Effect of Climate Variability on Crop Production: Evidence from Selected Communities in Rivers State Nigeria

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Abstract:

The study assessed the effects of climate variability on crop production in Ogba/Egbema/Ndoni local government of Rivers state of Nigeria. Both primary and secondary data were used for the analysis. The primary data were collected with the aid of focused group discussion field survey which covered six communities selected at random from the local government in 2020, with 30 farming households head selected from each community, totalling 180 farmers. The secondary data such as monthly rainfall, minimum and maximum temperature span the periods 1986 - 2020 and were sourced from Nigeria Meteorological Agency, while crop yield like cassava and yam were collected from Agricultural Development Programme Office Rivers State for the periods 1999 to 2020. The primary data were analysed using descriptive and inferential statistics techniques, while multiple regression techniques were employed in estimating the secondary data. The outcome of the study revealed that the mean annual rainfall of the area was 2235.9 mm, while the average temperature was 27.1°C. Annual maximum and minimum temperature were 31.4°C and 22.7°C respectively. The evidence shows that the rainfall and temperature over the duration decreases and increases respectively, and the shift in rainfall pattern that affected crop minimum and maximum temperatures were negatively correlated with crop production. Further inquiries also revealed that about 43.3 % and 68.5 % variation in cassava and yam respectively, were cuased jointly due to variation in monthly and annual rainfall, while about 4.5 % and 7.0 % variation in cassava and yam production respectively can be explained by variation in temperature. Hence, crop production required small amount and evenly distributed rainfall at early stage of its growth.

Keyword: Climate Variability, Crop Production, Communities, Nigeria
Gel Classification : C68, Q54, Q10

1. Introduction

Climate variability is one of the pressing problems that have threatened food security globally through its influence on agricultural production. Evidence had shown that the impact on developed countries is less severe due to natural advantage, high adaptation techniques and technology, mechanised agricultural system and wealth status (Akinbobola, Adedokun and Nwosa, 2015). These natural advantages had been argued to have aided the reduction of the adverse effect on agricultural activities of advanced societies, unlike their developing counterpart where the impact of climate variability is high owing to poor adaptation capacity, lack of early warning system, high level of temperature and low national income level (Akinbobola et al. 2015). Climate variability is the primary determinant of agriculture which provides humanity with food and fibre (Akinseye, Ajayi and Oladitan, 2013). Hence, many agricultural activities depend on climate change indicators such as temperature and rainfall among others. The variability of climate plays a significant role in agricultural production starting from land preparation to the final harvest (Akinseye et al. 2013, Sultan et al. 2014, Smith and Skinner, 2002; and Mesike and Esekhade, 2014), especially where there is little or no mechanised system.

It is obvious that the Nigerian agricultural production is predominantly rain-fed, which is vulnerable to seasonal variation (Eickemeier et al. 2014). The variability in season as experienced in Nigeria overtime has truly affects the livelihood of farmers and landless labourers who depend on the proceed of the agricultural activities for survival (Vermeulen et al. 2012). Thus, in some third world countries like Nigeria, agricultural production had been the main source of livelihood for rural dwellers. In the rural communities, agricultural activities generate more than 60% employment for the population and have, contributed about 30% of gross domestic product of the Nigerian economy (Hassan and Nhemachena, 2008). The expected long-term changes in rainfall patterns and shifting temperature zones are expected to have significant negative effects on agriculture, food and water security and economic growth (Kurukulasuriya et al. 2006, Klein et al. 2007, Nhemachena et al. 2010, Lobell et al. 2011, Uguru et al 2011; Dinar et al. 2012). The resultant higher temperatures, higher incidence of droughts and floods (Egbe et al. 2014 and Singh, 2014) as well as other weather related events pose production risks to farmers (Balmaissaka et al. 2016). Fluctuation in climate had subjected Nigeria's agricultural system under threat. Rural sustainability and food security are under serious threat as crop production takes significant aspect of agricultural activities in Nigeria (Ayinde et al. 2011). According to Porter et al. (2014) and IPCC (2014), the effect of climate change on crop production has always been consistent and negative especially countries in low-latitude. Lobell et al. (2011) also reported that 1°C rise in temperature could result to 10% reduction in crop yield except in high latitude countries. Following the report of World Bank (2016) forecast, climate variability could also result in 5% and 30% global crop yield losses in 2030 and 2080 respectively with developing countries experiencing a disproportionately large decline in crop yield due to decline in precipitation and increase in temperature (Cline, 2007 and Nhemachena, 2014). This implies that developed countries could experience increase in crop yield due to increase in precipitation, which in most cases compensate increase in temperature within the region (World Bank, 2016 and Parry et al. 2004).

The effectiveness of rainfall is dependent on temperature values which affect evaporation and transpiration, which in turn reduces the length of crop cycle (Wilt and Waibel, 2009; and Sultan et al. 2014). The variability of rainfall and temperature has significant influence on crop production in Nigeria (Akinseye et al. 2013); Eregha et al. 2014; Akinbobola et al. 2015; Okringbo et al. 2017; and Agba et al. 2017). The irregularity of sufficient rain can affect crop yields adversely if rains fail to arrive during the crucial growing stage of crops (Wilt and Waibel, 2009). Amidst, crop yields are highly sensitive to changes in temperature and water availability (Labell and Gourdji, 2012). High temperatures can depress or induce yields by accelerating crop development or damage the plant cells (Ezeaku et al. 2014, and Sanchez et al. 2014). Temperature increase and erratic rainfall pattern have threatened Rivers State with annual extreme climate events. Sea level rise from warming temperature has put the State at the risk of submergence. Over 128km^2 areas have submerged due to flood, this account for 19 % of the area (Meren et al. 2019). Rivers State has experienced subsequent occurrence of flood especially communities within the Orashi tributary which has led to reduced arable land availability for crop production. The areas that are frequently badly hit by flood disaster are Okwuzi, Obrikom, and Ndoma among others in Ogba/egbema/ndoni L. G. A. (Amadi and Ogonor 2015). This has led to loss of arable land, loss of agro-forestry, contamination of water, disease outbreak, loss of properties, destruction of crops, death etc. (Amadi, 2013). In view of the above discussion, it is pertinent to examine the effect of climate variability on crop production considering the fact that more than 50% of the population in River State is dependent on agriculture for their livelihood. Studies such as Akinseye et al. (2013), Eregha et al. (2014), Akinbobola et al. (2015), Agba et al. (2017), Okringbo et al. (2017) examined the perceived effect of climate variability on arable crop production in Nigeria, but no such study have anchored on the effect of climate variability on crop production with emphasize in Ogba/Egbema/Ndoni Local. Government Areas of Rivers State Nigeria. Specifically, the study assesses; (i) variability and trends of rainfall and temperature, (ii) trends in crop production and (iii) correlations of crop production with rainfall and temperature.

2. Review of Empirical Literature

Crop production is influenced by soil, relief, climate and diseases. Crop has an inherent relationship with climate and environment (Molua et al. 2010). Crop production depends on availability of arable land and it's affected by yield, which related to harvested areas, return per hectare and quantities produced (Agba et al. 2017). The yield or productivity of crops is enhanced by CO_2 which is primary raw materials utilized by crops (Schahczenski and Hill, 2009). The absorbed atmospheric CO_2 by crops is converted into organic carbon which is stored in their leaves, branches, stems and roots and soil in process called carbon sequestration, this act as a global bio-thermostat keeping temperatures in equilibrium. Bio-thermostat is the theory of climate change which stated that negative feedbacks from biological and chemical processes entirely or almost entirely offset whatever positive feedbacks might be caused by rising CO_2 (Bast, 2010). Najafi et al. (2018) study on the changes in global crop yields through changes in climate and technology shows the impact of CO_2 on crop yields to be greater in low GDP countries than in high GDP countries due poor access of technology. The increase in CO_2 level had contributed to a sustained upward trend in yield over time. It indicates that countries with high diurnal temperature range better responds to CO_2 enhancement especially in low GDP countries. In India, increased in atmospheric carbon dioxide decreased agricultural productivity and increased vulnerability of the landless and poor (Kumar and Gautan, 2014). Ezeaku et al. (2014) examined climate change effects on maize (Zea mays) production in Nigeria. The result indicated that at the current CO_2 level, the maize yield will decrease with increase in temperature. Hence, the study predicted that doubling the CO_2 level will increase maize yield at low temperature. In like manner, Eregha et al. (2014) and Agba et al. (2017) pointed that increased carbon dioxide had negative influenced on crop production in Nigeria.

Examining the effect of climate variable on yield of major food-crops in Nepal, Maharijan and Joshi (2013) shows that Change in climate variability has negatively influenced crop productivity. In their study, Maize and potatoes were adversely affected by the measures of climate variability in the area. Using Ricardian approach in determining the impacts of climate change on crop in Ethiopia, Derressa and Hassan (2009) reported that climate variables had significant effect on net crop revenue per hectare of farm. They also found that increase in seasonal precipitation during springs significantly increased net crop revenue per hectare, while increase in temperature significantly decreased net crop revenue per hectare both in summer and winter. Hence, investigating the economic impacts of climate change on agriculture and its implications on food security in Zimbabwe using cross-sectional Ricardian approach, Nhemachena (2014) showed that short distance to the capital, high livestock index and access to irrigation had significant effect on net farm revenue. Also, further investigation shows that short distance to capital and access to irrigation can help improve crop productivity, while livestock will serve as alternate livelihood to the small household farmers. In addition, Ochieng et al. (2016) studied the effects of climate variability and change on agricultural production in Kenya, and the result showed that increase in temperature has negative effect on total crop revenue and maize revenue but a positive effect on tea. Thus, they reiterated that low temperature can lead to scorching of tea plant especially at night. It indicated that increased rainfall had positive effect on crop and maize revenues but low rainfall was detrimental to tea production. Ali et al. (2017) study in climate change and its impact on the yield of major food crops in Pakistan had shown that increased in minimum temperature increased wheat yield but reduced rice production while decreased relative humidity increased yield of rice and sugarcane in the area. They further explained that the increased minimum and maximum temperature positively influenced sugarcane and maize production, and that low rainfall reduced maize and sugarcane production but high rainfall increased rice and wheat production. Further investigation shows that reduced sunshine hour had negative effect on rice and maize production.

In Nigeria, Agboola and Ojeleye (2007) studied the impact of climate change on food production in Ibadan Nigeria. The study revealed that farmers had experienced reduced food crop yield on the area due to reduction in rainfall and relative humidity as well as increase in temperature. In a similar study in Kwara state, Tunde et al. (2011) argued that increase in rainfall increased maize yield, while millet and sorghum required minimum rainfall. Further inquiries in their study show that selected crops under study do not require maximum temperature for its growth. The study indicated that the number of rainy days positively affected rice, maize, sorghum and sweet potato. In like manner, Apata (2016) study shows that climate change had negative effect on crop production through reduced crop yield, pest and disease manifestation, late maturity of crops and crop extinction. Okringbo et al. (2017) study in Bayelsa also revealed that rural farmers in the study area had observed some changes in their environment like the rate of rainfall, occurrence of erosion, flooding, lodging of crops, rise in sea level, deposition of unwanted debris in their farms, formation of hardpan in the soil surface, drying soil surface and long hotness of weather which restrain farmers on the kind of agricultural practice to adopt. In addition, Weli and Bajie, (2017) studied Adaptation of root crop farming system to climate change in Ikwerre Local Government Area of Rivers State, Nigeria. Their findings indicated crop failure, reduced crop yield, increase incidence of pest and diseases and delay in planting period as the direct effect of change in climate variables. These studies did not account for inter and intra annual variability of the climate variables which determine the distribution of the variables. The distribution of the variables has major effect of crop production.

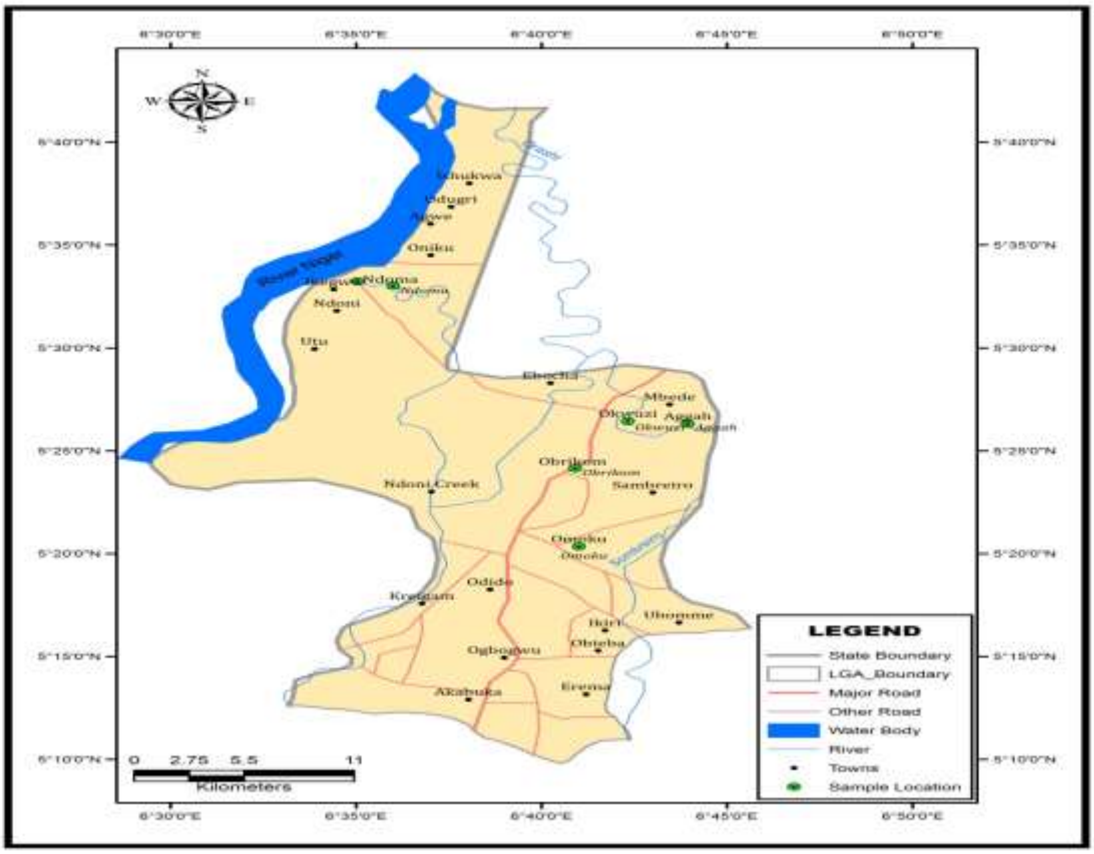
3. Research Methodology

Under this section, we discussed the study area, data for the study and the method adopted for the study.

3.1 Study Area

The study was conducted in Ogba, Egbema and Ndoni Local Government Area of Rivers State, Nigeria. The administrative headquarters is located at Omoku. The study area lies approximately at latitudes 5°10^{1}N and 5°40^{1}N and longitudes 6°25^{1}E and 6°45^{1}E. The area is bounded to the North by Delta State and to the East by Imo State (Fig. 1). It has a total land area of 150 km^2 and estimated population of 9,684 persons. They experience two major seasons; dry season and rainy season. The rainfall season is from March to October while dry season period is from November to February. Ogba/Egbema/Ndoni is one of the highest oil and gas production onshore of Niger delta. Despite that, agriculture is the major livelihood of this local community (Okpiliya et al., 2016). The major crops cultivated in this area are cassava, yam, maize, plantain, banana, vegetables etc. Soil texture varies across the region which shows that the soil can support different crop depending on the soil type.

Figure 1: Map of Selected Communities



Source: GIS Laboratory, Department of Geography, UNN

3.2 Data for the Study

The data used for this study include primary and secondary data. The secondary data used include rainfall, temperature and crop yield. Data on Rainfall and temperature covers 1986 - 2016 and were obtained from the Nigeria Meteorological Agency, while crop yield data for 1999 – 2014 were obtained from Agricultural Development Programme Rivers State. The limited scope of the secondary data is due to its availability, while the survey is extracted from dissertation. The primary data was collected with the aid of questionnaire sampled in the selected local government area. The local government area (LGA) is surrounded by web of rivers, which make it prone to sea level rise and flood. A purposive sampling technique was used to select six communities in this Local Government Area that mostly involve in crop production. The six communities include; Ikekwu, Ndoma, Okwuzi, Aggah, Obrikom and Omoku and 30 rural farmers were randomly selected from each of these communities, making it a sample size of 180 respondents.

3.3 Method of Estimation

Estimating the annual rainfall and seasonal rainfall, eqn.1 was used while mean temperature and seasonal temperature were computed using eqn.2. The data were analysed using descriptive and inferential statistics, as well as results obtained from multiple regression techniques.

$$A_R = \sum_{1=1}^{12} R_1 \text{------------------------------} 1$$

$$\overline{TT} = \frac{1}{12} \sum_{1=1}^{12} T_1 \text{------------------------------} 2$$

Where R and T; are the monthly rainfall and temperature respectively. *i*; is the number of year. $\overline{TT}$; is the mean annual temperature. In addition, the study adopted linear regression to determine the significant difference in the trends of rainfall and minimum and maximum temperatures. It is given as equation (3)

$$Y_{i,t} = \beta X_{i,t} + b \text{--} 3$$

Where Y; dependent variable, β; the slope, X; independent variable and b is the intercept. To determine production variation, relationship and effect of climatic variables, namely rainfall (seasonal and annual rainfall totals) and temperature (maximum and minimum) on crop production in the study area, bivariate correlation and multiple linear regression analyses were used. The regression model for a single crop was derived as in equation (4):

$$Y_{i,t} = \alpha + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} \ldots \beta_n X_{n,t} + \varepsilon_{i,t} \text{----------------------------------} 4$$

Where $Y_{i,t}$; is crop production at time *t*, α is the intercepts, $\beta_1, \beta_2, \beta_3, \ldots, \beta_n$ are the coefficients of the explanatory variables indicated by, X_{1t}, X_{2t}, X_{3t}, …, $X_{n,t}$. However, the explanatory variables in this study include seasonal and annual rainfall totals, and minimum and maximum temperatures. This technique is used to determine the relationship between climatic parameters and crop production, and to identify the most predictor variable (Alemayehu and Bewket 2016). Student's *t*-test was used to determine the significance relationship between the climate variables and crop production proxied with crop yields.

In addition, to examine inter-annual and intra-annual variability of rainfall, we estimated precipitation concentration index (PCI) and coefficient of variation using eqn.5 and 6 below.

$$PCI = 100X \left[\frac{\sum P_1^2}{\left(\sum P_i\right)^2} \right] \text{--} (5)$$

PCI indicate the heterogeneity pattern in rainfall at different scale. P_i; is rainfall amount of the i^{th} month; and ΣP_i^2; stand for the summation over the 12 months. PCI values of less than 10 indicate uniform monthly distribution of rainfall that is low precipitation concentration. Values between 11 and 15 indicate moderate concentration, while 16 to 20 indicate high concentration. However, any values above 21 indicate very high concentration. Coefficient of variation (CV) was calculated to evaluate the variability of rainfall. The degree of variability of rainfall events are classified as less (CV < 20 %), moderate (≥ 20 ≤ 30 %) and high (> 30 %). It is estimated using eqn.6 below.

$$CV = \left(S / \mu \right) \text{--} (6)$$

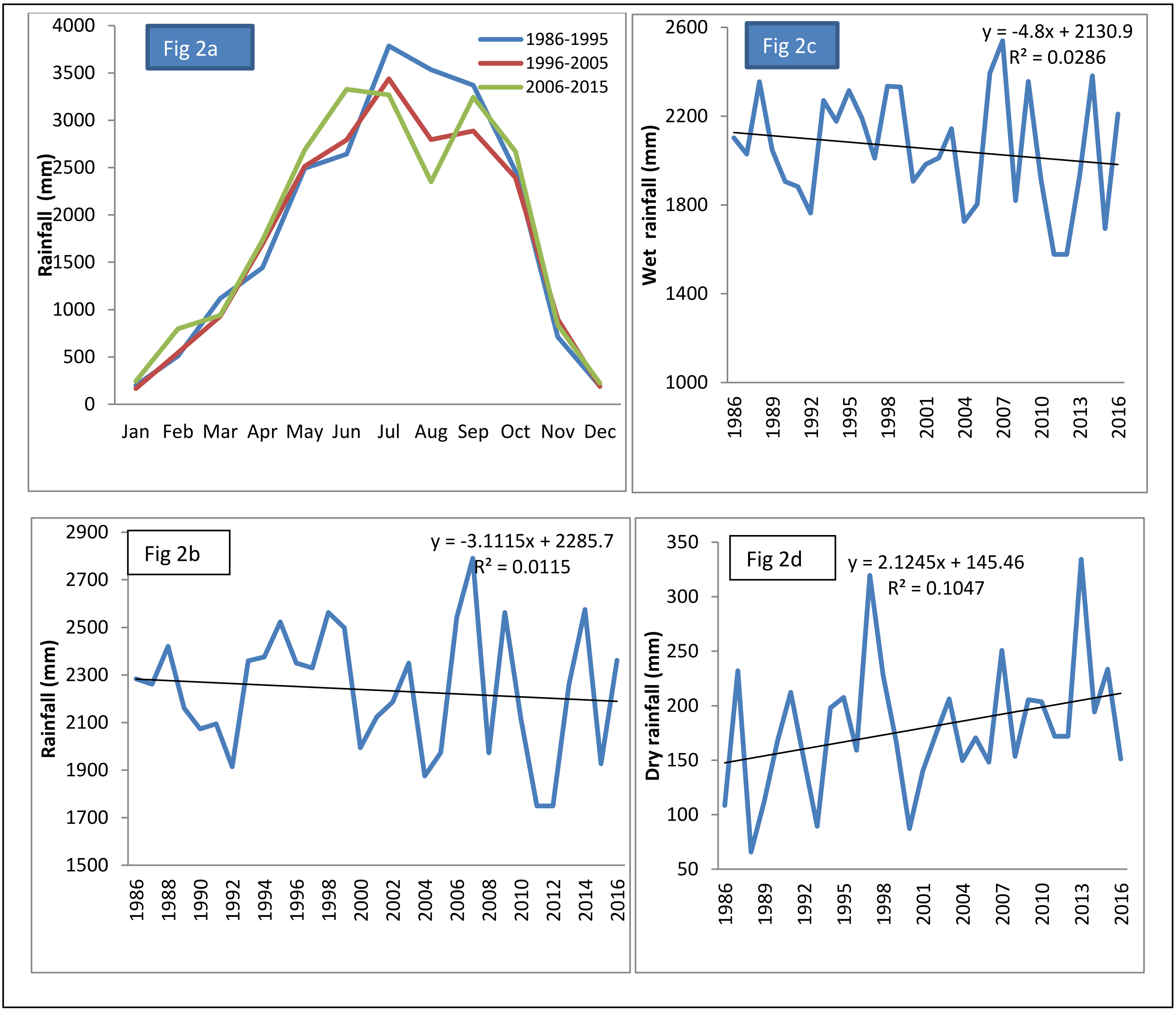
where *CV;* is the coefficient of variation, *S* and μ are the standard deviation and mean rainfall respectively.

4. Result Presentation and Discussion

4.1 Annual and Seasonal Rainfall Pattern

The rainfall pattern for three decades in Ogba, Egbema and Ndoni LGA from 2006 - 2015 (Fig. 2a), show a shift in the rainfall pattern in the study area, while 1986 - 1995 and 1996 -2005 recorded peak period of rainfall each which is in the month of July. However, from 2006 - 2015, the study found two peak periods. First peak occurred in June followed by a drop in rainfall from July to August, while another peak was recorded in September (see Fg. 2a below). The short dry season (sometimes called August break) was experienced in the month of July through August as against August through September. This change in rainfall pattern has tremendous effect on crop farming which may alter the growing season. The two peak periods of rainfall may be evidence that this region experience frequent flood occurrence. Hence, we also observed an increase in the total rainfall in February 2006 - 2015, which shows early arrival of rainfall in the last decades. The mean annual rainfall of the area is 2235.9 mm. The lowest rainfall in 2011 and 2012 was recorded in the study area. These years had the same amount of rainfall 1749.2mm. The rainfall trend (see Fig. 5 below) shows fluctuation all through the years.

Figure 2: Amount of Rainfall and the Study Areas



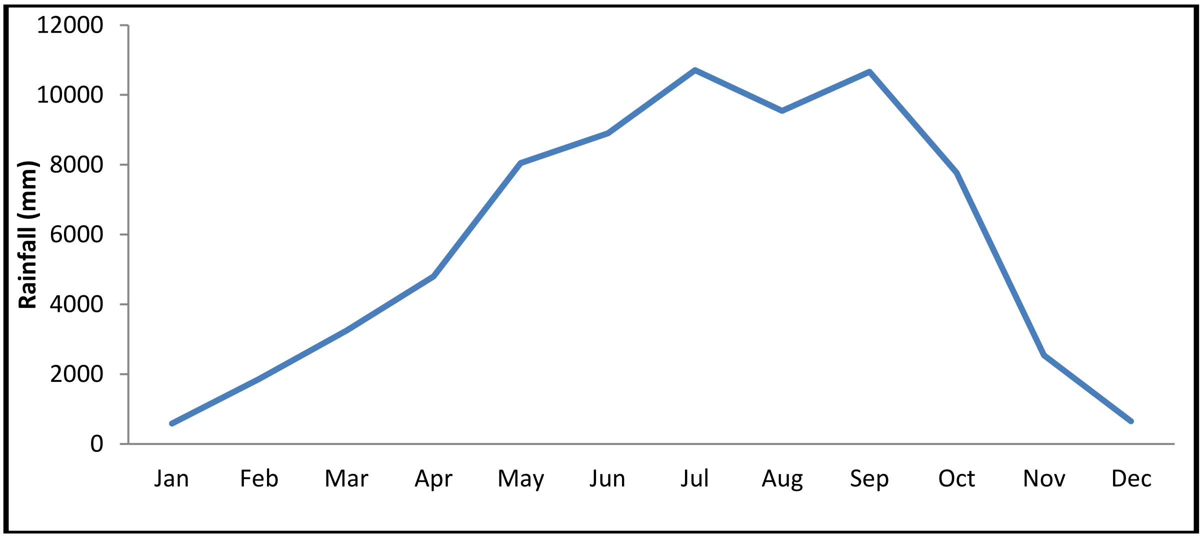
Source: Author's Conception.

Note: Fig. 2a: Monthly rainfall distribution for 3 decades (1986 - 1995, 1996 - 2005 & 2006 - 2015), Fig. 2b: The annual rainfall distribution (1986 – 2016), Fig. 2c: Annual rainfall distribution for wet season (1986 – 2016), and Fig. 2d: Annual rainfall distribution for dry season (1986 – 2016)

The coefficient of determinantion (R^2= 0.011) in rainfall (Fig. 2b) shows decline in rainfall for the past 31 years in the research area. Though, this is not significant at p = 0.05 level, but it suggest the concern on climate variability on crop production in the study area. The study area has wet season and dry season (see fig. 2c and 2d above) which extended from March to

October, as well as November to February respectively. There were gradual reduction in wet season rainfall and increase in dry season rainfall in the study area over the period of the study. The rainfall distribution for wet season was stastistically not significant as well, and dry season was found to be significant at p = 0.05. The highest rainfall distribution for wet season was recorded in 2013 (334.3 mm), while the lowest was in 1988 (65.7mm). Rainfall distribution in wet season is of importance for crop production as most farmers in the study area practise rainfed agriculture. There was variations in the distribution of wet season rainfall over the years with highest value recorded in 2007 (2540.1mm) followed by 2006 (2394.1mm). Hence, the lowest value was 1577.3mm which was recorded in 2011 and 2012. The seasonal rainfall followed the same trend with the annual rainfall which shows decline in rainfall distribution except for dry season for the past 31years. Using the linear regression model, the rate of change is defined by the slope of regression line. In this case, the rate of change were 2.124 mm/year, -4.8mm/year and -3.11 mm/year for dry season rainfall, wet season rainfall and annual rainfall respectively. This shows that wet season rainfall and annual rainfall decreased by 4.8 mm/year and 3.11mm/year respectively while the dry season rainfall increasd by 2.124 mm/year in the study area. This finding may be consistent with Uguru et al. (2011) who reported bimodal rainfall pattern and shift in second peak of rainfall from September to October 2001 – 2010 in South eastern part of Nigeria. The difference in the months of the peak rainfall period may be due to difference in the period of the rainfall data and location.

Fig 2e: Monthly rainfall variation (1986 – 2016)



Source: Author's Conception

Monthly rainfall (see Fig. 2e above) is also a measure of rainfall concentration in an area. Highest and lowest monthly rainfall were obtained in July (10711.50mm) and January (585.20) respectively. The inter-annual rainfall variability is shown by coefficients of variations as reported in table 1 below. The highest and lowest coefficients of variation (CV) were 105.26% in 1990 with 64.83 % of annual rainfall recorded in 2013. The wet and dry seasons (see table 2 and table 3 below); have highest percentage coefficient of variation (CV %) in the year 1990 (80.71%) and 2007 (119.36%) which also show high rainfall variation The lowest CV% value of 28.67% was recorded in the wet season in 2014. The annual rainfall, wet saeson and dry season rainfall show high inter-annual variability over the years (1986 – 2016). The rainfall variation in dry season was higher when compared to rainfall variation in wet season. High CV% for rainfall indicated that the rainfall of the area is unreliable and unpredictable. This may affact crop farmers ability to prdict when to start land preparation for crop production. Hence, this findings support the claim of Boureima et al. (2017) that argued that change in climate variables has made local farmer unable to predict when rain will fall thereby making their traditional knowledge unreliable about climate.

Table 1: Coefficient of variation for annual rainfall

Year	Mean	Standard Deviation (STD)	Coefficient of Variation (CV)	% of Coefficient of Variation (CV %)
1986	190.26	163.34	0.86	85.85
1987	188.44	140.26	0.74	74.43
1988	201.74	170.21	0.84	84.37
1989	180.02	143.92	0.8	79.95
1990	172.77	181.86	1.05	105.26
1991	174.53	136.03	0.78	77.94
1992	159.46	112.7	0.71	70.68
1993	196.65	152.82	0.78	77.71
1994	197.93	150.82	0.76	76.2
1995	210.25	149.88	0.71	71.29
1996	195.79	151.53	0.77	77.4
1997	194.15	136	0.7	70.05
1998	213.59	157.06	0.74	73.53
1999	208.18	163.35	0.78	78.46
2000	166.14	151.44	0.91	91.15
2001	176.95	131.93	0.75	74.56
2002	182.18	162.57	0.89	89.24
2003	195.8	165.99	0.85	84.77
2004	156.25	130.04	0.83	83.23
2005	164.46	117.5	0.71	71.44
2006	211.86	192.55	0.91	90.89
2007	232.57	170.5	0.73	73.31
2008	164.37	119.08	0.72	72.45
2009	213.54	148.76	0.7	69.66
2010	176.38	133.76	0.76	75.83
2011	145.77	109.83	0.75	75.35
2012	145.77	109.83	0.75	75.35
2013	188.3	122.07	0.65	64.83
2014	214.63	142.9	0.67	66.58
2015	160.56	130.01	0.81	80.97
2016	196.79	145.77	0.74	74.08

Source: Field Survey 2017.

The precipitation concentration index (PCI) values presented in table 2 below is less than 10 across the area which shows low rainfall concentration. The highest rainfall concentration was recorded in December (8.68%) followed by January (7.15 %), and the lowest occurred in July (3.42%). The result indicates that the difference in rainfall occurrence in rainy season was lower but high during dry season in the study area. This shows that the rainfall in rainy season was more homogenous. PCI result shows that the numbers of rain day were higher in July followed by June, August and September. The implication of this to crop farming is that it can cause flooding and water logging to the farm which can lead to poor soil aeration, decaying of crop root, nutrient leaching and fixation, washing away of top soil and death of crop. It can also affects the activities soil microbes. The result for rainfall concentration on December and January show more evenly distribution which support crop growth and development better, though it was in dry season. This is an indication that the crop farmers in this area have to shift with rainfall pattern to reduce crop loss.

Table 2: Seasonal Rainfall Variation and Precipitation Concentration Index (PCI)

		Coefficient of variation for wet season rainfall (March – October)														
Year		**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Mean		262.84	253.64	294.40	255.96	238.20	235.26	220.41	283.80	272.14	289.44	273.80	251.29	291.86	291.46	238.30
STD		151.09	122.00	126.51	111.00	192.25	123.63	80.18	102.32	127.16	117.04	116.69	111.79	128.59	133.20	134.21
C V		0.57	0.48	0.43	0.43	0.81	0.53	0.36	0.36	0.47	0.40	0.43	0.44	0.44	0.46	0.56
C V %		57.48	48.10	42.97	43.37	80.71	52.55	36.38	36.05	46.73	40.44	42.62	44.49	44.06	45.70	56.32
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Mean	247.94	251.51	267.92	215.70	225.39	299.26	317.51	227.37	294.63	239.13	197.16	197.16	240.66	297.65	211.66	276.30
STD	98.22	156.49	156.47	116.76	92.61	176.78	136.17	88.55	108.21	116.62	93.67	93.67	113.14	85.34	120.29	102.50
C V	0.40	0.62	0.58	0.54	0.41	0.59	0.43	0.39	0.37	0.49	0.48	0.48	0.47	0.29	0.57	0.37
C V %	39.61	62.22	58.40	54.13	41.09	59.07	42.89	38.94	36.73	48.77	47.51	47.51	47.01	28.67	56.83	37.10

Coefficient of variation for dry season rainfall (November - February)																
year		**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Mean		45.10	58.05	16.42	28.12	41.92	53.07	37.55	22.35	49.52	51.87	39.77	79.87	57.05	41.62	21.82
STD		49.17	58.27	14.37	32.48	28.01	51.74	42.99	21.11	40.28	15.47	61.18	111.98	53.43	30.87	20.24
CV		1.09	1.00	0.87	1.15	0.67	0.97	1.14	0.94	0.81	0.30	1.54	1.40	0.94	0.74	0.93
CV%		109.02	100.37	87.50	115.49	66.80	97.49	114.49	94.43	81.33	29.82	153.83	140.19	93.66	74.16	92.75
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Mean	34.97	43.52	51.55	37.35	42.60	37.05	62.67	38.35	51.38	50.90	42.98	42.98	83.58	48.58	58.35	37.78
STD	31.53	36.25	47.75	43.87	30.15	43.75	74.81	44.01	34.92	48.74	51.22	51.22	53.28	52.32	85.55	53.22
CV	0.90	0.83	0.93	1.17	0.71	1.18	1.19	1.15	0.68	0.96	1.19	1.19	0.64	1.08	1.47	1.41
CV%	90.14	83.28	92.62	117.45	70.78	118.08	119.36	114.77	67.96	95.76	119.19	119.19	63.75	107.72	146.62	140.89

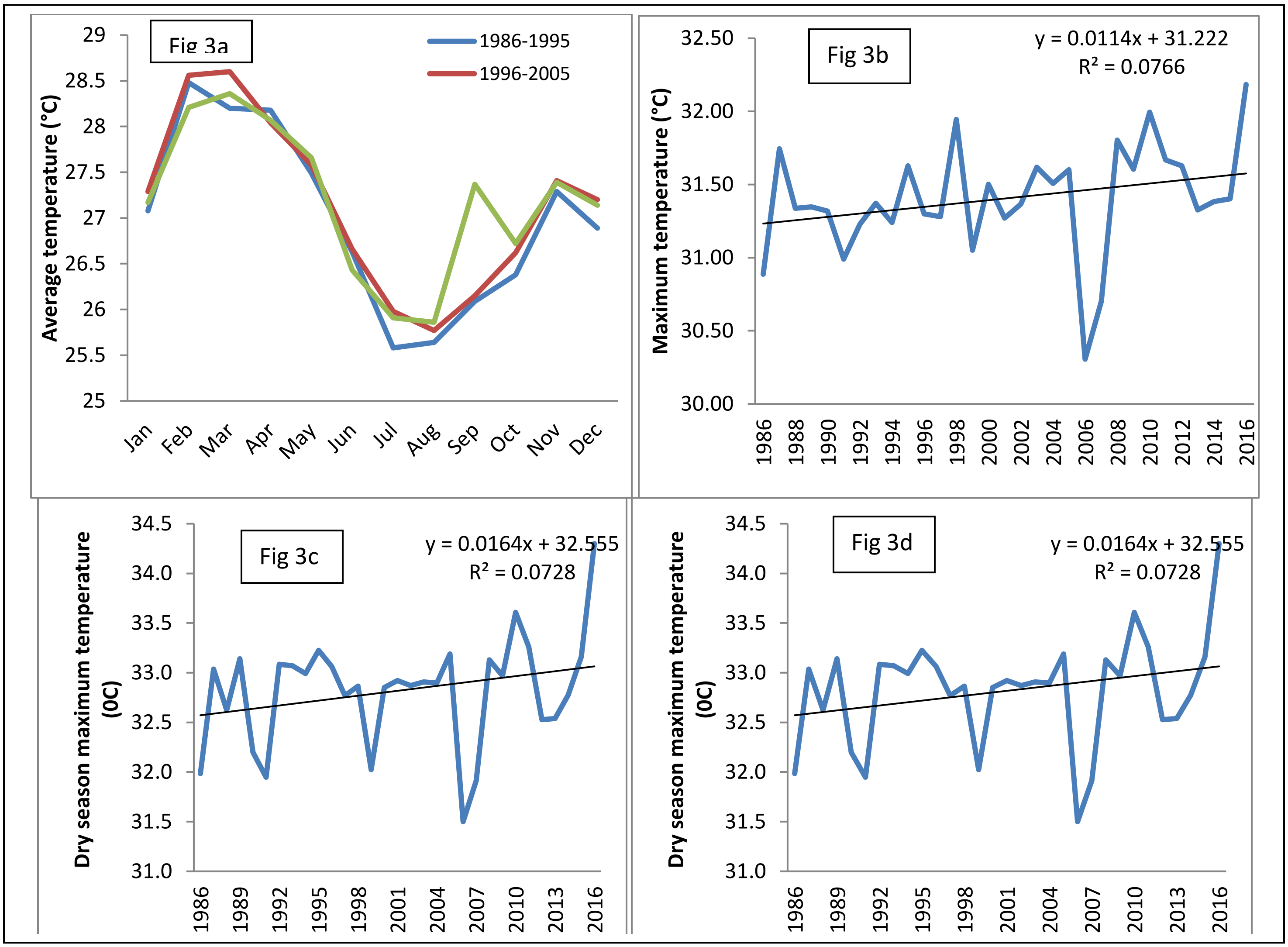
	The precipitation concentration index (PCI) of the study area											
Months	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun**	**Jul**	**Aug**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
PCI	7.15	4.99	4.06	3.70	3.62	3.59	3.42	3.61	3.54	3.62	4.30	8.68

Source: Field Survey 2017. STD stands for Standard Deviation

4.2 Analysis of Temperature Trend

The average temperature over the period of study was 27.1°C. The highest monthly temperature recorded as shown in fig.3a below occurred in the month of March (28.6°C) followed by February (28.56°C) in 1996 - 2005 for the three decades while the lowest monthly temperature occurred in the month of July (25.58°C) followed by August (25.64°C) in 1986 - 1995. From the monthly data which allows for the investigation of seasonal variation in temperature, it appears that the monthly temperatures were consistent for the three decades but there is a sharp increase in temperature in September (27.37°C) 2006 – 2015 (see fig. 3a below). The annual maximum and minimum temperature were 31.40°C and 22.75°C respectively (see fig. 3b & 3e (table 3B)).

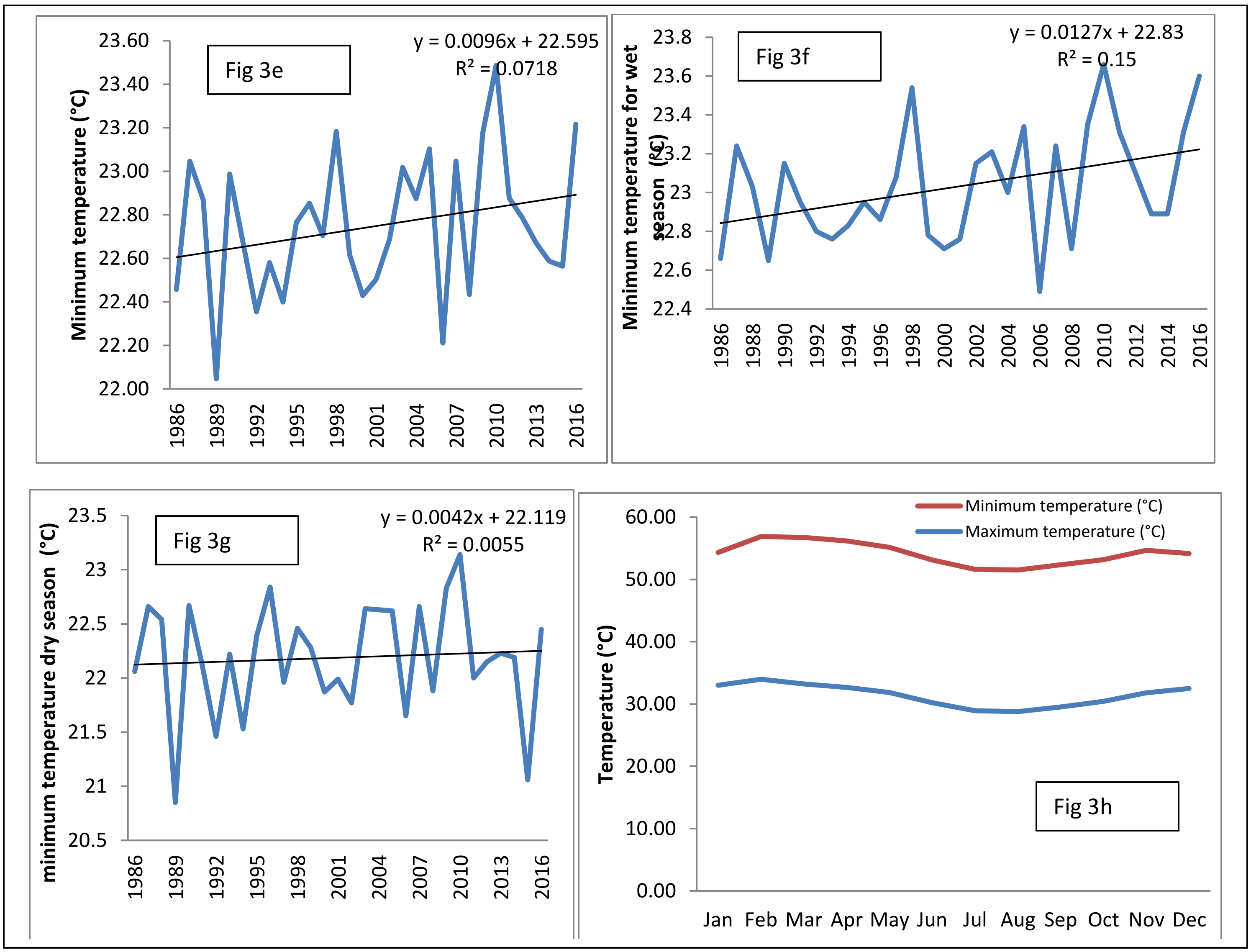
Figure 3A: Monthly and Annual Temperature in the Study Area



Source: Author's Conception. Fig 3a : Monthly temperature distrubution for 3 decades, Fig 3b: The annual maximum temperature (1986-2016), Fig 3c : Maximum temperature variability for wet season (1986 – 2016) and Fig 3d : Maximum temperature variability for dry season (1986 – 2016).

The annual maximum temperature in fig. 3b varied from 1986 - 2016 with low temperature recorded in 2006, followed by 2007, 1986 and 1991 while, the warmest years occur in 2016, 2010, 1998, 1987 and beyond. There were drops in temperature in 2013, 2014 and 2015,while 2008, 2009, 2010, 2011 to 2012 appear to represent the largest stretch of warmest period in this area. The highest increase in temperature for the last 31 years occurred in 2016 in study area. There was variation in minimum temperature trend but the coldest and warmest temperature occurred in 1989 and 2010 respectively. The warmest minimum temperature occurred in 2010 followed 2016, 1987 and 1998, while the colder years occurred in 2006,1989 and 1992. The trend shows that 2006 was the coldest year for both min. and max. temperature followed by the warmer temperature for both in 1987, 1998, 2010 and 2016. The coefficient of determination (R^2=0.076 and R^2=0.071) for maximum temperature (see fig. 3b) and minimum temperature (fig. 3e) respectively show increase in temperature trend for the past 31 years but not significant.

Table 3B: Monthly and Annual Temperature in the Study Area



Source: Author's Conception. Fig 3e: The annual minimum temperature (1986 – 2016), Fig 3f : Minimum temperature variability for wet season (1986 – 2016), Fig 3g : Minimum temperature variability for dry season (1986 – 2016) and Fig 3h Monthly temperature variation from 1986 to 2016.

Wet season and dry season minimum temperature (Fig. 3f & 3g) varied across the years. The highest minimum temperature for the wet season in 2010 is 23.66°C followed by 1998 and 2016. Reported highest dry season (23.14°C) occurred in 2010 followed by 1996, 2009 and 1990. The lowest minimum temperature occurred in 2006 with 22.49°C and 1989 with 20.85°C respectively. The minimum temperature for wet season is significant at $p = 0.05$ with coefficient of determination with $R^2 = 0.149$ (14.9%) while the dry season was not significant with $R^2 = 0.003$. Maximum temperature variations for the wet and dry seasons (Fig. 3c and Fig.3d) were statistically not significant but varied across the years. The highest maximum temperature for the dry season was recorded in the year 2016 with 34.3C followed by 2010 with 31.5C. Maximum temperature for wet season in years 1987, 2008, 2016 were the same (31.1°C) in the study area. The highest maximum temperature for wet season was 31.2°C and the lowest was 31.5°C in year 1998. The seasonal variations for the wet and dry seasons show increasing trend over the past 31 year. Using the linear regression model, the rate of change is defined by the slope of regression line. In this case, annual maximum temperature and annual minimum temperature increased to 0.011°C/year and 0.009°C/year in the study area. The result agreed with Elemayehu and Bewket (2016) which stated increaes in temperature trend and decline in rainfall trend may affect crop production in Ethiopia highland. In like manner, studies by Egbe et al. (2014) and Akinsonola and Ogunjobi (2014) in Nigeria reported that temperature increase for wet and dry season in Cross Rivers over three years data with 10 year interval (1990, 2000 and 2010) affected crop yield. They further pointed that the increase in temperature increases the rate of evapotranspiration which will result in the reduction in moisture available for crop growth and development. In a study by Nhemachena (2014), he also argued that increase in temperature and decline rainfall reduces crop yield and had significant effect on farmers revenue. In addition, from our findings, highest and lowest monthly maximum temperatures (Fig.3h) were recorded in February with 34.0°C and August with 21.3°C respectively. The monthly minimum temperature as shown in Fig. 3a reveals that the highest minimum temperature (23.52°C) record occurred in March and April while the lowest occurred in January (21.2°C).

In addition, our investigation shows that The inter annual coefficient of variation for temperature varied across the year (see table 3 below). The highest and lowest percentage coefficient of variations for annual maximum temperature were recorded in 1990 (CV 7.41 %) and 1999 (CV 4.47 %) while the annual maximum temperature for wet season recorded the highest in 1990 (CV 8.58 %) and lowest in 2008 (CV 4.52 %) as shown in table 3 (Column A) and table 4 (section A) respectively as shown below. The annual maximum temperature for dry season in table 4 (section B) below; shows less variation with CV 5.66 % in 1998 and CV 0.84 % in 1996 for highest and lowest temperature.The annual minimum tempareture also shows less variation with the highest in 2015 (CV 7.22 %) and lowest in 1996 (CV 1.80%).

Table 3: Inter Annual Coefficient of variation for annual rainfall

Column A: Coefficient of variation for annual maximum temperature					Column B: Coefficient of variation for annual minimum temperature				
Year	**Mean**	**STD**	**CV**	**CV %**	**Mean**	**STD**	**CV**	**CV %**	**Mean**
1986	30.89	1.74	0.06	5.65	22.46	0.71	0.03	3.18	22.46
1987	31.74	1.57	0.05	4.96	23.05	0.55	0.02	2.4	23.05
1988	31.34	1.9	0.06	6.05	22.87	0.73	0.03	3.18	22.87
1989	31.35	1.96	0.06	6.24	22.05	1.48	0.07	6.73	22.05
1990	31.32	2.32	0.07	7.41	22.99	0.6	0.03	2.6	22.99
1991	30.99	1.42	0.05	4.58	22.67	0.77	0.03	3.42	22.67
1992	31.23	2.26	0.07	7.22	22.35	1.06	0.05	4.73	22.35
1993	31.37	1.8	0.06	5.74	22.58	0.9	0.04	3.99	22.58
1994	31.24	2.06	0.07	6.6	22.4	1.12	0.05	5.02	22.4
1995	31.63	1.88	0.06	5.95	22.76	0.73	0.03	3.19	22.76
1996	31.3	1.82	0.06	5.82	22.85	0.41	0.02	1.8	22.85
1997	31.28	1.86	0.06	5.94	22.7	0.69	0.03	3.05	22.7
1998	31.94	2.19	0.07	6.86	23.18	1.2	0.05	5.18	23.18
1999	31.05	1.39	0.04	4.47	22.62	0.64	0.03	2.82	22.62
2000	31.5	1.95	0.06	6.2	22.43	0.78	0.03	3.46	22.43
2001	31.27	1.99	0.06	6.38	22.5	0.83	0.04	3.7	22.5
2002	31.37	1.72	0.05	5.49	22.69	0.83	0.04	3.68	22.69
2003	31.62	1.74	0.06	5.51	23.02	0.62	0.03	2.68	23.02
2004	31.51	1.99	0.06	6.31	22.87	0.47	0.02	2.07	22.87
2005	31.6	1.8	0.06	5.69	23.1	1	0.04	4.31	23.1
2006	30.31	1.64	0.05	5.42	22.21	0.65	0.03	2.91	22.21
2007	30.7	1.76	0.06	5.74	23.05	0.55	0.02	2.4	23.05
2008	31.8	1.69	0.05	5.33	22.43	0.78	0.03	3.48	22.43
2009	31.61	1.8	0.06	5.69	23.18	0.46	0.02	2	23.18
2010	31.99	2.07	0.06	6.47	23.49	0.64	0.03	2.74	23.49
2011	31.67	1.87	0.06	5.9	22.88	0.95	0.04	4.15	22.88
2012	31.63	1.66	0.05	5.24	22.78	0.86	0.04	3.75	22.78
2013	31.33	1.76	0.06	5.63	22.67	0.69	0.03	3.05	22.67
2014	31.38	1.62	0.05	5.17	22.59	0.68	0.03	2.99	22.59
2015	31.4	1.94	0.06	6.17	22.56	1.65	0.07	7.33	22.56
2016	32.18	2.25	0.07	7	23.22	0.95	0.04	4.11	23.22

Source: Field Survey 2017

Minimum tempareture for wet season has the highest in 1988 (CV 3.59 %) and lowest in 2015 (CV 0.47 %) while minimum temperature for dry season has highest CV 10.62 % in 1989 and lowest 1.23 % in 1990 as recorded in table 3 (column B), and table 4 (sections C and D) respectively. Less percentage coefficient of variation (> 20) indicate that temperature of the study area is reliable and predictable. Thus, the unpredictable nature of the temperature may result to delay in farming activities in the study area, with its consequence on food insecurity. This may likely affect the rural dweller's welfare through its effect on agricultural yield and income of the farmers. The multiplier effect may result to poor financing of of their children's education and health care, as it has been evidence that morethan 70% of the population of the study area are largely dependent on agriculture.

Table 4: Minimum and Maximum Variation in Temperature for Wet and Dry Season

Section (A)	Coefficient of variation for annual maximum temperature for wet season (March – October)																
Year	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Mean	30.34	31.1	30.7	30.45	30.88	30.51	30.3	30.52	30.36	30.83	30.42	30.54	31.48	30.56	-	30.45	30.61
STD	1.83	1.49	1.77	1.56	2.65	1.46	2.02	1.55	1.93	1.58	1.59	1.46	2.31	1.39	-	1.82	1.52
CV	0.06	0.05	0.06	0.05	0.09	0.05	0.07	0.05	0.06	0.05	0.05	0.05	0.07	0.05	-	0.06	0.05
CV %	6.02	4.8	5.77	5.11	8.58	4.78	6.68	5.08	6.36	5.12	5.22	4.8	7.33	4.55	-	5.99	4.96
Year		**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**		
Mean		30.97	30.81	30.81	29.71	30.1	31.14	30.92	31.19	30.87	31.18	30.72	30.69	30.52	31.13		
STD		1.71	1.91	1.66	1.68	1.85	1.41	1.75	1.96	1.75	1.86	1.74	1.46	1.75	1.71		
CV		0.06	0.06	0.05	0.06	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.05	0.06	0.05		
CV %		5.52	6.21	5.37	5.64	6.14	4.52	5.67	6.29	5.66	5.98	5.67	4.76	5.72	5.5		
Section (B)	**Coefficient of variation for maximum temperature for dry season (November - February)**																
Mean	31.98	33.04	32.62	33.14	32.2	31.95	33.08	33.07	32.99	33.23	33.06	32.77	32.86	32.02	32.85	32.92	32.87
STD	0.98	0.74	1.6	1.39	1.35	0.76	1.49	0.73	0.86	1.43	0.28	1.8	1.86	0.82	1.23	1.18	0.98
CV	0.03	0.02	0.05	0.04	0.04	0.02	0.04	0.02	0.03	0.04	0.01	0.05	0.06	0.03	0.04	0.04	0.03
CV %	3.07	2.25	4.9	4.2	4.2	2.37	4.5	2.2	2.6	4.32	0.84	5.48	5.66	2.55	3.74	3.57	2.99
Year		**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**		
Mean		32.91	32.9	33.19	31.5	31.91	33.13	32.97	33.61	33.26	32.53	32.54	32.77	33.16	34.3		
STD		0.98	1.45	0.64	0.7	0.68	1.55	0.99	1.25	0.77	0.6	1.18	0.9	0.71	1.68		
CV		0.03	0.04	0.02	0.02	0.02	0.05	0.03	0.04	0.02	0.02	0.04	0.03	0.02	0.05		
CV %		2.99	4.41	1.94	2.22	2.12	4.67	3.01	3.71	2.33	1.85	3.63	2.75	2.13	4.88		
Section (c)	**Coefficient of variation for minimum temperature for wet season (March – October)**																
Mean	22.66	23.24	23.03	22.65	23.15	22.95	22.8	22.76	22.83	22.95	22.86	23.08	23.54	22.78	22.71	22.76	22.15
STD	0.47	0.41	0.56	0.35	0.66	0.49	0.57	0.34	0.33	0.45	0.44	0.32	0.85	0.39	0.33	0.46	0.23
CV	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.04	0.02	0.01	0.02	0.01
CV %	2.09	1.75	2.45	1.53	2.87	2.13	2.49	1.5	1.46	1.98	1.91	1.4	3.59	1.69	1.44	2.02	1
Year		**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**		
Mean		23.21	23	23.34	22.49	23.24	22.71	23.35	23.66	23.31	23.1	22.89	22.89	23.31	23.6		
STD		0.42	0.49	0.51	0.4	0.41	0.55	0.38	0.5	0.3	0.44	0.35	0.26	0.11	0.59		
CV		0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0	0.02		
CV %		1.8	2.15	2.18	1.78	1.75	2.41	1.65	2.11	1.3	1.91	1.55	1.15	0.47	2.49		
Section (D)	**Coefficient of variation for minimum temperature for dry season (November - February)**																
Mean	22.06	22.66	22.54	20.85	22.67	22.11	21.46	22.22	21.53	22.39	22.84	21.96	22.46	22.28	21.87	21.99	21.77
STD	1.02	0.66	0.99	2.21	0.28	1.01	1.32	1.56	1.69	1.09	0.42	0.63	1.61	0.96	1.15	1.24	0.87
CV	0.05	0.03	0.04	0.11	0.01	0.05	0.06	0.07	0.08	0.05	0.02	0.03	0.07	0.04	0.05	0.06	0.04
CV %	4.6	2.9	4.38	10.62	1.23	4.56	6.16	7.04	7.86	4.85	1.84	2.85	7.16	4.3	5.27	5.63	3.98
Year		**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**		
Mean		22.64	22.63	22.62	21.65	22.66	21.88	22.83	23.14	22	22.15	22.23	21.99	21.06	22.45		
STD		0.83	0.37	1.6	0.73	0.66	0.97	0.46	0.83	1.25	1.19	1.04	0.89	2.34	1.16		
CV		0.04	0.02	0.07	0.03	0.03	0.04	0.02	0.04	0.06	0.05	0.05	0.04	0.11	0.05		
CV %		3.68	1.62	7.09	3.37	2.9	4.41	2	3.59	5.69	5.39	4.67	4.07	11.12	5.18		

Source: Field Survey 2017. STD; Standard Deviation, CV; Coefficient of Variation and CV%; percentage of Coefficient of Variation

4.3 Analysis of Crop production trend

In analyzing the trend, we used secondary data. However, cassava and yam crops were considered. From the three selected local government areas sampled (Ogba, Egbema and Ndoni) and six communities (Ikekwu, Ndoma, Okwuzi, Aggah, Obrikom and Omoku), thirty rural farmers were randomly selected from each of these communities, making it a sample size of 180 respondents. The results from the sample reveal that farmers in these areas cultivate different crops. However, About 88.3% of respondents cultivate Cassava which makes it the highest crop cultivated in the area followed by plantain (47.5%), Okro (25.1%) and yam (24%). Cassava being the dominant crop in this area may be because it can survive in different climatic zone and in different soil type. Etwire et al. (2017) indicate that cassava can withstand extreme level of precipitation due to its extensive root system. According to focus group discussion, the major emphasis for cassava was its low input demand, adaptability to infertile and degraded soil; and suitability to the local agro ecology.

Figure 4: Yam and Casava Yield

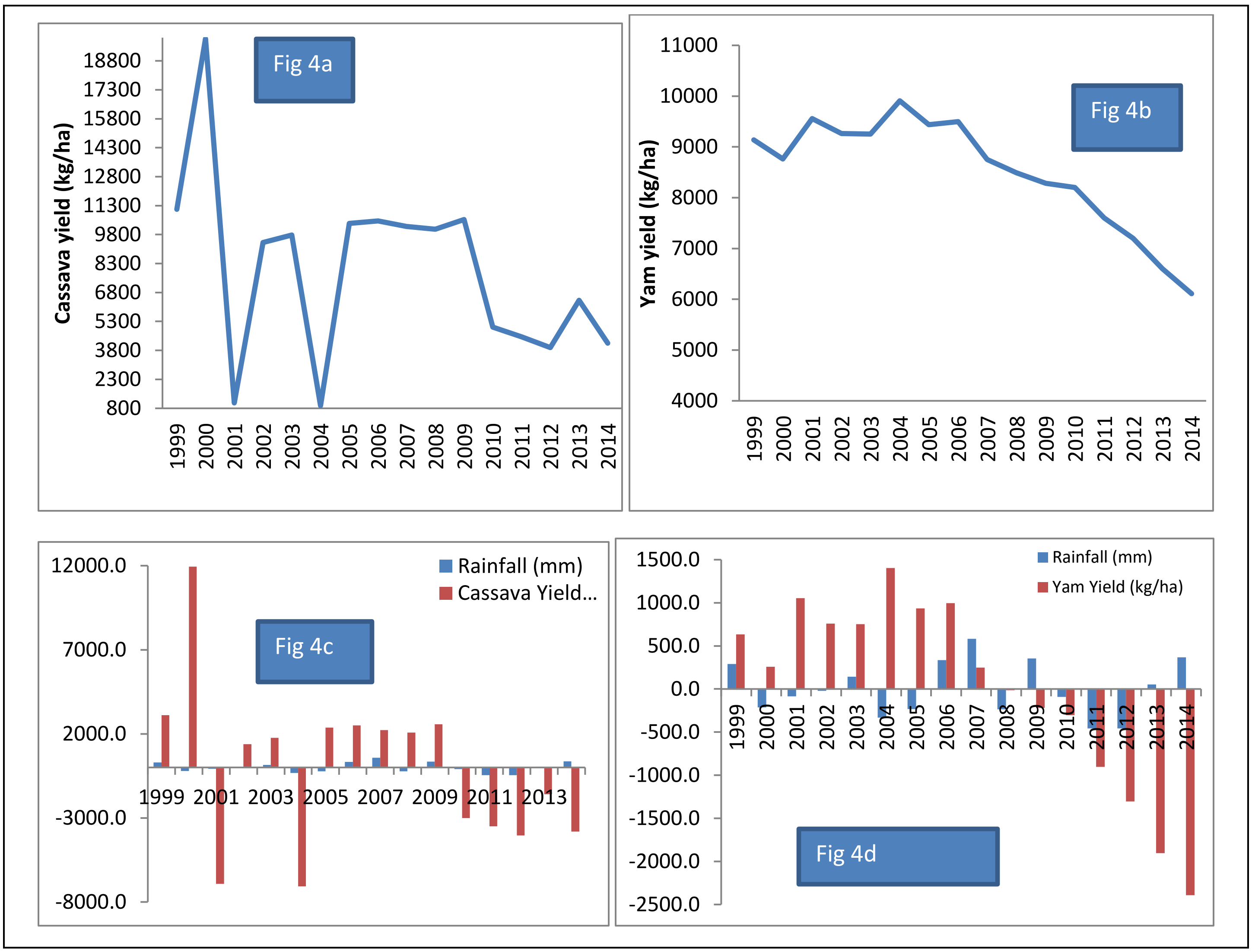


Figure 16 : Cassava yield from 1999 – 2014, Figure1 7 : Yam yield from 1999 – 2014, Figure 18: Rainfall and cassava production anomalies, and Figure 19: Rainfall and yam production anomalies

The crop trends for cassava and yam production in the study area are shown in figure 4 (fig. 4a and fig. 4b) respectively presented above. There is fluctuation in cassava yield trend from 1999 to 2014. The highest yield in cassava yield (19951kg/ha) was observed in 2000 while the lowest yield in cassava (936 kg/ha) was observed in 2004. There was consistent drop in cassava yields from 2010 – 2014 except in 2013 which showed a little increase in the yield of cassava. Yam yield trend also indicates drop in the yield from 2007 to 2014 except in 2013 while, the lowest yield (6110 kg/ha) and highest yield (9908 kg/ha) were recorded in 2014 and 2004 respectively. In addition, to explain crop production and rainfall variability in the study area, figure (see fig 4c & 4d above) was used and the results show crop production anomalies. The two dominant crops (cassava and yam) were analysed in relation to the rainfall variability. Cassava production was below average rainfall in 2001, 2004, 2010 and 2013 due to fall in amount of rainfall. Above average wet season rainfall was obtained in 1999, 2000, 2002, 2003, 2005, 2006, 2007, 2008 and 2009. Though, we experienced above average Cassava production in 2014 despite the fact that the amount of rainfall was below average rainfall in the year. Yam production was consitently decreasing due to fall in the amount of rainfall from 2010 to 2013 which is below average rainfall. Yam production and rainfall were above average in 1999, 2003, 2006 and 2007 but below average in 2009, 2013 and 2014.

To establish the correlation between rainfall, temperature and the crop production in the six selected communities sampled from a LGA, we adopted bivariate correlation method. Bivariate correlation coefficients between monthly, annual rainfall, temperature and crop production from 1999 to 2014 are shown in table 5 below.

Table 5: Bivariate correlation between rainfall, temperature and crop production

Crop	March	April	May	June	July	August	Sept	Oct	Annual	Maximum Temp	Minimum Temp
Cassava	-0.105	0.187	-0.088	-0.009	0.336	0.169	0.293	0.139	0.253	-0.179	-0.188
Yam	-0.168	-0.472	-0.268	-0.187	0.394	0.165	0.474	-0.152	-0.180	-0.244	-0.32

Source: Author's Conception. Decision at 5% level of significant, Temp represent temperature

Bivariate correlation analysis between monthly rainfall and cassava production is positively correlated except for March, May and June. Annual rainfall has a positive relationship with cassava yield but negatively correlated with yam yield. Thus, increase in annual rainfall increases cassava yield and decreases yam yield. Yam yield has a positive relationship with July, August and September rainfall. The negative relationship indicates that at the early stage of cassava and yam growth, it may require low rainfall amount. It may takes cassava and yam 4 to 5 months for its leaves to develop, which is from ending of June to July. Leaves attained maximum leaf area from July hence, the storage root enlarged. Negative relationship exist in yam yield in October and annual rainfall shows that increase in October and annual rainfall can lead to rotting of yam tuber and reduced yield. Bivariate correlation analysis between mean maximum and minimum temperatures and crop production (Table 13) were not significant but shows negative relationships. The increase in maximum temperature and minimum temperature will decrease cassava and yam yield in the study area. The increase in the maximum and minimum temperatures will increase the rate of evapotraspiration which reduce available moisture for crop growth. Climatic variables considered were weakly correlated and not statistically significance with crop yield. Maximum and minimum temperatures have negative relationship with crop production while rainfall variability has positive relationship with crop production. This result is found to be consistent with the work of Alemayehu and Bewket (2016) in Ethiopia highland.

In addition, we further examined the exent to which rainfall and temperature cause variation to crop production using regression analysis. We use cassava and yam because they are dominant crop produced in the study area. The regression results are summarised in table 6 below.

Table 6: Regression Results for crop production, rainfall and Temperature

	Monthly & Annual rainfall					Min & max temperature			
	Cassava	P-Value	Yam	P-Value		Cassava	P-Value	Yam	P-Value
Constant	2337.30		10285.69		Constant	91754.19		24840.9	
March	8.47	0.904	11.813	0.351	Max Temperature	– 1300.37	0.719	– 804.65	0.345
April	112.691	0.180	– 5.678	0.679	Min Temperature	– 1884.23	0.680	– 392.66	0.710
May	68.994	0.291	– 0.729	0.947					
June	85.413	0.289	7.22	0.596					
July	83.837	0.435	8.594	0.435					
Aug	63.080	0.516	5.750	0.516					
Sept	58.614	0.298	8.873	0.298					
Oct	67.747	0.564	6.278	0.564					
Annual	– 61.05	0.540	– 5.946	0.540					
R	0.658		0.826			0.212		0.264	
R^2	0.433		0.685			0.045		0.070	

Source: Author's Conception. Dependent Variables are Casava and Yam, and Decision at 5% level of significant

The regression results as shown in table 6 revealed that changes cassava and yam was as result of variation in monthly and annual rainfall as well as temperature. The coefficient of determination (R^2) indicate that 43.3 % and 68.5 % variation in cassava and yam were caused by variation in monthly and annual rainfall, while 4.5% and 7.0% variation in cassava and yam production can be explained by variation in temperature respectively. Furthermore, monthly rainfall were found to be positive but insignificantly related to casava yield. While the amount of rainfall in the months of March, June, July, August, September and October are positive but insignificantly related to Yam yield, April and May negatively and insignificantly affected yam yield. In like manner, we also observed that minimum and maximum temperature negatively and insignificantly affected casava and yam yield in the study areas respectively. But in the case of the effect of variation in annual rainfall on casava and yam production, we discovered a negative and insignicant effect of annual rainfall on Casava yield. Thus, we also noticed that annual rainfall influences yam yield positvely, though not significant. The result contracdicted the findings of Ochieng et al. (2016) which argued that rainfall and temperature significantly affect agricultural produce in Kenya. This difference in the findings may be due to difference in fertility of land, and other climate indicators.

5. Summary, Coclusion and Policy Suggestion

This study examined the effects of climate variability on crop production in six selected communities purposively sampled from the LGA in Rivers State Nigeria. Primary and secondary data were used. Secondary data covers historical records on rainfall, temperature and production yield (1986 – 2017), while primary data were collected with aid of structured questionnaire and used to ascertain the major crops produced in the areas sampled from January to March 2017. Due to unavailability of primary data on rainfall, temperature and crop production yield, secondary data was used as farmers do not keep records of such data for a long period of time. Also, the six communities were selected due to its vulnerability to climate variability and involvement in crop production. The empirical evidence from the study shows that highest increase in temperature which occured last 31years ago, reoccured in 2016. During the year, there was a significant reduction of crop production and food insecurity in the study area. Further investigation also shows shift in rainfall pattern in the area with two peak periods observed in June and September for 2006 to 2015. We also observed short-dry season (August break) in the month of July and August for 2006 to 2015 as against August and September in the previous decades. Subsequently, moderate variability in annual and wet season rainfall, with high variability in dry season rainfall was noticed, and during this period there may be improvement in crop production as against the rainy and high temperature season.

The precipitation concentration index (PCI) results show homogenous rainfall in the study area during rainy season. The investigation revealed higher number of rain day in July than any other months within the scope of the study (i.e. 1986 – 2017), and this may result to flooding and water logging, which possibly reduce farm activities in the area. The rainfall concentration on December and January was found to be evenly distributed. Also, the percentage coefficient of rainfall variability was high while that of temperature was less. Thus, suggesting the unreliable and unpredictable of rainfall in the area. In addition, from the correlation result, it was evident that annual and seasonal rainfalls were positive correlated with cassava production except for the months of March, May and June but negatively correlated with yam production except for July, August and September. We also observed that minimum and maximum temperatures are negatively related to crop production, and the regression result indicates that the coefficient associated with rainfall is larger than those of temperature. Hence, in as much as temperatures predict crop production, the amount of rainfall strongly contributed to climate variability in the study areas. In view of the above discussion, high temperature and heavy rainfall negatively affected crop production in the area, and this may cause further declined in crop production, and consequenly result to decline in farmer’s income and food security in the area.

In view of the above findings, we therefore suggests that the authorities of Rivers State and Nigeria in general should device policy means of reverting the effect of climate variability on crop production. Hence, we therefore suggest that; (a) The development of new crop varieties that have short gestation period and tolerant to increased temperature and flood. Research on early maturing crop varieties that are heat tolerant and less water stress should be encouraged, and formulation of polices that will support efficient funding of research institutes and biotechnology centres in Nigeria, particularly in Rivers State should be of great concern. (b) Policies that will encourage bikes building in the flood most prone area should be implemented. This will help to slow down water flow and divert the water into irrigation channel in other location where it can be used to irrigate crop. (c) The government authorities should encourage and support planting of trees and hedges around the farm. This will help to slow down water flow and reduce run off time, and the vegetation will also reduce impact of rainfall in soil. The authorities must ensure that the trees should be planted in such a way that there is maximum solar radiation penetration in the fields as some crops do not do well in a shaded field. (d) Flood based structure like storage pond may be encouraged and constructed at the lowest part of the crop farm to store surplus water. This will enable the water slowly soak into the subsoil or use for irrigation when the need be. (e) Ground water-lifting technologies like motor pump and solar or wind-powered pumps may be adopted to reduce the ground water. This will lead to arable land rehabilitation and bring more land into crop production. (f) Weather forecasting should be well equipped and establish in rural areas because most crop production in Nigeria are carried out in rural communities. The information on weather should be broadcasted in local language to enhance farmer's understanding and to prepare for flood on time. Finally, there should be synergy between the government and the farmers in formulating and implementing policies that may help reduce the effect of climate variability of crop production. This may be encouraged by way of bottom-up approach to enable the rural farmers to participate as they are the most vulnerable to the impact of climate variability.

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