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Assessment of Temperature and Rainfall Variability over South Eastern Nigeria: Implication to Flooding and Erosion Management

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ABSTRACT

Rainfall and temperature variability, trends and pattern have posed serious challenges across the globe. Studies have shown that the global climate has varied slowly over the past decades and it is expected that it will continue to vary in future. Therefore, this work examined annual and decadal distribution, pattern, trends, anomalies of rainfall and temperature in South-Eastern Nigeria. The

rainfall and temperature data were obtained from Nigerian Meteorological Agency (NIMET) for a period of 30 years for five states of Rivers, Imo, Abia, Cross Rivers and Enugu States respectively. The data were grouped into three decades of (1987-1996), (1997-2006) and (2007-2016) which were analyzed using the descriptive statistics and 3rd order polynomial trend. It was observed that in the first decade (1987-1996) rainfall was high in Rivers and Imo States; and in the second decade (1997-2007) rainfall was high in Abia State and the third decade rainfall was high in Cross River and Enugu States respectively. The mean annual temperature from 1987-2016 had persistent increase in temperature in all the state since 2001 and 2002. The analysis of long time trends in the time series showed notable fluctuations in the pattern of polynomial trend in rainfall and temperature. Abia, Enugu and Cross River States have positive trends while Rivers and Imo states have negative trends in rainfall. Temperature showed positive tread across the states. This shows an evidence of climate variability. The increasing surface air temperature and associated heat enhances spread of diseases and its epidemics as well as sea level rise. However, temperature increase results to flooding and erosion while extreme temperature gives rise to drought in the region. It is therefore recommended for planners to manage agriculture and outbreak of diseases by considering the predictability of temperature and rainfall variability, trends and anomalies for better human comfort and livelihood.

Key words: Climate Variability, Temperature, Rainfall, South Eastern Nigeria.

1. INTRODUCTION

Climate variability has become an important environmental, social and economic issue. The hour-to-hour, day-to-day and season-to-season changes in the atmospheric conditions results to the concept of weather. These weather processes are studied in their extended time series in decades, centuries and up to interval of millions of years giving rise to the concept of climate [1]. Climate variability is a shift in the mean state of the climate in temporal and spatial scales. It is the deviation of climatic statistics over a given period of time such as month, season and year when compared to long-term statistics for the same calendar period. Variability may be due to natural internal processes within the climate system known as internal variability, also to variations caused by anthropogenic external factors known as external variability [2]. The fluctuations comprising climate variability can influence patterns of rainfall, temperature and other variables on timescales anywhere from few weeks to decades. The rising atmospheric temperature has increased evapo-transpiration and consequently increased condensation, precipitation and flooding in recent times over Nigeria. Studies have shown that the global warming has increased the water holding capacity of the atmosphere and thus the risk of more precipitation [3].

The climate system is continually changing due to the interactions among the components of volcanic eruption, solar variations and changes in atmosphere as well as land uses. Changes in the climate systems are caused by natural processes and anthropogenic actions. It is observed that internal changes in the climate system such as variations in ocean currents and atmospheric circulation can result to climate variability or changes [4]. The observed changes and causes of climate variability are due to human influence on the climate system as contributed by greenhouse gases. Also, recent climate changes have had widespread impacts on human and natural systems. [5]Global warming itself has carbon dioxide as its chief driver [6], others are water vapour, chlorofluorocarbons (CFCs), methane, tropospheric ozone and nitrous oxide. These gases are termed greenhouse gases as they are relatively open to solar radiation but absorb and emit terrestrial radiation thereby increasing warming of the earth [6]. These temperature increases bring about different challenges which vary from region to region. It could be negative for some and for others it could be positive and for others a combination of both. Africa has been considered to be the world's most endangered region with regard to climate change due to the tender or immature nature of its economy [7]. Incidentally, the concentration of the greenhouse gases in the atmosphere is on the increase [5], this implies a greater future warming and further changes in the climate of the world. According to [8],[9] and [3] stated that spatial and temporal variations in temperatures were noticed in Nigeria where air temperature has been on the increase which has similarly shown different periods of warming and cooling phases over the last century in Nigeria. The ability to understand the trend of rainfall and temperature of a country over a period of time will give a clearer view of the nature, present and future climate of that area; this will help in economic planning and for sustainable agriculture, water resources and hydrological circle. Several researchers have used the time series data to analyze the trend of rainfall in Nigeria and other parts of Africa and their findings show that there is inter annual decadal rainfall variability very peculiar to Africa [10].

2. MATERIALS AND METHOD

2.1. Description of Study Location

The geographical location of South-Eastern Nigeria falls within latitude 4°10′N to 7°08N and longitude 5°30′E to 9°27′E. The region occupies an area of 75, 488 km^2. 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 South-Eastern Nigeria states for this study are Abia, Enugu, Cross River, Rivers and Imo respectively. These states fall into two geopolitical zones in Nigeria namely the south-south and south-east. Rivers and Cross River states are in the South-South geopolitical zone while Abia, Anambra, Ebonyi, Enugu and Imo are in the South-East. The weather stations used for this work which is located in South Eastern Nigeria is shown in Figure 1.

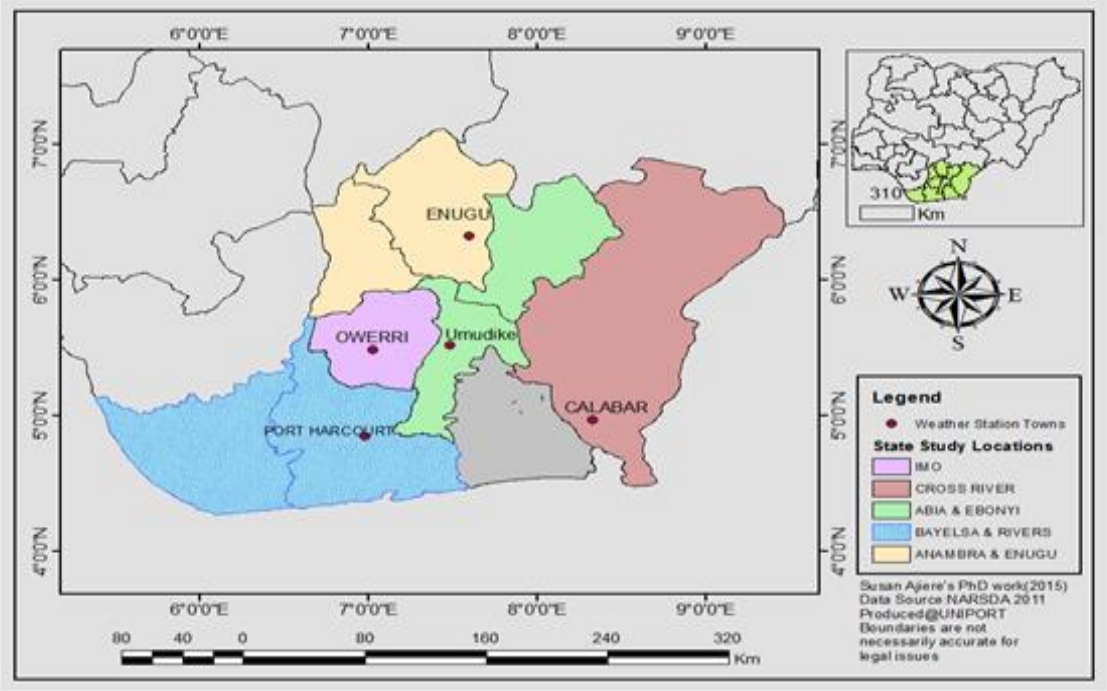

Figure 1 Map of South-Eastern Nigeria

2.2. Materials and Method

The secondary data were the monthly rainfall and temperature of some stations in the south-eastern region in Nigeria for a period of 30 years (1987-2016) which were collected from the Federal Meteorological Services Oshodi in Lagos State. A total of five metrological stations were used in this study which includes Enugu representing Enugu State, Owerri representing Imo, Umudike representing Abia State, Port Harcourt representing Rivers State and Calabar representing Cross River State. The monthly rainfall and temperature data collected were further converted to annual and decadal values. The monthly, annual, decadal rainfall and temperature averages, polynomial trends obtained were used to determine the general pattern and characteristics of rainfall and temperature in the study area.

3. RESULTS AND DISCUSSION

3.1. Decadal Distribution of Rainfall

The results showed that Abia State experienced highest rainfall in the second decade (1997-2006) with 2189.5mm, while in the first decade (1987-1996) it had rainfall of 2118.6mm and in the third decade (1997-2016) had rainfall of 2162.3mm which was higher than the first decade. The results showed increase in rainfall from first decade to second decade. Cross River State showed highest rainfall in the third decade (2007-2016) with 3313.9 mm. It had lowest rainfall in the first decade (1987-1996) with rainfall of 2938.5mm which indicated increase in rainfall in the state. Enugu State showed highest rainfall in the third decade (2007-2016) at 1840.3mm having lowest rainfall in the second decade (1997-2006) with rainfall of 1830.6mm indicating slight increase in rainfall in the state.

Imo State showed highest rainfall in the first decade (1987-1986) at 2526.2mmhaving lowest rainfall in the third decade (2007-2016) with rainfall of 2278.7mm indicating decrease in rainfall. Rivers State showed highest rainfall in the first decade (1987-1986) with 2371.5mm, having lowest rainfall in the third decade (2007-2016) with rainfall of 2253.5mm indicating decrease in rainfall. There was rainfall increase in Abia State, Cross River State and Enugu State while Imo State and Rivers State experienced decrease in rainfall (Table 1).

Table 1 Decadal Distribution of Rainfall (mm) across the States

	Abia	Cross/River	Enugu	Imo	Rivers
1987-1996	2118.6	2938.5	1837.2	2526.2	2371.5
1997-2006	2189.5	2968.5	1830.6	2292.6	2298
2007-2016	2162.3	3313.9	1840.3	2278.7	2253.5

3.2. Decadal Distribution of Mean Maximum, Mean Minimum and Mean Temperature across the States

In this study Table 2 shows the decadal minimum temperature, Table 3 shows decadal maximum temperature and Table 4 shows decadal mean temperature over some states of the south eastern Nigeria in the order of first decade (1987-1996), second decade (1997-2006) and the third decade (2007-2016) respectively.

In Abia State, the highest maximum temperature was recorded in the second decade (1987-2006) with maximum temperature of 31.63 ºC while the decade with the lowest minimum temperature was the first decade (1987-1986) having minimum temperature of 22.35ºC. The mean temperature is highest in the second decade with mean temperature of 27.2.ºC while the first decade experienced the lowest mean temperature of 26.7ºC indicating slight increase in temperature.

In Cross River State, the highest maximum temperature was the third decade (2007-2016) with temperature of 30.96 ºC having lowest minimum temperature in the first decade (1987-1986) with minimum temperature of 23.01ºC. The mean temperature was highest in the third decade with temperature of 27.1ºC while the first decade experienced the lowest mean temperature of 26.8ºC indicating increase in temperature.

In Enugu State, the highest maximum temperature was the third decade (2007-2016) with maximum temperature of 32.39 ºC having lowest minimum temperature in the second decade (1997-2006) with 22.42ºC. The mean temperature is highest in the third decade with mean temperature of 27.5 ºC while the first decade experienced the lowest mean temperature of 27.4ºC indicating slight increase in temperature.

In Imo State, the decade with the highest maximum temperature was the third decade (2007-2016) having maximum temperature of 32.47 ºC while the decade with the lowest temperature was the first decade (1987-1986) with 23.07ºC. The mean temperature was highest in the third decade with mean temperature of 28.1 ºC while the first decade experienced the lowest mean temperature of 27.5. ºC indicating increase in temperature.

In Rivers State, the decade with the highest maximum temperature was the third decade (2007-2016) having temperature of 31.7 ºC while the decade with the lowest minimum temperature was the first decade (1987-1986) with 22.6 ºC. The mean temperature was highest in the third decade having mean temperature of 27.3ºC while the first decade experienced the lowest mean temperature of 26.9 ºC indicating increase in temperature.

Table 2 Decadal Distribution of Minimum Temperature (°c) across the States

	Abia	C//River	Enugu	Imo	Rivers
1987-1996	22.35	23.01	22.49	23.07	22.64
1997-2006	22.8	23.14	22.42	23.84	22.75
2007-2016	22.77	23.29	22.59	23.69	22.92

Table 3 Decadal Distribution of Maximum Temperature (°c) Across the States

	Abia	Cross/River	Enugu	Imo	Rivers
1987-1996	31.03	30.63	32.23	31.94	31.22
1997-2006	31.63	30.93	32.34	32.45	31.56
2007-2016	31.52	30.96	32.39	32.47	31.7

Table 4 Decadal Distribution of Mean Temperature (°c) across the State

	Abia	Cross/River	Enugu	Imo	Rivers
1987-1996	26.7	26.8	27.4	27.5	26.9
1997-2006	27.2	27.0	27.4	28.1	27.2
2007-2016	27.1	27.1	27.5	28.1	27.3

It was observed that in the first decade (1987-1996) rainfall was high in Rivers and Imo State and in the second decade (1997-2007) rainfall was high in Abia State and in the third decade rainfall was high in Cross River and Enugu State respectively. This showed that there was increase rainfall in Cross River, Enugu and Abia States while Imo and Abia States had a decrease in rainfall. It is noticeable that temperature increased in all the decades. The decade with the highest temperature was the third one for all the states which implies that all the states experienced increased in temperature. The coolest decade was the first, where minimum temperature was lowest. However, all the states of study experienced increase in temperature while the minimum temperature was experienced in the first or the second decade which shows that the environment is becoming warmer in the southeastern Nigeria.

3.3. Anomalies in the Climatic Parameters over the States

Temperature

The annual mean temperature anomalies from 1987 to 2016 in Abia State are presented in Figure 5. The result of the fourth order polynomial showed that the annual mean temperature anomalies fluctuated with increase in temperature between 1987 and 2016. In the period of 1987- 1997 (10 years) the curve was below the average mean, while between 1998 - 2009(12 years later), it was above the mean and dropped below the mean again for another 4 years (2010-2013) and in 2014 - 2016 temperature rose indicating increased temperature variability and warming in Abia state over time.

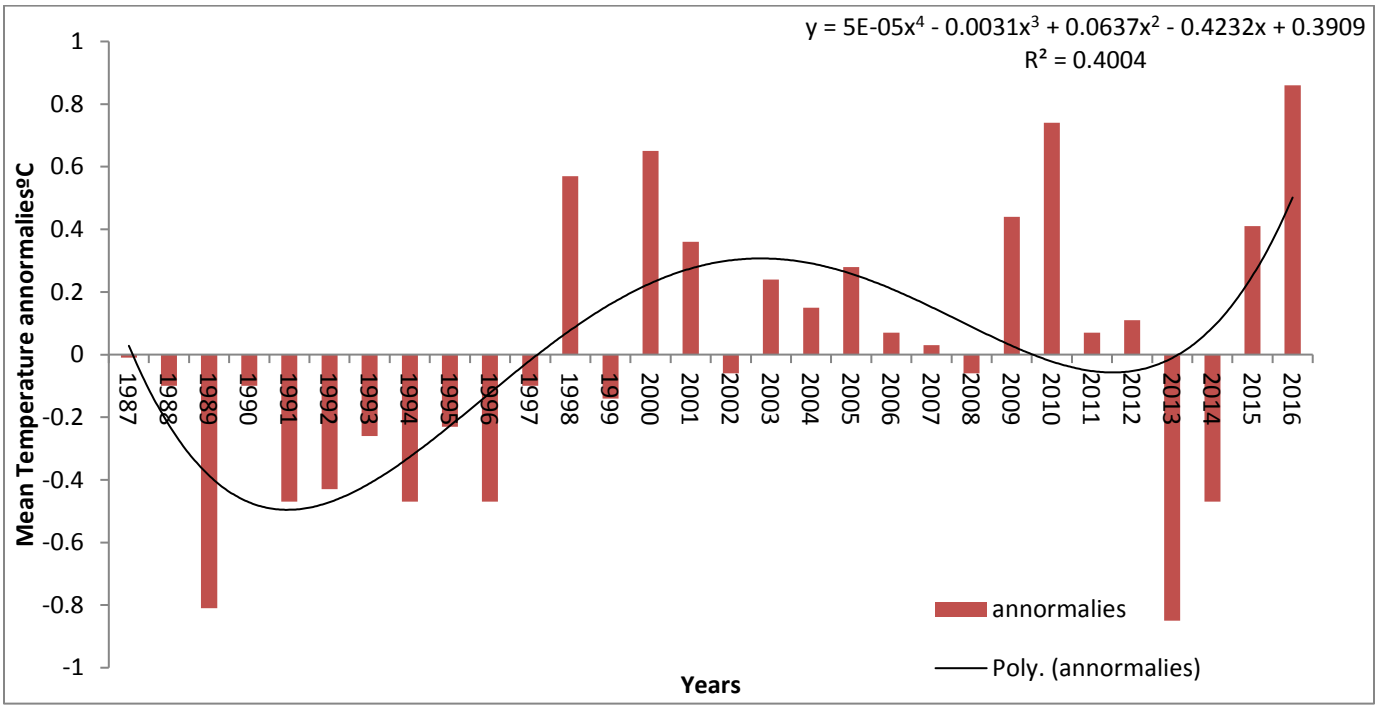

Figure 5 Annual mean temperature anomalies in Abia State (1987-2016)

Cross River State experienced some anomalies in temperature as shown in the mean annual temperature anomalies from 1987-2016of the third order polynomials (Figure 6). This showed a gradual increase in mean temperature in the states. The climatic period of 1987- 2002 (16 years) was marked below average mean, while between 2003 - 2016 (14 years) mean temperature was marked above the average mean indicating rise in temperature from the year 2003. This variability ascertained warming of climate and evidence that the mean annual temperature anomalies have been gradually increasing over the years.

The annual mean temperature anomalies from 1987 to 2016 in Imo State are presented in Figure 7. Result of the third order polynomial depicted a declining trend from 1988, in 1996 the trend started to increase and towards the end of the year of study it experienced a decline. Mean temperature was below the mean between 1987-1999 (13 years) and above the mean for 14 years (2000-2013) gradually declining in 2014. This showed variability of climate indicating increase in temperature from the beginning of the study period and gradually decreased from 2014.

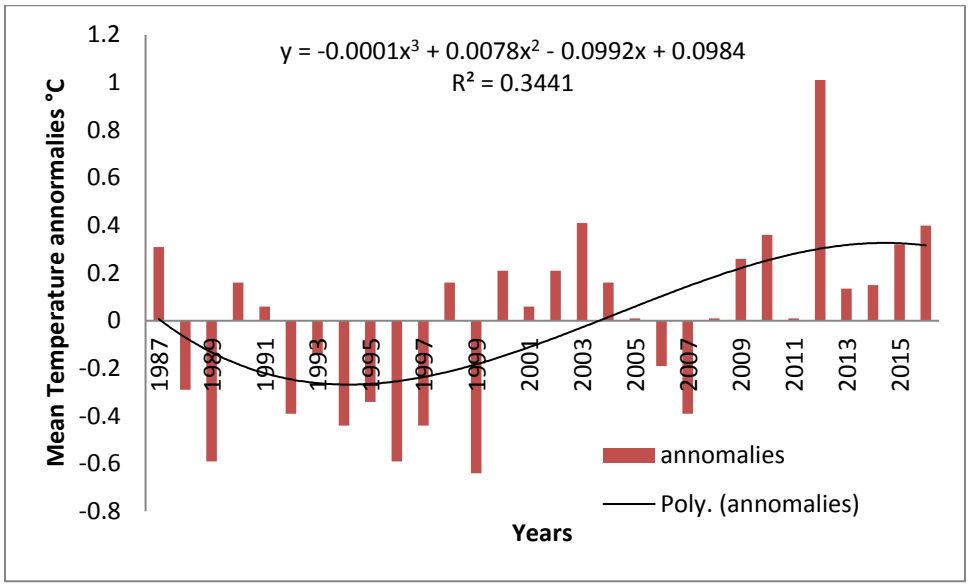

Figure 6 Anomalies of annual mean temperature over Cross River State 1987-2016

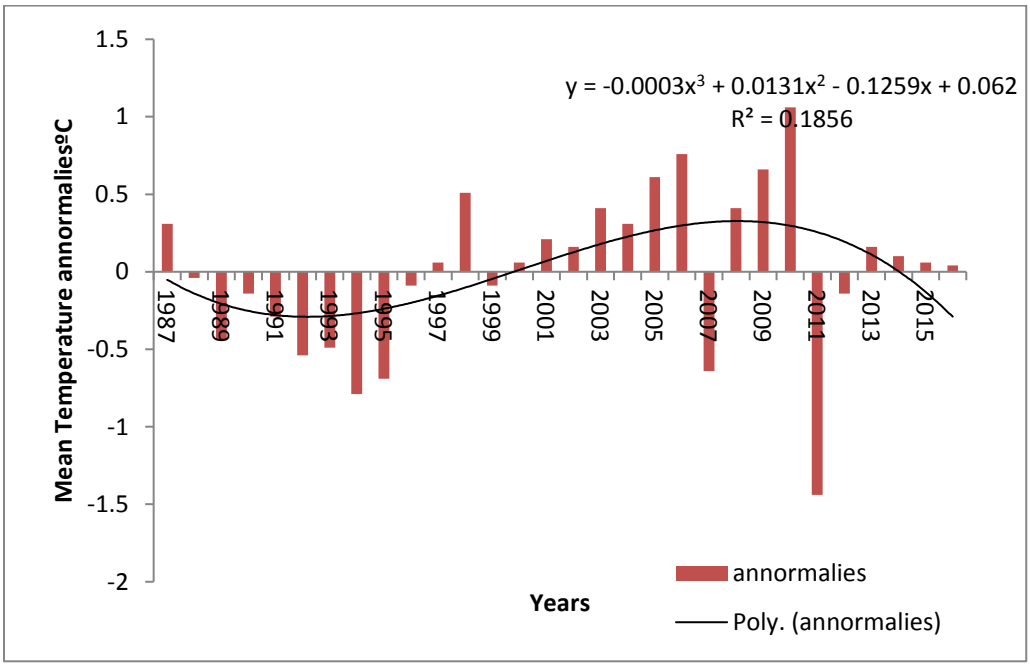

Figure 7 Anomalies of annual Mean Temperature over Imo State 1987-2016

The result of the second order polynomial showed that the annual mean temperature anomalies in Enugu State had negative trend from 1987 to 1997 and upward trend thereafter till 2016 (Figure 8). This showed that for the first 10 years, temperature was on the decrease and in 2010 temperature started increasing showing temperature variability and environmental warming.

River State experienced some anomalies in temperature, the mean annual temperature anomalies from 1987-2016in the third order polynomials is presented in Figure 9. This showed variability and a gradual increase in mean temperature in the state. The decadal climatic period of 1987- 2002 (16 years) was marked below average mean, while between 2003 - 2016 (14 years) mean temperature was marked above the average mean which indicated an increase in temperature from 2003 . This showed a warming climate and evidence that the mean annual temperature anomalies had increased gradually over time.

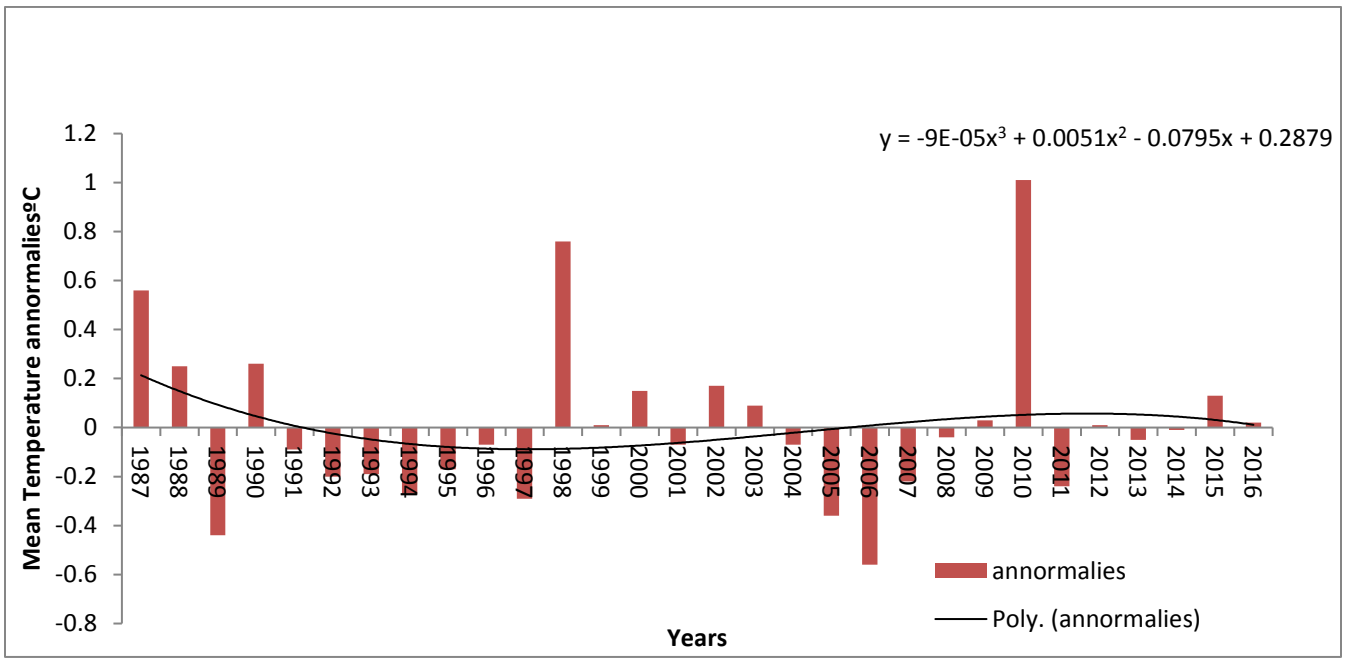

Figure 8 Anomalies of annual mean temperature over Enugu State 1987-2016

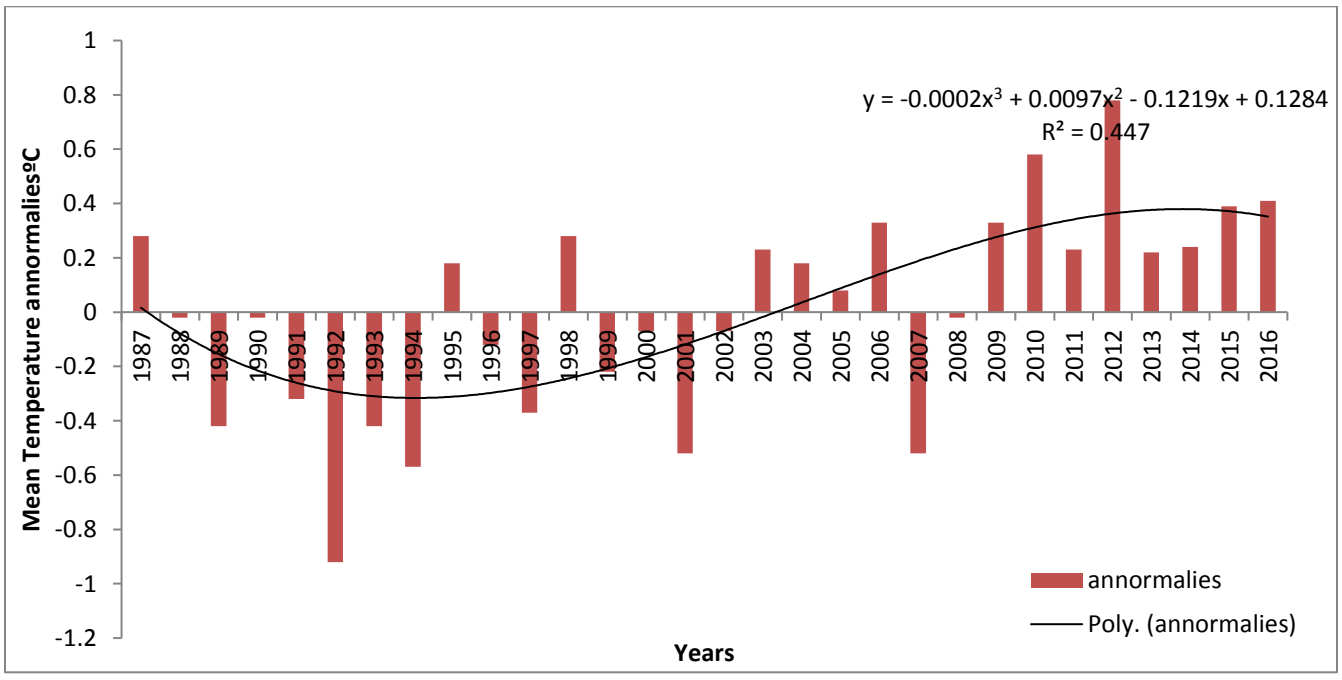

Figure 9 Anomalies of annual Mean Temperature over Rivers State 1987-2016

The result of the third order polynomial trend across South-Eastern Nigeria showed variability and the mean annual temperature anomalies have been increasing over time for all the states of study except Enugu and Imo states where there were recovery tendencies.

Rainfall

The trend of annual mean rainfall anomalies in Abia State between 1987 and 2016 is presented in Figure 10. The result of the third order polynomial showed that the annual rainfall in Abia State had increasing trend from 1987 up to 2000 and a decreasing trend till 2016.

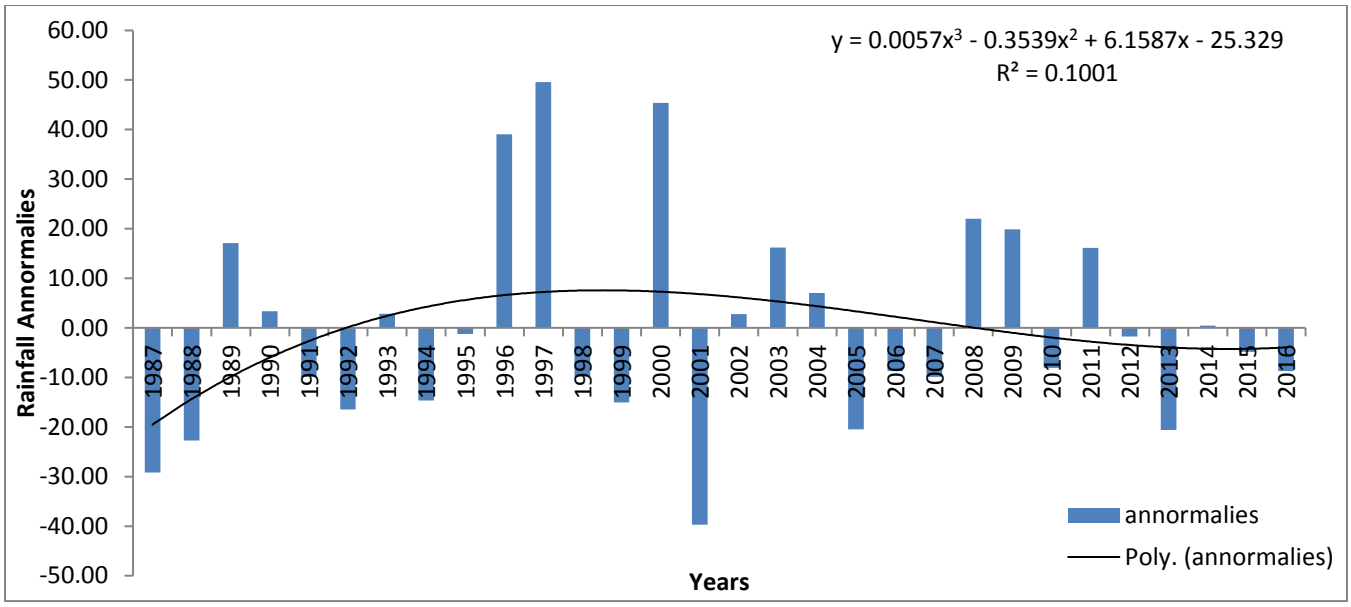

Figure 10 Anomalies of annual Mean Rainfall over Abia State 1987-2016

In Cross River State, the annual rainfall anomalies from 1987-2016 is presented in Figure 11. Result of the third order polynomial showed that the annual rainfall was below the mean from 1987-2004 and in 2005 annual rainfall went above the mean. It showed both positive and negative anomalies where positive anomalies could result to flooding while the negative anomalies could result to drought.

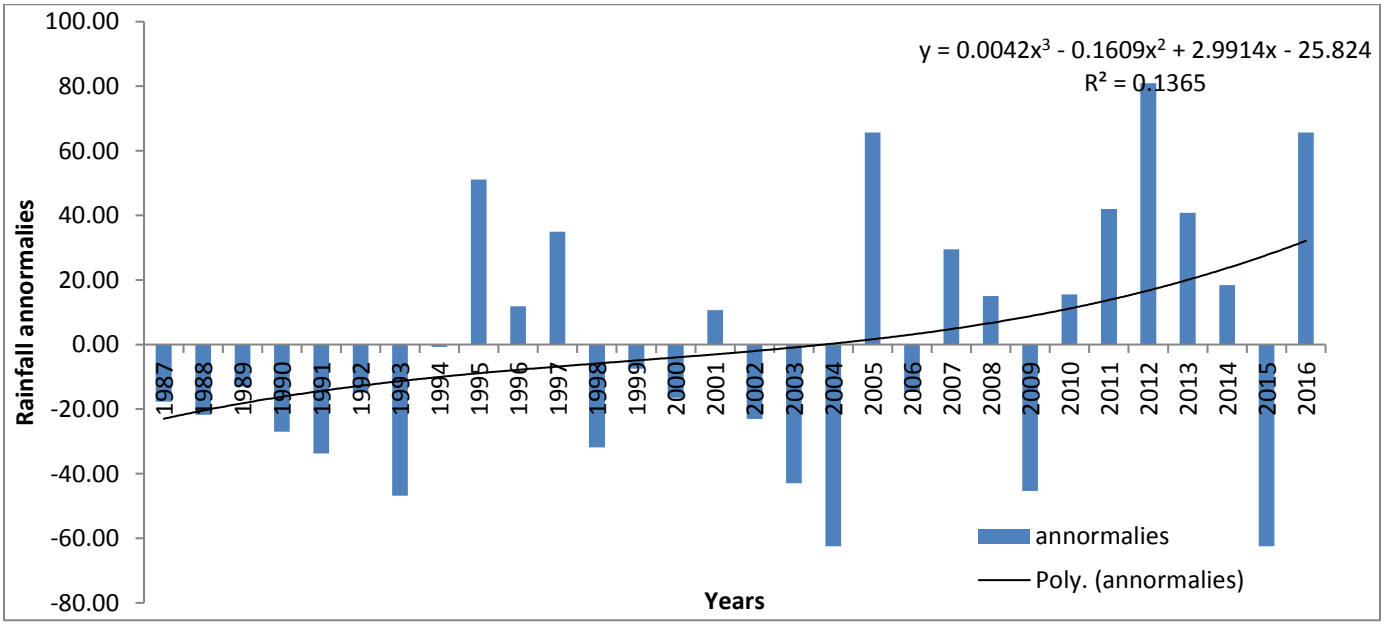

Figure 11 Anomalies of annual Mean Rainfall over Cross River State 1987-2016

Enugu State annual rainfall anomalies from 1987-2016 is shown in Figure 12. The third order polynomial showed that the annual rainfall in Enugu State experienced increasing trend from 1987-2009 and from 2010 to 2011 a decrease was noticed but from 2012 the trend rose drastically indicating serious variability.

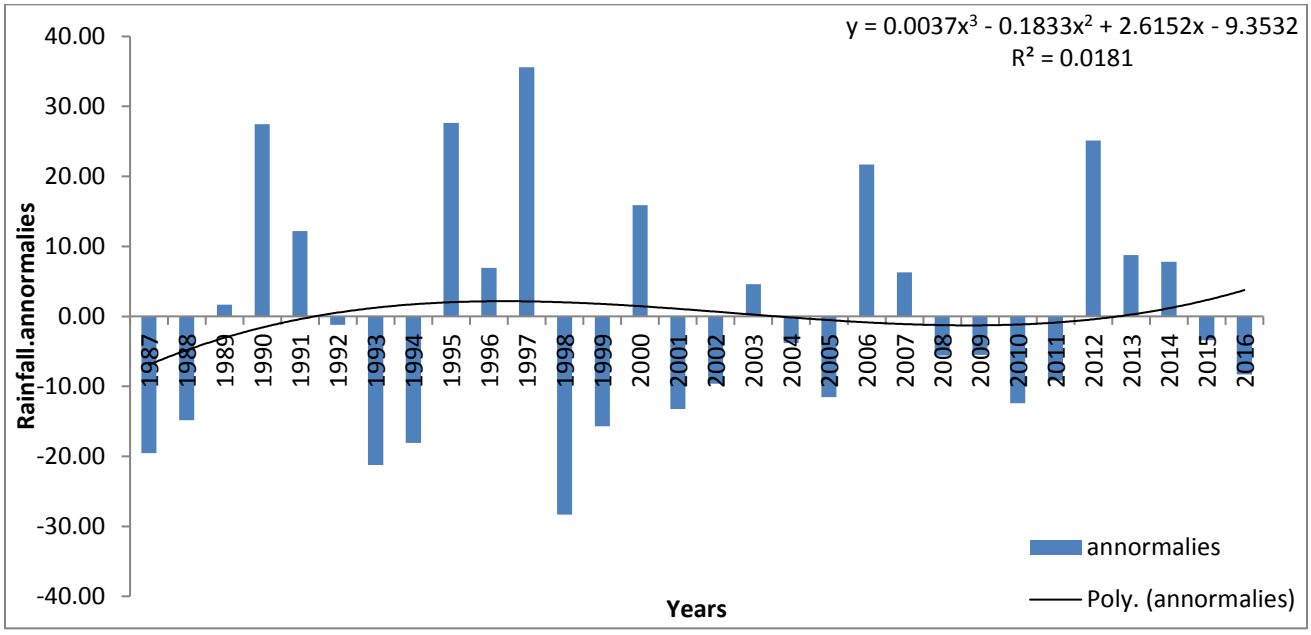

Figure 12 Anomalies of Annual Mean Rainfall over Enugu State 1987-2016

The third order polynomial of annual rainfall anomalies for Imo State is shown in Figure 13. Imo States showed a negative trend. There was increase in rainfall from 1987-1997 and gradually decreased from 1998 to 2016. The Imo State would be at the risk of drought if the trend continues to go down.

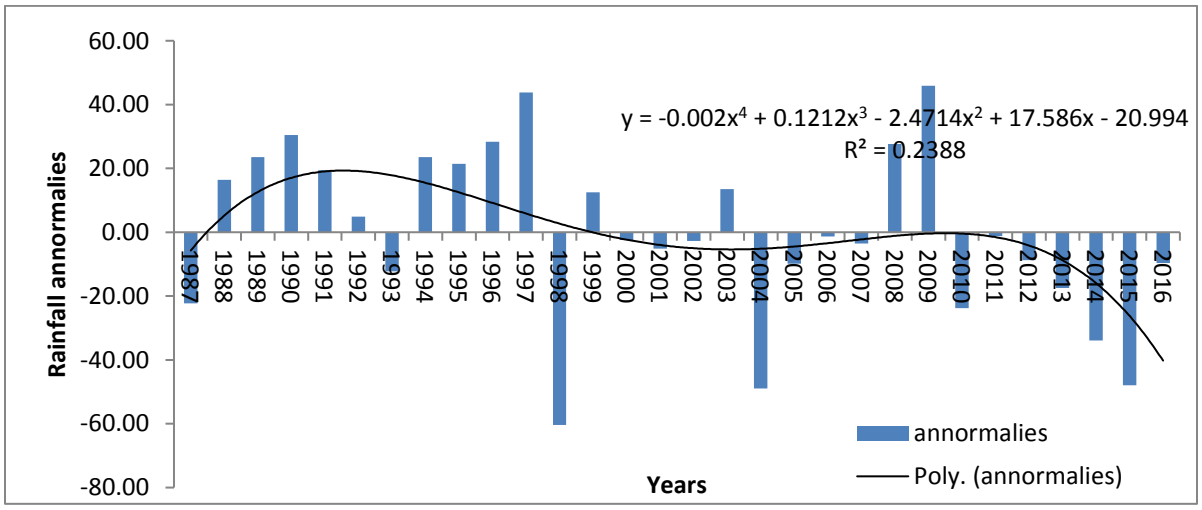

Figure 13 Anomalies of Annual Mean Rainfall Over Imo State 1987-2016

Rivers State annual rainfall anomalies from 1987-2016 is shown in Figure 14. The third order polynomial showed that the annual rainfall anomalies experienced a negative trend. There was decrease in rainfall from 1987-2016 but 2007 and 2008 had rainfall above the mean. The state might be at risk of drought if the trend continues to go down.

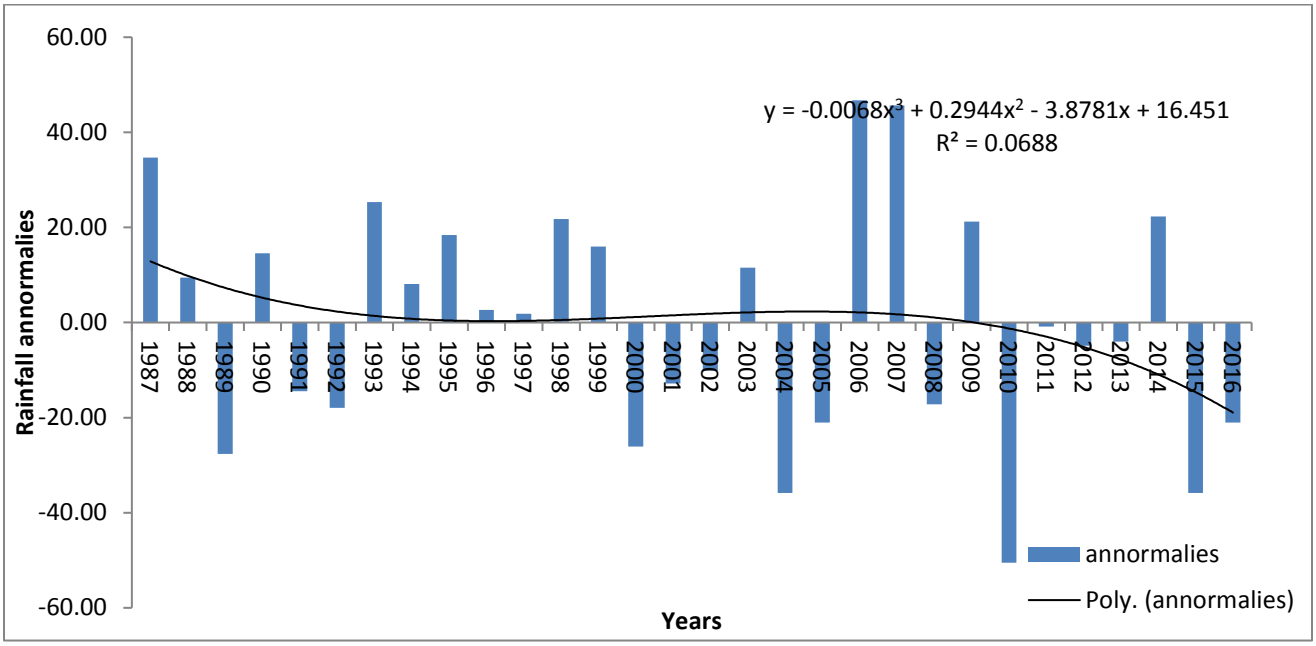

Figure 14 Anomalies of Annual Mean Rainfall Over Rivers State 1987-2016

The mean annual temperature and rainfall anomalies using the 3rd order polynomial graph showed the variable nature of rainfall and temperature across the states of study. The mean annual temperature from 1987-2016 had persistent increase in temperature in all the state since 2001 and 2002. This showed temperature variability and warming of climate parameters and evidence that the mean annual temperature anomalies have been increasing with time for all the states of study except Enugu and Imo States where there were recovery tendencies. The mean annual rainfall showed a positive tread in Cross River and Enugu states which suggests increase in rainfall and negative trend in Abia, Imo and Rivers. To a large extent they showed variability in the mean annual temperature and rainfall anomalies.

4. CONCLUSION

This work has been able to establish the fact that there is an evidence of climate variability of rainfall and temperature in South-Eastern Nigeria for the period of 1987-2016. The changing patterns of rainfall and temperature in the region is in line with the recent warning by IPCC (2007, 2014) about evidence of climate variability change in Africa. NIMET (2016) warned about evidence of climate change in Nigeria. The Government of all states should be well informed about these changes in rainfall and temperature to enhance proper preparedness and planning. Key staff should be trained, weather stations should be properly equipped and encouraged to give accurate weather forecast in each state. Finally this research is a tool for further research in climate studies in order to manage flooding and drought especially in the developing nations of the world like Nigeria.

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In this article, Dr.Ajiera Suzan and Dr.Nwaerema Peace jointly gathered the data, wrote the script and did the data analysis together. This article does not have any conflict of interests.

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