

The Effects of Rainfall Variability on Cassava, Yam, and Maize Yields in Imo State, Nigeria, 1987-2016: A Correlational Analysis

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Abstract

This research examined the impact of rainfall variability on the production of selected food crops in Imo State from the year 1987 to 2016. Rainfall variability has been one of the major causes of agricultural failures for certain crops in Imo State. Rather than having a study involving a single crop analysis of the relationship between rainfall variability and crop yields, the study used three food crops. The study looked at the state's rainfall and crop yield trends over a 30-year period. To accomplish this goal, the researcher gathered secondary data in the form of rainfall and yield statistics for cassava, yam, and maize during a 30-year period. These data were obtained from the Nigerian Meteorological Agency (NIMET) and the Agricultural Development Programme (ADP) offices in Imo state, based on the state's three agricultural zones (Orlu, Okigwe, and Owerri). Statistical analyses such as ANOVA, Pearson's Product-Moment Correlation Analysis, and Regression analysis were performed on the collected data. Tables and figures were used to present the results. The findings demonstrate that rainfall changed greatly between 1987 and 2016, with the Owerri zone receiving the most total yearly rainfall and the Okigwe zone receiving the least. Furthermore, it was discovered that there was a very weak association between rainfall variance and agricultural yields (negative). Furthermore, the study found that variation in rainfall could only predict 4.7% of the variance in cassava yield, 8.2% of the variance in yam yield, and 12.2% of the variance in maize yield, indicating a negligible effect. Rainfall variability, therefore, affects maize yields more than cassava and yam yields, indicating that other factors such as temperature variations, moisture content, soil fertility, farm practices and management may have influenced the annual yields of the studied crops.

Keywords: Rainfall Variability, Rain-Fed Agriculture, Food Security, Crop Yields, Imo State.

Introduction

Rainfall variation which is an aspect of climate change that has given man every reason to be concerned about its increasing consequences on the environment (Asha et al., 2012; Thornton et al., 2014; El-Tantawi et al., 2021; Woldeeselassie et al., 2021). Ayinde et al. (2011) opined that climatic fluctuation is putting Nigeria's food production sector (agriculture) under serious threat and stress. This implies that rural sustenance and food security in Nigeria is under serious threat as food crop production takes significant aspect of agricultural activities in Nigeria (Merue et al., 2015). According to Etale and Ayunku (2015), agriculture is the largest economic sector in many developing countries, including Nigeria.

However, this sector of the economy is being impacted by changes in climate and weather conditions.

Agboola and Ojeleye (2007) examined the impact of climate change on food crop production in Nigeria. The study revealed that though farmers have noted various changes in climate conditions over two to three decades, there is still decline in crop yields till date due to reduction in rainfall and relative humidity and as well as increase in temperature. This implies that adaption of farmers to climate change in Nigeria is very poor or inadequate. In the same vein, Ayinde et al. (2011) examined the effect of climate change on agricultural production in Nigeria and the study covered the period 1980-2002 using time series data. It revealed that temperature variation had negative effect on agricultural productivity while rainfall was found to exert positive effect on agricultural productivity. In the same manner, Tunde et al. (2011) analyzed the effect of climate variables on crop production in Patigi, Kwara State, using time series data covering 1999-2008. The study revealed that rainfall highly correlated with maize production but weakly correlated with Millet production and Sorghum. Temperature however was found to correlate with rice and groundnut production negatively. Moreso, Sowunmi and Akintola (2010) empirically examined the effect of climate variability on maize production in Nigeria. The study specifically analyzed the dynamic link between changes in climatic elements and agronomic parameters for maize production in different ecological zones of Nigeria for the period of 1980-2002. They employed the two-way analysis of variance and the coefficient of variation techniques of analyses. It revealed the existence of significant difference between annual rainfall, temperature and output of maize in the seven identified ecological zones. These are all indications that rainfall variation with increase in temperature significantly affects crop yield.

Imo state which is in the South-Eastern part of Nigeria is one of the food producing states in Nigeria. In recent decades the State's agricultural sector has been bedeviled by soil erosion in so many parts due to climate variation. This environmental and atmospheric phenomena have impacted negatively on the food production sector of the State's economy as farm outputs are declining annually. Rainfall in the state keep varying on a great scale, and recently has increased dramatically leading to loss of agricultural lands in many parts of the state such as Orlu, Njaba, and Ideato areas (Okoro, 2023). The resultant effect is sharply on food production. Against these backdrops, this study tends to examine the effects of variation in rainfall duration, onset and cessation on the yields of cassava, yam and maize in Imo State for a period of thirty (30) years beginning from 1987 to 2016. Having noted other factors that could contribute to variations in crop yields such as soil moisture, temperature and sunshine, rainfall is being assessed independently to ascertain its level of impact on crop yield in the study area.

Imo State in the last three decades has experienced erratic, and irregular rainfalls occasioned by climate variability. The normal rainfall pattern and trend in the state is usually an early onset of rain and late cessations with double maxima witnessed during the months

of July and September having an intermediate dryness in few days of August. However, the trend has changed over time with some years recording late onset with early cessations, early onset with early cessation, late onset with late cessation and early onset with late cessation culminating in variation in the yields of food crops (Tandzi & Mutengwe, 2020). This has literally changed the normal pattern of rainfall, affecting the amount, and duration of rains annually and consequently causing confusion to farmers especially in the rural communities.

On the other hand, with the high increase in population witnessed in the state, one would expect food crop production to rise geometrically but disappointingly, that is far from reality. Food crop production has not grown in proportion to rapid population growth with many scientists and researchers such as Akahga et al. (2021) pointing to change in climatic factors such as rainfall, temperature, humidity and other factors as being responsible. Imo State practice rain-fed agriculture and if there are no rains, food crops such as cassava, yam and maize may experience growth failure (Asha et al., 2012; Merue et al., 2015). However, when the rain become excessive, it leads to rotting of food and tuber crops such as yam (Olemeforo, 2012). This situation could as well impact the total annual crop yield in the state especially if the excessive rains culminate into floodings.

Rainfall being an important climatic element exerts great influence on agricultural activities especially cultivation and growth of crops (Sok et al., 2021). This very element is varying in intensity, duration and amount over the past three decades in the study area, resulting to irregular crop yields and harvest (Fosu-Mensah, 2012). Therefore, it is very essential this study investigates the impact of variations in rainfall on the yields of these selected crops keeping other climatic factors constant. The result of this assessment will be vital to addressing the problems of low crop yield and food insecurity in the state through sufficient engagements with professionals in the fields of climate and agriculture.

Statement of the Problem

Peasant farmers and atmospheric scientists, have unequivocally confirmed the existence of global climate change, climate variability, rainfall and temperature oscillation. Over Nigeria and Imo State in particular, there seem to be no significant departure from these global experiences on issues of climate variability or the variability of the principal parameters of climate notably, rainfall.

In addition, it has been observed over recent time how food crop yields are growing irregularly deviating from the norm and resulting to dwindling harvest after every planting season. Stapple food like garri which is processed from cassava crops has gone high in price making it more difficult for poor inhabitants of the state to afford. In the last 30-40 years (3-4 decades) ago, cassava, yam and maize were among the largest food crops produced in the state that fed the populace sufficiently until recently when marketers have to travel to other states to import them. Therefore, it is very important this study investigates the impact of variations in rainfall on the yields of cassava, yam, and maize while bearing other in mind.

Objectives and Research Questions

To achieve the stated aim of this study, the following objectives were pursued;

1. To examine the trend of rainfall in Imo State from 1987-2016.
2. To examine the variation in the yields of cassava, yam, and maize from 1987-2016.
3. To ascertain how the onset and cessation of rainfall affect the production of the selected food crops.
4. To determine the relationship between variation in rainfall and yields of the selected crops in the study area.

Research Questions

In view of the stated objectives, it became necessary to ask the following pertinent questions;

1. Is there any variation in rainfall in the study area?
2. Has food crop yield varied significantly during the period of this study?
3. Does onset and cessation of rainfall affect the production of these selected food crops in the study area?
4. Does any relationship exist between rainfall variation and quantity of food crops produced in the study area?

Research Hypotheses

The study tends to test the following hypotheses:

Ho: There is no significant variation in rainfall in Imo State between 1987-2016.

Ha: There is a significant variation in rainfall in Imo State between 1987 - 2016

Ho: There is no significant relationship between rainfall variation and the yields of cassava, yam, and maize in Imo State.

Ha: There is a significant relationship between rainfall variation and the yields of cassava, yam and maize in Imo State

Literature Review

Effects of Rainfall Variation on Food Crop Production

Generally, rainfall regime is the most important climatic factor influencing crop production. This is because rainfall has the biggest effect in determining the crops that can be grown in different environments, the type of agricultural system to be practiced in different parts of the world, the farming system, the sequence and timing of farming operations (Adejuwon, 2005; cited in Ayanlade and Orimoogunje, 2010 and Tunde et al., 2011). In respect to the above, Tunde et al. (2011) and Fosu-Mensah (2012) identified some important factors guiding rainfall in relation to crop production. According to them, the number of rainy days (the length of the rainy season), time of fall (onset) and total amount of fall, cessation and the type of soil are some of the important factors guiding rainfall in relation to crop

production. Therefore, an interruption in the onset, length of the rainy season and cessation will affect soil moisture (soil moisture deficit and enhanced soil moisture), hence, crop development. According to Fosu-Mensah (2012), soil moisture deficit and also the timing of moisture deficits during growing seasons cause crop damage in stages of plant development. As such, water use for a given crop is a function of both the amount of water available to the crop and when that water is available relative to crop demand. On one hand, Rosenzweig et al. (2001) affirmed that enhanced soil moisture encourages the spread of nematodes and roundworms that inhabit water films or water-filled pore spaces in soils. Moreover, increases in rainfall intensity and amount leads to higher rates of soil erosion, leaching of soil nutrients and agricultural pollutants, and runoff that carries soil and associated nutrients into surface water bodies leaving the soil impoverished to support plant growth (Kumar et al., 2004; cited in Gornall et al., 2010). If erosion and leaching of soil rates go unchecked, continued soil impoverishment would eventually force farmers to abandon their lands (Khan et al., 2009). From the foregoing, both direct and indirect effects of moisture stress make crops more vulnerable to damage by pests, especially in the early stages of their development.

According a study by Esekade and Mesike (2014), land use is to a large extent dependent on rainfall among other factors. This is because rainfall in any location influences its vegetation cover including the type and yield and distribution of most crops. Esekade and Mesike (2014) further emphasized on the importance of rainfall to the growth of notable tree crops such as cocoa, rubber and oil palm especially in the rain forest zone.

According to Cheke and Tratalos (2007) cited in Gornall et al. (2010), rainfall variability has the tendency to cause pest migration. A typical example is the migration pattern of locusts into Sub-Saharan Africa which Mowa and Lambi (2006) believe is influenced by variability in rainfall patterns. The migration of these locusts into Sub-Sahara Africa poses danger to food security and livelihoods in the region. Historically, many of the largest declines in crop productivity have been attributed to sudden low precipitation events (Kumar et al., 2004; Sivakumar et al., 2005 cited in Gornall et al., 2010). An open question is how susceptible food crop production might be to increased rainfall variability? Several studies have been carried out on specific crops in different parts of the world to reveal the situation on ground. For example, according to Wheeler and Osbourne (2013) between 1960 and 2009, rice yields declined significantly as a result of low rainfall. Consideration of the observed relationship between yield and climate suggests that the significant reduction in rainfall may have contributed to the reduction in rice yield. Similarly, recent analysis by Asha et al. (2012) in India also concluded that the yields of sorghum, maize, pigeon pea, groundnut, wheat and onion have decreased by up to 43.03, 14.09, 28.23, 34.09, 48.68 and 29.56 kilograms per hectare respectively. The decrease in the crops yield, according to sampled farmers is attributed to the reduction of rainfall. Irrespective of the afore-stated studies, Cabas et al. (2010) are of the view that, with prolonged rainfall, some crops are likely to exhibit reduced yields while others will show improved yields. A case in point is a research carried out in Argentina which showed that during the last decades of the twentieth century, increases in

the yield of summer crops were caused primarily by increases in precipitation (Magrin et al., 2005). However, it is important to note that, minor changes in rainfall pattern during stages of crop production threaten crop productivity particularly if the rains fail to arrive during the crucial growing stage of the crops (Mowa and Lambi, 2006). Generally, at aggregated level as well as at the plot level, rainfall variability is a primary cause of inter annual yield variability (Thornton et al., 2014).

Rainfall variability is becoming a worrisome phenomenon especially in less developed countries such as Nigeria where most farmers depend on rainfall and where there are little or no adaptive strategies in place to mitigate the negative effects of this climatic variation. Though there have been awareness on climate change to farmers but those of them in the rural communities are yet to come to terms with the concept of rainfall variability. Some farmers in Imo State which is the focus of this study believe that long hours of sunshine, late onset of rains, long period of dryness, flooding and low crop yields are the result of end time according to Okorie et al. (2019). It simply implies that more efforts are required to create awareness for rural farmers on the current event of rainfall variability and educate them on the best adaptive and mitigation processes to savage the effects of this variation in rainfall on food crop yields.

Furthermore, Okorie et al. (2019) suggests that food crises currently in the state of Imo can be partly attributed to changing climate among other contributing factors. From the result of their study, farmers in Imo state also attributed low crop yields to irregular trend or pattern of rainfall. However, the result of their study indicated a very weak relationship between crop yields and rainfall variability in Owerri. In the same vein, Iliyasu et al. (2019) also studied the effects of rainfall variability on cassava yields in Owerri North. Their findings shows that 54% of variation in cassava yields can be explained by variations in rainfall, maximum and minimum temperature acting together. Meanwhile, this study is only interested on the contribution of rainfall variation to variations in the yields of cassava, yam and maize. Similarly, Akagha et al. (2021) investigated the effects of rainfall variation on cassava yields in Owerri West local government area of Imo state and reported a slight increase in cassava yields and also a weak positive correlation (relationship) between the two variables. Also, long period of no rain regarded as late onset (dry spell) followed by intense rain can cause flooding, which could encourage fungi and pest attacks on leaves, roots and tuber crops (Tandzi & Mutengwe, 2020).

Materials and Methods

The Study Area

Imo state derives its name from the Imo River. The state lies within latitudes 4°45'N and 7°15'N and longitudes 6°50'E and 7°25'E. Imo State has boundaries with Abia in the East, Anambra State in the north with Rivers State in the South. The state covers an area of 5100km². The capital is Owerri which is the largest city in Imo State (Imo State government,

2011). Figure 1 shows the place of Imo State in Nigeria while Fig 2 shows the various Local Government Areas in the state.

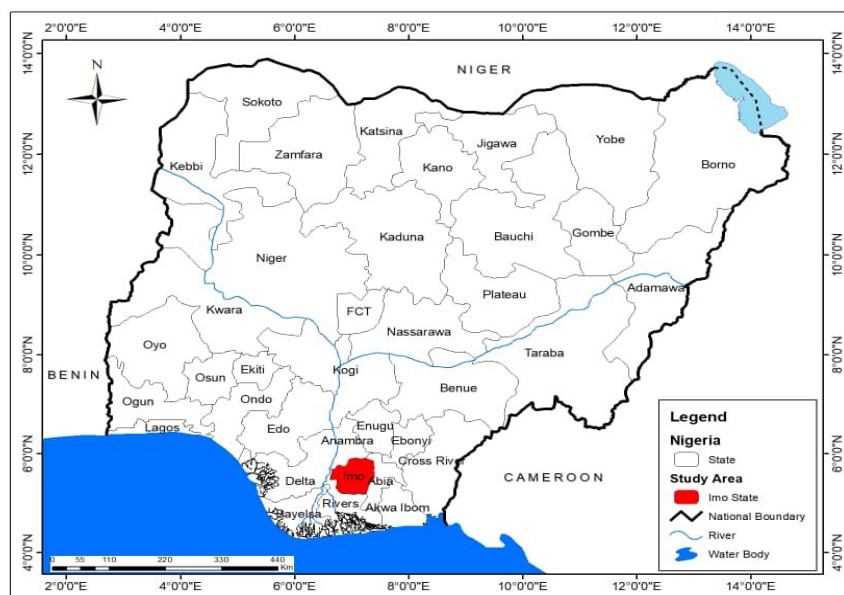


Figure 1: Nigeria Showing Imo state

Source: Imo State Ministry of Lands and Survey, 2023

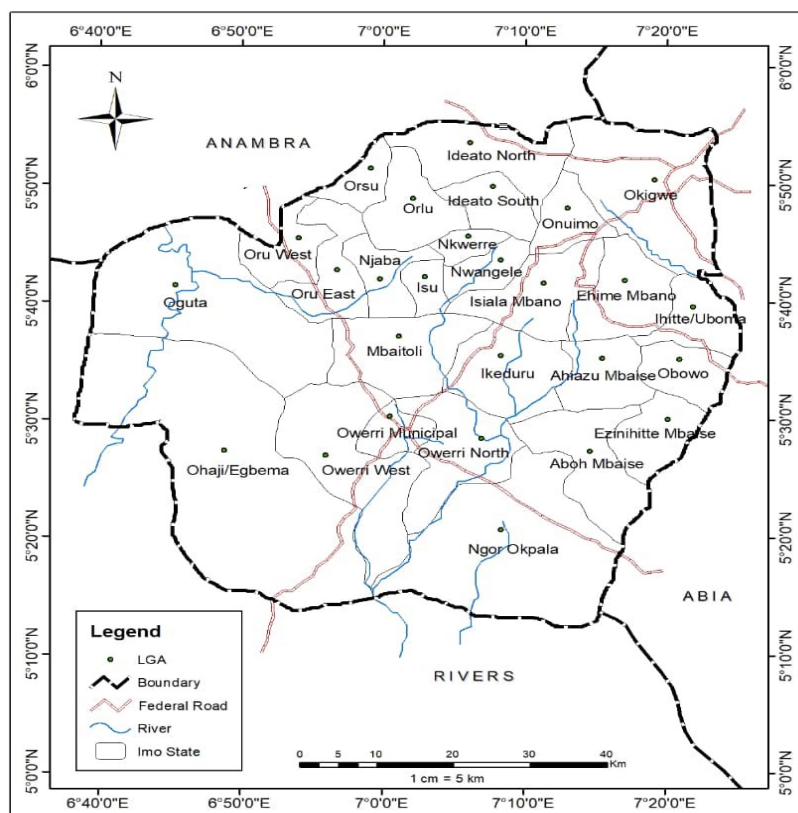


Figure 2: Imo State showing the 27 local government areas.

Source: Imo State Ministry of Lands and Survey, 2023

The climate of Imo State is equatorial. Rainfall distribution is bimodal, with peaks in July and September and a two-week break in August. There are two main climate regimes: a dry season and a wet season. Generally, the rainy season begins in April and lasts till October or early November. From March to May, there are violent storms which can destroy crops and houses (Okorie et al., 2012). Rainfall is often at its maximum at night and during the early morning hours. Annual rainfall ranges from 1500 to 2200mm. However, variations occur in rainfall amount from year to year. Temperatures are high and similar all over the state. The hottest months are from February to April, with the mean annual temperatures above 20°C. The mean daily maximum air temperatures range from 28°C to 35°C, while the mean daily minimum air temperature ranges from 19°C to 24°C. The minimum and maximum temperatures are 22.5°C and 31.9°C respectively while the daily sunshine rate is about 4.4h. The influence of the harmattan lasts for about nine weeks (i.e. from late December to late February). Imo State has a high humidity, an average annual relative humidity of 75% and it is highest in the rainy season when it rises to about 90%. The rate of evaporation and evapo-transpiration are 3.0mm/day and 136mm/month respectively (Chukwuocha and Dozie, 2011).

Research Design

This study adopted the quantitative research approach which involves descriptive and correlational data analysis (Creswell, 2012; Shraddha et al., 2013; Pandey & Pandey, 2015). This approach was used to determine the effects of variation in rainfall on the yields of cassava, yam and maize with the aid of regression analysis. Furthermore, correlational approach was also adopted to test the nature of relationship between the variables. Here, Pearson Product Moment Correlation model was used. Also, descriptive method was used to describe the characteristics of data, their averages, percentages and trends. Correlational and descriptive methods provided a clear picture of the data characteristics, trends and relationships as in a real life situation. The sampling technique used was the purposive sampling method which allowed the researcher choose crops based on the purpose of the research and because they are the most staple food crops in the study area. This technique helped to eliminate bias and increased validity and reliability of the data collected. The study used secondary data collected from Nigerian Meteorological Agency (NiMET) and Agricultural Development Program (ADP) in Imo State. The meteorological data of rainfall were collected purposively due to the importance of moisture to the growth and development of the crops. The results were presented in tables, graphs and charts.

Methods of Data Collection

Data on rainfall and crop yields were collected for each of the three agricultural zones of the state namely; Orlu, Okigwe and Owerri zones for a period of thirty (30) years beginning from 1987 to 2016. The researcher collected data based on the goal and objectives of the study in order to maintain the scope of the study. The 30 year period was chosen due to availability of data from NiMET. The rainfall data were collected as average rainfall amount in millimeter (mm) for every month within the years of this investigation while data on crop yields were collected as total annual crop yield in metric tonnes (mt) for each year.

Methods of Data Analysis

For the analyses, rainfall variability was analysed using Analysis of Variance (ANOVA). The relationship between rainfall variation, and crop yield in the study area was analysed using the Pearson's Product Moment Correlation Coefficient. The Coefficient of determination was used to ascertain the percentage contribution of rainfall variation to crop yield which also shows how an increase in one variable (rainfall) can be traced to another (crop yield). This method was also used by Yamusa et al. (2015) to assess the relationship between crop yield and dry spell in North West Nigeria. Furthermore, to determine the effect of rainfall variability on crop yields, the regression analysis was employed. This statistical analysis was also used by Okorie et al. (2019) to achieve the same objective.

Data Access and Ethics

The two data sets used in this study are available at NiMET and ADP offices in Imo State. However, given that rainfall data and crop yield data are obtained from a public domain, the study received an ethical exemption from the Imo State University research ethics center.

Results and Discussion

The annual rainfall totals of the three zones with their respective means were presented on table1. The result on the table clearly shows how rainfall varied in time and space, year to year across the agricultural zones and the state at large.

Table 1: Annual Rainfall Totals(mm) for Imo State from 1987-2016

Year	Orlu Agric Zone	Okigwe Agric Zone	Owerri Agric Zone	State Mean
1987	1824.4	1761.0	1958.6	1848.0
1988	1693.3	1635.4	1975.8	1768.1
1989	2005.8	1943.2	2073.6	2007.5
1990	2019.2	2000.0	2031.5	2016.9
1991	2732.7	2692.9	2860.7	2762.1
1992	2160.8	2650.6	2155.7	2322.3
1993	1654.4	1657.8	1727.6	1679.9
1994	1805.1	1831.5	1918.9	1851.8
1995	1907.7	1913.2	2177.9	1999.6
1996	1837.7	1882.5	1961.1	1893.9
1997	1857.8	1939.3	2211.7	2002.9
1998	1868.0	1860.1	1961.7	1896.6
1999	2121.0	2113.2	2173.8	2136.0
2000	1924.3	1971.5	2142.2	2012.6
2001	2415.0	2554.5	2680.4	2549.9
2002	2185.6	2169.1	2283.1	2212.6
2003	2046.7	1936.2	2168.9	2050.6
2004	2049.4	1964.6	2265.3	2093.1
2005	1929.4	1820.4	2252.7	1999.1
2006	2062.6	1895.0	2350.3	2102.6
2007	1895.4	1738.9	2115.3	1916.5
2008	1835.9	1677.0	1938.4	1817.1
2009	2151.3	2138.8	2138.4	2142.8
2010	1740.1	1729.0	2203.1	1890.7
2011	2982.2	2390.6	3162.6	2845.1
2012	2345.6	1937.5	2363.2	2215.4
2013	2009.9	2090.7	2135.4	2078.6
2014	1762.3	1936.4	1935.2	1878.3
2015	1851.8	1793.0	1977.6	1874.2

Year	Orlu Agric Zone	Okigwe Agric Zone	Owerri Agric Zone	State Mean
2016	1987.9	1854.3	2353.2	2065.1
	60663.3	59478.2	65653.9	2064.4

Source: Nimet, Imo State, 2023

The result on table1 shows that Orlu zone had about fourteen (14) years with over 2000mm of rainfall while Okigwe had nine years (9), and Owerri zone had fifteen (15). However, the mean annual rainfall for the state indicates that Imo State received its highest rainfalls in 2011. Therefore, 1993 was the driest year during these 30years while 2011 was the wettest as shown on figure1. At the end of the period of this investigation, the state recorded an average rainfall of 2064.4mm.

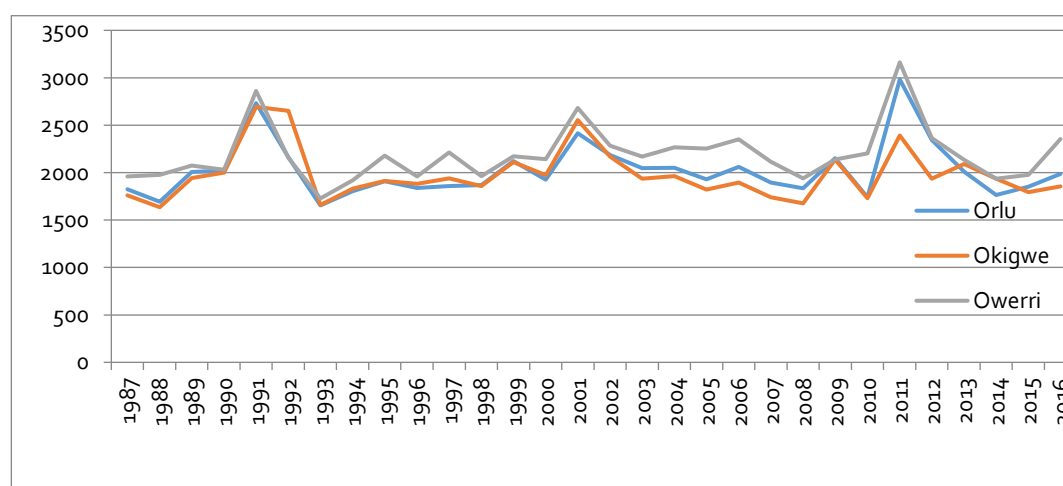


Figure 1: Mean Annual Rainfall for Orlu, Okigwe and Owerri Zones between 1987-2016

Time Series of Mean Annual Rainfall of Imo State Between 1987-2016

From table 2, it was observed that rainfall pattern was irregular, thus the trend had no definite pattern. For example, from the first year being 1987, mean annual rainfall amount was 1848.6mm and in the following year being 1988, the amount of rainfall decreased by 80.5mm. However, 1994 and 1995 saw increase in rains by 171.9 and 147.8mm respectively while 1996 recorded a decrease of 105.7mm.

Starting from the second decade, there was an increase in rain by 109mm, then decreased in the next year (1998) by 106.3mm and increased again by 239.4mm in 1999 while the year 2000 recorded a lower amount of 2012.6mm indicating another downward trend (a decrease of 123.4mm). This downward trend was maintained as rainfall amount decreased again to 1874.2mm in the year 2015 and finally increased by 190.9mm to 2065.5mm in 2016 seen on figure 2.

Table 2: Time series of Mean Annual Rainfall of Imo State between 1987-2016

Year	Rainfall (mm)	Variation
1987	1848.0	
1988	1768.1	-80.5
1989	2007.5	239.4
1990	2016.9	9.4
1991	2762.1	745.2
1992	2322.3	-439.8
1993	1679.9	-643
1994	1851.8	171.9
1995	1999.6	147.8
1996	1893.9	-105.7
1997	2002.9	109
1998	1896.6	-106.3
1999	2136.0	239.4
2000	2012.6	-123.4
2001	2549.9	537.3
2002	2212.6	-337.3
2003	2050.6	-119.5
2004	2093.1	42.5
2005	1999.1	-94
2006	2102.6	103.5
2007	1916.5	-186.1
2008	1817.1	-99.4
2009	2142.8	325.7
2010	1890.7	-252.1
2011	2845.1	954.4
2012	2215.4	-630
2013	2078.6	-136.8
2014	1878.3	-200
2015	1874.2	-4.1
2016	2065.1	190.9

Source: Author's statistical analysis, 2023

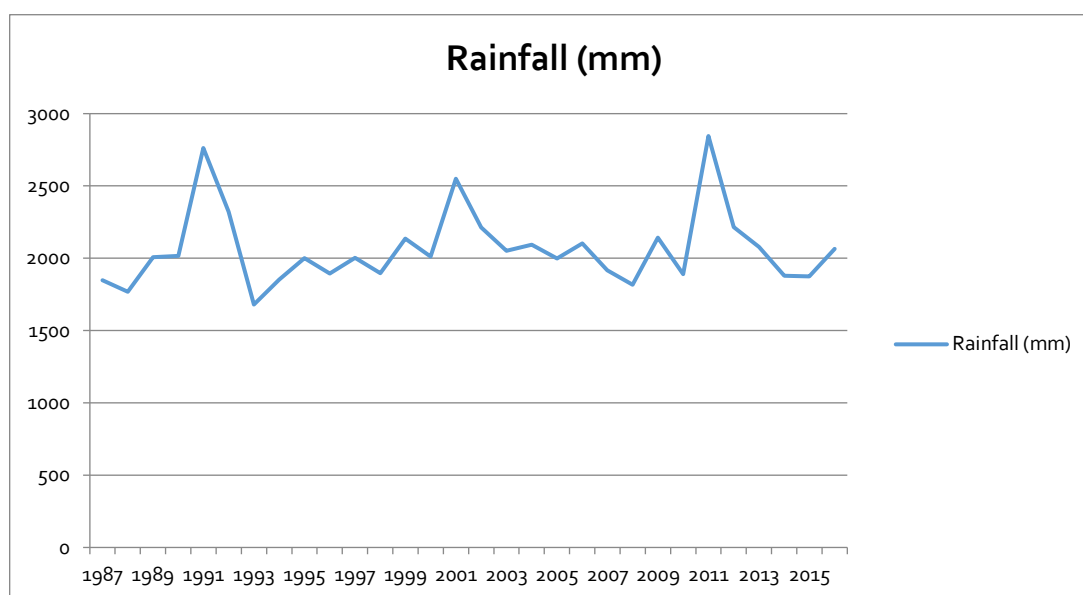


Figure 2 : Annual Rainfall Trend of Imo State between 1987-2016

Total Annual Crop Yield for Imo State

The result on table 3 shows the total annual crop yield for cassava, yam and maize produced by each of the three agricultural zones of Imo State between 1987-2016.

Table 3: Total Annual Crop Yield (mt/ha) in Imo State by Agricultural zones from 1987-2016

Year	Orlu Agric Zone	Okigwe Agric Zone	Owerri Agric Zone	State Total
1987	11.63	9.51	14.89	36.03
1988	11.38	9.51	14.84	35.73
1989	11.23	8.18	14.75	34.46
1990	11.21	8.49	14.67	34.47
1991	11.07	8.28	14.45	33.80
1992	10.98	8.40	14.66	33.84
1993	11.08	8.56	15.10	34.74
1994	11.63	9.51	14.89	36.03
1995	11.11	8.56	14.68	34.35
1996	13.34	8.99	14.59	36.92
1997	11.74	7.13	12.61	31.48
1998	12.32	8.65	14.24	35.21
1999	10.92	8.22	14.63	33.77
2000	10.17	6.99	15.49	32.65
2001	12.12	7.44	13.65	33.21
2002	11.52	7.06	14.81	33.46
2003	7.90	8.56	13.88	30.34
2004	10.68	8.66	14.11	33.45
2005	10.70	6.83	14.30	31.83

Year	Orlu Agric Zone	Okigwe Agric Zone	Owerri Agric Zone	State Total
2006	12.97	6.14	14.67	33.78
2007	12.35	5.91	14.35	32.61
2008	11.23	8.20	12.02	31.45
2009	13.11	8.53	13.04	34.68
2010	13.22	5.94	13.65	32.81
2011	10.75	8.50	11.30	30.55
2012	12.33	8.76	-	21.09
2013	12.47	9.22	15.98	37.67
2014	12.40	9.34	16.08	37.82
2015	12.65	8.98	15.32	36.95
2016	11.62	8.95	15.36	35.93
	347.83	246.0	417.01	1010.84

Source: Imo Agricultural Development Programme, Owerri, 2023

According to the result presented on table 3, Imo State produced a total of 1010.84metric tonnes of cassava, yam and maize from the year 1987 to 2016. Out of this total yield, Owerri zone contributed the highest figure of 417.01 metric tonnes, followed by Orlu zone with 347.83metric tonnes while Okigwe zone with 246.0 metric tonnes was the least for the period studied (see figure 3). Moreso, the State recorded its highest yield of 37.82 metric tonnes in the year 2013 while its lowest yield (21.09 metric tonnes) was recorded in 2012. In the same vein, Owerri zone recorded its highest amount of crop yield being 16.08 metric tonnes in 2014 while its lowest was 0 in 2012 which could be directly attributed to the great flood of 2012 that submerged most of the farming communities in the zone. Again, Okigwe zone recorded its highest crop yield of 9.51 metric tonnes in 1987, 1988 and 1994 with its lowest amount 5.91 metric tonnes coming in 2007. Orlu zone recorded its highest yield as 13.34 metric tonnes in 1996 and its lowest as 7.90 metric tonnes in 2003. The result on table 3 indicates that crop yield varied from year to year which may be attributed to so many factors such as rainfall variations and other climatic and non-climatic factors. Figure 3 shows that crop yield varied along-side rainfall for 30years.

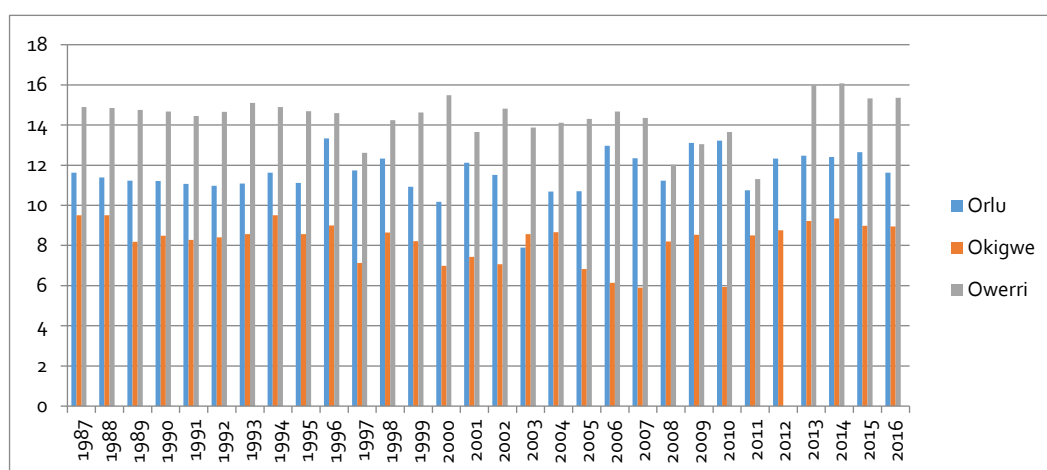


Figure 3: Crop yield by Agricultural zones

Rainfall Variation In Imo State between 1987-2016

As an integral part of the objectives of this study, variation in rainfall during this period under investigation was ascertained using Statistical Package for Social Sciences (SPSS) to conduct standard deviation, and Analysis of Variance (ANOVA) on rainfall. The result of the analysis is shown on table 4a, 4b, and 4c.

In order to address this objective, the null hypothesis stating “there is no significant variation in rainfall pattern in imo State between the year 1987 to 2016” was tested. It could be recalled that on table 2 and 3, there were noticeable variations in rainfall amounts, duration, onset and cessations. However, the main point is to ascertain if this variation is significant, hence the use of ANOVA to analyse the rainfall characteristics of the state for 30years.

One-way Analysis of Variance (ANOVA) was conducted to determine if annual rainfall totals (mean scores of rainfalls between 1987 and 2016) were significantly different in the three zones (Orlu, Okigwe and Owerri zones) of Imo State. On that note, mean scores of rainfalls between 1987 and 2016 were classified into three groups: Orlu zone (n = 30), Okigwe zone (n = 30), Owerri zone (n = 30). Consequently, the following hypothesis was tested under ANOVA:

HO: There is no significant statistical variation in annual rainfall totals for the three zones in Imo State.

HA: There is a significant statistical variation in annual rainfall totals for the three zones in Imo State.

In terms of homogeneity of variances for mean annual rainfall values, Levene's test of homogeneity of variances in Table 4a was insignificant ($p = .992$), an indication that there was no homogeneity of variances of the mean annual rainfall values. Accordingly, results of ANOVA conducted for mean annual rainfall values between 1987 and 2016 which are shown in Table 4b, indicate that mean annual rainfall values were statistically and significantly different between the three zones in Imo State, $F(2, 87) = 4.409, p < .05$. Therefore, we reject

the null hypothesis and accept the alternate hypothesis, which states that there is a significant statistical variation in annual rainfall totals for the three zones in Imo State.

Table 4a. Levene's Test of Homogeneity of Variances for mean annual rainfall values between 1987 and 2016

Levene Statistic	df1	df2	p - value
.008	2	87	.992

Table 4b. ANOVA Results for variation in 1987-2016 Mean Annual rainfall values for the three zones in Imo State

	Sum of Squares	df	Mean Square	F	p - value
Between Groups	716109.121	2	35805.560	4.409	.015
Within Groups	7065283.715	87	81210.158		
Total	7781392.836	89			

Figure 4 is a graph of 1987-2016 mean annual rainfall values against the three zones of Imo State. The lack of monotonicity in the graph is a clear indication that there were significant differences in the mean values analyzed. The significant difference determined by the ANOVA test is clearly attributable to the variability and lack of monotonicity in the graph.

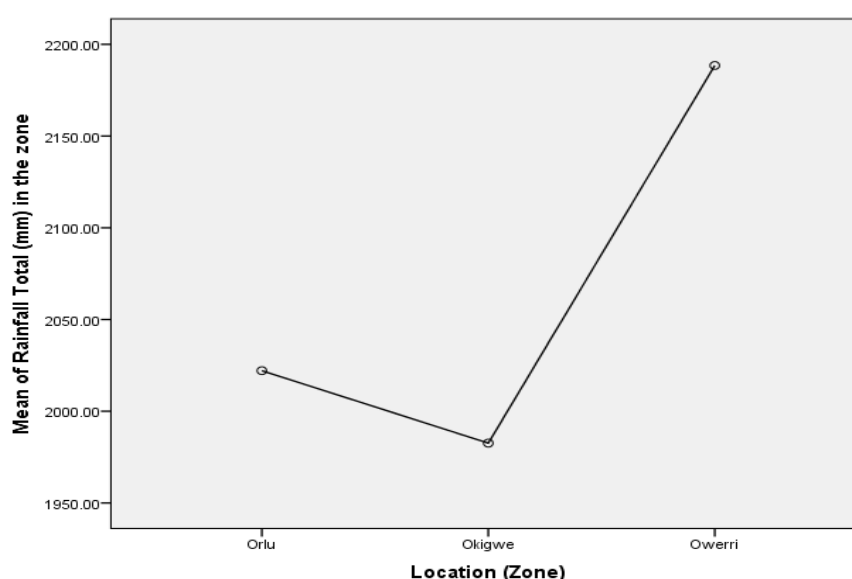


Figure 4. Graph of mean annual rainfall values and the three zonal locations

Due to the statistically significant difference identified in the differences in mean annual rainfall values for the three agricultural zones in Imo State, a post-Hoc analysis using Tukey's Honest Significant Difference (HSD) test was carried out. The essence of carrying out the post-Hoc was to exactly determine where the significant difference (from the

ANOVA) in mean annual rainfall lies. On that note, Tukey's HSD results are shown in Table 4c.

Table 4c. Post-Hoc Test on the variation in 1987-2016 mean annual rainfall values using Tukey's HSD

(I) Location	(J) Location	Mean Difference (I-J)	Std. Error	p-value	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Orlu	Okigwe	39.50333	73.57996	.853	-135.9466	214.9532
Owerri	-166.35333	73.57996	.067	-.341.8032	9.0966	
Okigwe	Orlu	-39.50333	73.57996	.853	-214.9532	135.9466
Owerri	-205.85667*	73.57996	.017*	-.381.3066	-30.4068	
Owerri	Orlu	166.35333	73.57996	.067	-9.0966	341.8032
Okigwe	205.85667*	73.57996	.017*	30.4068	381.3066	

*The mean difference is significant at the 0.05 level.

Tukey's HSD post-Hoc test results indicate that there was a 205.85 (95% CI, -.04 to .28) difference in mean rainfall in Okigwe zone to Owerri zone, which was statistically significant ($p = .017$). However, there was a 39.50 (95% CI, -135.94 to 214.95) difference in mean annual rainfall in Orlu zone to Okigwe, which was statistically non-significant ($p = .853$). Also, there was a 166.35 (95% CI, -341.80 to 9.09) difference in mean annual rainfall in Orlu zone to Owerri zone, which was statistically non-significant ($p = .067$). On that note, the post-Hoc test on ANOVA of mean annual rainfall from 1987 to 2016 indicates that the significant difference in mean annual rainfall in Imo State lies between Okigwe zone and Owerri zone.

Relationship Between Rainfall Variation and Crop Yield

This research tends to examine the relationship between rainfall variation and food crop yield (cassava, yam and maize) in Imo state between 1987-2016. The researcher employed the Pearson's Product Moment Correlation Coefficient (r) to determine the significance of the relationship between rainfall variation and the yield of the selected crops. To do this statistical analysis, the independent variable (rainfall) was correlated in each case against the dependent variables (cassava, yam, and maize) for a period of 30 years.

Hypothesis:

Non-significant relationship between rainfall and crop yields.

Preliminary analyses showed the relationships to be linear with all the variables normally distributed, and there were no significant outliers. On that note, correlation coefficients and their significance for the four variables considered are shown in Table 5. The results indicate that there was no statistically significant correlation between rainfall and the yield of the three crops considered in the analysis. Therefore, we do not reject the null hypothesis and posit that there is a non-significant relationship between rainfall and crop yield. However, correlations between the yields of the three crops and rainfall were all negative, with maize

yield and rainfall having the highest correlation coefficient, $r(28) = -.359$, $p = .052$. Furthermore, results from Table 5 indicate that all the crop yields were positively correlated with each other, cassava yield and yam yield having the only significant positive correlation coefficient, $r(28) = .730$, $p = <.001$.

Table 5. Pearson's product-moment correlation coefficients and p-values annual rainfall and crop yields from 1987 to 2016

	Annual Rainfall	Cassava yield	Yam yield	Maize yield
Annual Rainfall	1			
Cassava Yield	-.217 (.249)	1		
Yam Yield	-.286 (.125)	.730* (.000)	1	
Maize Yield	-.359 (.052)	.150 (.429)	.311 (.095)	1

*Correlation is significant at the 0.05 level

The Effect of Rainfall Variation on Crop Yield in Imo State Between 1987 – 2016.

The fulcrum of this study is to ascertain if rainfall variation during this period of 30 years had any significant effect on crop yields. To achieve this objective, the study posited a null hypothesis stating that rainfall variation has no significant effect on crop yield in Imo State between the year 1987 to 2016. In other to test this hypothesis, the study employed the use of regression model with the aid of SPSS software.

Linear Regression

In order to understand the relationship between rainfall and the yield (metric tons per hectare) of the three selected crops (Cassava, Yam, and Maize), linear regression was applied. The essence of this was to determine if rainfall can predict the yield of any or all the three crops. Considering the independent variable to be "X" and the dependent variable to be "Y", a simple linear regression model is thus:

$$Y = \beta_0 + \beta_1 X + \epsilon.$$

Where: β_0 is the intercept (also known as the intercept or constant),

β_1 is the slope parameter (also known as the slope coefficient), and

ϵ represents the errors.

From the coefficient results in Table 6, annual rainfall variation in Imo State between 1987 and 2016 leads to -.001 (95% CI, -.004 to .001) metric tons per hectare decrease in cassava yield. Table 6 which also shows the overall model fitness for cassava yield and rainfall, indicates that rainfall did not statistically predict cassava yield, $F(1,28) = 1.384$, $p = .249$, accounting for 4.7% of the variation in cassava yield between 1987 and 2016 ($R^2 = .047$) which was adjusted to 1.3% (Adjusted $R^2 = .013$), an insignificant size effect.

Table 6. Coefficients for annual rainfall prediction of Total Cassava Yield in Imo State between 1987 and 2016

Model	Unstandardized Coefficients		Standardized Coefficients	t	p-value	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
Model Constant	19.216	2.504		7.674	.000	14.087	24.345
Model predictor: Annual Rainfall of Imo State between 1987 and 2016	-.001	.001	-.217	-1.176	.249	-.004	.001

Model fitness: $F(1, 28) = 1.384$, $p = .249$, $R = .217$, $R^2 = .047$, Adjusted $R^2 = .013$, Standard Error = 1.72147, Durbin-Watson = 1.864

Figure 5 which shows a graph for predicting cassava yield based on rainfall, indicates that the regression equation predicted cassava yield = $-0.001 + 19.216 \times (\text{annual rainfall})$.

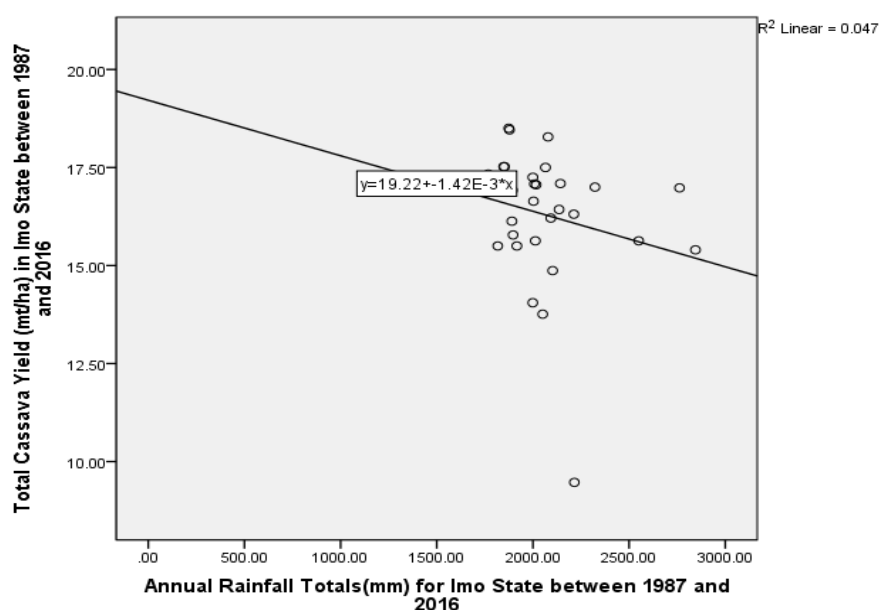


Figure 5. Graph for prediction of cassava yield based on annual rainfall in Imo State between 1987 and 2016

From the coefficient results in Table 7, annual rainfall variation in Imo State between 1987 and 2016 leads to -0.002 (95% CI, -0.004 to 0.000) metric tons per hectare decrease in yam yield. Table 7 which also shows the overall model fitness for yam yield and rainfall which indicates that rainfall did not statistically predict yam yield, $F(1, 28) = 2.496$, $p = .125$, accounting for 8.2% of the variation in yam yield between 1987 and 2016 ($R^2 = .082$) which was adjusted to 4.9% (Adjusted $R^2 = .049$), an insignificant size effect.

Table 7: Coefficients for annual rainfall prediction of Total Yam Yield in Imo State between 1987 and 2016

	Unstandardized Coefficients		Standardized Coefficients	T	p-value	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
Model Constant	18.559	2.098		8.845	.000	14.261	22.857
Model predictor: Annual Rainfall for Imo State between 1987 and 2016	-.002	.001	-.286	-1.580	.125	-.004	.000

Model fitness: $F(1, 28) = 2.496$, $p = .125$, $R = .286$, $R^2 = .082$, Adjusted $R^2 = .049$, Standard Error = 1.44262, Durbin-Watson = 1.864

Figure 6 which shows a graph for predicting yam yield based on rainfall, indicates that the regression equation predicted yam yield = $-0.002 + 18.559 \times (\text{annual rainfall})$.

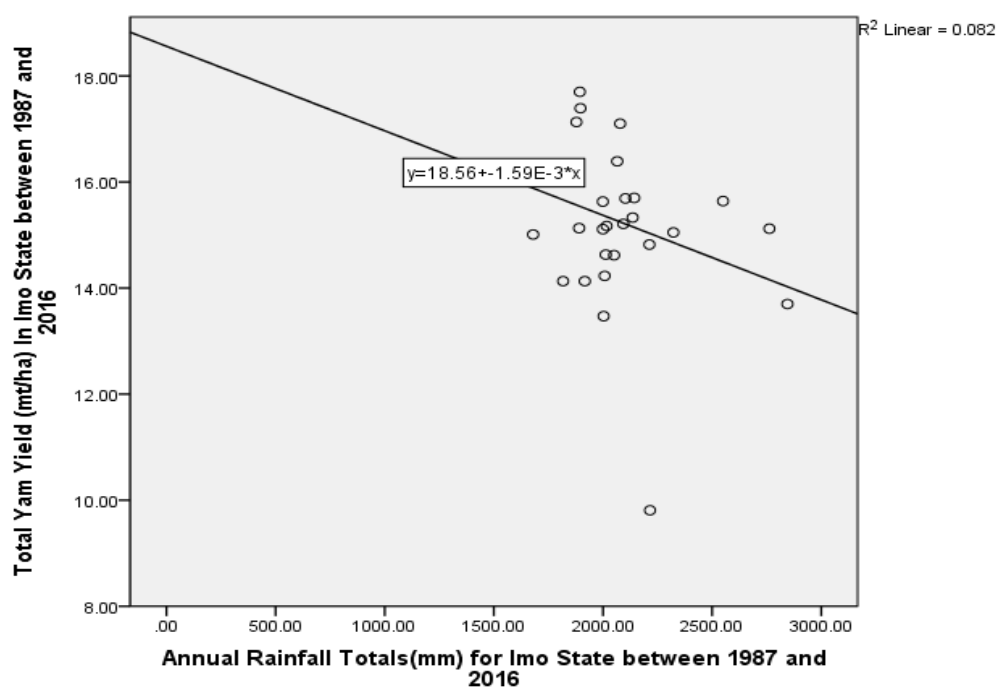


Figure 6 Graph for prediction of yam yield based on annual rainfall in Imo State between 1987 and 2016

From the coefficient results in Table 8, annual rainfall variation in Imo State between 1987 and 2016 leads to -.001 (95% CI, -.001 to .000) metric tons per hectare decrease in maize yield, between 1987 and 2016. Table 8 which also shows the overall model fitness for maize

yield and rainfall, indicates that rainfall statistically predicts maize yield, $F(1,28) = 4.134$, $p = .042$, accounting for 12.9% of the variation in maize yield between 1987 and 2016 ($R^2 = .129$) which was adjusted to 9.8% (Adjusted $R^2 = .098$), a low to medium size effect. Therefore, the null hypothesis was rejected.

Table 8 Coefficients for annual rainfall prediction of Total Maize Yield (mt/ha) In Imo State

	Unstandardized Coefficients		Standardized Coefficients	t	p-value	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
Model Constant	3.189	.551		5.787	.000	2.060	4.318
Model predictor: Annual Rainfall for Imo State between 1987 and 2016	-.001	.000	-.359	-2.033	.042	-.001	.000

Model fitness: $F(1, 28) = 4.134$, $p = .042$, $R = .359$, $R^2 = .129$, Adjusted $R^2 = .098$, Standard Error = .37884, Durbin-Watson = 1.957

Figure 7 which shows a graph for predicting maize yield based on rainfall, indicates that the regression equation predicted maize yield = $-0.001 + 3.189 \times (\text{annual rainfall})$.

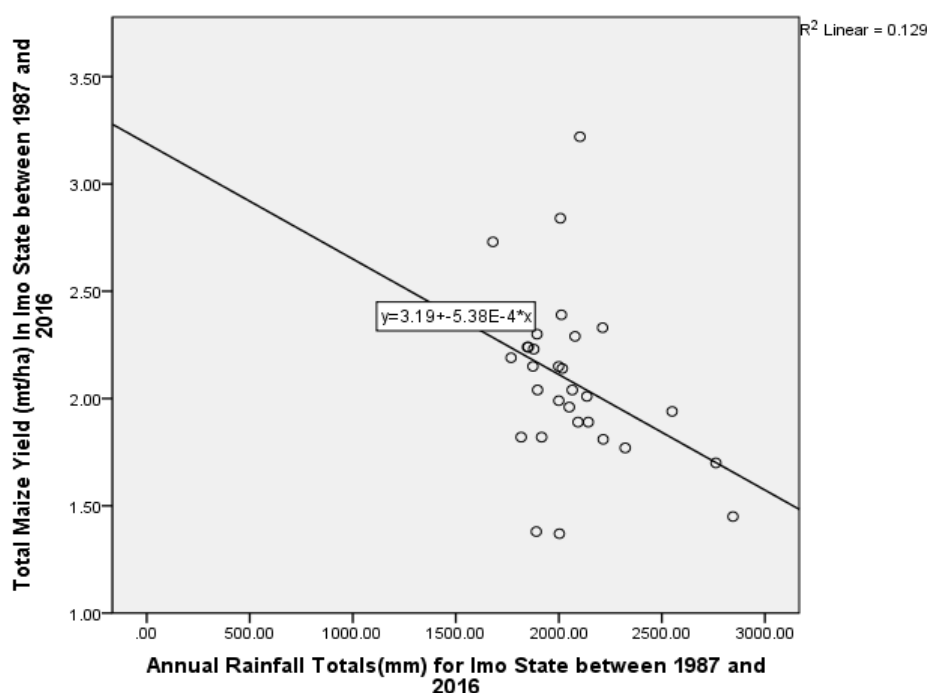


Figure 7: Graph for prediction of maize yield based on annual rainfall in Imo State between 1987 and 2016.

Discussion of Findings

The result of this study shows that during the period of this study, Imo state experienced erratic and irregular rainfall going by the range of difference between the highest annual

rainfall and the lowest (El-Tantawi et al., 2021; Kilavi et al., 2018; Yamusa et al., 2015; Podleśny & Podleśna, 2011). It is expected that during the year 1993, tuber crops such as cassava and yam may experience low yields due to low rainfall but this was not so with a reported 34.00 metric tonnes per hectare. This is in contrast to the findings of Tandzi and Mutengwa (2020). Rainfall is needed for soil moisture and when it becomes erratic, the yields of tuber crops may be impacted. However, this is not the case in the study area as rainfall could only predict an insignificant amount of cassava and yam yields. On the contrary, 2011 with the highest annual rainfall recorded one of the lowest total annual crop yield of 30.55 metric tonnes per hectare for the 30year period. This could be as a result of flooding of farmlands, and consequent rotting of tuber and root crops as suggested by Olemeforo (2012). In spite of the variations in crop yield, the state recorded a total of 1010.84 metric tonnes of cassava, yam and maize from 1987-2016. At the end of the investigation, it was observed that Imo state had its highest crop yield in 2014 (37.82 metric tonnes) with its lowest coming in 2012 (21.09 metric tonnes), the year when most of the farmlands in the state were submerged by water especially in Owerri and Orlu zones (Davey et al., 2019; Sok et al., 2021). The result also show that Owerri zone contributed 41.25% of the total crop yield in the state while Orlu and Okigwe contributed 34.41% and 24.34% respectively.

Furthermore, the result of the analyses on the significance of the variation in rainfall shows that rainfall actually varied in the three agricultural zones (El-Tantawi et al., 2021). The result of the one way analysis of variance indicates that there was no homogeneity of variance in the means of the annual rainfall values, therefore there were significant variation in rainfall justifying the rejection of the null hypothesis. This result implies that rainfall varied significantly from 1987 to 2016 which has the capacity to alter crop yields. Similarly, the Post-hoc test shows that there was 205.85mm difference in mean annual rainfall between Okigwe and Owerri zones, 39.50mm difference between Orlu and Okigwe while there was 166.35mm of difference in mean annual rainfall between Orlu and Owerri zones. The result indicates that the most significant difference in mean annual rainfall is between Okigwe and Owerri zone. This result is in consonant with the findings of Okorie (2015) in his study of rainfall variability in Imo state between 1980-2009 which reported shifts and changes in rainfall pattern from one part of the state to another.

In addition, the study conducted a correlation analysis to determine the form of relationship between rainfall and crop yields. The result shows a weak relationship between rainfall and the yields of the three crops. This implies that there is no significant relationship between rainfall variation and crop yields in Imo state from 1987 to 2016, therefore the null hypothesis was accepted. This result is in contrast to the findings of Iliyasu et al. (2019) report of 54% increase in cassava yields as a result of rainfall variation. This could be due to the limitation of this study to only rainfall without considering other factors like temperature, soil moisture, and farm practices.

Finally, the result of the regression analysis shows that between 1987 to 2016, annual rainfall variation led to -0.001 decrease in cassava yield which strongly suggests that rainfall variation during this period did not statistically predict cassava yield. Further, rainfall variation accounted for only 4.7% of variation in cassava yield for the 30 years period. This signifies that rainfall variation had insignificant effect on the yield of cassava in Imo state from 1987-2016. Moreover, the result indicates that rainfall variation led to -0.002 decrease in yam yield (negative) which means that rainfall did not statistically predict yam yield. In addition, rainfall variation accounted for 8.2% of variation in cassava yield which signifies an insignificant effect on yam yield. This probably suggests that cassava and yam require almost the same natural condition for growth and development. Moreover, the result shows that rainfall variation led to -0.001 decrease in maize yield. However, the overall model fitness for rainfall and maize yield indicates that rainfall statistically predicts maize yield accounting for 12.9% of variation in the yield of maize between the year 1987 to 2016. Similarly Okorie et al.(2019) reported 0.03% variation in cassava production and 1.19% variation in maize production whereas Akagha et al. (2021) reported a little increase in cassava yield but a weak relationship between rainfall variation and crop yields. This result implies that rainfall variation had little effect on the yields of the selected crops which strongly suggest that other factors such as soil conditions (fertility), temperature, method of farming may be the major contributors to variation in crop yields in the study area (Akagha et al., 2021).

Conclusion

Rainfall variability is considered as an offshoot of climate change in recent times. Climate change has presented to the world so many atmospheric phenomena with rainfall variability inclusive. This variability includes changes in rainfall pattern, seasonality, duration and amount. Some of these changes are observed monthly, while others are observed annually in form of late onset, late cessation, early onset, and early cessation of rainfalls. The rainfall pattern some times are very irregular and erratic in nature as observed during this study.

This investigation was on the effect of the change in rainfall pattern on the yield of cassava, yam and maize in Imo state. The study was carried out using meteorological data (rainfall) from Nimet and quantity of crop yield obtained from Imo ADP between the year 1987-2016 (being 30 years). These set of data were subjected to statistical analysis such as ANOVA, correlation coefficient analysis and the regression analysis. From the results obtained, it was found out that rainfall in Imo State has varied over 1987-2016. Though, there is rainfall variation, but its relationship with crop yield was too weak, hence the effect on the quantity of crop yield is too minimal and not significant except for maize.

Although rainfall is vital for plant growth, but its variation acting as a lone factor, has a very minimal influence on food crop yields in Imo State during these years. However, from the study of other researchers, rainfall with other climatic factors exert significant influence on crop yield. Therefore this study concludes thus; other factors such as temperature,

humidity, soil moisture, farm management practices may have caused the wide spread variation in crop yields and should be investigated. Limiting this study to 30 years due to available data could have played a part in the type of result obtained. Therefore, the study suggests an increase in the period of study to about five decades to have better understanding of the rainfall crop yield nexus. Weather information should be disseminated to farmers both in the rural and urban areas. This information will equip them with proper timing, adaptation and mitigation strategies for agricultural practices in the state. Nimet should make daily weather forecast available to the farmers in the state to enable them programme their farming calendar on seasonal basis.

Conflict of Interest

The author declares no conflict of interest.

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