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RESEARCH ARTICLE

ASSESSMENT OF RAINFALL VARIABILITY FOR SUSTAINABLE AGRICULTURE IN OWERRI, IMO STATE, NIGERIA

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ABSTRACT

Rainfall variability and agricultural sustainability have been of major concern to the Climatologists, Agriculturists and farmers in general. The net potential effect of severe changes in rainfall pattern is the disruption in crop production leading to food insecurity, joblessness and poverty. As a major concern to increase food production, this study seeks to assess the rainfall variability in Owerri City with a view to enhancing agricultural sustainability. The study used rainfall data (1981-2018) from Nigerian Meteorological Agency. Correlation and Regression techniques were employed for analysis. The result shows that there is no significant relationship between the number of rainy days and annual amount of rainfall. Also, there is no significant relationship between the length of rainy season and number of rainy days in the study area. The study also shows four years forecast of rainfall in the study area. The result shows an evidence and upsurge of low agricultural produce, food insecurity and hunger in the nearest future, and therefore recommends some sustainable agricultural practices that can boost yield, good health and healthy environment and reduce the effect of climate change.

KEYWORDS

Rainfall Variability, Onset and Cessation, Climate Change, Sustainable Agriculture, Food Security.

1. INTRODUCTION

Rainfall is arguably the meteorological phenomenon that has the greatest impact on human activity (Vogel, 2000). It is an indispensable resource and a major natural occurrence in food production especially in the developing world (Kyei-Mensah et al., 2019). However, it remains one of the most elusive weather parameters to predict. Rainfall is a renewable resource, highly variable in space and time and subject to depletion or enhancement due to both natural and anthropogenic causes (Abaje, 2010). Because of its occurrence, mostly in the low-pressure zone of the earth, and its proximity to the Atlantic Ocean in the south, Nigeria experiences heavy rainfall especially in the southern part of the country (Ewona and Udo, 2008; Ewona et al., 2013).

Climate is, with particular reference to rainfall, known to be changing worldwide and there has been growing concern as to the direction and effects of these changes on settlement and infrastructures (Chaponniere and Smokhtin, 2006). Climate change has caused a shift in the seasonal variation of weather and climate, and thus a shift in the normal timing and length of wet and dry season and increase in the seasonal fluctuation of the water bodies (Odjugo, 2010). The possibility for rapid and irreversible changes in the climate system exists, although there is a large degree of uncertainty about the mechanisms involved, also about the likelihood or time-scales of such transitions (Osang et al., 2013; Obi et al., 2013; Ushie et al., 2014). Rainfall variability refers to the changes in the mean state and other statistics (such as standard deviation, the occurrence of extremes, etc.) of rainfall on all spatial and temporal scales beyond that of individual precipitation events (Odjugo, 2010).

Climate change and variability has increased the threat of food insecurity among many farming communities (Nicholson, 2001; Akudugu et al., 2012; Antwi-Agyei et al., 2013). For state whose economy largely depends on efficient and productive rainfed agriculture, rainfall patterns and trends are often quoted as one of the major causes of several socio-economic problems like food insecurity in the state, and the frequency of extreme rainfall events is projected to increase almost everywhere (Ekwe et al., 2014). Rainfall extremes are projected to increase more than the mean and intensity of precipitation events (Udo, 2002; Intergovernmental Panel on Climate Change, 2007; Osang, et al., 2013, Ushie et al., 2014).

A studied the climate variability and crop production in Tanzania. They found that climate variability reduced yields by 4.2, 7.2 and 7.6% for maize, sorghum and rice, respectively (Rawhani et al., 2011). In their study, discovered that rainfed agriculture which is practiced in the central clay plains of Sudan is affected by high rainfall variability in time and space and between seasons (Yousif et al., 2018). They asserted that farmers in

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areas having high rainfall and extended growing season could grow suitable crops and varieties, and their appropriate management practices should be implemented. In areas of low rainfall and short growing seasons, farmers could grow crops of short maturing varieties. The impacts of rainfall variability on crop production within the Worobong Ecological Area of Fanteakwa District, Ghana, stated that rainfall variability is evident in the region and that the yields of crops have declined over the period (Kyei-Mensah et al., 2019).

Variations in rainfall patterns in Nigeria are greatly affecting the agricultural productivity. Farmers in the southern part of Nigeria begin cultivation at the beginning of the rainy season. They start planting their crops as the rains begin to fall in April (Okecha, 2003; Osang et al., 2013; Udoimuk et al., 2014; Obot et al., 2010). Late onset, early cessation, low quantity and poor quality of rain also affect crop yield, and these lead to food insecurity and economic downturn. In the event and occurrence of climate change and associated problems, there is need for agricultural sustainability. Agricultural sustainability is an agriculture which is able to continually provide food and other resources to a growing world population without compromising the ability for current or future generations to meet their needs (Velten et al., 2015).

Sustainable agriculture is an integrated system of plant and animal production practices having a site specific application that will, over the long term: (a) satisfy human food and fiber needs; (b) enhance environmental quality; (c) make efficient use of non-renewable resources and on-farm resources and integrate appropriate natural biological cycles and controls; (d) sustain the economic viability of farm operations; and (e) enhance the quality of life for farmers and society as a whole (U.S. Farm Bill, 1990). Reganold, Papendick, and Parr opined that for a farm to be sustainable, it must produce adequate amounts of high-quality food, protect its resources and be both environmentally safe and profitable (Reganold et al., 1990). Also, instead of depending on purchased materials such as fertilizers, a sustainable farm relies as much as possible on beneficial natural processes and renewable resources drawn from the farm itself. Sustainable agriculture comprises management procedures that work with natural processes to conserve all resources, minimize waste and environmental impact, prevent problems and promote agro-ecosystem resilience, self-regulation, evolution and sustained production for the nourishment and fulfillment of all (MacRae et al., 1989).

Today, concerns about sustainability centre on the need to develop agricultural technologies and practices that: (i) do not have adverse effects on the environment (partly because the environment is an important asset for farming), (ii) are accessible to and effective for farmers, and (iii) lead to both improvements in food productivity and have positive side effects on environmental goods and services. Sustainability in agricultural systems incorporates concepts of both resilience (the capacity of systems to buffer shocks and stresses) and persistence (the capacity of systems to continue over long periods) and addresses many wider economic, social and environmental outcomes (Pretty, 2008). Agricultural Systems high in sustainability can be taken as those that aim to make the best use of environmental goods and services while not damaging these assets (Pretty, 1998; Tilman et al., 2002; Swift et al., 2004; Tomich et al., 2004; Scherr and McNeely, 2008).

The idea of agricultural sustainability, though, does not mean ruling out any technologies or practices on ideological grounds. If a technology works to improve productivity for farmers and does not cause undue harm to the environment, then it is likely to have some sustainability benefits. Agricultural systems emphasizing these principles also tend to be multifunctional within landscapes and economies (Dobbs and Pretty, 2004). They jointly produce food and other goods for farmers and markets, but also contribute to a range of valued public goods, such as clean water, wildlife and habitats, carbon sequestration, flood protection, groundwater recharge, landscape amenity value and leisure/tourism. In this way, sustainability can be seen as both relative and case dependent and implies a balance between a range of agricultural and environmental goods and services (Pretty, 2008).

In view of the foregoing, the researchers, after looking at the food decline in the region and the persistent effect of climate change, deem it fit to carry out a research of this kind as the study would go a long way to expose and enlighten the farmers about the climate situation, so that they can be involved in the agricultural best practices that promote crop yield, environmentally friendly, and will eventually reduce hunger drastically.

2. Materials and Methods

2.1 The Study Area

Owerri City is located between latitudes 5°20'N and 5°35'N of the Equator and between longitudes 7°00'E and 7°10'E of the Greenwich Meridian. It broadly occupies an area of approximately 104 km^{2}. It is found in the southeastern Nigeria and comprises three Local Government Areas namely Owerri West, Owerri North and Owerri Municipal. The city serves as the principal administrative and socio-economic hub for both Owerri Metropolis and Imo State in Nigeria. Owerri City is a humid tropical urban settlement, and sedimentary basin of Southeastern Nigeria.

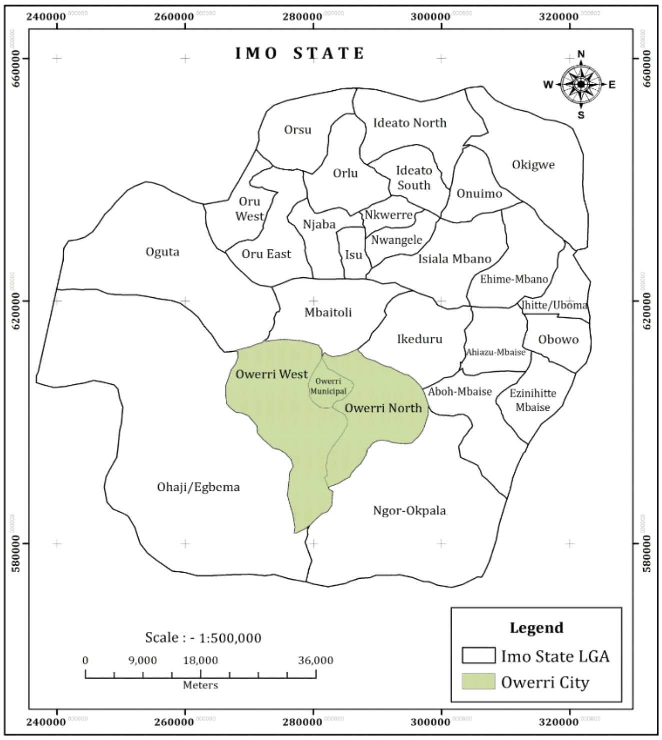

Figure 1: Map of Imo State showing Owerri City Area (Source: Researchers' work)

The geomorphology and geologic structure of Owerri City consists of two principal formations: the sedimentary sequence of the Benin formation (Miocene-Recent), and the underlying Ogwashi-Asaba formation (Oligocene) (Opara et al., 2012; Onwuadiochi et al., 2020). This formation consists of fine sand, medium sand, coarse sand to gravel, with clay and silt lenses (Opara and Okereafor, 2012). The terrain of Owerri is characterized by two types of landforms; highly undulating ridges and nearly flat or low topographical trend (Opara and Okereafor, 2012). The study area is within rainforest belt of Nigeria. It has two distinct seasons - rainy and dry seasons. The rainy season begins in April and ends in October while the dry season starts in November and ends in March (Uma and Egboka, 1986). However, a gradual shift in these periods has been observed, which is attributable to climatic change (Onwuadiochi et al., 2020).

The temperature, rainfall and humidity encourage a luxuriant plant growth (Onyeagocha et al., 2014). The city experiences a mean annual temperature of 27.5˚C which, throughout the year, owing to occurrence of torrential rains, hilly terrains, unregulated deforestation, related anthropogenic activities, and the rough characteristics of the urban physical surfaces, is prone to fluctuations (Mathew-Njoku and

Onweremadu, 2007). The mean annual relative humidity is 75 percent (Onyeagocha et al., 2014; Onwuadiochi et al., 2020). The study area is drained by the Oramiriukwu, Ogochia and some tributaries of Imo River (Opara et al., 2012). At the completion of the 1991 national census, the city population stood at 127,213 (National Bureau of Statistics, 1991). In 2006, the population attained 555,500 (National Bureau of Statistics, 2006).

2.2 Data Collection

The rainfall data needed for this study was obtained from the Nigerian Meteorological Agency (NIMET), for the period of 38 years (1981-2018). The study predominantly relied on secondary sources.

2.3 Data Analysis

The monthly or daily values of rainfall for each year were summed for the 38-year period. The data collected were analyzed with the aid of Minitab 18 and statistical package for social sciences (SPSS 23.0). Analytical techniques employed in achieving the research target include the correlation and regression techniques.

For the correlation analysis, the Pearson's method was employed due to the nature of data collected.

The formula runs thus:

$$r = \frac{Cov\,(M,N)}{\sqrt{(Var\,(M))(Var\,(N))}} = \frac{\sum_{i=1}^{T}[(M-\bar{M})(N-\bar{N})]}{\sqrt{\left[\sum_{i=1}^{T}(M-\bar{M})^2\right]\left[\sum_{i=1}^{T}(N-\bar{N})^2\right]}} \qquad (Eq.2)$$

Were,

r is the correlation coefficient,

$Cov\,(M,N) = \sum_{i=1}^{T}[(M-\bar{M})(N-\bar{N})]$ is the covariance of M and N series,

$Var\,(M) = \sum_{i=1}^{T}(M-\bar{M})^2$ is the variance of M series,

$Var\,(N) = \sum_{i=1}^{T}(N-\bar{N})^2$ is the variance of N series

T = Total number of observations,

$\bar{M}$ and $\bar{N}$ are mean values of series of M and N values,

M and N are variables of interest.

Attempt was made to determine the onset, cessation and duration of the rainy season in the study area for the period under investigation. This was based on method of where onset of rains in Nigeria is defined in terms of the time of receiving an accumulated amount of rainfall in excess of 51 mm (Walter, 1967). The cessation is the date after which no more than 51 mm of rain is expected. The duration between onset and cessation of rains represents the number of rainy days or length of rainy season. The method described in is an effective method for determining effective rainfall by growing season in the tropics (Walter, 1967). This method has been applied by to study seasonality in the Niger Delta belt of Nigeria (Adejuwon, 2012). The rainfall threshold value is defined thus: a day in which the rainfall amount is accumulated to 51 mm is regarded as a rainy day and designated onset, while the cessation of rains is the date after which less that 51 mm of rain is expected. This amount ensures sufficient moisture in the soil to maintain crop growth and gives a reasonable guarantee that planting would be successful if started two weeks later (Adejuwon, 2012). The onset, cessation and duration of rainfall were calculated for Owerri city using the Cumulative Index Analysis (Adejuwon, 2012; Walter, 1967).

3. Results and Discussion

Table 1: Annual Rainfall Totals (1981-2018)

Year	Rainfall(mm)
1981	2136.9
1982	2404.4
1983	1695
1984	2163.6
1985	2376.3
1986	2121.1
1987	2070
1988	2698.4
1989	2581.5
1990	2731.9
1991	2565.1
1992	2424.1
1993	2182.8
1994	2626.1
1995	2622.3
1996	2705.5
1997	2272.5
1998	1641.5
1999	2496.5
2000	2293.8
2001	2304.2
2002	2042.2
2003	1893.7
2004	1735.6
2005	2545.5
2006	2914.8
2007	2914.8
2008	2749
2009	2916.7
2010	2331.6
2011	2351.7
2012	2260.7
2013	2156.5
2014	1958.4
2015	2369.9
2016	1352.8
2017	1305.7
2018	1312
Total	86225.1
Mean(X)	2269.1
SD	59.7
C.V	2.63%

Source: Researchers' Computation

Matthew-Njoku and Onweremadu in 2007 stated that the total annual rainfall amount recorded in the city ranges between 2000mm and 3000mm. But following the trend, it is very conspicuous that there is drastic decline in recent times, especially in 2016 to 2017 and 2018 with total annual rainfall of 1352.8mm, 1305.7mm and 1312mm respectively. The annual rainfall in Owerri City varies from slightly over 1305.7 mm to more than 2900 mm for the 38 years period under study. The mean annual rainfall for the period is 2269.1 mm, while the standard deviation and coefficient of variation are 59.7 mm and 2.63% respectively.

3.1 Onset, Cessation and Rainfall Duration

It is evident that onset of rains was predominantly in the months of February and March followed by January with the number of years for the individual months under the 38 years period being 15,15 and 7 years respectively (Table 5). The cessation period was found to be predominantly November followed by October and December with the number of years for the individual months under the 38 years period being 22, 13 and 3 years, respectively (Table 5). Thus, rainfall starts in Owerri City around February/March and terminates in November/October.

Table 5: Annual Rainfall Onset, Cessation and Number of Rainy Days

S/N	YEAR	ONSET OF RAINFALL	CEASATION DATE OF RAINFALL	RANGE	NUMBER OF RAINY DAYS	LENGTH OF RAINY SEASON (MONTHS)
1	1981	25TH JAN	23RD OCT	25-296	271	9
2	1982	22ND JAN	7TH NOV	22-311	289	10
3	1983	20TH MAR	15TH NOV	79-319	240	8
4	1984	10TH MAR	28TH OCT	69-301	232	8
5	1985	27TH JAN	7TH NOV	27-311	284	10
6	1986	13TH JAN	25TH OCT	13-298	285	9
7	1987	14TH MAR	12TH NOV	73-316	243	8
8	1988	4TH MAR	11TH DEC	63-345	282	9
9	1989	18TH MAR	28TH NOV	77-332	255	8
10	1990	10TH APRIL	16TH NOV	100-320	220	7
11	1991	14TH MAR	27TH OCT	73-300	227	7
12	1992	15TH MAR	10TH NOV	74-314	240	8
13	1993	17TH FEB	28TH NOV	48-332	284	9
14	1994	28TH FEB	5TH NOV	59-309	250	8
15	1995	7TH JAN	31ST OCT	7-304	297	9
16	1996	7TH FEB	23RD OCT	38-296	258	8
17	1997	11TH MAR	25TH NOV	70-329	259	8
18	1998	28TH MAR	21ST OCT	87-294	207	7
19	1999	1ST FEB	17TH NOV	32-321	289	9
20	2000	27TH MAR	20TH NOV	86-324	238	8
21	2001	28TH FEB	24TH OCT	59-297	238	8
22	2002	2ND MAR	1ST NOV	61-305	244	8
23	2003	14TH FEB	3RD NOV	45-307	262	9
24	2004	28TH FEB	29TH OCT	59-302	243	8
25	2005	9TH FEB	27TH OCT	40-300	260	8
26	2006	25TH JAN	27TH OCT	25-300	275	9
27	2007	25TH JAN	29TH OCT	25-302	277	9
28	2008	17TH MAR	5TH NOV	76-309	233	8
29	2009	13TH FEB	7TH NOV	44-311	267	9
30	2010	13TH FEB	4TH NOV	44-308	264	9
31	2011	7TH FEB	30TH OCT	38-303	265	8
32	2012	18TH FEB	13TH NOV	49-317	268	9
33	2013	22ND FEB	13TH DEC	53-347	294	10
34	2014	15TH MAR	12TH NOV	74-316	242	8
35	2015	17TH FEB	13TH DEC	48-347	299	10
36	2016	13TH MAR	4TH NOV	72-308	236	8
37	2017	30TH MAR	21ST NOV	89-325	236	8
38	2018	21ST FEB	23RD NOV	52-327	275	9

Source: Researchers' work, 2019

3.2 Relationship between the Number of Rainy Days and Annual Rainfall of Owerri City

This is used to show the nature of relationship and degree of relationship between the variables.

Table 6: Relationship between the Number of Rainy Days and Annual Rainfall

Year	Number of rainy days(X)	Annual rainfall (Y)
1981	271	2136.9
1982	289	2404.4
1983	240	1695
1984	232	2163.6
1985	284	2376.3
1986	285	2121.1
1987	243	2070
1988	282	2698.4
1989	255	2581.5
1990	220	2731.9
1991	227	2565.1
1992	240	2424.1
1993	284	2182.8
1994	250	2626.1
1995	297	2622.3
1996	258	2705.5
1997	259	2272.5
1998	207	1641.5
1999	289	2496.5
2000	238	2293.8
2001	238	2304.2
2002	244	2042.2
2003	262	1893.7
2004	243	1735.6
2005	260	2545.5
2006	275	2914.8
2007	277	2914.8
2008	233	2749
2009	267	2916.7
2010	264	2331.6
2011	265	2351.7
2012	268	2260.7
2013	294	2156.5
2014	242	1958.4
2015	299	2369.9
2016	236	1352.8
2017	236	1305.7
2018	275	1312

Source: Researchers' work, 2019

3.3 Hypotheses Testing

3.3.1 Hypothesis One

There is no significant relationship between annual rainfall and number of rainy days.

3.3.2 Statistical Tool

Correlation Analysis and Regression Analysis at 5% level of significance.

3.3.3 Output

Correlation: Rainfall, NUMBER OF RAINY DAYS
Pearson correlation of Rainfall and Number of rainy days = 0.275
P-Value = 0.094

Interpretation: The correlation between the variables is 0.275 which is less than 0.5. This implies that the relationship between the variables is weak although positive. The P-values of the pearson's correlation is greater than 0.05 which is an indication of existence of enough evidence to accept the null hypothesis and conclude that there is no significant relationship between number of rainy days and volume of rainfall in Owerri. The conclusion can be confirmed using regression analysis.

3.3.4 Regression Analysis: Rainfall versus NUMBER OF RAINY DAYS

The regression equation is

Rainfall = 960 + 5.06 NUMBER OF RAINY DAYS
Predictor Coef SE Coef T P
Constant 960.3 764.5 1.26 0.217
NUMBER OF RAINY DAYS 5.060 2.944 1.72 0.094

R-Sq = 7.6% R-Sq (adj) = 5.0%

Interpretation: R-Square shows percentage of variation in the dependent variable that can be explained by the independent variable. In the model used, the R-Square is 7.6 percent which implies number of rainy days is responsible for 7.6 percent of the annual rainfall.

3.4 Analysis of Variance

Source DF SS MS F P
Regression 1 516126 516126 2.95 0.094
Residual Error 36 6289604 174711
Total 37 6805730

Interpretation: The model shows that an increase in the number of rainy days will lead to increase in volume of rainfall (Holland 2004; Hobbs et al., 2008; Balkcom et al., 2012). The coefficient of determination of 7.6% is considerably low which implies number of rainy days is not adequate to predict volume of rainfall in the region (Hassanali et al., 2008; Bale et al., 2008; AGP, 2020). The P-value of the model formulated is 0.094 which implies the model is not significant. Therefore, there exists enough evidence to accept the null hypothesis.

3.4.1 Relationship between the Number of Rainy Days and Length of Rainy Season

This is used to show the nature of relationship and degree of relationship between the variables

Table 7: Relationship between the Number of Rainy Days and Length of Rainy Season

Year	Number of rainy days(X)	Length of rainy season (Y)
1981	271	9
1982	289	10
1983	240	8
1984	232	8
1985	284	10
1986	285	9
1987	243	8
1988	282	9
1989	255	8
1990	220	7
1991	227	7
1992	240	8
1993	284	9
1994	250	8
1995	297	9
1996	258	8
1997	259	8
1998	207	7
1999	289	9
2000	238	8
2001	238	8
2002	244	8
2003	262	9
2004	243	8
2005	260	8
2006	275	9
2007	277	9
2008	233	8
2009	267	9
2010	264	9
2011	265	8
2012	268	9
2013	294	10
2014	242	8
2015	299	10
2016	236	8
2017	236	8
2018	275	9

Source: Researchers' work, 2019

3.5 Hypothesis Two

There is no significant relationship between length of rainy season and volume of rainfall in Owerri City.

3.5.1 Statistical Tool

For test of relationship between variables, regression analysis or correlation analysis can be used (AGP, 2020). A significant regression model is an indication of significant relationship and high correlation value with high P-value is an indication of significant relationship between the variables (Morison et al., 2008; Pretty, 1995).

3.5.2 Output

Correlations: Rainfall, LENGTH OF RAINY SEASON (MONTHS)
Pearson correlation of Rainfall and LENGTH OF RAINY SEASON (MONTHS) = 0.129
P-Value = 0.439

Interpretation: The correlation between the variables is 0.129 which is less than 0.5. This implies taht the relationship between the variables is weak although positive (Altieri, 1995; Wilkins, 2008). The P-values of the pearson's correlation is greater than 0.05 which is an indication of existence of enough evidence to accept the null hypothesis and conclude that there is no significant relationship between the number of rainy days and length of rainy season in Owerri City (Kochewad et al., 2017). The conclusion can be confirmed using regression analysis.

3.5.3 Regression Analysis: Rainfall versus LENGTH OF RAINY SEASON (MONTHS)

The regression equation is
Rainfall = 1679 + 69.6 LENGTH OF RAINY SEASON (MONTHS)

Predictor Coef SE Coef T P
Constant 1679.0 757.3 2.22 0.033
LENGTH OF RAINY SEASON (MONTHS) 69.63 88.99 0.78 0.439

R-Sq = 1.7% R-Sq (adj) = 0.0%
Interpretation: R-Square shows percentage of variation in the dependent variable that can be explained by the independent variable. In the model used, the R-Square is 1.7 percent which implies number of rainy days is responsible for 1.7 percent of the length of rainy season.

3.6 Analysis of Variance

Source DF SS MS F P
Regression 1 113817 113817 0.61 0.439
Residual Error 36 6691913 185886
Total 37 6805730

Interpretation: The model shows that an increase in length of rainfall will lead to increase in volume of rainfall (Goulding et al., 2008; Moss, 2008; Srivastava and Ngullie, 2009). The coefficient of determination of 1.7% is considerably low which implies length of rainfall is not adequate to predict volume of rainfall in the region (Palm et al., 2001; Srivastava and Ngullie, 2009; Bunting, 2007). The P-value of the model formulated is 0.439 which implies the model is not significant. Therefore, there exists enough evidence to accept the null hypothesis (Balkcom et al., 2012; Leakey et al., 2005; Leakey, 2017a; Pretty, 2008;).

4. CONCLUSION

This study has in a clearer way shown that rainfall variability will have copious effect on virtually all agricultural activities in the study area. The study shows that the length of rainy season has declined in recent times which is very disastrous for agricultural practices, and if no proactive measures are taken, will eventually lead to reduced quantity of agricultural produce, hence, aggravating hunger among the populace. The study reveals that rainfall starts in Owerri City around February/March and terminates in October/November. This is because the onset of rainfall is predominantly in the months of February/March and cessation of rainfall is predominantly in the month of November followed by October. Also, it was shown in the study that there is no significant relationship between the number of rainy days and annual amount of rainfall in Owerri City. It also shows that there is no significant relationship between the length of rainy season and number of rainy days in the study area.

Truthfully, it has been discovered in the course of this study, that Owerri City experiences climate change effects and this is more evident in the agricultural practices. This, therefore, entails that for agricultural produce to be increased and for hunger to be reduced drastically; there is need for sustainable agriculture. For agricultural sustainability to be practiced by farmers in the study area, the study therefore, recommends the following principles:

- Integrated Pest Management (IPM), which uses ecosystem resilience and diversity for pest, disease and weed control, and seeks only to use pesticides when other options are ineffective. Integrated Pest Management (IPM), also known as Integrated Pest Control (IPC) is an ecosystem approach to crop production and protection that combines different management strategies and practices to grow healthy crops and minimize the use of pesticides. IPM aims to suppress pest populations below the economic injury level (EIL). The UN's Food and Agriculture Organization defines IPM as "the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms. IPM is thus an important part of Integrated Plant Production Management (IPPM) and sustainable crop production intensification. By enhancing the ecosystem function, by making the agricultural ecosystem healthier, more ecosystem services are provided: in this case, pest control.
- Integrating biological and ecological processes such as nutrient cycling, nitrogen fixation, soil regeneration, competition, predation and parasitism into food production processes.
- Integrated nutrient management (INM), which seeks both to balance the need to fix nitrogen within farm systems with the need to import inorganic and organic sources of nutrients and to reduce nutrient losses through erosion control. Integrated nutrient management is an approach that seeks to both increase quality of production and protect the environment for posterity. It relies on nutrient application and conservation, new technologies to increase nutrient availability to plants, and the dissemination of knowledge between farmers and researchers.
- Minimizing the use of non-renewable inputs that cause harm to the environment or to the health of farmers and consumers.
- Livestock based integration farming systems, such as dairy cattle, pigs and poultry, including using zero-grazing cut and carry systems. Livestock based integrated farming system provides an opportunity of increasing economic yield per unit area per unit time to small and marginal farmers. In this system, waste materials are effectively recycled by linking appropriate components. Thus, minimize the environment pollution. Recycling of product, byproducts and waste material in integrated farming system are the factors responsible for the sustainability of farming system.
- Conservation tillage, which reduces the amount of tillage, sometime to zero, so that soil can be conserved and available moisture used more efficiently. Conservation tillage is defined as a system that leaves enough crop residues from cover crops and/or cash crops on the soil surface after planting to provide at least 30% soil cover. Together with cover crops, conservation tillage has the potential to reduce erosion, increase rainfall infiltration, reduce subsurface compaction, and maximize soil organic carbon (SOC) accumulation, which positively affects many soil physical and chemical properties.
- Aquaculture, which incorporates fish, shrimps and other aquatic resources into farm systems, such as into irrigated rice fields and fish ponds, and so leads to increases in protein production.
- Making productive use of the knowledge and skills of farmers, thus improving their self-reliance and substituting human capital for costly external inputs.
- Agroforestry, which incorporates multifunctional trees into agricultural systems and collective management of nearby forest resources. It is a collective name for land-use systems and practices in which woody perennials are deliberately integrated with crops and/or animals on the same land-management unit.
- Making productive use of people's collective capacities to work together to solve common agricultural and natural resource problems, such as for pest, watershed, irrigation, forest and credit management.
- Water harvesting in dry land areas, which means formerly abandoned and degraded lands can be cultivated, and additional crops can be grown on small patches of irrigated land owing to better rain water retention, and improving water productivity of crops.

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