXT)-2.172(MAMNT)-2.528(ATR)	-4.85	59.10	1.43	0.769	***

MAR- Mean Annual Rainfall; MAS-Mean Annual Sunshine; MAMXT-Mean Annual Maximum Temperature; MAMNT-Mean Annual Minimum Temperature; ATR- Annual Temperature Range. ***, **, * = significance at 1%, 5%, 10%

Table 3 shows the regression and correlation of individual climatic factors and yields from 2001 through 2020. The regression equations were significant for predicting cocoyam yield but not significant for predicting yam and cassava yield. The regression equations 2 to 5 are significant in the prediction of Cocoyam yield. Equation 2 shows that Mean Annual Sunshine Hour (MASH) can predict output with a coefficient of determination (R²) of 19.40% which though is not appreciably high. The value of 19.40% shows that Mean Annual Sunshine Hour (MASH) accounts for about 19.40% of the variability in Cocoyam yield. Similarly, Equation 3 shows that Mean Annual Maximum Temperature (MAMXT) can singly predict Cocoyam yield significantly with a coefficient of determination (R²) of 11.2%.

Equation 4 shows that Mean Annual Minimum Temperature (MAMNT) can singly predict Cocoyam yield significantly with a coefficient of determination (R²) of 38.30%. Equation 5 shows that Mean Annual Temperature Range (ATR) can singly predict Cocoyam yield significantly with a coefficient of determination (R²) of 20.30%. Very moderate positive correlations (R = 0.441, R = 0.450) were recorded for the association between Cocoyam yield with Mean Annual Sunshine Hour (MASH) and Cocoyam yield with Annual Temperature Range (ATR) respectively. The correlation coefficient of 0.441, and 0.450 shows a moderate association between cocoyam yield with MASH and ATR respectively. Thus, an increase in cocoyam yield was moderately associated with an increase in MASH and ATR. Low positive correlation (R = 0.331) was recorded cocoyam yield with Mean Maximum Temperature (MMT). High positive correlation (R = 0.619) was recorded for the association between Cocoyam yield and Mean Annual Minimum Temperature

(MAMT). Thus, an increase in Cocoyam yield was highly associated with an increase in Mean Annual Minimum Temperature.

Table 3: Regression of Individual Climatic factors on Crop yields from year 2001 through 2020

Regression Equations	A	R ² %	SEM	R	SIG
CASSAVA					
1. Cassava output = 5.745-0.032(MAR)	15.745	1.40	3.92	0.119	NS
2. Cassava output = 6.087+0.841(MAS)	6.087	3.20	3.89	0.179	NS
3. Cassava Output = -17.167+0.861(MAMXT)	-17.167	5.10	3.85	0.227	NS
4. Cassava output = 10.883-0.008(MAMNT)	10.883	0.00	3.95	0.007	NS
5. Cassava Output = 9.499+0.136(ATR)	9.499	1.20	3.92	0.111	NS
YAM					
1. Yam output = 17.396-0.021(MAR)	17.396	0.30	5.36	0.057	NS
2. Yam output = 6.958+1.313(MAS)	6.958	4.20	5.25	0.206	NS
3. Yam Output = -4.575+0.579(MAMXT)	-4.575	1.30	5.33	0.112	NS
4. Yam output = 17.658-0.149(MAMNT)	17.658	0.80	5.34	0.092	NS
5. Yam Output = 12.111+0.232(ATR)	12.111	1.90	5.31	0.140	NS
COCOYAM					
1. Cocoyam output = 5.877+0.009(MAR)	5.877	0.40	2.15	0.060	NS
2. Cocoyam output = 1.077+1.131(MASH)	1.077	19.40	1.94	0.441	**
3. Cocoyam Output = -15.221+0.695(MAMXT)	-15.221	11.20	2.03	0.335	**
4. Cocoyam output = -2.223+0.403(MAMNT)	-2.223	38.30	1.69	0.619	***
5. Cocoyam Output = 9.904-0.301(ATR)	9.904	20.30	1.93	0.450	***

MAR- Mean Annual Rainfall; MAS-Mean Annual Sunshine; MAMXT-Mean Annual Maximum Temperature; MAMNT-Mean Annual Minimum Temperature; ATR- Annual Temperature Range, NS-Non Significant

4. Conclusion

It was obvious that variation in climate change can affect the yield of some selected tuber crops. Rainfall was highest for the 20 years under study in 2006, while annual range in temperature was highest in 2015. Cassava, yam and cocoyam were highest in 2013 while, yam was highest in 2010, 2011 and 2012 and cocoyam is highest in 2016.

The regression equation for the crop yield with climatic factor showed that Mean Annual Sunshine Hour (MASH), Mean Annual Maximum Temperature (MAMXT) Mean Annual Minimum Temperature (MAMNT) and Mean Annual Temperature Range (ATR) with low coefficients of determination (R²) can singly predict cocoyam yield.

Very moderate positive correlations were recorded for the association between Cocoyam yield with Mean Annual Sunshine Hour (MASH) and Cocoyam yield with Annual Temperature Range (ATR) respectively. A Low positive correlation was recorded cocoyam yield with Mean Maximum Temperature (MMT) while a high positive correlation was recorded for the association between Cocoyam yield and Mean Annual Minimum Temperature (MAMT). Thus, an increase in Cocoyam yield was highly associated with an increase in all these climatic factors, MASH, ATR MMT and MAMT.

It is recommended that more data on crop yield should be kept at Enugu ADP office of the ministry of Agriculture Enugu State to enable the use of more data up to 30 years and above.

References

- Agboola, T. and Ojeleye, D. 2007. Climate change and food production in Ibadan. Nigeria Afri Crop Science Conference Proceedings, 8: 1423-1433.
- Arnell, NW. 1992. Impacts of climatic change on river flow regimes in the UK. Water and Environmental Management, 6: 432-442.
- Chikezie, C., Ibekwe, UC., Ohajianya, DO., Orebiyi, JS., Ehirim, NC., Henri-Ukoha, A., Nwaiwu, IUO., Ajah, EA., Essien, UA., Anthony, G. and Oshaji, IO. 2015. Effect of climate change on food crop production in Southeast, Nigeria: A co-integration model approach. International Journal of Weather, Climate Change and Conservation Research, 2(1):47-56.
- Dixon, J., Gulliver, A. and Gibbon, D. 2001. Farming systems and poverty: Improving farmers' livelihoods in a changing world. Experimental Agriculture, 39: 109-110.
- Eregha, PB., Babatolu, JS. and Akinnubi, RT. 2014. Climate change and crop production in Nigeria: An error correction modelling approach. International Journal of Energy and Policy, 4: 297-311.
- FAO 2004. The world food summit five years later: Mobilizing the political will and resources to banish world hunger. Rome: FAO.
- FAO 2006. The State of Food Insecurity in the World. Rome.
- FAO, IFAD, UNICEF, WFP and WHO. 2019. The state of food security and nutrition in the world, 2019. Safeguarding against economic slowdowns and downturns. Rome: FAO.
- Ishaya, S., Hassan, SM. and James, SE. 2014. Post-adaptation vulnerability of cereals to rainfall and temperature variability in the Federal Capital Territory of Nigeria. Ethiopian Journal of Environmental Studies & Management 7(5):532-547, 2014ISSN:19980507doi:<http://dx.doi.org/10.4314/ejesm.v7i5.7>.
- Manyong, VM., Ikpi, A., Olayemi, JK., Yusuf, SA., Omonoma, BT., Okoruwa, V. and Idachaba, FS. 2005. Agriculture in Nigeria: Identifying Opportunities for Increased Commercialization and Investment in USAID/IITA/UI Project Report Ibadan, Nigeria. 159.
- Mohammed-Lawal, A. and Atte, OA. 2006. An Analysis of Agricultural Production in Nigeria. African Journal of General Agriculture, 2(1): 1-6.
- Nweke, FI., Ugwu, BO., Dixon, AGO., Asadu, CLA. and Ajobo, O. 1997. Cassava 290 production in Nigeria: A function of farmer access to market and to improved production and processing technologies. COSCA working paper No. 21. Collaborative study of cassava in Africa, International Institute for Tropical Agriculture, IITA, Ibadan, Nigeria.
- Ziervogel, G., Nyong, B., Osman, C., Conde, SC. and Dowing, T. 2006. Climate variability and change: implications for household food security. Assessment of impacts and adaptations for

climate change (AIACC) Working Paper No. 20, January 2006. The AIACC Project Office,
International Start Secretariat, Washington DC, USA