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ARTICLE

Impacts of Climate Variability on Sustainable Agriculture in Imo State, Nigeria

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ABSTRACT

Rainfall and Temperature are important factors in agriculture especially in Nigeria where rain-fed agriculture is practiced extensively and agriculture contributes to food security and provides employment for urban and rural dwellers. Therefore, climate variability represents a major danger to agriculture by modifying the rainfall and temperature pattern, thereby resulting to a big peril in the sustainability of agriculture. This is the reason all countries of the world are concerned about the effects of climate variability on agriculture. This work therefore, examined the impact of climate variability on rainfall and temperature in Imo State, South Eastern Nigeria. The rainfall and temperature data were gotten from Nigerian Meteorological Agency (NIMET) for a period of 30 years which was analyzed by using descriptive statistics, decadal distribution, trend graph anomalies and 5 year moving average. The analysis showed increasing trend pattern in yearly maximum, minimum temperature and decrease in annual rainfall, The third order polynomial trend shows a decrease in the anomaly of annual mean rainfall (y = -0.0002x4) and a persistent increase in the mean temperature anomaly especially in the second decade (1996-2007).The discoveries show that there is a notable variability in temperature and rainfall pattern which revealed an increase in temperature and decrease in annual rainfall. This calls for serious attention as people in this part of Nigeria critically depend on rainfall for agricultural practices. It is recommended that government should support the agricultural sector by providing mechanized farming systems such as irrigation and drilling of water borehole in farm sites for agriculture, especially for the rural farmers and create awareness to the farmers on recent trends in climate issues to achieve sustainable agriculture.

1. Introduction

Agriculture is an important sector in the economy of a nation. In recent times, so many countries in the world are focusing and investing in agriculture because of its importance by encouraging and granting loans to youth to be involved in agricultural production and of course in Nigeria several private enterprises', NGOs are partnering with the

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government to bring a revolution in agriculture. If agricultural production increases it will reduce unemployment by creating jobs, increase the availability of food, improve the economy of the nation and agricultural sustainability can be achieved. The greater part of the individuals in Imo State engages in agricultural activities and trading of agricultural product. Imo state is significantly known for crops such as, cassava, maize, cocoyam and vegetables additionally the intercropping system of agriculture is practiced with yam, cassava, cocoyam, and maize as the major arable crops, while oil palm, banana/plantain and citrus are the major permanent crops. The inhabitants of Imo state are predominantly farmers producing food crops such as cassava, yam, and maize [1]. The impact of climate variability on agricultural production has been connected to global warming and the resulting change in climate is projected to aggravate a decrease in agricultural production in light of the fact that global warming might incite unfavorable climatic condition for agricultural practice [2]. Therefore, sustainable agricultural production system is significant and it includes a decent way to deal with food production that will guarantee consistent increase in productivity without undermining the chances of generations to come. This will include production practices that guarantee environmental conservation and insignificant aggravation to the natural eco support system because agriculture is imperative to the economy and people of a nation. Some countries of the sub-Saharan Africa are highly vulnerable to the impacts of climate change this is because agricultural production in most sub-Saharan African countries is dependent on weather and climate, unlike some developed countries that practice mechanized agriculture where several agricultural activities are supported mechanically [2-3].

2. Literature Appraisal

Climate variability has impacted a lot of sectors in the economy of a nation including agriculture. Its impact on agriculture is visible especially among those nations that depend on climate variables (such as temperature, rainfall for growth and agricultural sustainability. This is the major reason variability on rainfall and temperature is liable to affect agriculture. Variability is an inevitable aspect of climate and variability spans across many time and space scales and it includes occurrences such as El Niño/La Niña, droughts, multi-year, multi-decade, and multi-century changes or fluctuations in precipitation and temperature patterns. Climate in a thin perspective is defined as the "average weather condition of a place", or better defined, as the statistical measurement of the mean and variability of important number of specific variables (such as precipitation, temperature or wind) over a timeframe going from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. Climate from a more extensive perspective is the state, including a statistical description of the climate system [4].

Climate Variability is defined as the variations in the mean state and other statistics of the climate on all temporal and spatial scales, far off individual weather events. The expression "Climate Variability" is frequently used to denote deviations of climatic statistics over a specified timeframe (e.g. a month, season or year) when contrasted with long-term statistics for a similar period of calendar and is computed by these deviations, which are typically called anomalies [4]. In another definition Variability might happen due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external factors: external variability [5]. Climate originates from the reallocation and changes in the measure of energy around the world, which lead to changes in pressure, temperature and other climate variables. The amount and movement of energy result from a huge number of factors, including those external to earth's framework (for example the measure of radiation produced from the sun) and internal ((for example volcanic action obstructing solar radiation from reaching the earth's surface). In this way, the weather at any given place and time will be impacted by various climate variability factors [5].

Agriculture is susceptible to harsh weather conditions which can be as a result of climate variability. This can influence agricultural production and sustainability and ultimately affects the economy of a nation. In the tropical environment where rain-fed agriculture, is very important for agricultural production, the onset and cessation of the rains determine the traditional practices of farmers, for example, land readiness, crop assortment choice and planting to harvesting [6]. New techniques have been initiated in some nations of the world to ameliorate the variable nature of climate variable such as irrigation, improved seedlings, crop varieties and other agronomic management procedures to help support the system towards a better food production. Notwithstanding massive advancements in agricultural production technology, weather and climate actually assume an outstanding part in affecting agricultural production across the world especially in Africa [7-9]. Specifically, under rain-fed conditions the production capability of a crop relies upon the climatic conditions of an area [10]. Rainfall is very important to agriculture especially in the tropics because of the relatively high temperature all through the year with a persistently high rate of evaporation [11]. Rainfall not just

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decides the length of the growing season of any location [12] but on the other hand is imperative to planting, germination and the prosperity of yield development [13]. It has also been noticed that growth processes resulting to yield in agricultural crops can be slowed down due to irregular nature of rainfall even in wet season [14].

In Imo state several research works has been carried out on climate variability /climate Change impact on agricultural and findings shows that variability in rainfall and temperature has great impact on agricultural production. Rainfall variability in Imo state contributes to the high variations recorded in the productivity and productivity efficiency of the major food crops such as maize and cassava and a decline in crop yield was also observed. [15-16]. It is a practice in the study area that the onset of the rains harmonizes with the time of land preparation, planting and germination in the agricultural schedule, especially under rain-fed agricultural practice. The resultant moisture deficiency emerging from the declining trends of rainfall could be aggravated by the high temperatures [17], which are typically connected with the onset of the wet season in addition to high evapo-transpiration resulting essentially from high temperatures. This is further convoluted with the regular drought incidences which characterize the planting season in the forest belt [13] where the south eastern region of Nigeria is found. The increasing mean maximum temperature in the last two decade after 1990's gave a steady variation in rainfall, length of humid period, length of growing period and the onsets of rainfall with noticeable effect, development and growth of crop yield [18-19]. Climate variability therefore give rise to one of the greatest hindrance to the accomplishment of food security and poverty reduction in the region as both are interrelated processes. It was assumed in this study that the fluctuations in rainfall and temperature regimes are the basic climatic parameters responsible for climate variability over Imo State of Nigeria, as this is the situation in different parts of the world. It is therefore on this premise that this paper focused on climate variability on growing season rainfall and temperature, its implication towards sustainable agriculture in Imo State Nigeria

3. Research Methods

3.1 Overview of the Study Area

Imo State is located between latitude 4°45′N and 7°15′N and longitude 6°50′E and 7°25′E, with an area of about 5100 km2. It lies within the humid tropics and is generally characterized by a high surface air temperature regime year-round. Mean minimum temperature is 23.5°C, mean maximum temperature is 32.3 ºC and mean temperature is 27.9 ºC [20]. Two seasons, wet and dry, are observed in the year, the rainy season which begin in April to October, while the dry season ranges from November to March. Figure 1 shows the location of Imo State.

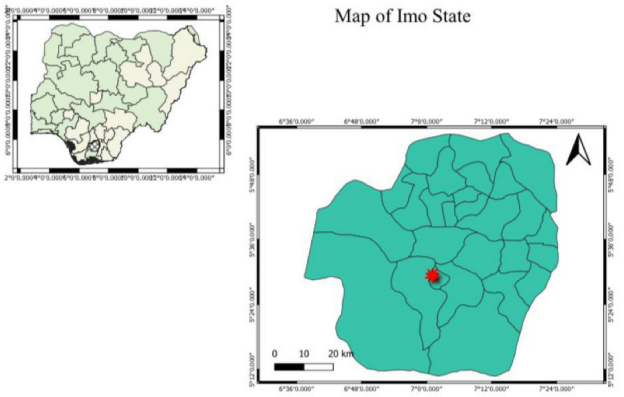

Figure 1. Map of Imo State

3.2 Research Database

The secondary data were the monthly rainfall and temperature data of Imo State in South-Eastern Nigeria for a period of 30 years (1987-2016) which was collected from the Federal Meteorological Services Oshodi in Lagos State. The monthly rainfall and temperature data collected were further converted to annual values. From these values we derived the monthly, annual, decadal rainfall and temperature averages, anomalies, trends, 5 year moving average obtained were used to determine the variability of rainfall and temperature in the study area

4. Results and Discussion

4.1 The Distribution of Rainfall and Temperature

Rainfall and Temperature distribution in Imo State, shows the basic properties of all the variables in this study and the mean monthly and annual rainfall totals, mean temperature, minimum, maximum temperature for the period of study (1987-2016).

(1) Mean monthly rainfall totals

The mean monthly rainfall (Table 1) shows an overall change in the pattern of monthly rainfall, the month of August has the highest rainfall with mean of 377mm. While, the month with the lowest rainfall is December with mean of 17.44mm this shows an overall change in the monthly rainfall pattern.

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Table 1. Mean monthly rainfall in Imo State (1987-2016)

Months	Rainfall (mm)
January	20.97
February	43.01
March	91.73
April	174.06
May	262.06
June	318.38
July	373.29
August	377.21
September	373.94
October	259.09
November	54.64
December	17.44

(2) The Mean Monthly Maximum, Minimum and Mean Temperature in Imo State

Maximum Temperature:

The mean monthly maximum temperature (Table 2) shows that, the month with the highest maximum temperature in Imo State is February with mean of 35ºC while the month with the lowest maximum temperature is 29ºC in July. The results reveal that the peak of maximum temperature is during the dry season in February.

Minimum Temperature:

The mean monthly minimum temperature (Table 2) shows that, the mean monthly highest minimum temperature is march with 24ºC while the month with the lowest value of minimum temperature is January with mean as 23ºC.

Mean Temperature:

The mean monthly temperature results (Table 2) indicates that mean monthly temperature was highest in February with 29.7 ºC while the lowest mean Temperature falls in the month of July with the mean as 26.25 ºC

The Minimum, Maximum and Mean Temperature is highest in February and March which is the peak of the dry season.

4.1.2 The Annual Rainfall Pattern

(1) Annual Rainfall

The total annual rainfall across the state of study for the period of study (1987-2016) (Table 3) shows that, the years with the most highest rainfall totals in Imo State is 2009 and 1997 with 2916.7mm and 2891.4mm, respectively, while the years with the lowest rainfall totals is 1998 and 2004 with rainfall totals as 1641.5mm and 1777.8mm.This show a decrease in rainfall.

Table 3. Annual rainfall totals in Imo State (1987-2016)

	Year	Rainfall Totals (mm)
Annual highest rainfall	1997	2891.4mm
	2009	2916.7mm
Annual lowest rainfall	1998	1641.5mm
	2004	1777.8mm

(2) The mean annual maximum, minimum & mean temperature

The mean maximum annual temperature (Table 4) shows that, the year with the highest Maximum Temperature in Imo State is 2010 with Temperature as 33 ºC while the year with the lowest maximum temperature is 1991 with temperature as 32 ºC.

Table 2. Mean monthly temperature in Imo State from 1987-2016 in ºC

States	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Lowest	Highest
Max	33.91	35.16	34.30	33.41	32.34	30.97	29.42	29.50	30.42	31.29	33.02	29.42 (July)	35.16 (Feb)
Min	22.83	24.32	24.48	24.32	23.85	23.45	23.07	23.03	23.21	23.23	23.70	22.83 (Jan)	24.48 (Mar)
Mean	28.37	29.74	29.39	28.87	28.09	27.21	26.25	26.27	26.81	27.26	28.36	26.25 (July)	29.74 (Feb)

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The mean annual minimum temperature (Table 4) shows that, the year with the highest minimum Temperature is 2010 with Temperature as 25 ºC while the year with the lowest minimum temperature is 1994 with temperature as 22.ºC.

The year with the highest mean temperature (Table 4) is 2010 with mean temperature as 28.9 ºC while the year with the lowest mean temperature is 1994 with mean temperature as 27 ºC. The results show that Temperature is on the increase in Imo State.

Table 4. Annual highest & lowest maximum temperature in Imo State (1987-2016) in ºC

	Highest /year	Lowest /year
Max Temperature	33.21 / (2010)	31.6 / (1991)
Min Temperature	24.6 / (2010)	22.3/ (1994)
Mean Temperature	28.9 / (2010)	27.0 / (1994)

4.1.3 The Decadal Distribution of Rainfall Totals, Minimum, Maximum, and Mean Temperature (ºC)

The decadal distribution of rainfall totals, maximum, minimum and mean temperature (ºC) is represented as follows: The first decade is from 1987 to 1996, second decade is1997 to 2006 and the third decade are from 2007 to 2016.

(1) Decadal distribution of Rainfall totals

The results in table 5 shows that Imo State has the highest rainfall totals in the first decade (1987-1986) with 2526.2, while the decade with the lowest rainfall is the third (2007-2016) with rainfall totals as 2278.7 which is a decrease in rainfall. This shows that the state is experiencing a decrease in rainfall.

(2) Decadal distribution of maximum, minimum and mean temperature (ºC)

The results in table 5 shows the decade with the highest maximum temperature is the third decade (2007-2016) with maximum temperature as 32.5 ºC while the decade with the lowest minimum temperature is the first decade (1987-1986) with 23.1 ºC. The third decade mean temperature is highest with mean temperature as 28 ºC while the lowest mean temperature is the first decade experienced the as 27.5. ºC this result shows that there is an increase in Temperature, if temperature continues to increase; it shows that the environment is becoming warmer and this is not favorable for agriculture

Table 5. The decadal distribution of rainfall (mm), maximum, minimum and mean temperature (ºC) (1987-2016.)

	Rainfall (mm)	Minimum Temperature (ºC)	Maximum Temperature (ºC)	Mean Temperature (ºC)
1987-1996	2526.2	23.07	31.94	27.5
1997-2006	2292.6	23.84	32.45	28.1
2007-2016	2278.7	23.69	32.47	28.1

4.2 Annual Rainfall Trend for the Period of Study (1987-2016).

The Rainfall Trend in Imo state (Figure 1) shows that rainfall fluctuated greatly, but with a downward trend of -1.1255x value per year which is a decrease in rainfall

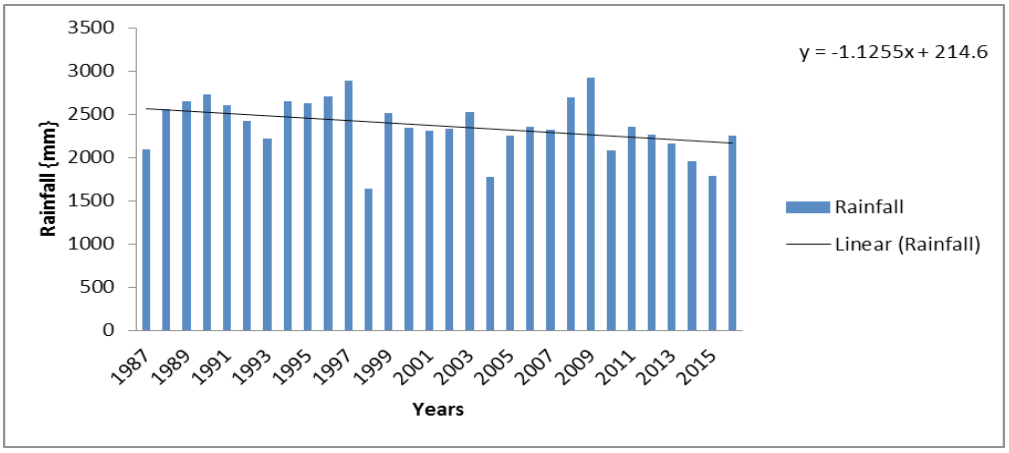

Figure 1. The annual rainfall trend in Imo State (1987-2016)

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observed during the period of Study, with highest rainfall in 2009 with 243.06mm values and the lowest rainfall was in 1998, with 136.79mm values. This shows that rainfall is reducing in Imo State and if it persists, it will not favor agricultural production because the farmers in the state depend on rainfall for their agricultural practice.

4.3 The Maximum, Minimum and Mean Temperature Annual Trend Analysis Result for the Period of Study (1987-2016).

The maximum temperature (Figure 2) fluctuated greatly and it shows an increasing trend. The highest temperature is in 2010 and the value is 33 ºC while lowest temperature is 1991 and the value is 31. ºC, also 2011 with the value of 32 ºC. The trend line shows that it is positive the value of 0.0215x value per year, which is show an increase in maximum temperature, while the minimum temperature (Figure 3) shows that it fluctuated greatly too, with a positive trend, and highest temperature in 2010 and the value is 25 ºC while the lowest value is 22 ºC in 1994 and 23ºC in 2011. There is a positive trend of 0.0243x value per year; this shows an increase in minimum temperature.

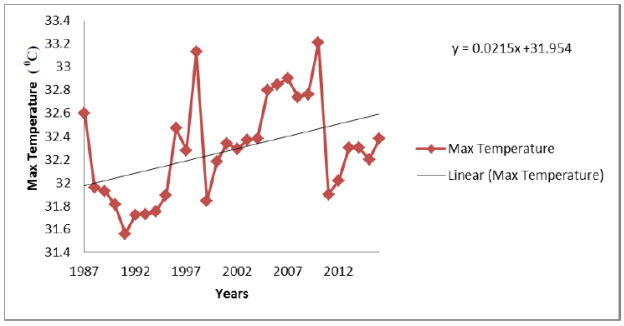

Figure 2. The annual trend of maximum temperature of Imo State (1987-2016)

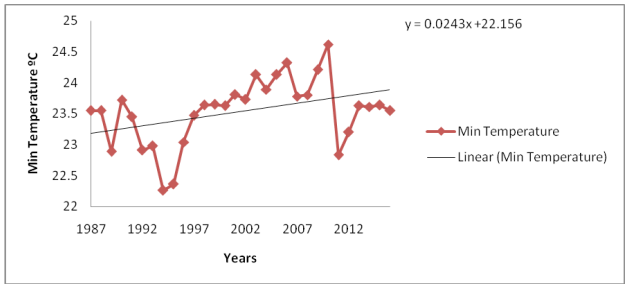

Figure 3. The annual trend of minimum temperature of Imo State (1987-2016)

The trend analysis for mean temperature (Figure 4) shows a great fluctuation with a positive trend and highest temperature in 2010 and has the value of 29 ºC and lowest temperature is in 2011 and has the value of 26ºC. This is a positive trend with a trend of 0.0151x value per year. This shows an increase in mean temperature and co-incidentally, minimum, maximum and mean temperature was highest in 2010. This marked 2010 as the hottest year for the study period. This result of minimum, maximum and mean temperature shows variability and increase in temperature, if this temperature continues to increase in the state, it's likely to affect agricultural production and drought incidence in the state.

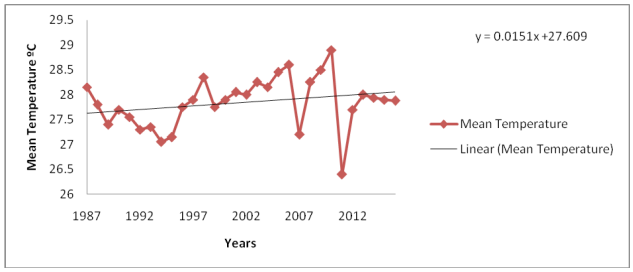

Figure 4. The annual mean temperature trend of Imo State (1987-2016)

4.4 A 5 Year Moving Averages for Rainfall and Temperature in Imo State (1987-2016)

The linear regression trend and 5-year moving average line to the annual rainfall and temperature observation data. The idea of moving averages depends on the possibility that any enormous sporadic parts of time series at any point in time will have a less significant impact on the trend. So, moving average brings a smothering effect on the graph to smooth out short-term fluctuations and feature longer-term cycles or trends. The moving averages for rainfall (Figure 5) shows an increasing trend before 2009 and after 2009 a decreasing trend started and 2008 has the highest peak in rainfall while 2015 has the lowest point while the moving average for temperature (Figure 6) shows that temperature was lowest in 1996 and 2000 temperature started increasing. The attributes of rainfall and temperature changes during those years might be due to countless reasons particularly climate change/ climate variability and when a place experiences a decrease in rainfall and increase in temperature especially in a rain fed environment, most likely would greatly affect agricultural production.

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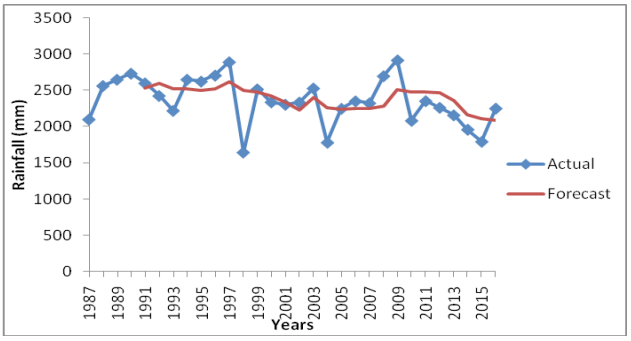

Figure 5. A 5-year moving averages for Rainfall in Imo State (1987-2016)

Figure 6. A 5- year moving averages for mean temperature in Imo State (1987-2016)

4.5 The Trend Anomalies of Mean Annual Temperature and Rainfall in Imo State from 1987-2016

(1)Temperature

The annual mean temperature trend anomalies from 1987 to 2016 in Imo State is shown in figure 7. The third order polynomial result depicts a declining trend from 1988 and in 1996 the trend started to increase and towards 2014 it experienced a decline. The Mean temperature was below the mean between 1987 and 1999 (13 years) and above the mean for 14 years (2000-2013) before declining in 2014, this shows variability in Temperature and it is increasing, and a gradual decrease from 2014 which indicate a decrease in temperature. The third order polynomial result shows temperature variability and warming climate which shows that annual mean temperature anomalies have been increasing with time but with a recovery tendency. The discoveries in this work are identified with studies done in Nigeria, which have also demonstrated various times of warming and cooling stages over the last century [21-23].

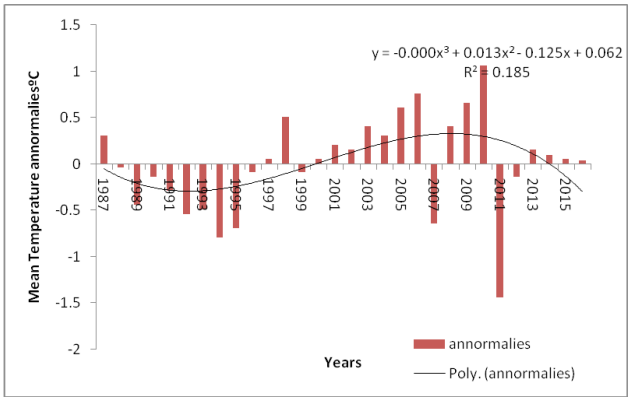

Figure 7. The anomalies of mean annual temperature over Imo State (1987-2016)

(2)Rainfall

The third order polynomial showed indicated that the annual rainfall anomalies in Imo State (figure 8) experienced a decreasing trend. There was an increase in rainfall 1987-1997 and a decrease from 1998 till 2016 with slight variability in the trend. The state might be at the risk of facing a drought if rainfall continues to decrease. This is accordance with the report of [24] that greater rainfall variability in semi-arid Africa will upset endeavors to improve food security combat malnourishment in Nigeria [21] and in Imo state a decrease in rainfall is observed, so the need for alternative source of water to support agricultural such as irrigation farming is very important for agricultural sustainability.

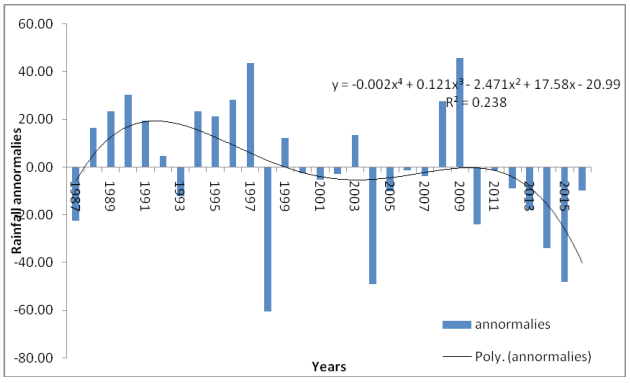

Figure 8. The anomalies of mean annual rainfall over Imo State (1987-2016)

5. Conclusion

Sustainable agriculture is very important to preserve life and growth of the economy of a nation. Therefore, government at all level should set up adaptive measure in guaranteeing that there is increase in agricultural production in the county as it is clear that Imo state experiences

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climate variability which could adversely impact on agricultural activities and consequently affect food supply, as this is a global phenomenon that is also influencing other nations of the world. However, the study observed that there has been annual fluctuation in temperature and rainfall, increase in temperature trend and decrease in rainfall trend across the years of study and in the last three decades studied, there are visible changes and variability in the pattern of temperature and rainfall in the state. The evidence seen on steady increase in surface temperature and decrease in rainfall is not favorable for agriculture especially in the state where agriculture is majorly dependent on rain-fed as its major source of water, this calls for serious concern. Therefore alternative sources of water supply and mechanized agricultural practice such as irrigation farming, drilling of bole hole in farm sites should be introduced in the state and weather reports should be published seasonally to support the agricultural sector in planning to reducing the risk of food shortage and policies on climate and sustainable agriculture should be implemented in the state.

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