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Spatial Analysis of Rainfall and Temperature Regimes over Selected States of Southeastern Nigeria: Implications for Agricultural Practices

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Abstract
The investigation of rainfall and temperature patterns is of great concern to government of nations, especially since it is evident that changes in their characteristics are especially detrimental for economies that are climate dependent. In south eastern Nigeria Rainfall and temperature have major impacts on agriculture, ecological setting and water resources management. Also with the recent interest and investment of the government to improve on agriculture, necessitates an investigation of the patterns of rainfall and temperature, since agriculture is still large climate dependent. Expost-facto research method in the context of quasi experimental research design was adopted for the study. Data for rainfall and temperature were obtained from Nigerian Meteorological Agency (NIMET). Analysis of data was achieved using descriptive statistics and analysis of variance. Results showed that there is an upward trend in the rainfall of Abia and Enugu States (0.1026mm and 0.0089mm per annum, respectively) while that of Imo State is a downward trend (1.1255 mm per annum). On the other hand, mean temperature is increasing annually in all the states at the rate of 0.0199 in Abia State, 0.00009 in Enugu state and 0.0151 in Imo state, per annum. The analysis of variance result was significant at $p<0.05$, revealing that, Rainfall, minimum temperature, maximum temperature and mean temperature were significantly different spatially. This study observed changes and irregularities in the pattern of rainfall and temperature in the south eastern region of Nigeria as a result, the study strongly advocates for a re-examination of anthropogenic actions that will transcend into environmental friendly interactions between man and the environment in the region.
Keywords: Spatial, Rainfall, Temperature, Food-Security, South-Eastern

1.0 Introduction

Rainfall and temperature variation has been a major concern to Climatologists, Economist, politician Agriculturist and even non-professionals, because of its effects on natural and social systems (Nwagbara, 2008). Scientist believes that climate change results from global warming as a result of the emission of greenhouse gases into the atmosphere which in itself has posed a lot of threat to the climate of the world (IPCC, 2001). However, the implication of a changing climate varies from region to region.

Nevertheless, Africa has been considered to be the world's most endangered region with regard to these issues of climate change, due to the tender and immature nature of its economy (IPCC, 2007). Incidentally, the concentration of the GHGs up in the atmosphere is on the increase IPCC (2014), and implies greater future warming and further changes in the climate of the world. Rainfall and temperature are important tools for climate studies, due to their impacts on vegetation, ecological settings and water resource management of an area (Igwenagu, 2015).

In Nigeria the variability and change in pattern of extremely high or low rainfall and temperature are very important for agriculture as well as the economy of the nation (Igwenagu, 2015); most especially in the south-eastern Nigeria, where agriculture is dependent on climate. Understanding the trends of the rainfall and temperature in the region, is therefore essential for meaningful agricultural development (Ekwe *et al*., 2014).

Sadly, with all the alarming effects of recent trends of rainfall and temperature on agricultural practices in the study area, there is paucity of information from the literature on rainfall and temperature regimes particularly its implications for agricultural production (Amadi *et al*., 2014; Karaburun *et al.,* 2012; IPCC, 2007; Karaburun *et al.,* 2012). This is the gap which this paper intends to fill. This study is thus set out to attempt a spatial analysis of rainfall and temperature regimes over selected states of Southern-Eastern, Nigeria.

2.0 Materials and Methods

The geographical location of Southeastern Nigeria falls within latitude 4º10'N to 7º08N and longitude 5º30'E to 9º27'E (see fig 1). The region has an area of 75, 488 km2, it is bounded to east by the Republic of Cameroun, to the west by Delta State, to the north by Benue State and to the south by the Gulf of Guinea. The states in

southern Nigeria used for this work are Abia, Enugu and Imo states .

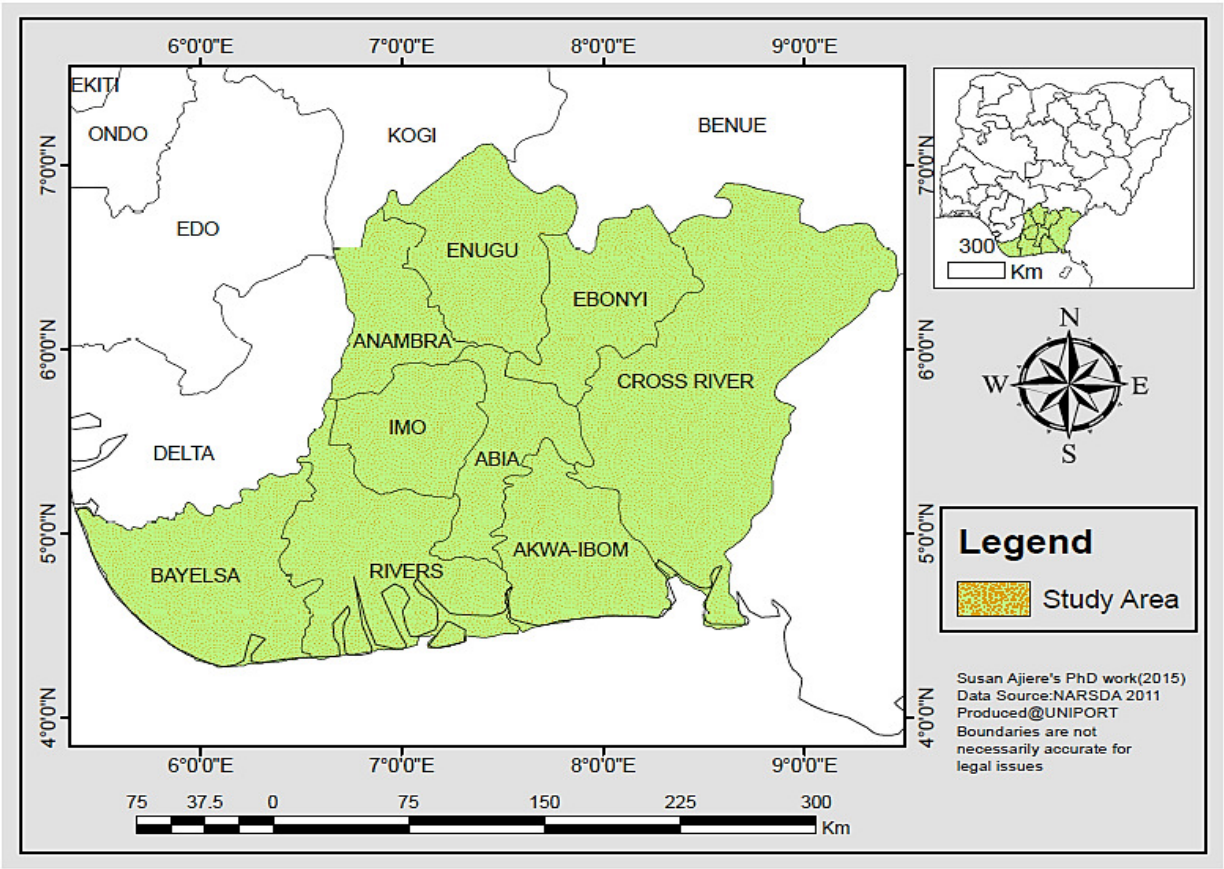

Fig 1: South Eastern Nigeria showing state capitals.

In terms of climate the area can be classified under the tropical type based on the koppens classification. The climate there is controlled by the tropical continental and tropical maritime air masses. The seasons are; the rainy and dry seasons. There is however a short dry season which occurs between the end of July and early August and is known as August Break, although in recent years, there has been a disruption in the occurrence of this break and Akpodiogaga-a & Odjugo, (2010) identifies it as evidence of climatic change. Nonetheless, anthropogenic activities, which include deforestation, oil exploration & exploitation, over-cultivation etc, have altered the climate of the area and the result is a downward trend in crop yields for farmers and hence on food security.

In terms of methods, the study used the expost-facto research method in the framework of quasi experimental research design. Data for rainfall and temperature was obtained from Nigerian Meteorological Agency (NIMET) for a period of 30years. However, to find out the spatial variation in rainfall and temperature, Analysis of variance was used (ANOVA). The justification for this is that the researcher intended to find out the variation in rainfall and temperature across the three selected states. Furthermore, descriptive statistics, trend analysis, rainfall and temperature were also carried out.

3.0 Results and Discussions

The result of this analysis shows a general change in rainfall and temperature regime. The annual rainfall totals across the study area for the period of study (1987-2016) (Table 1) shows that, the years with the highest rainfall totals in Abia state is 1997 and 2000 with rainfall totals as 2751.9mm and 2701.3mm , Enugu State is 1997 and 2012 with 2263.4mm, and 2137.7mm respectively, while, Imo State is the year 2009 and 1997 with 2916.7mm and 2891.4mm. The epoch with the lowest rainfall totals in Abia state is 1987 and 2001 with rainfall totals 1806.7mm and 1680.6mm, Enugu State is 1993 and 1998 with rainfall totals as 1581.1mm and 1496.1mm and Imo State is 1998 and 2004 with rainfall totals as 1641.5mm and 1777.8mm respectively. Also worthy of note is that, across the states there are changes in the rainfall pattern and there has been an increase in rainfall in all the states between 1997 -2012.

Table 1: Annual Rainfall totals across selected states of South eastern Nigeria

States	Year of highest rainfall	Amount (mm)	Year of highest rainfall	Amount in (mm)
Abia	1997 and 2000	2751.9 and 2701.3	1987 and 2001	1806.7 and 1680.6
Enugu	1997 and 2012	2263.4 and 2137.7	1993 and 1998	1581.1 and 1496.1
Imo	1997 and 2009	2891.4 and 2916.7	1998 and 2004	1641.5 and 1777.8

The mean annual maximum temperature across the state of study (Table 2) shows that, the year with the highest Maximum temperature in Abia State is 2009 and 2010 with a mean of 32.00 ºC and 32.17 ºC respectively. For Enugu State, it is in 1987 and 2010 with mean values of 33.13 ºC and 32.90 ºC respectively and Imo State it is in 2007 and 2010 with mean values of 32.90 ºC and 33.21 ºC respectively. While the mean annual lowest minimum temperature (Table 3) for Abia states is 2013 and 2014 with mean as 21.97 ºC and 22.00 ºC respectively, Enugu State is 1989 and 2006 with mean values of 21.68 ºC and 21.85 ºC and Imo State is 1994 and 1995 with mean as 22.26 ºC and 22.36 ºC

Table 2 Annual mean, max & min highest temperatures across selected states of South Eastern Nigeria.

States	Year	Highest Max Temp (^{0}C)	Year	Highest Min Temp (^{0}C)	Year	Highest Mean Temp (^{0}C)
Enugu	1987	33.1	2010	23.9	2010	28.4
Abia	2010	32.2	2016	23.4	2010	27.8
Imo	2010	33.2	2010	24.6	2010	28.9

Table 3 Annual mean, maximum and minimum lowest temperatures across some selected states of South Eastern Nigeria (1987-2016) ºC

State	Year	Max temp	year	Min temp	year	Mean Temp
Enugu	2005	31.4	1989	21.7	2006	26.8
Abia	1991	30.5	1989	21.7	1989	26.2
Imo	1991	31.6	1994	22.3	1994	27.0

Mean temperature shows that the year with the highest mean temperature for Abia State is in 2010 with mean as 27.8 ºC, Enugu State is 2010 with mean as 28.4 ºC, Imo State is 2010 with mean as 28.9 ºC and the results show that temperature was high in all the states in 2010. While the year with the lowest mean temperature in Abia State is 1989 with mean of 26.2 ºC. Enugu State is 2006 with mean of 26.8 ºC, and Imo State is 1994 with mean as 27 ºC. Furthermore, there is an increase in temperature in all the states investigated, however, Imo State emerged as the hottest state with the highest temperature and Enugu State is the coolest.

The trend of annual rainfall in Abia state from 1987 to 2016 can be seen in Figure 2. It is evident that the annual rainfall fluctuated greatly at the beginning of the study year, with minimal fluctuation towards the end of the epoch. This shows a slight increase in rainfall and a weak positive trend. In Enugu State rainfall (Fig 3) shows that rainfall fluctuated greatly at the beginning of the study years with variations and a positive trend which shows a slight increase in rainfall.

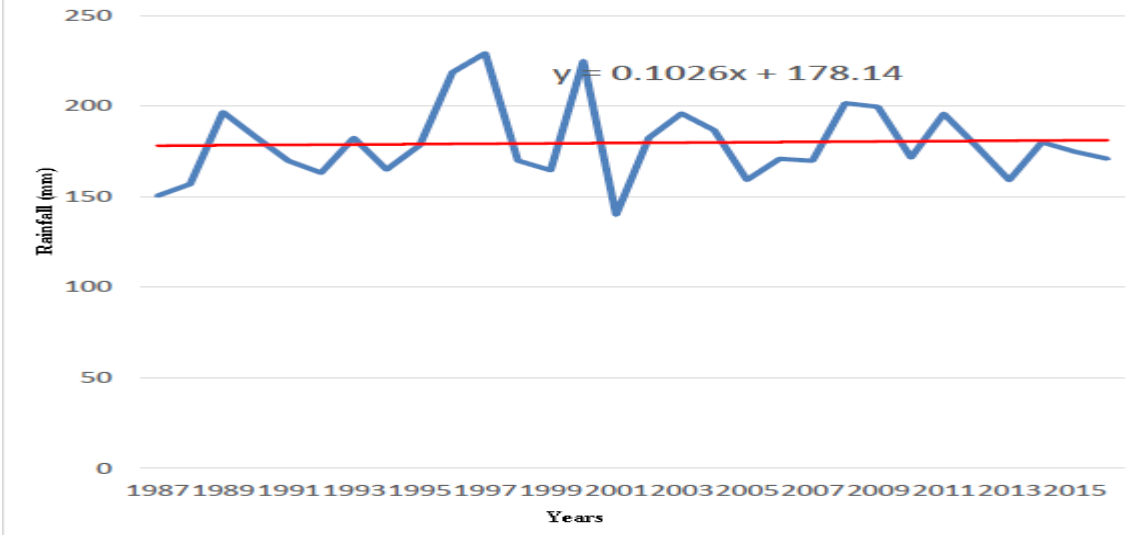

Fig 2 Annual rainfall total Trend for Abia State

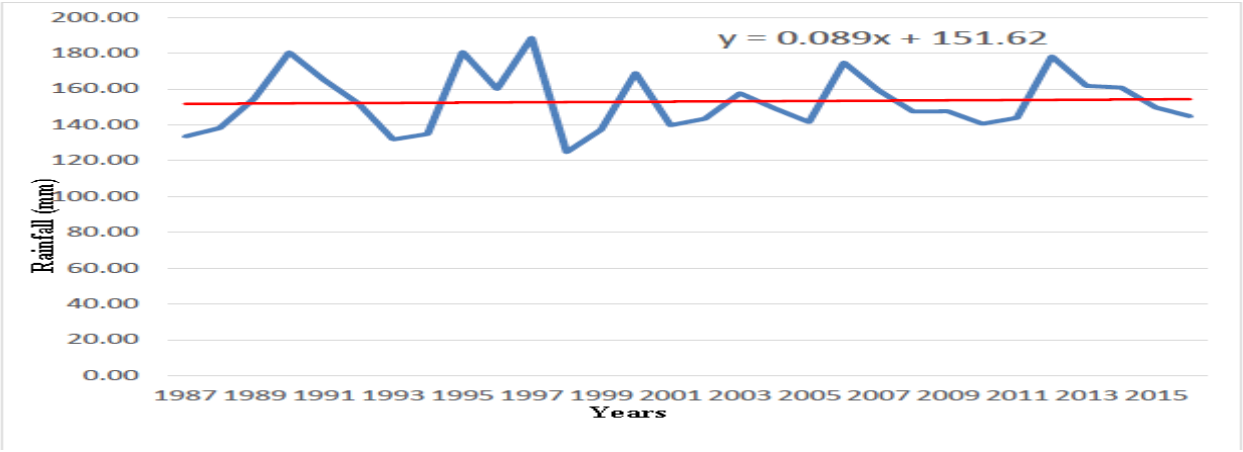

Fig 3 Annual rainfall total Trend of Enugu State

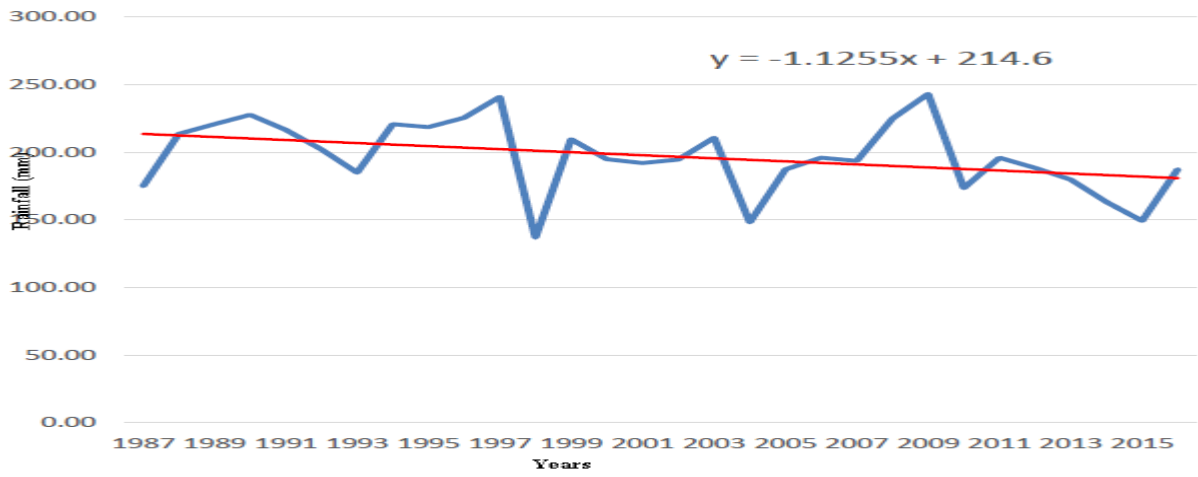

Fig 4 Annual rainfall total Trend of Imo State

Finally, Imo state (fig 4) shows that rainfall fluctuated greatly, but with a negative trend which is a decrease in rainfall observed during epoch of Study, with highest rainfall in 2009 with 243.06mm respectively. This shows irregularity in the rainfall pattern.

In Abia state, the Maximum temperature trend analysis (Fig 5), shows that it fluctuated greatly with a positive trend. This shows an increasing upward trend. The highest maximum temperature was in 2010 with value of 32.17 ºC and lowest in 1991 with the value of 30.5 ºC. The minimum temperature fluctuated greatly (Fig 6), with a positive trend which is an increasing upward trend was observed with highest values in 1998, 2000 and 2010 with 23.3 ºC and the lowest value in 1989, with the value of 21.6 ºC, also low in 2013 and 2014 with value of 21.9 ºC and 22 ºC respectively. The maximum temperature trend analysis of Enugu state (Fig 7) shows that it fluctuated greatly, with a positive trend which shows a slight increase with highest temperature in 1988 with the value of 33.13 ºC, and lowest point in 2005 with the value of 31.35 ºC. It went up to 32.0 ºC in 2010, it shows a week positive trend, which is a slight increase in maximum temperature.

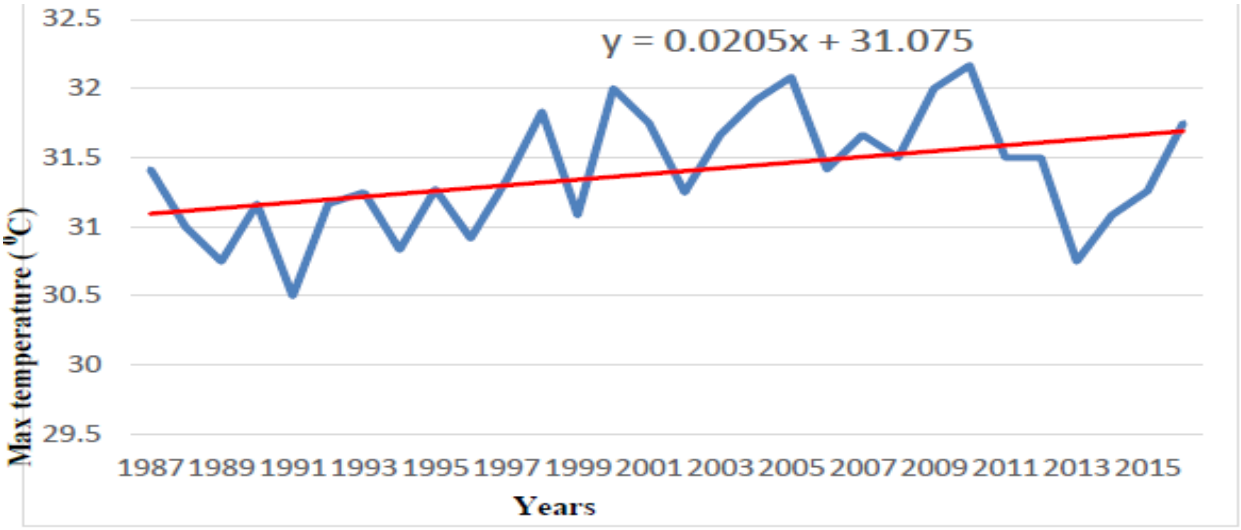

Fig 5 Annual Trend of mean maximum temperature of Abia State

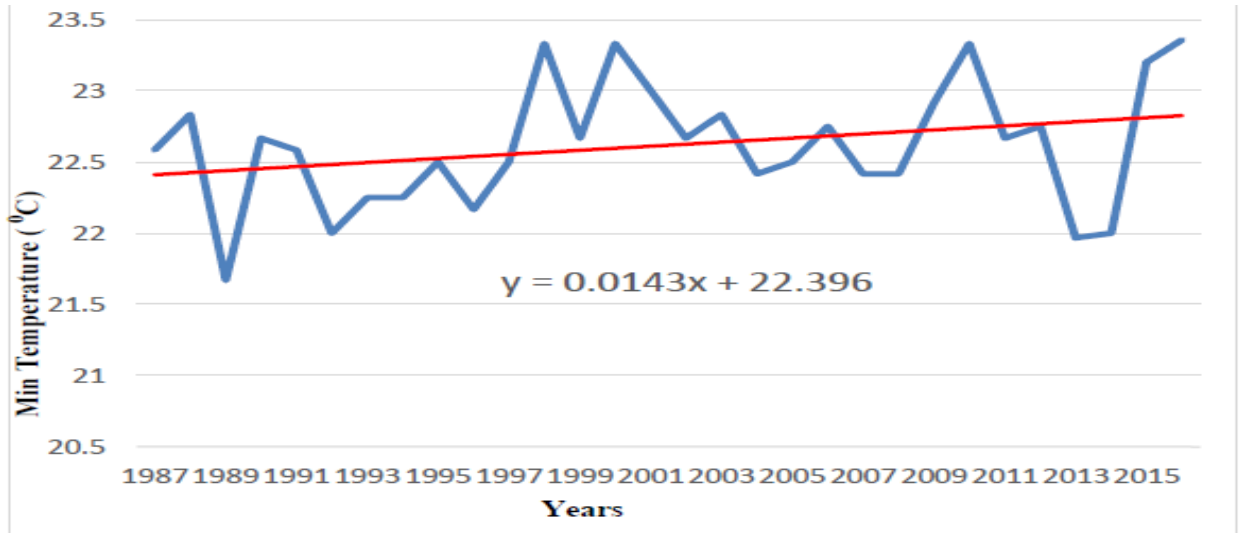

Fig 6 Annual Trend of mean minimum temperature of Abia State

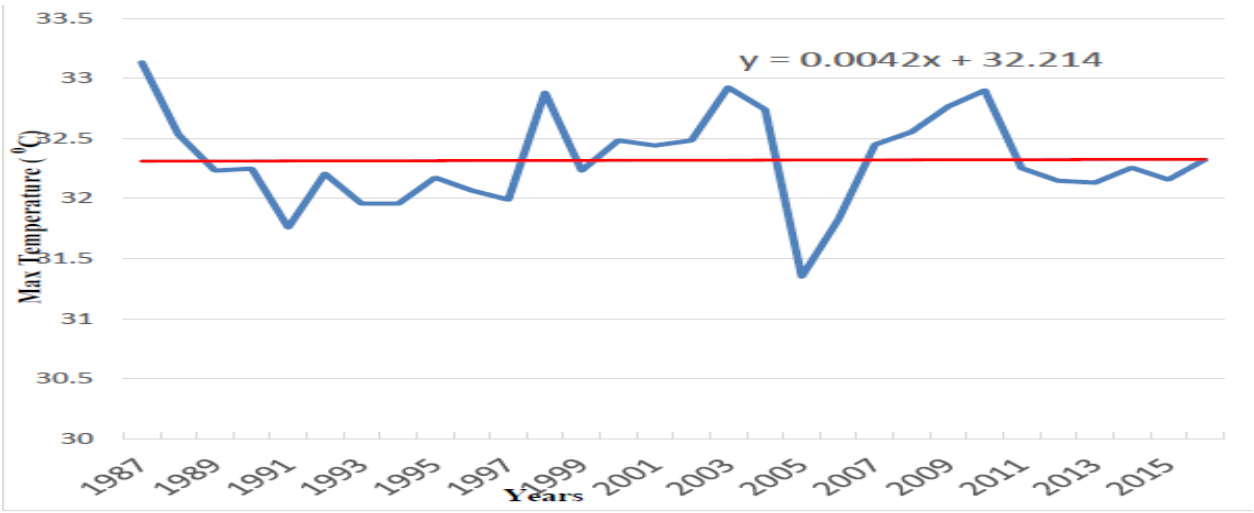

Fig 7Annual Trend of mean maximum temperature of Enugu state.

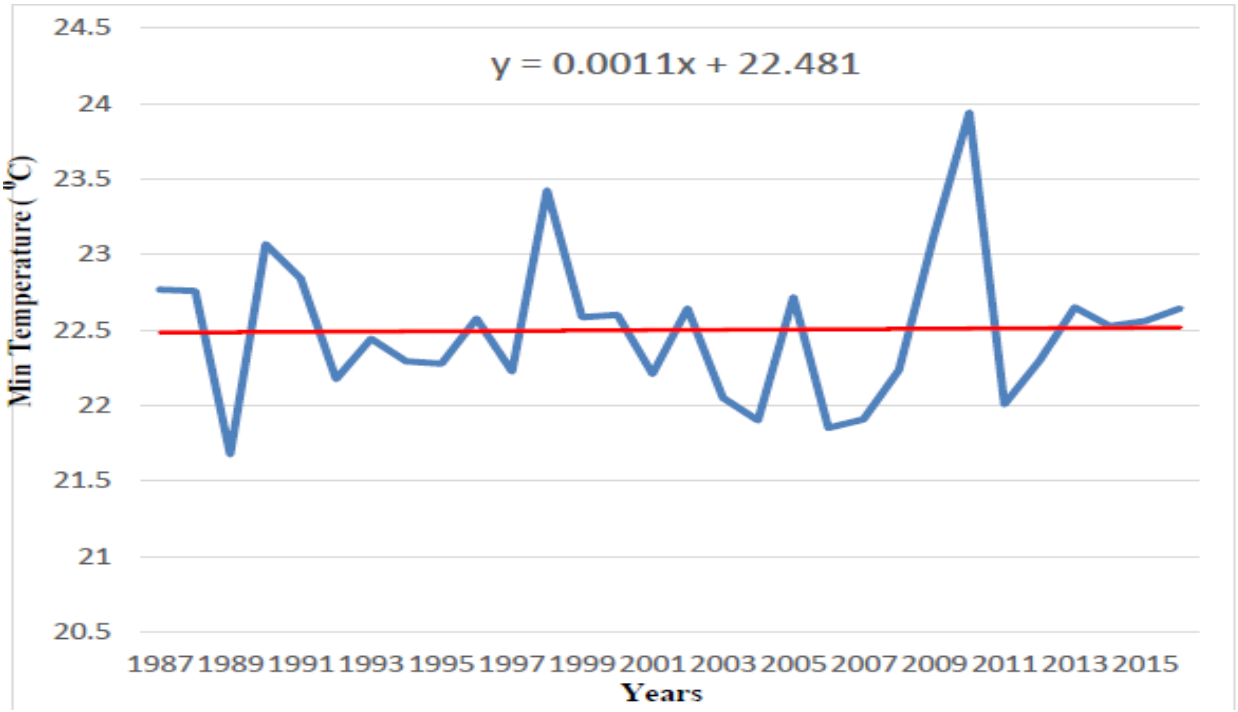

Fig 8 Annual Trend of mean minimum temperature of Enugu state

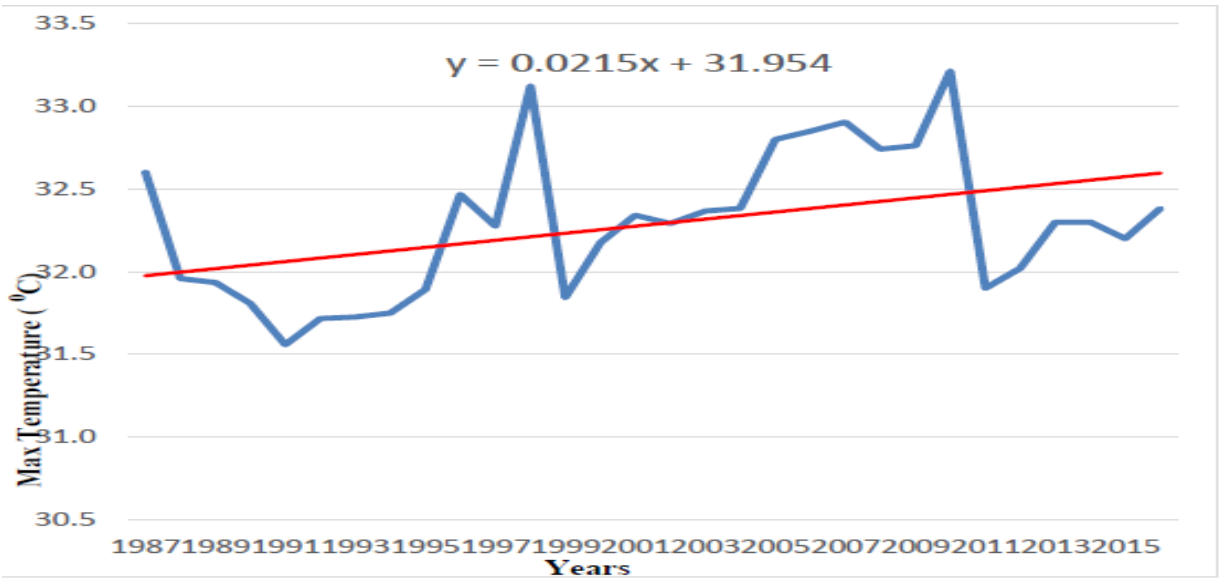

Fig 9 Annual Trend of mean maximum temperature of Imo state

Nevertheless, the minimum temperature for Enugu fluctuated greatly (Fig.8), and it shows a slight increase in trend. It was highest at 2010, with the value of 23.94 ºC, with the lowest value in 1989 with the value of 21.67 ºC. It went low in 2011 with the value of 22 ºC. This shows a weak positive trend, which is a slight increase in minimum temperature.

Finally, Imo state, maximum temperature fluctuated greatly Fig (9) with a positive trend which shows an increasing upward trend which is an increase in maximum temperature, with highest temperature in 2010 of 33.2 ºC. In terms of minimum temperature of Imo State (Fig.10) indications are that it fluctuated greatly too with a positive trend and it shows an increasing upward trend, which was highest at 2010, with the value of 24.6 ºC. This is an increase in minimum temperature.

Using the trend analysis represented by the least square line, the annual mean maximum temperature of Abia State is increasing at 0.0205 per annum, Enugu State is increasing at 0.0042 per annum and Imo State is increasing at 0.0215 per annum Imo state has the highest rate of increase while Enugu has the least.

For annual mean minimum temperature, Abia State is increasing at 0.0143 per annum, Enugu State is increasing at 0.0011 per annum, and Imo State is increasing at 0.0243 per annum. Also evident is that, Abia State,

and Imo State have the highest increase in minimum temperature than Enugu State. The increase in minimum temperature also indicates that the period which is hitherto cold (Harmattern season) is getting hotter in Abia, and Imo. This is in line with the work done by UNFCCC, (2014), where findings indicated that temperatures in Nigeria have been on the increase in the last five decades and have been very significant since 1980s

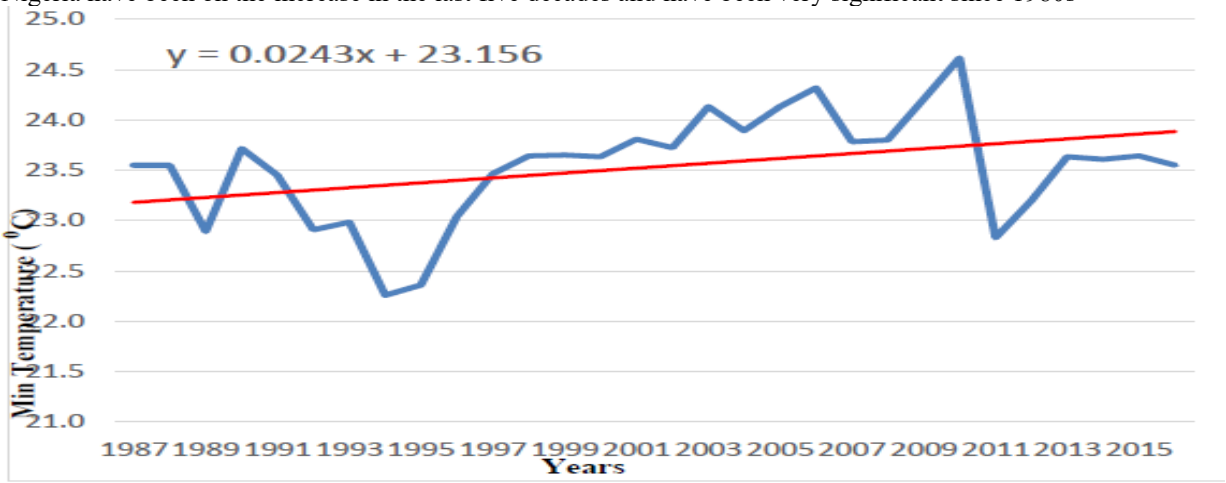

Fig 10. Annual Trend of mean minimum temperature of Imo state

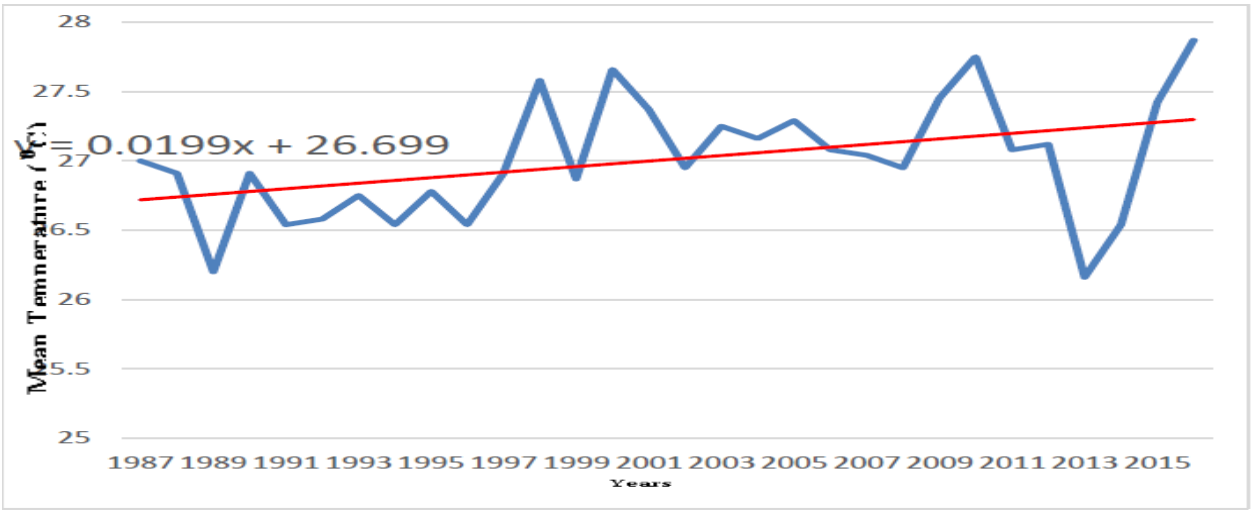

Fig 11 Annual mean temperature trend of Abia state

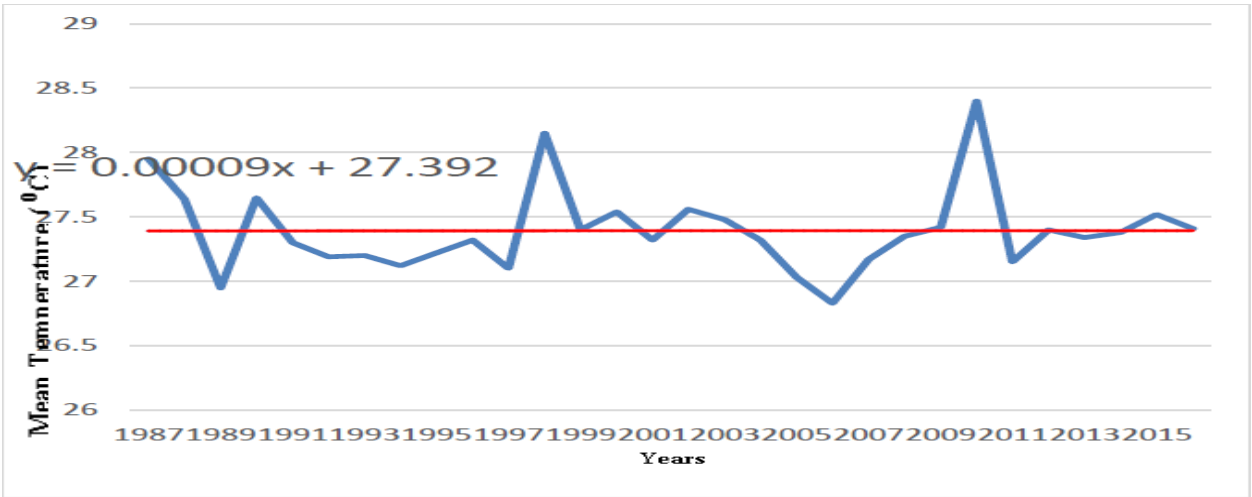

Fig 12 Annual mean temperature trend of Enugu state

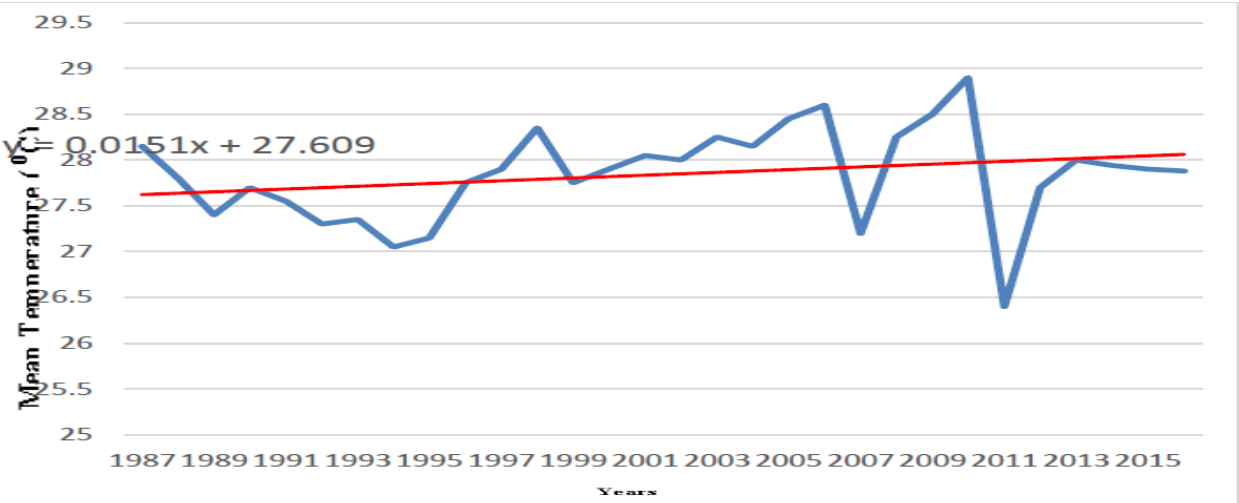

Fig 13 Annual mean temperature trend of Imo state

The trend analysis for mean temperature of Abia State (Fig 11) shows that it fluctuated with a positive trend ,and it shows an increasing upward trend with highest temperature in 2016 with the value of 27.87 ºC and lowest point in 2013 with the value of 26.16ºC, indicating an increase in mean temperature. The trend analysis for mean temperature of Enugu State (Fig 12) shows that it fluctuated with a very week positive trend, and it shows very little close to zero increasing trend with highest temperature in 2010, with the value of 28.4 ºC and lowest point in 2006 with the value of 26.83 ºC. Imo State trend analysis for mean temperature (Fig 13) shows that, it fluctuated with an increasing positive trend with highest temperature in 2010 with the value of 28.9 ºC and lowest point in 2011 with the value of 26.4 ºC.

The trend analysis revealed that, the annual mean temperature of Abia State is increasing at 0.0199 per annum, Enugu is increasing at 0.00009 per annum, and Imo is increasing at 0.0151 per annum, while Abia state has the highest rate of increase in mean temperature per annum and Enugu has the least.

Rainfall, minimum, maximum and mean temperature across the states were significantly different among the states (Table 4) at $p<0.05$. The Fisher Pairwise Comparisons determined whether the mean differences between specific pairs of groups are statistically significant and found that the difference in rainfall and temperature among the states did not occur by chance (see table 5).

Table 4,Analysis of Variance of Rainfall, Min Temperature, Max **Temperature,** Mean **Temperature**

	F-Value	P-Value
Rainfall	61.42	0.000
Min Temperature	24.17	0.000
Max **Temperature**	77.31	0.000
Mean **Temperature**	20.80	0.000

Table 5 Grouping Information of rainfall Using the Fisher LSD Method and 95% Confidence

Factor	N	Mean of rainfall	Grouping of rainfall	Mean of min temperature	Grouping of min Temp	Mean of max temp	Grouping of max temp	Mean of Mean temperature	Grouping of Mean temperature
Imo	30	197.15	A	23.5327	A	32.2862	A	27.8423	A
Abia	30	179.73	B	22.6175	B	31.3927	B	27.0083	C
Enugu	30	153.00	C	22.4983	C	32.3193	A	27.3937	B

4.0. Implication of temperature and rainfall regimes in agricultural practices in South Eastern Nigeria.

Agriculture is strongly influenced by weather variables such as temperature and rainfall regimes. While farmers are often flexible in dealing with weather and year-to-year variability, there is nevertheless a high degree of adaptation to the local climate in the form of established infrastructure, local farming practice and individual experience. Temperature and rainfall regimes can therefore be expected to impact on agriculture, potentially threatening established aspects of farming systems but also providing opportunities for improvements. Higher growing season temperatures can significantly impact agricultural productivity, farm incomes and food security (Battisti and Naylor 2009). In mid and high latitudes, the suitability and productivity of crops are projected to increase and extend northwards, especially for cereals and cool season seed crops (Maracchi *et al*. 2005; Tuck *et al*. 2006; Olesen *et al*. 2007). Crops prevalent in southern Europe such as maize, sunflower and soya beans could also become viable further north and at higher altitudes (Hildén *et al*. 2005; Audsley *et al*. 2006; Olesen *et al*.

2007). Here, yields could increase by as much as 30 per cent by the 2050s, dependent on crop (Alexandrov *et al*. 2002; Ewert *et al*. 2005; Richter & Semenov 2005; Audsley *et al*. 2006; Olesen *et al*. 2007). For the coming century, Fisher *et al*. (2005) simulated large gains in potential agricultural land for the regions such as the Russian Federation, owing to longer planting windows and generally more favourable growing conditions under warming, amounting to a 64 per cent increase over 245 million hectares by the 2080s. In areas, such as South Eastern Nigeria, where temperatures are already close to the physiological maxima for crops, higher temperatures may be more immediately detrimental, increasing the heat stress on crops and water loss by evaporation. A 2°C local warming in the mid-latitudes could increase wheat production by nearly 10 per cent whereas at low latitudes the same amount of warming may decrease yields by nearly the same amount. Different crops show different sensitivities to warming. It is important to note that large uncertainties in crop yield changes for a given level of warming.

5.0 Conclusion

This study has been able to establish that there is spatial variation of rainfall and temperature in south Eastern Nigeria for the period under study and this is as a result of the effect of climate change on the climatic parameters in this region. The changing patterns and fluctuations of rainfall and temperature in the region is in line with the earlier warning by IPCC (2007, 2014, NIMET, 2016). The fluctuation and change in pattern of rainfall shows, inconsistency in the pattern of rainfall which makes it difficult to rely on particularly for agricultural practices. There is serious need for alternative source of rain for agricultural processes. This is because crops have their level of tolerance for temperature as well as rainfall; thus, if temperature and rainfall patterns continue to fluctuate as observed in this study, it has the potential to affect agriculture produce negatively. The variation in rainfall, minimum, maximum and mean temperature across the three states that were statistically significant showed that the effect of climate change on the climatic parameters vary within the region. This finding therefore indicates that serious ameliorative steps must be taken to cushion the effects of climate change in the region.

6.0 Recommendations

Given the finding of this study and the understanding that the analyzed rainfall and temperature can affect the agricultural system of South Eastern Nigeria, the study therefore recommends the following:

1) proper training should be giving to key personnel especially in the agricultural sector, on climate change preparedness and mitigation; who will be involved in educating the farmers.
2) There should be well-equipped weather stations in each state and possibly extend it to some universities involved in climate studies. This will help to give accurate weather forecast,
3) improve agricultural techniques such as irrigation, greenhouse farming systems, mulching etc. Since it evidence that rainfall and temperature patterns are changing
4) Strongly and implementable environmental policies to reduce the emission of greenhouse gasses which poses a great threat to the area's climate systems.
5) A cohort study to link weather fluctuation to agricultural activities in the study

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