Atmospheric and Climate Sciences, 2018, 8, 274-285
http://www.scirp.org/journal/acs
ISSN Online: 2160-0422
ISSN Print: 2160-0414

Assessing the Impact of Climate Change on Maize (*Zea mays*) and Cassava (*Manihot esculenta*) Yields in Rivers State, Nigeria

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How to cite this paper: Ajiere, S.I. and Weli, V.E. (2018) Assessing the Impact of Climate Change on Maize (*Zea mays*) and Cassava (*Manihot esculenta*) Yields in Rivers State, Nigeria. *Atmospheric and Climate Sciences*, **8**, 274-285.
https://doi.org/10.4236/acs.2018.82018

Received: April 8, 2018
Accepted: April 27, 2018
Published: April 30, 2018

Abstract

Globally climate change has threatened agriculture and food security which is of great importance to the economy of a nation. In Nigeria it has become a great concern to the government and people because of the obvious changes in the climate systems, therefore, assessing the impact of climate change on crop yield in an oil producing state is of great importance especially where rain fed agriculture is the main determinant for crop yield. Expost-facto research method in the context of quasi experimental research design was adopted for the study. Data for rainfall and temperature and that for crop yields were obtained from Nigerian Meteorological Agency (NIMET) and federal ministry of Agriculture; Agricultural Development Program (ADP) respectively. Analysis of data was achieved using descriptive statistics, trend graphs and multiple linear regressions. Results showed that there had been a steady but gradual increase in the annual minimum, maximum and mean temperatures over the study period of thirty years and a decrease in rainfall. Mean temperature is increasing annually at the rate of 0.0253 per annum and rainfall is decreasing at the rate of −0.5817 mm per annum. The multiple regression model showed r^2 values of 0.28 for maize and 0.29 for cassava revealing that only 28% - 29% of maize and cassava yields could be explained by rainfall and temperature in the state and the result was significant at $p < 0.05$ revealing that cassava and maize yields significantly depended on rainfall and temperature. This study strongly advocates for a better and practicable environmental policies and improved agricultural techniques alternative source of water which will include irrigation farming, mulching since it is evident that there is a reduction in rainfall and increase in temperature in the state while creating sustainable food security.

Keywords

Climate Change, Maize, Cassava, Food Security, Rivers State Nigeria

1. Introduction

The changes occurring in the climate pattern which is caused by global warming have affected so many sectors in the world of which agriculture is inclusive. Agricultural sector is very important to the Nigerian economy and the world; consequently, the change occurring in the climate pattern is a threat to the development of agriculture (Chikezie *et al*., 2015: IPCC, 2007) [1] [2]. Agricultural production in Nigeria is highly vulnerable to climate change; it is one of the most important sectors that are extremely relevant to Nigeria's economy. This is because of its importance in sustaining livelihoods, job creation and poverty reduction. It also secures food, fuel and contributes to economic development. Majority of the population in the study area engages in agricultural production at a subsistence level despite the fact that the country depends heavily on the oil industry for its budgetary revenues.

The concept of climate change has become an important environmental, social and economic issue. It is an unprecedented challenge every nation is facing and its impacts over the past decades are tending towards global warming indicating that an urgent action needs to be taken towards preparedness and adaptation (Lefort *et al*., (2015) [3]: NIMET, 2016) [4]. Consequently, regional weather and climate dynamics are key influential aspects of the global changing climate. The hour-to-hour, day-to-day, and season-to-season changes in the atmospheric conditions implies weather; and when these processes are viewed in terms of extended time series of decades, centuries and up to interval of millions of years, then it is known as climate (Yu, *et al*., 2015) [5]. In other words, climate change connotes nonconformity with the established climate (known climate patterns) derived using statistical tests or physical science models on observed means of the weather elements, that is sustained over a normal or two (IPCC, 2014) [6]. Climate change is referred to as any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007) [2] it is also referred to as any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer). IPCC, 2007) [2] Climate change is an observed change in the climatic elements of a country or region from 30 years upward which has been statistically proven.

Scientist believes that human activities over the past century have contributed to climate change through GHGs emissions. These GHGs come majorly from fossil fuels in quests for energy production, even though deforestation, industrial activities, and some agricultural practices emit gases into the atmosphere. These GHGs trap heat and as a result cause warming. This occurrence is called the greenhouse effect and is natural and necessary to support life on Earth. However, the increase of GHGs in the atmosphere can change the Earth's climate system and result in dangerous effects to human health, welfare and to the ecosystems. (IPCC, 2007) [2] Changes in patterns of precipitation, melting-glaciers, temperatures of the sea surfaces, rising sea level around the world, acidification of the oceans due to elevated carbon-dioxide in the atmosphere, and this also determines responses by plants and animals (United States Environmental Protection Agency, 2010) [7] climate and weather still remains the main causal factor for agricultural production and sustainability Changes in rainfall pattern are likely to lead to severe water shortages and/or flooding with far reaching implications on agriculture, forestry, fishing and health systems. Rising temperatures will cause shifts in crop growing seasons which affects food security.

Climate change impact on crop yields has become a major concern (Lamboll *et al.,* 2015) [8] in this region About 35 percent of the country's GDP comes from agriculture and related activities, and about 80% of the poor live in rural areas and work primarily in agriculture (IPCC, 2007) [2]. Rivers State which is located in the Niger delta region of Nigeria are particularly vulnerable to climate change because of their dependence on rain fed agriculture, high levels of poverty, low levels of human and physical capital, poor infrastructure, pollution from oil companies and low level of technology (IPCC, 2007) [2]. Rainfall in the past two decades shows a positive and negative anomaly which corresponds to the wet/flood years recorded in Nigeria (Nwagbara, 2015) [9]. The effect of these changes on crop yield is low returns on agricultural investments and hence on food security.Food is essential to human life, health and well-being. It is therefore critical to examine the effect of climate change on maize and cassava since these crops, account for 40% of food consumption in this region (Nwaiwu *et al.,* 2014) [10].

These two crops are cash crop and can be cultivated easily or in a mechanized way and by low-income and peasant farmers. It can still be utilized by livestock keepers as livestock feed substitute (Lamboll *et al.*, 2015) [8]. Cassava and maize are both very important in the tropics as food crop and well suited for intercropping with short duration crops. This research identified the trends and changes in rainfall pattern and temperature and the impact of change in the climatic parameters (rainfall, temperature) on the yield of these crops (maize and cassava).

2. Geography of the Study Area

Rivers State is one of the 36 states of Nigeria. According to census data released in 2006, the state has a population of 5,198,716, making it the sixth-most populous state in the country (Weli, & Bajie, 2017) [11]. Its capital and largest city, Port Harcourt, is economically significant as the center of Nigeria's oil industry. Rivers State is bounded on the South by the Atlantic Ocean, to the North by Imo, Abia and Anambra States, to the East by Akwa Ibom State, and to the West by Bayelsa and Delta states (**Figure 1**). Rainfall is generally seasonal, variable, as

Source: Department of Geography, UNIPORT (2018).

Figure 1. Rivers state showing Port Harcourt Metropolis.

well as heavy it fall in all the months of the year but occurs more between the months of March and October through November. The wet season peaks in July and September the dry months are January and February. Average temperatures are typically between 25˚C - 28˚C.

3. Methodology

In terms of methods, the study deployed the expost-facto research method in the context of quasi experimental research design. Data for rainfall and temperature and that for crop yields were obtained from Nigerian Meteorological Agency (NIMET) for a period of 30years and federal ministry of Agriculture; Agricultural Development Program (ADP) also for a period of 30 years. 30 year because the Bruckner cycle assumption was imbibed. The justification for selecting the crops (Cassava and Maize) used for the study, is that the crops are the most consumed food crops in the region under review. To find out the rates of crop yields dependence on rainfall and temperature, the multiple linear regressions was deployed. Finally, descriptive statistics, trend graph where used to identify the observed changes in the climate of Rivers state.

4. Results and Discussions

The result of this analysis shows a general change in the seasonal rainfall and temperature regime. The month with the highest monthly rainfall is July and September with monthly mean as 348.92 mm and 364.68 mm respectively and lowest rainfall is December with 26.40 mm. The well-known august break was not observed, infact August recorded a very high amount of rainfall of 316.58 mm. The planting season for maize is March /April once the rain is a bit steady and harvesting is June-August. It can also be planted twice a year if rainfall permits it. Cassava is grown almost throughout the year march to November and with the new improved cassava stems harvesting is done 6 to 18 months after planting making it preferable to the seasonal crops of yam, beans or green peas. The major constraint to its primary production is the change in the pattern of Rainfall and Temperature, and if not properly managed can in turn determine its secondary productivity, for example there could be failure in the growth of cassava if there is no rainfall at all under rain-fed agriculture setting, or fall too much this can cause serious erosion and leaching of the soil nutrient leading to low output. (Nwaobiala & Nottidge, 2013) [12]. It was also observed that rainfall was at its peak (July, August and September) towards the end of the growing season and beginning of another planting season for maize, which cannot be tolerated by both crops especially maize. Minimum temperature was lowest in January with 21.25˚C, maximum temperature was highest in March with 33.68˚C while mean temperature was highest march with 28.47˚C which can be tolerated by both crops but cassava displays an exceptional ability to adapt to changes in different climatic conditions (Nwaiwu *et al.*, 2014) [10].

There are evidences of changing climate such as temperature and rainfall in Rivers State. In agreement with the observed global trend there has been an increasing trend in the annual maximum, minimum and mean temperature anomalies in Rivers State from 1987-2016 (**Figure 2**). There has been a persistent increase in temperature in the state since 2001 and 2002 for mean temperature. This to a large extent shows a warming climate and evidence that the mean annual temperature anomalies have been increasing with time.

Also the mean annual rainfall anomalies from 1987-2016 over are shown in **Figure 3** shows that Rivers state experienced both negative and positive anomalies. The positive anomalies indicate wetter than normal rainfall which can results to flooding (if anomalies is greater than 1.0) while the negative anomalies are indicators of drier than normal rainfall or drought (if anomalies is less than −1.0).

The annual rainfall trends in Rivers State (**Figure 4**) showed significant variation in spatial and temporal patterns of rainfall which affected maize and cassava yield across the states. It is observed that rainfall fluctuated greatly, with a negative slope which is a downward trend and a decrease in rainfall. Employing the trend analysis represented by the least square line, the total rainfall Rivers State is decreasing at −0.5817 mm per annum.

The maximum temperature (Figure 5) shows that it fluctuated with an

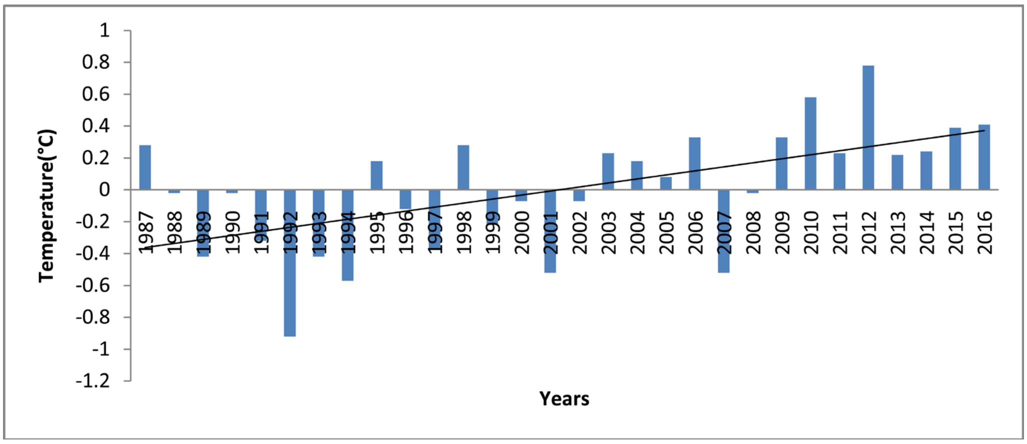

Figure 2. Anomalies of annual mean temperature over Rivers State 1987-2016.

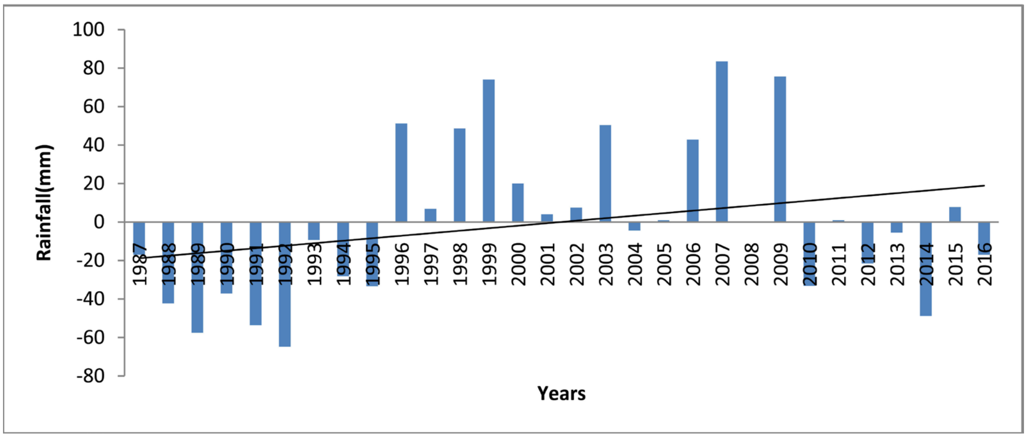

Figure 3. Anomalies of annual mean rainfall over Rivers State 1987-2016.

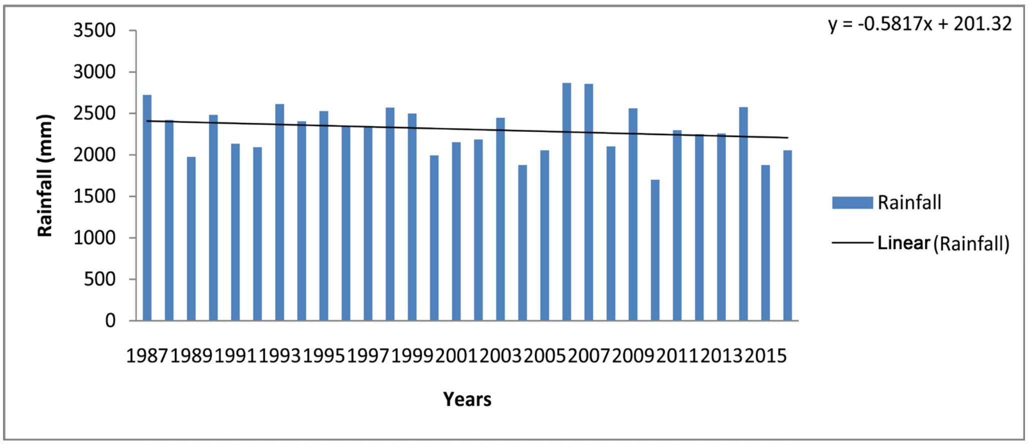

Figure 4. Annual rainfall trend in Rivers State.

increasing positive trend which is an increase in maximum temperature. with highest maximum temperature in 2006 with the value of 32˚C and lowest maximum temperature in 1992 with the value of 30.3˚C, and 2013 with 31.3˚C. Using the trend analysis represented by the least square line, the annual mean maximum temperature of Rivers State is increasing at 0.0211 per annum

While the minimum temperature (Figure 6) fluctuated greatly, with an increasing upward trend this is an increase in minimum temperature, with highest value in 2010, with the value of 23.5˚C with the lowest value in 2001 with the value of 21.0˚C this shows a positive trend Using the trend analysis represented by the least square line, Rivers State is increasing at 0.0137 per annum.

Finally the mean temperature (Figure 7) shows that the trend line fluctuated with an increasing positive trend which is an increase in mean temperature. And it shows an increasing upward trend with highest temperature in 2012 with the value of 26.25˚C and lowest point in 1992 annual mean temperature of is increasing at 0.0253 per annum. In rivers State it is observed that minimum temperature, maximum Temperature and mean Temperature is on the increase but maximum and mean Temperature seems to be increasing more than minimum

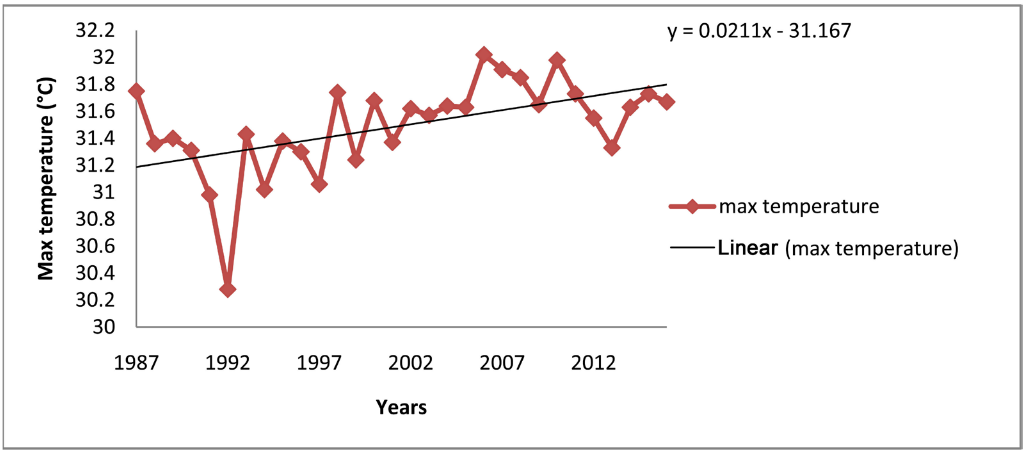

Figure 5. Annual Trend of maximum temperature of Rivers State.

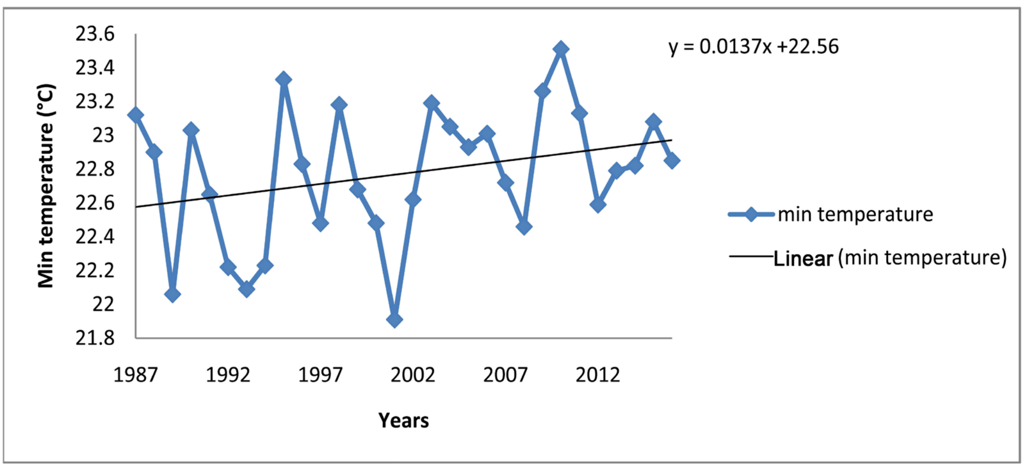

Figure 6. Annual trend of minimum temperature of Rivers State.

Temperature. The trend graph has shown that across the year, which covers the two seasons in the state (dry and wet season), there are fluctuations in the rainfall and temperature pattern.

The trend analysis for maize and cassava fluctuated greatly (Figure 8) and (Figure 9) and it shows a downward negative trend which is a decrease in maize

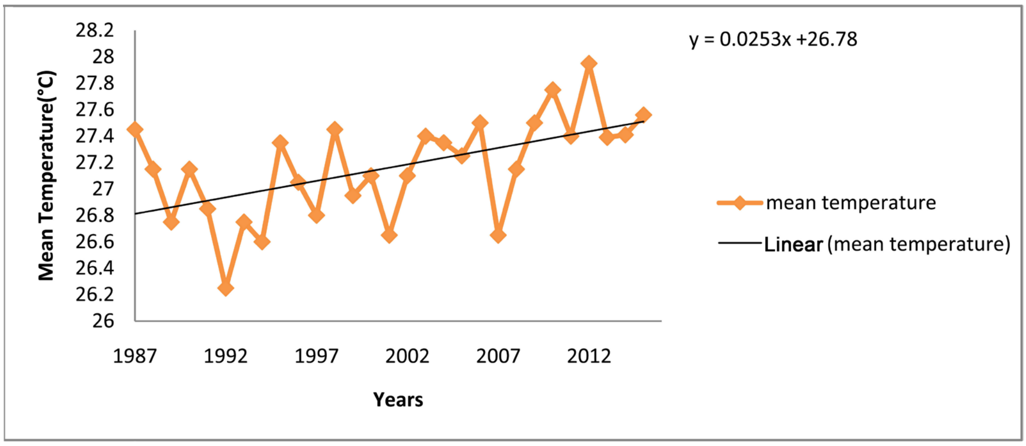

Figure 7. Annual trend of mean temperature of Rivers State.

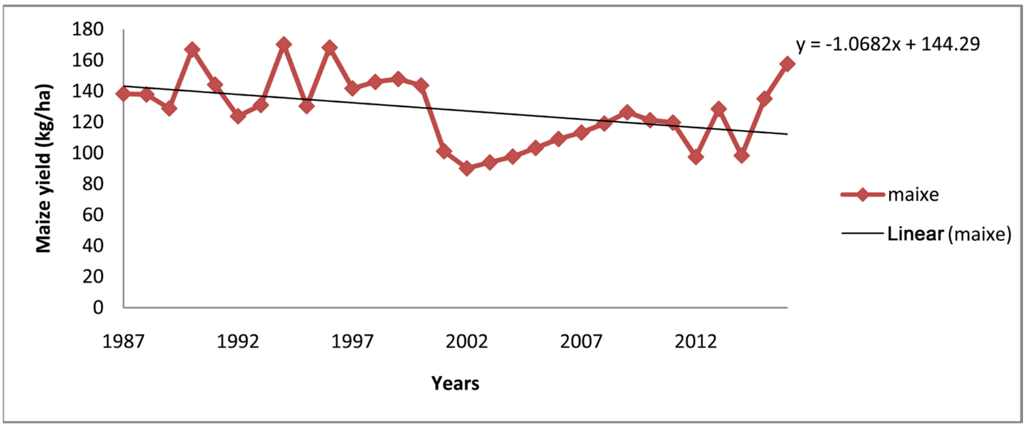

Figure 8. Trend of maize yield in Rivers State.

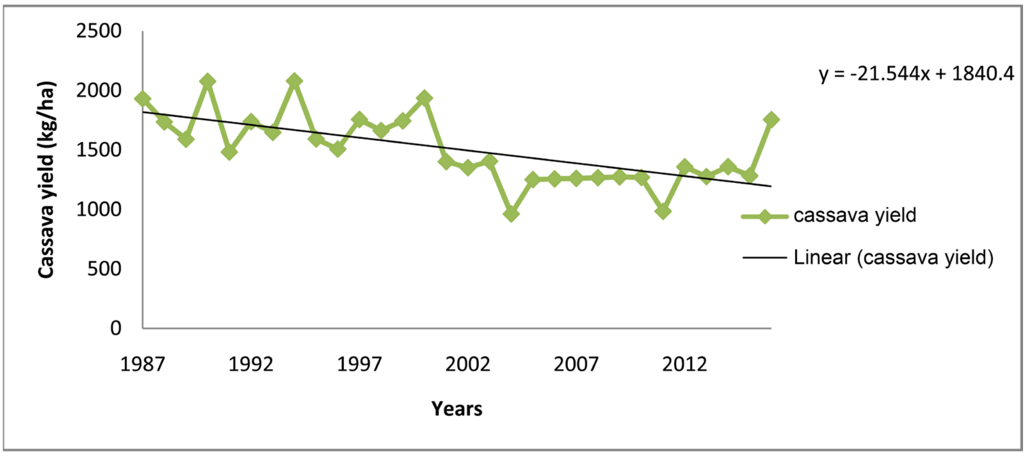

Figure 9. Trend of cassava yield in Rivers State.

and cassava yield. So it is observed that the decrease in rainfall and increase in Temperature in the state is affecting the yield of maize and cassava. The decrease in rainfall and increase in temperature can affect other crops because rainfall and temperature are the key determinants for crop growth in Nigeria.

The regression analysis on the impact of climate change variables (rainfall and Temperature) on the maize yield in is presented in Table 1 for Rivers State, the predictors (rainfall and temperature) together produced an r coefficient of.531, revealing that there is a correlation between rainfall temperature, and crop yield However, the combine effects of both rainfall and temperature on maize yields produced an r^2 of 0.282. This signifies that rainfall and temperature can only explain 28% of maize yields in Rivers state, leaving the other 72% to soil types, farming techniques applied, and maize species used. All of which have not been used as predictors in the current study.

Table 2 shows that the model is significant at F (5.307) = p < (0.05). This shows that maize yield in the area significantly depends on rainfall and temperature in Rivers state

However, Table 3 reveals that the effect of Temperature is higher for maize yields than Rainfall at Beta (−3.220; p < 0.05 so an increase in temperature over a period of time can lead to a decrease in maize yield.

For cassava yield (see Table 4) the predictors (rainfall and temperature) together produced an r coefficient of 0.537, revealing that there is a correlation

Table 1. Regression model summary of maize yield in Rivers State.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	0.531[a]	0.282	0.229	46.46380	0.282	5.307	2	27	0.011	0.570

a. Predictors: (Constant), temperature_rivers, rainfall_rivers; b. Dependent Variable: maize_yield.

Table 2. ANOVA of maize yield in Rivers State.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	22,912.478	2	11,456.239	5.307	0.011[a]
	Residual	58,289.884	27	2158.885		
	Total	81,202.362	29			

a. Predictors: (Constant), temperature_rivers, rainfall_rivers; b. Dependent Variable: maize_yield.

Table 3. Regression coefficients of maize yield in Rivers State.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2413.822	719.582		3.354	0.002
	rainfall_rivers	−0.013	0.034	−0.061	−0.376	0.710
	temperature_rivers	−85.257	26.481	−0.525	−3.220	0.003

a. Dependent Variable: maize_yield.

between rainfall temperature, and crop yield However, the combine effects of both rainfall and temperature on cassava yields produced an r^2 of 0.289. This signifies that rainfall and temperature can only explain 29% of cassava yields in Rivers state, leaving the other 71% to soil types, farming techniques applied, and maize species used. All of which have not been used as predictors in the current study.

Table 5 shows that the model is significant at F (5.482) = $p < (0.05)$. This shows that maize yield in the area significantly depends on rainfall and temperature in Rivers state

However, Table 6 reveals that the effect Temperature is higher on cassava than Rainfall at Beta −3.308; $p < 0.05$ so an increase in Temperature over a period of time can lead to a decrease in Cassava yield.

5. Conclusion

In conclusion this work has been able to establish that there is an evidence of climate change in Rivers State Nigeria. The changing patterns of rainfall and temperature in the region is in line with the earlier warning by IPCC (2007, 2014, NIMET, 2016) [4] [11]. The fluctuation and change in pattern of rainfall showed a decrease in rainfall the state and increase in Temperature which is not favorable for crop yield. It was also noted that rainfall and temperature impacted on the yield of maize and cassava (but temperature has more impact than

Table 4. Regression model summary of cassava yield in Rivers State.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	0.537[a]	0.289	0.236	472.13583	0.289	5.482	2	27	0.010	0.527

a. Predictors: (Constant), Temperature, rainfall_Rivers; b. Dependent Variable: cassava.

Table 5. ANOVA[b] of cassava yield in Rivers State.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2,443,993.329	2	1,221,996.665	5.482	0.010[a]
	Residual	6,018,630.574	27	222,912.243		
	Total	8,462,623.903	29			

a. Predictors: (Constant), Temperature, rainfall_Rivers; b. Dependent Variable: cassava.

Table 6. Regression coefficients[a] of cassava yield in Rivers State.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	24,918.658	7311.938		3.408	0.002
	rainfall_Rivers	0.096	0.347	0.045	0.277	0.784
	Temperature	−890.057	269.087	−0.537	−3.308	0.003

a. Dependent Variable: cassava.

rainfall) in the states this ranged from 28% - 29%. The implication of this is that, rainfall and temperature can only explain the percentages above, leaving the other 71% to soil types, farming techniques applied, and cassava stems used. All of which have not been used as predictors in the current study, thus suggesting a need for further studies in which these factors will be included.

6. Recommendations

Food security is very important to a nation. The Government of Rivers State needs to invest and pay more attention to the Agricultural sector especially food production. The youths of the states should be empowered to go in to agriculture to ensuring that three is food in the state because it is evident that the climate systems are changing as a result, Government should develop better and sustained environmental policies that will benefit agriculture, especially crop yield. There is also the need to educate stakeholders, and farm agents on the realities and effect of climate change and adaptive measures that can be taken. Furthermore, alternative sources of water such as drilling bore hole in farm sites, irrigation farming should be introduced to the farmers since it is evidence that there is a reduction in rainfall in the state.

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