Inter-Annual Variability Of Rainfall In Some States Of Southern Nigeria

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Abstract: The study inter-annual variability of rainfall in some states in Southern Nigeria focuses on analyzing the trends and fluctuations in annual rainfall over six states in Southern Nigeria, covering a period of 1972 – 2012. In order to ascertain the variability's, and to model the annual rainfall for future prediction to enhance policy implementation, the quantitative and descriptive analysis techniques was employed. The rainfall series were analyzed for fluctuations using Standardized Anomaly Index (SAI), whereas the trends were examined using Statistical Package for Social Science Software (SPSS 17.0). At 95 percent confidence level, observations in the stations may be signals that the wetter period dominates the drier periods in this study. Each of the series contains two distinct periods when the rainfall anomalies (negative and positive) of a particular type were most significant. The period where the annual rainfall is above one standard deviation from the mean annual rainfall is considered Wet, and the period below one standard deviation from the mean annual rainfall is considered Dry for each station. The results of the linear trend lines revealed an increase in rainfall supply over the period of study especially of recent. The annual rate of increase in rainfall over the period of investigation 1972 - 2012 were; 15.21mm/year for Calabar, 2.18mm/year for Port Harcourt, 22.23mm/year for Owerri, 3.25mm/year for Benin City, 5.08mm/year for Enugu, and 16.29mm/year for Uyo respectively. The variability in amount of annual rainfall revealed that, in 2012 Calabar received the highest amount of rainfall of about 4062.70mm and the least value of 2099.4mm in 1973. In Porthacourt, the highest amount of rainfall occurred in 1993 with a value of 3911.70mm and the least value in 1983 with a value of 1816.4mm. Owerri recorded the highest amount of rainfall of about 3064.0mm in 2011, and the least value occurred in 1986 with a value of 1228.4mm. In 1976, Benin received the highest amount in rainfall of 2435.5mm and the least value of 1190.7mm occurred in 1983. Enugu received 2262.4mm as the highest amount of rainfall in 1997 and the least occurred in 1981 with a value of 913.10mm. From the period of investigation, Uyo received 3172.9mm as the highest amount of rainfall in 2011 and the least value of 1562mm in 1983. The predicted values for the modeled data suggests continues increase in amount of annual rainfall in all the locations. From the cumulative mean deviation graphs, Calabar and Uyo indicate a tendency towards flood, while the other stations reveal a tendency towards drought.

Keywords: Rainfall, Inter-Annual, Climate, Precipitation and Southern Nigeria

GENERAL INTRODUCTION

Brief Geography Of Nigeria: Nigeria lies on latitude 10^{o}N and longitude 8^{o} E which indicate that it is within the tropics. Nigeria shares land borders with the republic of Benin in the West, Chad and Cameroun in the East and Niger in the North, its coast lies on the Gulf of Guinea in the South and it border Lake Chad in the North-east. Basically, Nigeria climate is tropical.

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Facts about Calabar: Calabar is the capital of Cross River state. It is located at the southern part of Nigeria. It lies between latitude 5^{0}50N longitude 8^{0}20E. The metropolis comprises of Calabar municipality and Calabar south local Government Areas with an area of 1,480 square kilometer. It is bordered by the great Kwa River to the east and Calabar River to the west. The urban area is on the eastern bank of the Calabar River, with its growth to the south hindered by the mangrove swamps.

Facts about Porthacourt: Porthacourt is the capital of River State, Nigeria. It lies along the Bonny River and located in the Niger Delta. According to the 2006 census, Porthacourt has a population of 1,382,592. Its coordinates are 4.75^{0} N, 7^{0} E with an area of 360 square kilometer (140 sq miles).

Facts about Owerri: Owerri is the capital of Imo State in Nigeria, located at 5.485^{0}N latitude and 7.035^{0}E longitudes. Set in the heart of Igbo land, consist of 3 Local Government Areas including Owerri Municipal, Owerri North and Owerri west. It has an estimated population of about 400,000 as of 2006 census figure and it is approximately 40 square miles (100km^{2}) in area. It is bordered by the Otamiri River to the east and Nworie River to the South.

Facts about Benin: Benin City is the capital of Edo state in southern Nigeria with an estimated population of 1,147,188 2006 census. It is located at 6.34^{0} north latitude 5.63^{0} east longitude and 80 meters above sea level. It is approximately 25 miles north of the Benin River. It is situated 200 miles by road to Lagos. Benin is the center of Nigeria rubber industry, but processing palm nuts for oil is also an important traditional industry.

Facts about Enugu: Enugu is the capital of Enugu State in Nigeria. It is located in the southeastern Nigeria. The city lies at $6^{0}30$ north latitude, $7^{0}30$ east longitudes. It covers an area of 7,660.2 square meters with an estimated population of about 3,267,837 2006 census figures. It accounts for 2.3 percent of Nigeria<s population density 262 people per square kilometer.

Facts about Uyo: Uyo is a city in South Eastern Nigeria and it is the capital of Akwa Ibom state, a major oil producing state of Nigeria. The city became the capital f Akwa Ibom State on September, 23^{rd}, 1987 following the creation of the State from erstwhile Cross River State. The University of Uyo resides in this city. The population of Uyo, according to the 2006 Nigeria census which comprises of Uyo and Itu is 436,606 while the urban area including Uruan, is 554,906. It lies on the coordinates: 5.0232305^{0}N 7.9238892^{0}E.

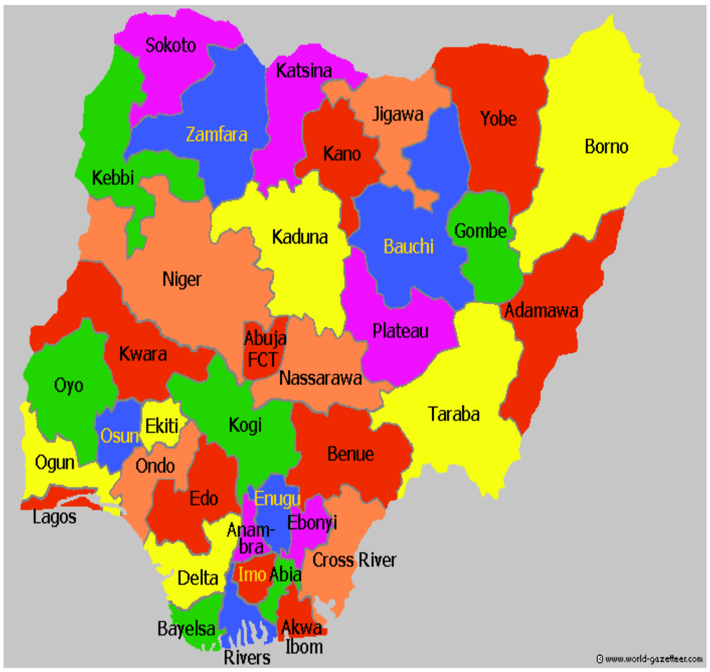


Fig 1.1: *Map of Nigeria showing the locations covered by the study area.*

AIMS OF STUDY

The main aim of this work is to establish the trend and distributional pattern of the rainfall regime in the study areas. For the attainments of the main goal are the following specific objectives;

1 Define, statistically the annual rainfall temporal trend and fluctuations as strategic planning tools.
2 To determine the possibilities of experiencing flood (Wet) or drought (Dry) periods in the study areas.
3 To model and provide forecast values of the annual rainfall for the study areas. This will help in the formulation of agricultural policies and adequate environmental and water resource management in Nigeria.

SIGNIFICANCE OF STUDY

This Study have shown that, some parts of Nigeria have been experiencing increase in the amount of rainfall over the years especially of recent. There are periods of extreme rainfall and also periods of less rainfall, thus leaving many with the fear of experiencing flood or drought. Since most of the studies on the variable (rainfall), by researchers have shown how possibly one can delineate periods of likely occurrence of flood or drought, there may be a limited empirical literature connecting the variables in most parts of the country. This study is to fill the gap on the subject matter. The study is also significant in determining the projected values of annual rainfall to enable one have knowledge of the future.

SCOPE OF THE STUDY

The study will utilize SPSS and Microsoft Excel 2010 to analyze the data spanning from 1972 through 2012, thus making use of 2,832 data points for effective rainfall analysis of the locations. The choice of the study period is dependent on data availability. The variable used in this study is monthly rainfall data summed to obtain annual rainfall for all the stations to enhance analysis. Graphs and linear regression will reveal the variability inherent in annual rainfall of a particular place.

LIMITATION OF STUDY

The major limitation of the study encountered, typical of such was quality and limited availability of data of some states in southern Nigeria. An attempt to extend the data length to 2013 was constrained by the merging of NIMET with other agencies, thus had to fall on 2012. One would be cautions of modeling large variables and interpreting the result. The result of the SPSS employ to some selected state in southern Nigeria base on available data. This results might not be applicable to other states of the southern Niegria, on less studies are carried to generalized the finding made in this work.

Background Knowledge

There is now scientific consensus that global climate is changing (Kandnji, Verchot and Mackensen, 2006). Observation shows that as climate changes, changes are occurring in the amount, intensity, frequency and type of precipitation. These aspects of precipitation generally exhibit large natural variability, and El Nino and changes in atmospheric circulation patterns such as the North Atlantic Oscillation have a substantial influence, Mcilveen, (1992), Udo, *et al*., (2002) & Ryan, (2005). Pronounce long-term trends from 1990 to 2005 have been observed in precipitation amount in some places. Significantly wetter in eastern North and south American, Northern Europe and central Asia, but drier in Sahel, southern Africa, The Mediterranean and southern Asia (Trenbert *et al.* 2007). Africa is already a continent under pressure from climate stresses and is highly vulnerable to the impacts of climate change. Floods and droughts can occur in the same area within months of each other (UNFCCC, 2007). Climate change is a serious threat to poverty eradication and sustainable development in Nigeria. This is because the country has a large rural population directly depending on climate sensitive economic and development sector and natural resources for their subsistence and livelihood, Oladipo, (2008) & Osang et al (2013). Generally, the study of weather and climatic elements of a region is vital for sustainable development of agriculture, and planning. Particularly, rainfall and temperature temporal are deemed necessary as such can indirectly furnish the "health" status of an environment. Extreme weather events that can lead to drought and prolonged heat spell, flooding etc can assess through the statistical analysis of a regions temporal rainfall region. Rainfall variability is of climatologic interests, because it allows an evaluation of the magnitude of the departure of an individual year from the long-term mean and thus the frequency of extreme event persistence in departure patterns, trends in climate series, spatial pattern of variability and comparison with departure series for other climate indices. Climate is therefore the enduring regime of the atmosphere. To specify climate, the day to day values of weather elements are collected and averaged over a suitable period or time scale. The idea behind the "average" weather" is that, a long term series of observation of weather element would produce an average (Normal) value to which each element would always tend to return, Lamb (1968), & Osang et al (2013). Normal climate is the arithmetic average of climatic element such as temperature, rainfall, wind, relative humidity etc, over a prescribed 30year interval. The 30year interval was selected by international agreement, base on the recommendation of the international meteorological conference in warsaw in 1933. This period is long enough to filter out the short term inter-annual fluctuations and anomalies, but sufficiently short so as to be use to reflect longer term climatic trends, (www.aos.wisc.edu|nsco|normals.html). This variability can be used therefore to calculate rainfall probabilities and the likely occurrence of period of rainfall shortage often referred to as drought or excess rainfall often referred to as flood. The degree to which rainfall amounts vary across an area or through time is an important characteristic of the climate of an area. The subject area in meteorology or climatology is called "rainfall variability". There are two types (or components) of rainfall variability, areal and temporal. The study of the latter is important in understanding climate change. The variation of rainfall amounts at various locations across a region for a specific time interval is termed Areal variability (time does not vary). While the variation of rainfall amounts at a given location across a time interval is temporal variability (area does not vary), Osang et al (2013) & Trenbert *et al.* (2007).

METEOROLOGICAL PARAMETER UNDER STUDY

Rainfall as climate element is a condensed water vapour in the atmosphere, which is a liquid form of manifestation of precipitation in the earth atmosphere system. It is often in the form of small drop of water, shower or storm. It is one of the strongest determinants of tropical micro climate. Nigeria is located in the low pressure zone of the earth and due to its proximity to the Atlantic Ocean, it experiences heavy rainfall especially in the Southern part of Nigeria.

MODELING RAINFALL

In order to correctly model rainfall, firstly the factors related to rainfall as its falls to the ground need to be determined. Other factors include, a falling object dropped at a certain height. As the object falls to the ground, gravitational force acts on the object, acceleration and velocity are also important factors to be considered as the distance of the object from the ground and time taken to reach the ground. The drag force also plays an important role when rainfall drops to the ground. To develop a model taking into account the factors mentioned, we consider forces upon falling objects, by applying Newton's second law of motion, which state that

F = ma _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ (1)

Where F is the force, m the mass of the object, and 'a', it acceleration. This can be used to model a rain drop with constant acceleration that is, ignoring air resistance. It is known that acceleration, 'a' is the first derivative of velocity, 'v' and the second derivative of position, 's', thus can be written as $a = \frac{dv}{dt} = \frac{d^2s}{dt^2} \quad - \quad - \quad - \quad (1)$

For a falling object, a = g, we then get:

$$\frac{dv}{dt} = a = g$$

$$\frac{dv}{dt} = g \quad - \quad - \quad - \quad (2)$$

Obtaining a differential equation for a rain drop with constant acceleration, for which, in order to solve it, we need set some initial conditions, the rain drop is starting at rest from a height of 1000m in air, thus the origin. Since constant acceleration. g = 9.87m/s^2 at origin, V(0) = 0, S(o) = 0, t = 0 equation (2) can be written as

dv = gdt - - - - (3)

Integrating both sides

$$\int dv = \int gdt$$

$$v = gt + k \quad - \quad - \quad - (4)$$

To find the constant of integration the initial condition must be used, thus, equation 4 becomes

0 = g(o) + k

k = 0

Substituting k = 0 into equation (4)

V = gt - - - - (5)

Recall also that

$$\frac{ds}{dt} = v \quad - \quad - \quad - \quad (6)$$

Equations (5) and (6) gives

$$\frac{ds}{dt} = gt \quad - \quad - \quad - \quad (7)$$

Applying basic integration to solve the differential equation

$$ds = gt\,dt \quad - \quad - \quad - \quad (8)$$

$$\int ds = \int gt\,dt$$

$$\int ds = g\int t\,dt$$

$$S = \frac{gt^2}{2} + k \quad - \quad - \quad - \quad (9)$$

To find the constant k, initial conditions are applied again

$$0 = \frac{g(0)^2}{2} + k$$

k = 0, we know get

$$S = {}^1\!/_2\, gt^2 \quad - \quad - \quad - \quad - \quad (10)$$

As stated above, S = 1000m, g = 9.87m/s^2. Substituting these values into equation 10, we get;

$$1000 = \frac{1}{2}\, x\, 9.87\, x\, t^2$$

2000 = 9.87t^2

$$t^2 = \frac{2000}{9.87}$$

$$t = \sqrt{202.63} \cong 14.23sec$$

To determine the velocity of the rain drop upon arriving on the ground, we can use equation (5)

V = gt

V = 9.87 x 14.23

= 140.45m/s

We have now modeled a rain drop falling from a given distance, 1000 meters which experience constant acceleration of $9.87m/s^2$. From the results, it shows that, it will take a rain drop 14.23 seconds to reach the ground and its velocity upon reaching the ground will be 140.45m/s. This model is unrealistic, as the rain drop was said to fall form a distance of one kilometer, and only gravitational force is considered. In reality, the rain drop is subject to air resistance and thus dragged upwards. Considering the constant acceleration model, it can be said that it will work for any size of rain drop, since neither acceleration nor velocity depend on mass, Osang et al (2013) & (Ati et al. 2009). Having found this model for rainfall, a more realistic one can be developed taking in account the air resistance which is the force that acts against anything that moves through the atmosphere or air. The amount of air resistance is dependent upon the sphere of the object and its cross sectional area. Once a drop grows to about 5mm in diameter, it breaks into smaller drops due to turbulence and other factors. Research shows that for every small drop with diameter d ≤ 0.008cm experience a drag force which is proportional to the velocity, Emerson & Brandon (2005).

DETERMINATION OF NUMBER OF RAIN DROP IN A COLUMN OF PRECIPITATION

In line with (Ati et al. 2009), rainfall occurs over a flat rectangular surface of length a and breadth b that is almost the same everywhere. The volume of accumulated water ($V\omega$) may be given as:

$$V\omega = A.d$$
$$= (a.b).d$$

Where A is the area covered by the water (a.b) and d is the column of accumulated water (depth) expressed either in inches, or millimeters. In order to estimate how many rain drops are in the column, we need to find the volume of a single rain drop and also a model for the rain drop. If we consider it as a sphere of radius R, the rain drop volume V_d will be;

$$V_d = \frac{4\pi}{3}R^3.$$

Therefore, the number of drops will be

$$N = \frac{V\omega}{Vd}$$
$$= \frac{(a.b).d}{\frac{4\pi}{3}R^3}$$
$$= 3\frac{(a.b).d}{4\pi R^3}$$
$$= \frac{0.24(a.b)d}{R^3}$$

The factors that determine the motion of water under the ground were put together by the famous French scientist Henry Darcy (1803 - 1858), which we refer today as Darcy's law. It may be cast into:

$$\begin{matrix} ground\ water \\ velocity \end{matrix} = \frac{permeability}{porosity}\ \frac{difference\ \ in\ height}{distance} = \frac{K}{P}\cdot\frac{h}{L} = \frac{Kh}{PL}$$

In the Darcy's laws, the two ratios are; permeability over porosity and the second is Rise over Run. Porosity is the proportion of void space in material – holes or cracks unfilled by solid material within grains. Permeability is a measure of how readily fluids pass through the material and is related to the extend which pores or cracks are interconnected. Most ground water moves relative slowly through rocks underground. Because it moves in response to differences in water pressure and elevation, water within the saturated zone tends to move downward following the slope of the water table. The stepper the slope of the water table, the faster the ground water moves. Water table slope is controlled largely by topography. How fast ground water or other materials through which it passes. If rocks pores are small and poorly connected, water moves slowly, the reverse is the case when openings are large and well connected, Mcilveen, (1992), Udo, Osang et al (2013), *et al*., (2002) and Ryan, (2005)..

TROPICAL RAINFALL

Tropical rainfall is of prime importance as it can either be life-giving or life taking as the case may be if excess rainfall produces floods or insufficient rainfall results in drought. Apart from its relevance on life, tropical rainfall is also important for global climate and weather. Over two-thirds of global precipitation falls in the tropics. As a result, a large amount of energy in the latent heat form is released in the low latitudes. The energy not only balances radiation heat losses but it is used to power the global atmospheric circulation. Thus, an understanding of the geographical distribution of rainfall is a leeway to understanding the global distribution of heat sources that drive the globe's atmospheric heat regime. Rainfall is probably the most variable element of tropical climates. The annual total differs from year to year and from one place to another. Its spatial and temporal variations are also demonstrated by characteristic seasonal and diurnal distribution, intensity, duration and frequency of rain-days, Udo, *et al*., (2002), Ryan, (2005).

THE ORIGIN OF TOPICAL RAINFALL

Mcilveen, (1992), Udo, *et al*., (2002) & Ryan, (2005) pointed out that, the origin of rainfall in the tropics can be classified into three different types namely; conventional, cyclonic and Orographic. Conventional rainfall is the result of free convection due to heating alone, dynamic processes such as convergence or physical forcing over mountain ridge. Conventional rainfall generally occurs over a limited spatial scale of between $10\text{-}20km^2$ and $200\text{ -}300km^2$. This type of rainfall is characterized, therefore, by considerable spatial variability. Cyclonic rainfall is produced by horizontal convergence of moist air in a circular area of low pressure where the velocity maximum exists. Its most impressive expression is in tropical cyclone where the combined processes of cyclonic inflow and convention produce intense rainfall. Cyclonic storms typically last between one to five days, which contrasts with the short life span of individual convention cells. The area affected by cyclonic precipitation may be large, as throughout their lifetimes, tropical cyclonic storms can move several hundred kilometers. Orographic rainfall is the result of condensation and cloud formation in moist air that has been physically forced over topographic barriers. Convectional processes in the tropics may aid orographic rainfall formation. It finds its best expression on windward slopes that face into a sustained moist flow of air such as the trade winds. Orographic precipitation unlike cyclonic precipitation is not mobile and its limited to the mountain barrier to which it owes its origin. Regardless of the type of rainfall or climate, all rainfall is the result of upward movements of moist air (Mcilveen, 1992). Although for uplift to occur, the atmosphere needs to be in a state of conditional potential or convective instability. The stability states depend, however on the relationship of the actual environmental lapse rate to the dry and moist adiabatic lapse rates, Ati et al. (2009).

CLIMATE OF NIGERIA (RAINFALL)

Nigeria's climate is characterized by strong latitudinal zones, becoming progressively drier as one moves north from the coast. Rainfall is the key variable, and there is a marked alternation of dry and wet seasons in most areas. The two air masses that control rainfall in the country are; the moist northward moving maritime air coming from the Atlantic Ocean and the dry continental air coming from African landmass. The zone where the two air masses meet constitute the well known Inter Tropical Discontinuity (ITD). Topographic relief plays a significant role in local climate only around the Jos plateau and along the eastern border highlands. In the coastal and southern portion of Nigeria, the rainy season usually begins in February or March as most Atlantic air, known as the southwest monsoon that invades the country, Ati et al. (2009), Udo, *et al*., (2002), Ryan, (2005). The beginning of rain is usually marked by incidence of high winds and heavy but scattered squall. The scattered quality of this storms rainfall is noticeable in the north in dry years, when rain may be abundant in some small areas while other contiguous places are completely dry. By April or early May in most years, the rainy season is under way throughout most of the area south of the Niger and Benue river valleys. Farther north, it is usually June or July before rains really commence. The peak of rainy season occurs through most of northern Nigeria in August, when air from the Atlantic covers the entire country. In the southern regions, this period marks the August dip in precipitation. Although rarely completely dry, this dip in rainfall, which is especially marked in the southwest, can be useful agriculturally, because it allows a brief period for grain harvesting, Ryan, (2005) & Osang et al (2013). From September through November, the northeast trade wind generally brings a season of clear skies, moderate temperatures, and lower humidity for most of the country. From December through February, however, the northeast trade winds blow strongly and often bring with them a load of fine dust called harmattan from the Sahara. These dust-laden winds often appear as a dense fog and cover everything with a layer of fine particles. The Harmatan is more common in the north but affects the entire country except for a narrow strip along the southwest coast. An occasional strong Harmatan can sweep as far as Lagos, providing relief from high humidity in the commercial capital of the country and pushing clouds of dust out to sea, Ati et al. (2009).

CAUSES OF RAINFALL IN NIGERIA

According to Udo, *et al*.,(2002) and Ryan, (2005), the distribution of rainfall in Nigeria both in time and space is controlled by four main rain producing factors which are invariably operative in the West Africa region to which Nigeria is a part. The factors include; The monsoonal air from the Atlantic Ocean. The organized belt of thunderstorm, the distribution lines which trade roughly from East to West. The location of the surface position of the Inter-Tropical Discontinuity (ITD) and the associated weather zones. The relief factors. The major cause of rain production is moisture moving in three dimensional zones of temperature and moisture contrasts known as Weather Fronts. If enough moisture and upward motions are present, precipitation falls from convective clouds (those with strong upward vertical motion) such as cumulonimbus (thunder clouds) which can organize into narrow rain bands. (Udo *et al.*, 2002). The intensity and duration of rainfall are usually inversely related, i.e high intensity storms are likely to be of short duration and low intensity storms are likely to have long duration, (Udo, *et al*., 2002), (Ryan, 2005). In view with (Afangideh *et al*., 2013),

$$\text{rainfall intensity (mm/year)} = \frac{\text{Annual rainfall amount}}{\text{Annual rainfall duration}}$$

DROUGHT

Drought is a period of unusually persistent dry weather that persists long enough to cause serious problems such as crop damage and water supply shortages. There are basically four ways drought could be view; In Meteorology, it is a measure of the departure of precipitation from normal. Due to climate differences, what might be considered a drought in one location of the country may not be a drought in another location. In Agriculture, it is a situation where the amount of moisture in the soil no longer meets the need of a particular crop. In Hydrological, it occur when surface and subsurface water supplies are below normal, and in Socioeconomic it refers to the situation that occurs when physical water shortages begin to affect people. Mckee *et al* (1993) developed a drought monitoring index (SPI) to quantify precipitation deficit for multiple time scale. The index uses long-term precipitation records for desired period of time which will be fitted to a probability distribution. If a particular rainfall event gives a low probability on the cumulative probability function, then this is indicative of a likely drought event. If the value gives +2 and above , the drought intensity is extremely Wet, but if it gives -2 and less it indicates extreme drought event. According to NOAA, (2014) a climate prediction center, drought severity index by division shows that -4 or less indicates extreme drought, -3.0 to -3.9 indicates severe drought +4 and above extreme moist while +3.0 to +3.9 very moist spell.

RAINFALL

Meteorological data have shown that rainfall pattern in Nigeria has changed in the past decades. Oladipo (1995) reported that decline in the rainfall in Nigeria started in the beginning of the 1960s when a decade of relatively wet years ended. According to him, the persistence of below-mean rainfall in the last two decades before 1995 in Nigeria is an indication of an abrupt change in climate. The Nigeria environment lie predominantly in the tropics having two seasons - the wet and dry seasons. The wet season occurs from May to September, while the dry season begins in October and ends in April. The agricultural sector is highly sensitive to rainfall pattern especially in southern Nigeria where rain-fed agriculture is mainly practiced (NOAA, 2008). The annual cumulative rainfall amounts of 300 – 1000mm were recorded in the northeast, parts of Katsina and Kano in the northwest and Ilorin in the central region. The entire southeast and parts of Akure, Benin, Ijebu Ode and Oshogbo in the southwest had 2000 – 3000mm of rainfall in the year. The rest of the country experienced rainfall between 3000 – 4500mm. The highest cumulative rainfall amount of 4224.0mm recorded at Eket is about 269.3mm less than the 2009 record high at the same station.

Nguru, like in the year past, recorded the lowest rainfall of 447.8mm. (Nigeria Climate Bulletin, 2010). Christoph and Fink, (2005), Studied rainfall trends over west Africa from 1991 – 2004, they showed average rainfall interms of the 1950 – 1990 mean event through the years 1999 and 2000 were exceptionally wet. In USA, Karl et al. (1995b) employed the threshold value of 50.8mm rainfall. Their studies found a steady increase in the percentage of annual precipitation derived from extreme events exceeding the threshold value contributed mainly by change in spring and summer rainfall. Rainfall varies widely over short distances and from year to year though it is generally latitude dependent. Part of the coast along the Niger Delta, where the raining season is year round receive heavy down pour each year. For instance, the wettest city in Nigeria, receives more than 4000mm of rainfall annually, (Ewona and Udo, 2009). Obot et al, (2010) found that the total amount of rainfall across Nigeria in selected locations in each of the six zones within a 30 years period (1978-2007) from the Mann Kendall test reveals an increasing trend in only one out of the six locations. Maiduguri (North East) where formally the trend was decreasing, (Hess et al. 1995) is now witnessing an increasing trend of 9.46 mm of rainfall per year. This trend was non-existing in a sub 20 year period of (1978-1997) but came out when another sub period of (1988-2007) was examined. The latter period seems to be a period of ‘change’ showing erratic pattern in four out of the six zones when compared to the former period. It appears that the minimum rainfall witnessed in a location does not necessarily have to do with the geographical or cardinal placement of that location. The outcome of this detected significantly increasing trend could lead to either rainfall disasters like erosion and flooding or rainfall blessings like increased water level and availability, bomber harvest for farmers, and an end to deforestation and other aridity hazards hitherto witnessed in this location. Nicholson (1978), for the period between the 16^{th} and 20^{th} centuries, investigated the rainfall conditions in the Sahel and other African regions and found from proxy records several significant rainfall fluctuations in the Sahel and other part of Africa during the five (5) century period. Total rainfall is strongly correlated with the extreme frequency and extreme intensity indices, suggesting that extreme events are more frequents and intense during years with high rainfall. Due to an increase in the number of rain days during such years, the proportional contribution from extreme events to the total rainfall depends on the method used to calculate the index (Haylock and Nicholls, 2000). Since rainfall is somewhat irregular even within the rainy season and sometimes periodic, researchers seem to be more comfortable with working on such parameters as total rainfall. Extreme intensity, extreme frequency, total rainfall days (where a rainfall day is a day rain gauge measures 1mm rain or above), (Haylock & Nicholls, 2000; Hess et al. 1995). Sharon (2000), reveals that remarkable fluctuations in annual rainfall has occurred over nearly the entire continent. Acheampong, (1987) suggests that the dry years over the Sahel was due to the weakening of the upward motions in the monsoons at the height of the rainy season owing to stronger inversions and / or large –scale subsidence. In Nigeria, Olaniran (1991b) found that rainfall in the dry years support the hypotheses of a restricted northward advance of the Inter Tropical Discotinuity (I.T.D), whilst those of the wet years support that of considerable northward incurtion of the I.T.D. lack of rainfall over major subtropical deserts has been attributed to the sinking and drying of the air aloft, as a result of high albedo over the regions. This is known as Biogeographical Feedback Mechanism.

CHANGING RAINFALL PATTERNS IN NIGERIA

Global warming has brought about changes in weather patterns toward an intensified water cycle with stronger floods and droughts. In Nigeria, global warming has had a significant impact on rainfall-undoubtedly, the most significant component in agricultural practice, and the defining element in seasonal change. Rainfall has grown more intense with frequent and devastating floods. 2012 was indeed a tragic year, country wide, as intense rains left in their wake wanton destruction of lives and properties. On 2, July 2012, many Nigerian coastal and inland cities experienced heavy rains. In mid-July 2012, flooding in Ibadan, Oyo State capital, caused many residents to flee from their homes. In late July 2012, at least 39 people were killed due to flooding in Plateau State. Heavy rainfall caused the Lamingo Dam to overflow near Jos, sweeping across a number of neighborhoods and approximately 200 homes were submerged or destroyed. In that year also, discharge of water from a dam in neighboring Cameroon, as a result of a downpour, triggered one of the most disastrous floods in the northern part of the country. Worst hit was Adamawa State, where no fewer than 89 schools were severely flooded, prompting the state government to indefinitely postpone the resumption of schools for the new academic year. The Nigerian Meteorological Agency, NIMET, had, in March that year, warned about imminent heavy rainfall and the attendant flooding in many parts of the country, but the warning was either ignored or not taken seriously. Several conferences have been held on the international scene to check the release of harmful gases that are causing increase in global temperatures. Tope, (2013).

DATA SOURCE

Rainfall data in years of 41 years (1972 - 2012) for six (6) stations were obtained from the archives of Nigeria Meteorological services dept. of Calabar, Portharcourt, Benin, Enugu, Owerri, and Uyo. Availability and reliability of the annual rainfall data, were considered foremost as these locations are longstanding operational synoptic stations, standard equipments and personnel; the data obtained where high grade. The instrument used in measuring rainfall is the rain gauge. It involves routine observation of amount of precipitation for period of one to 24 hours. It is collected in a bottle placed in a removable copper bucket. This facilitates handling and pouring to reduce heat lost by evaporation. Rainfall is measured in millimeters with eight observations for a 24 hour period.

DATA ANALYSIS

From the rainfall data obtained, annual rainfall series was computed and analyzed for trend and fluctuation using Standardized Anomaly Index (SAI). The standardized Anomaly Index is calculated for individual station using the following equation.

$$X_{ij} = \frac{1}{N_j}\sum_{i=1}^{N_j}\frac{|r_{ij} - \bar{r_i}|}{\sigma_i}$$

Where X_{ij} is the normal departure for the year j,

r_{ij} is that year's annual rainfall total at station i.

$\bar{r}_i$ is the mean rainfall of station 1's total for the base period.

σ_i is the standard deviation of station I's total for the base period.

N_j is the Number of stations with complete records in the year j.

Gregory, S. (1989) suggested the use of regression analysis for assessing the trends of rainfall series. Regression analysis has been used to search for trends in annual rainfall series in Sierra Leone (Bowden, D. J. 1980). The regression analysis was used in this study.

FLUCTUATIONS IN ANNUAL RAINFALL

The annual rainfall distributions in the study area are shown in fig. … A closer look at each of these figures shows that the (annual) rainfall distribution has no clear cut pattern of, say, cycle or randomness. The governing equation for determining these fluctuations is given by:

$$X_j = \frac{|r_j - \bar{r}_i|}{\sigma_i}$$

Where X_j normalized departure (Standardized Anomaly Index),

r_j is the annual rainfall for the year j,

$\bar{r}_i$ is the mean annual rainfall for the station I and

σ_i is the standard deviation of station I's annual rainfall.

ANALYTICAL TECHNIQUES

Definitions or explanations of the terminology used in the analysis of data are given below

(1) Mean: This is the most common measure of central tendency for a variable measured at the interval level. It is often referred to as the 'average'. It is the sum of individual values of a variable divided by the total number of the variables.

In mathematical notation:

$$\bar{X} = \frac{\sum_{i=1}^{N} X_i}{N}$$

Where:

$\bar{X}$ = means of variable X

X_i = values of the variable X

$\sum$ = summation sign.

N = total number of observation of the variable X

(ii) Deviation: this is the difference between the values of the variables X and the mean variable $\bar{X}$. in mathematical notation, it is given as

$$d = X_i - \bar{X}$$

Where

X_i = values of variable X

$\bar{X}$ = mean of variable X

d = Deviation

(iii) Mean Deviation

$$MD = \frac{\sum |X_i - \bar{X}|}{N}$$

Where

$\bar{X}$ = mean of the values of variable

X_i = values of variable X

N = number of observation of variable X

(iv) Variance: this is a measure of dispersion of data about the mean of an interval level variable. This statistics is one way of measuring how closely the individual value of the variable cluster around them.

In mathematical notation

$$\sigma^2 = \frac{\sum_{i=1}^{N} [X_i - \bar{X}]^2}{N}$$

Where

σ^2 = Variance

X = A variable

X_i = values of variable X

N = Number of observation of variable X

(v) Standard deviation: this is another measure of dispersion about the mean of an interval level. Standard deviation is the square root of variance. In mathematical notation

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N} [X_i - \bar{X}]^2}{N}}$$

Where

σ = Standard deviation

X = A variable

$\sum$ = summation

N = Number of observations of variable X

(vi) Coefficient of variation: This is used to compare the variability of any two distributions which may be measured in different units. It is expressed as a percentage of the standard deviation to the arithmetic mean and is denoted as

$$\textit{Coefficient of Variation} = \frac{\text{Standard Deviation } X 100\%}{Mean}$$

ii) Standardized Anomaly Index (SAI): The value of the Standardized Anomaly Index (SAI) for the given year j is given by:

$$X_j = \frac{r_{ij} - \bar{r}_j}{\sigma_i}$$, Where

X_j = Normalized departure

X_{ij} = Annual rainfall for the station in the year j

$\bar{r}_j$ = Mean Annual Rainfall for the station i

σ_i = standard deviation of the I's annual rainfall

In order to get the required equation of the regression line $(y = mx + C)$, the normal equations

$$nc + m\sum X = \sum y$$

$$c\sum X + m\sum X^2 = \sum xy$$

Need to be solved for m and c
Where n = period of investigation
M = slope (Annual rate of change of rainfall in mm/year)
$\sum$ = summation sign.
X = Time (years)
C = intercept

RESULTS AND DISCUSSIONS

In order to show the trends and fluctuations of annual rainfall of the six stations (Calabar, Porthacourt, Benin, Owerri, Enugu, and Uyo), the annual rainfall values which have been analyzed by using Statistical Package for Social Sciences (SPSS Software 17.0) were plotted against the period of investigation. Fig. 4.1 - Fig. 4.30 reveals that there has been an increase in the amount of annual rainfall in the study areas over the period of investigation.

Fluctuation and Trend in Annual Rainfall in Calabar

The annual rainfall variability in Calabar is shown in Figures 4.2 and 4.3. The graph is plotted using Microsoft Excel 2010. The annual rainfall series contains two distinct periods when rainfall anomalies of a particular type were most consistent. There exist two types of rainfall anomalies namely; negative rainfall anomaly (i.e. annual rainfall below the mean annual rainfall) and the positive anomaly (i.e. annual rainfall above the mean annual rainfall). 43.9 percent of the period of investigation experience strong negative departure from the mean annual rainfall for Calabar (Fig. 4.2 and 4.3). The persistence of negative anomalies for these years suggests that Calabar has been experiencing dry conditions since 1972 to about 1993. 29 percent of the study period in contrast were years of rainfall enhancement in Calabar with strong positive departure from the mean annual rainfall. The positive rainfall anomalies during this year suggests that Calabar has been experiencing wet conditions since 1979 to a period of about 1981 where dry conditions repeated until 1996 which marks the beginning of another wet conditions till present. Figure 4.1 shows a line and least square composite graph of the annual rainfall regime for Calabar. The y axis represents the annual rainfall in mm, the x axis represents the time in years. Trend in annual rainfall series in Calabar under investigations smoothening out with the five year moving average (running mean) shows that annual rainfall above long term mean rainfall lasted from 1978 to 1984. From the early 1980s to late 1990s, the rainfall was below the long term mean and with the above average rainfall appearing between 1997 to 2001 again, latter dropping afterward. The increase rainfall series for the station is statistically defined by the function Y= 15.21x + 2636. The trend line suggests an increase in the amount of rainfall at the rate of 15.21mm per year with coefficient of determination of 0.193. Figure 4.4 show that Calabar recorded the highest value of annual rainfall of 4062.7mm in 2012 and the lowest value of annual rainfall of 2099.4mm in 1973. This shows a clearer picture that there has been a rapid increase in the amount of annual rainfall in Calabar. This is slightly higher than the findings of Ewona and Udo 2009.

Table 4.1 *Calabar Annual Rainfall (mm), Standardized Anomaly Index*

CALABAR.		
YEARS	**Annual Rainfall(mm)**	**Standardized anomaly index**
YEAR1972	2954	-0.00512
YEAR1973	2099.4	-2.06623
YEAR1974	2556	-0.96501
YEAR1975	2715.65	-0.57997
YEAR1976	2992.8	0.088457
YEAR1977	2646.7	-0.74626
YEAR1978	3296.1	0.819952
YEAR1979	2811	-0.35001
YEAR1980	3553.6	1.440988
YEAR1981	2736.9	-0.52872
YEAR1982	2809	-0.35483
YEAR1983	2347.2	-1.46859
YEAR1984	2495.4	-1.11117
YEAR1985	2945.4	-0.02586
YEAR1986	2609.7	-0.8355
YEAR1987	3009.7	0.129216
YEAR1988	2723.4	-0.56128
YEAR1989	2765.6	-0.4595
YEAR1990	2728.5	-0.54898
YEAR1991	2661.9	-0.7096
YEAR1992	2896.5	-0.1438
YEAR1993	2511.3	-1.07282
YEAR1994	2904.6	-0.12426
YEAR1995	3649.7	1.67276
YEAR1996	3215.3	0.62508
YEAR1997	3486.8	1.27988
YEAR1998	2911.5	-0.10762
YEAR1999	3003.5	0.114263
YEAR2000	3663.4	1.705802

YEAR2001	3130	0.419354
YEAR2002	2697.8	-0.62302
YEAR2003	2657.7	-0.71973
YEAR2004	2886.1	-0.16888
YEAR2005	3771	1.96531
YEAR2006	2893.5	-0.15103
YEAR2007	3428.2	1.138549
YEAR2008	2886.9	-0.16695
YEAR2009	2527.1	-1.03471
YEAR2010	3071.7	0.278747
YEAR2011	3487.8	1.282292
YEAR2012	4062.7	2.668829

.2: Annual

Fig 4.1: *least square trend analysis for Calabar*

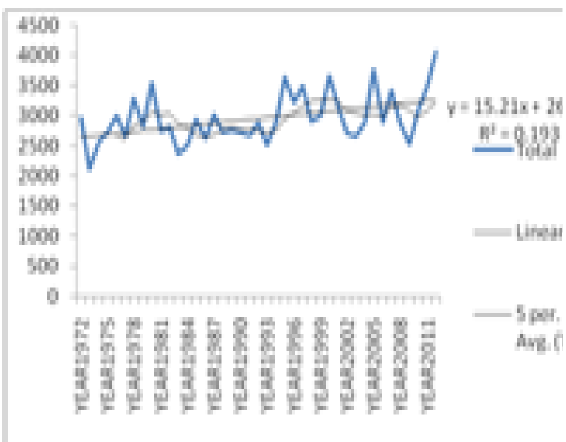


Fig 4.4: *Comparative Bar Chart showing rainfall variation in Calabar*

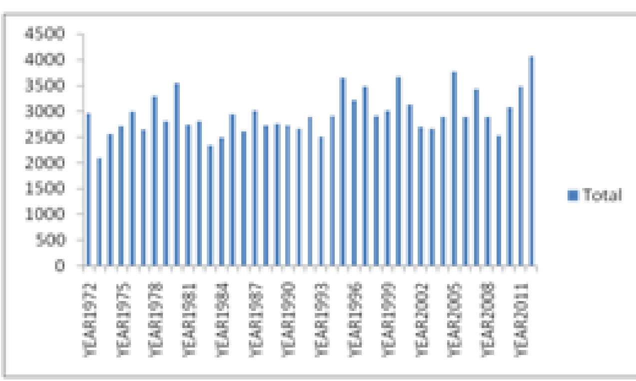
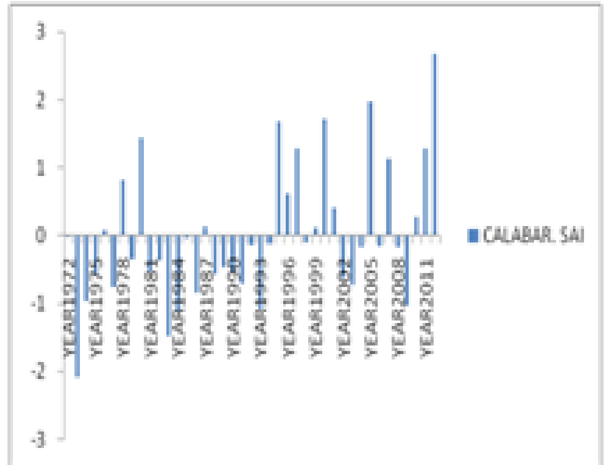


Fig 4.3: *Modeled Annual Rainfall fluctuation with respect to SAI for Calabar.*



Fluctuation and Trend in Annual Rainfall for Port Harcourt

Fig. 4.7 and 4.8 reveals the annual rainfall variability in Porthacourt. About 49 percent of the study period experienced strong negative departure from the mean annual rainfall. This suggests that Porthacourt experienced dry conditions in these years. About 29 percent of the period of study where years of rainfall enhancement with strong positive departure from the mean annual rainfall. This suggests that the station has experienced wet condition during these years. 10 percent of the study period experienced annual rainfall below one standard deviation from the mean annual rainfall and 12 percent experienced annual rainfall above one standard deviation from the mean annual rainfall in the station. Fig 4.6 shows that the running, mean was below the long term mean from the beginning of the data to the late 1970s, from that point rainfall was above the average up to the early 1980s. The rainfall was again below average from about 1985 up to early 1990s. From 1994, there has been a rising and falling i.e. above and below average rainfall in the station of recent (Fig. 4.5). The trend line which is linear suggest a small increase in the amount of annual rainfall in the station for the period of observation, increasing at the rate of 2.18mm per year with coefficient of determination of 0.003. The fluctuating and increase temporal series is defined by Y = 2.180x + 2392. Fig 4.9 shows that the station recorded 3911.7mm as the highest amount of annual rainfall in 1993 and 1816.4mm as the least value in 1983 for the period of investigation.

Table 4.2** Port Harcourt **Annual Rainfall (mm), Standardized Anomaly Index

PORTHACOURT		
YEARS	**Annual Rainfall(mm)**	**Standardized anomaly index**
YEAR1972	2225	-0.48668
YEAR1973	1837.4	-1.37271
YEAR1974	2204.6	-0.53331
YEAR1975	2526.9	0.203444
YEAR1976	2328.3	-0.25054
YEAR1977	2235.5	-0.46268
YEAR1978	2261.9	-0.40233
YEAR1979	3338.8	2.059401
YEAR1980	3328	2.034712
YEAR1981	2909.5	1.078046
YEAR1982	2817.5	0.867739
YEAR1983	1816.4	-1.42072
YEAR1984	2362.5	-0.17236
YEAR1985	2206.8	-0.52829
YEAR1986	2133.5	-0.69585
YEAR1987	2763.9	0.745213
YEAR1988	2333.6	-0.23843
YEAR1989	1865.5	-1.30848
YEAR1990	2073.3	-0.83346
YEAR1991	2029.9	-0.93267
YEAR1992	1972.4	-1.06411
YEAR1993	3911.7	3.369017
YEAR1994	2370	-0.15522
YEAR1995	2490.9	0.12115
YEAR1996	2419.5	-0.04207
YEAR1997	2313.2	-0.28506
YEAR1998	2567	0.295111
YEAR1999	2499.6	0.141038
YEAR2000	1994.3	-1.01405
YEAR2001	2150	-0.65813
YEAR2002	2496.8	0.134637
YEAR2003	2738	0.686007
YEAR2004	1989.5	-1.02502
YEAR2005	2607.7	0.388148
YEAR2006	2960.8	1.195315
YEAR2007	2866	0.978607
YEAR2008	2049.9	-0.88695
YEAR2009	2842.2	0.924202
YEAR2010	2513.2	0.172127
YEAR2011	2317.4	-0.27546
YEAR2012	2285.1	-0.3493

***Fig 4.6:** least square trend analysis for Porthacourt*

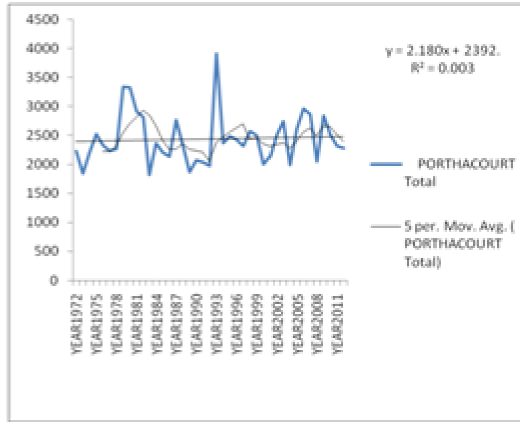


***Fig 4.7:** Annual Rainfall fluctuation with respect to SAI for Porthacourt.*

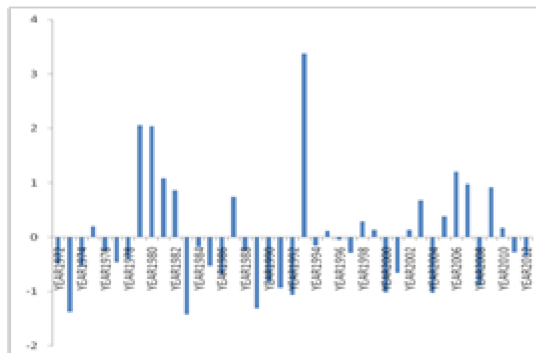


***Fig 4.8:** Modeled Annual Rainfall fluctuation with respect to SAI for Porthacourt.*

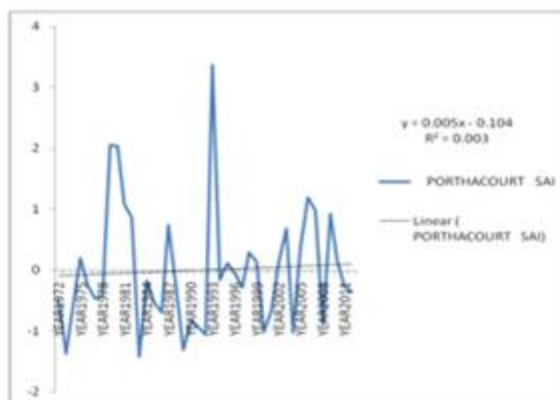
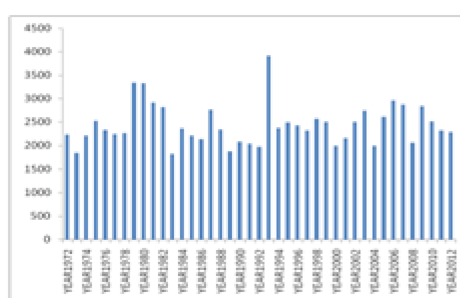


***Fig 4.9:** Comparative bar chart showing rainfall variation in Porthacourt.*



Fluctuations and trend in annual rainfall for Benin

Fig. 4.12- 4.13 shows the annual rainfall variability in Benin. About 44 percent of the period of study experienced strong negative departure from the mean annual rainfall. These negative anomalies suggest that dry conditions were being experience during this period. Also 42 percent of the period were years of rainfall with strong positive departure from the mean annual rainfall. This suggests that, the station experiences wet conditions in these years. Seven percent of the period of investigation experienced annual rainfall below and above one standard deviation from the mean annual rainfall. Fig 4.11 shows that the running mean for Benin was above the long-term mean from the beginning of the data up to the early 1980s. From that point rainfall was below average up to 2006. After that there was a sharp increase to the end of the data. The trend line suggests that there has been a slight increase in the amount of rainfall received over the period of investigation at the rate of 3.24mm per year, with a coefficient of determination of 0.015. Fig. 4.14 shows that the station recorded the highest amount of annual rainfall of 2435.5mm in 1976 and the least value of annual rainfall of 1190.7mm in 1983.

Table 4.3 *Benin Annual Rainfall (mm), Standardized Anomaly Index*

BENIN		
YEARS	**Annual Rainfall(mm)**	**Standardized anomaly index**
YEAR1972	1699.3	-0.52675
YEAR1973	1974.4	0.364412
YEAR1974	2193.2	1.073196
YEAR1975	2306.5	1.440221
YEAR1976	2435.5	1.858106
YEAR1977	2288.8	1.382884
YEAR1978	2433.7	1.852275
YEAR1979	1742	-0.38843
YEAR1980	1619.4	-0.78558
YEAR1981	1558.6	-0.98254
YEAR1982	1585.7	-0.89475
YEAR1983	1190.7	-2.17432
YEAR1984	1650	-0.68645
YEAR1985	1786.2	-0.24525
YEAR1986	1411.4	-1.45938
YEAR1987	1406.5	-1.47525
YEAR1988	1450.2	-1.33369
YEAR1989	1681.1	-0.58571
YEAR1990	1824.5	-0.12118
YEAR1991	1948.7	0.281159
YEAR1992	1678.7	-0.59348
YEAR1993	1630	-0.75124
YEAR1994	1529	-1.07842
YEAR1995	2069.2	0.671508
YEAR1996	1975.5	0.367975
YEAR1997	2202.9	1.104618
YEAR1998	1544.2	-1.02918
YEAR1999	1563.2	-0.96764
YEAR2000	1988.2	0.409115
YEAR2001	1870.7	0.028484
YEAR2002	1743.8	-0.3826
YEAR2003	1810.7	-0.16588
YEAR2004	1888.3	0.085498
YEAR2005	2069.2	0.671508
YEAR2006	1721	-0.45646
YEAR2007	2179.4	1.028492
YEAR2008	2063	0.651424
YEAR2009	2081.48	0.711288
YEAR2010	1916.7	0.177497
YEAR2011	2256.8	1.279222
YEAR2012	2369.8	1.645276

Fig 4.11: *least square trend analysis for Benin*

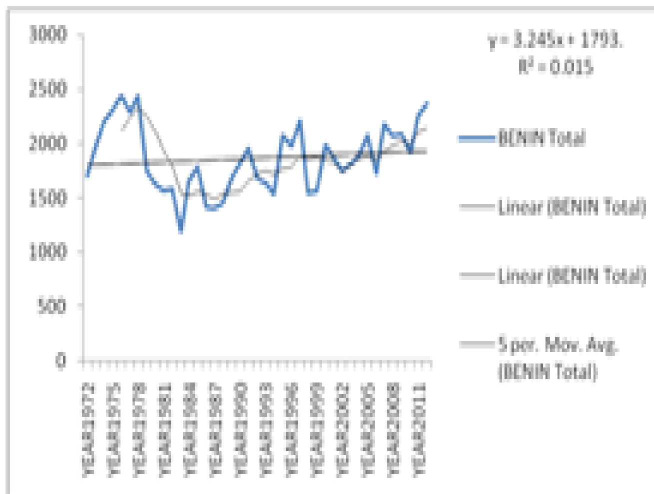


Fig. 4.12: *Annual Rainfall fluctuation with respect to SAI for Benin.*

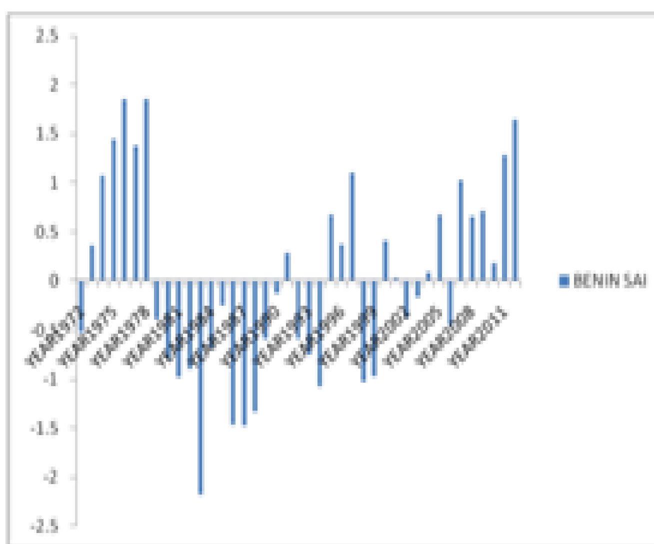


Fig 4.13: *modeled Annual Rainfall fluctuation with respect to SAI for Benin.*

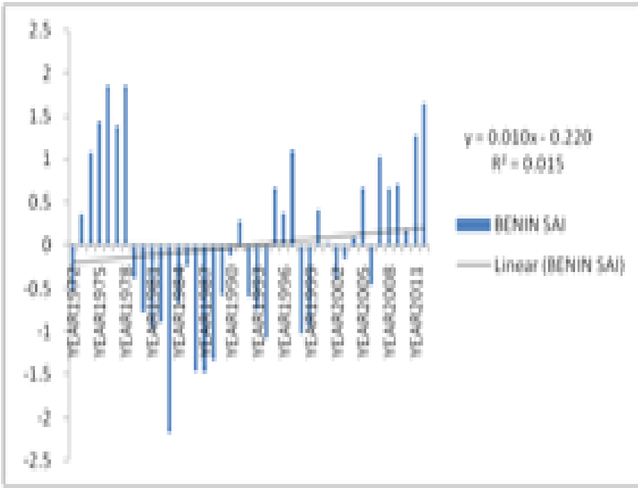
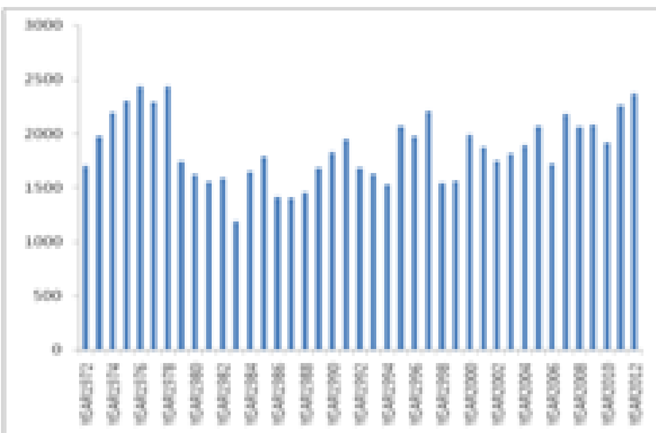


***Fig 4.14:** comparative bar chart showing rainfall variation in Benin*



Fluctuation and Trend in Annual Rainfall in Owerri

Fig.4.17- 4.18 shows that 39 percent of the period of investigation experience strong negative departure from the mean annual rainfall. This suggests that the station has experience dry condition during the period especially from 1972 to about 1987. In contrast, 37 percent of the period of investigation experienced enhanced rainfall with strong positive departure from the mean annual rainfall indicating that the station experienced wet conditions during this period. 12 percent each experienced annual rainfall below and above one standard deviation from the mean annual rainfall. This suggests that Owerri experience wet condition during this period (fig.4.17-4.18). Twelve percent each experience annual rain fall below and above one standard deviation from the mean annual rainfall for Owerri. The inference is in line with the drought monitoring index developed by, McKee, et al 1940. Fig 4.16 shows that the running mean was below average from the beginning of the data up to late 1970s where it began to rise above average. It was seen to fall below again from 1984 to about 1990. From 1990 to 1999 it was above average and again fell below from that point to the end of the data. This clearly shows the fluctuating pattern in rainfall regime in the station. The regression equation y = 22.23x + 1651, suggests an increase in the amount of rainfall at the rate of 22.23mm per year with coefficient of determination of 0.364. Fig 4.19 shows that the station received 3064.0mm of annual rainfall in 2011 as the highest value and 1228.4mm in 1986 as the least amount of annual rainfall.

Table 4.6** Owerri **Annual Rainfall (mm), Standardized Anomaly Index

OWERRI		
YEARS	**Annual Rainfall(mm)**	**Standardized anomaly index**
YEAR1972	1632.6	-1.10105
YEAR1973	1535.44	-1.32133
YEAR1974	1780.9	-0.76483
YEAR1975	1420.4	-1.58215
YEAR1976	1808.3	-0.70271
YEAR1977	1585.7	-1.20738
YEAR1978	1879.3	-0.54174
YEAR1979	2538.2	0.9521
YEAR1980	2642.2	1.187886
YEAR1981	1827.1	-0.66009
YEAR1982	1968.9	-0.3386
YEAR1983	1647.7	-1.06682
YEAR1984	1249.3	-1.97006
YEAR1985	1545.3	-1.29898
YEAR1986	1228.4	-2.01745
YEAR1987	2341.2	0.505467
YEAR1988	2149.1	0.069942
YEAR1989	1969.9	-0.33634
YEAR1990	2474.4	0.807454
YEAR1991	2577.6	1.041427
YEAR1992	2016.5	-0.23069
YEAR1993	1860.1	-0.58527
YEAR1994	2532.5	0.939177
YEAR1995	2669.8	1.250461
YEAR1996	2549.4	0.977493
YEAR1997	2200.8	0.187155
YEAR1998	2069.4	-0.11075
YEAR1999	2249.8	0.298247
YEAR2000	2240.2	0.276482
YEAR2001	2234.9	0.264466
YEAR2002	2559.5	1.000391
YEAR2003	1840.8	-0.62903
YEAR2004	2328.3	0.47622
YEAR2005	2069.2	-0.1112
YEAR2006	2014	-0.23635
YEAR2007	2358.5	0.544689
YEAR2008	2670	1.250914
YEAR2009	2102.5	-0.03571
YEAR2010	2827.4	1.607767
YEAR2011	3064	2.144181
YEAR2012	2588.7	1.066593

***Fig 4.16:** least square trend analysis for Owerri*

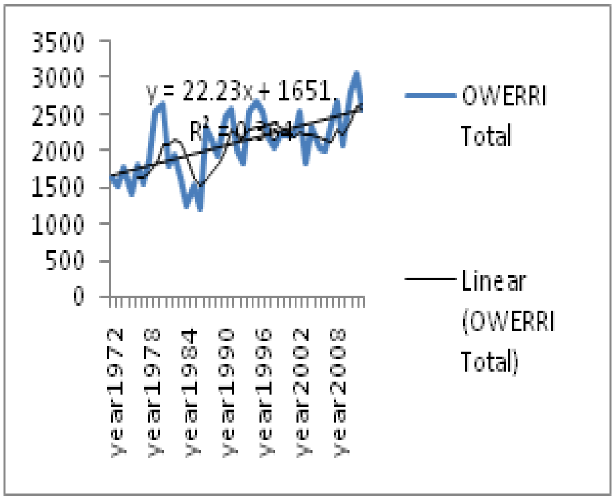


Fig 4.17: *Annual Rainfall fluctuation with respect to SAI for Owerri.*

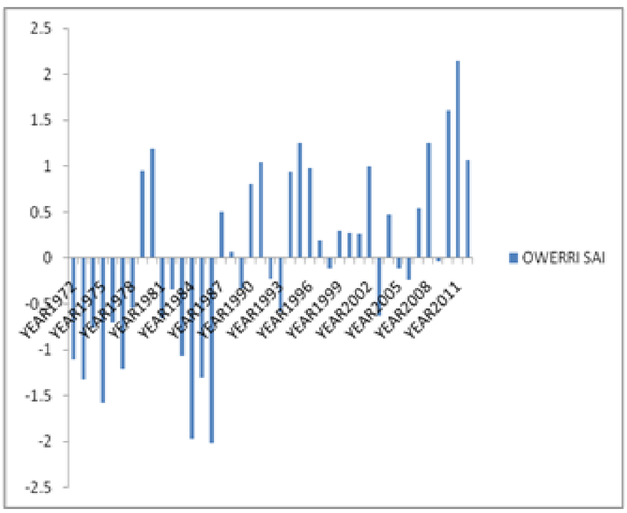


Fig 4.18: *Modeled Annual Rainfall fluctuation with respect to SAI for Owerri.*

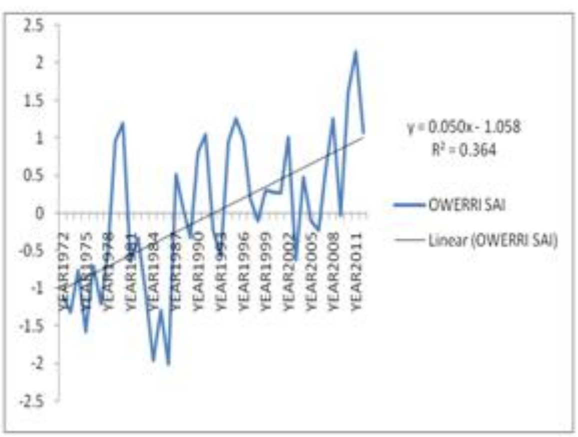
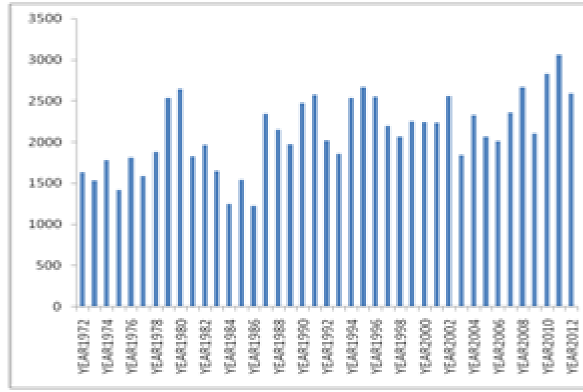


Fig 4.19: *comparative bar chart showing rainfall variation in Owerri*



Fluctuation and trend in Annual Rainfall for Enugu

Fig 4.22 and 4.23 shows the annual rainfall variability for Enugu. The station is marked by about 34 percent negative departure from the mean annual rainfall, suggesting that dry condition were being experienced during the period. Thirty seven percent of the period of investigation experienced years of rainfall. The positive anomalies that are being experience suggest wet conditions for the station in these years, Twenty two percent and 10 percent period of investigation experience annual rainfall below and above one standard deviation from the mean annual rainfall. Fig 4.21, shows a running mean above the long term mean from the beginning of the date until early 1980s where the rainfall was below average up to about 1990. After that it has always experienced a slight increase and decrease (above and below average) as shown in the figure. The trend line shows that there is an increase in the amount of rainfall of 5.08mm.per year with coefficient of determination of 0.053. Fig 4.24, shows that the highest amount of annual rainfall recorded is 2262.4mm in 1997 and the least value of 913.1mm occurred in 1981 through the period of investigation.

Table 4.7** Enugu **Annual Rainfall (mm), Standardized Anomaly Index

ENUGU		
YEARS	**Annual Rainfall(mm)**	**Standardized anomaly index**
YEAR1972	1979.7	0.887506
YEAR1973	1448.9	-1.13239
YEAR1974	1829.4	0.315558
YEAR1975	1545.8	-0.76365
YEAR1976	1983.1	0.900445
YEAR1977	1696.8	-0.18904
YEAR1978	2090.8	1.310284
YEAR1979	1704.2	-0.16088
YEAR1980	1566.6	-0.6845
YEAR1981	913.1	-3.17131
YEAR1982	1779.4	0.125288
YEAR1983	1930.9	0.701804
YEAR1984	1450.6	-1.12592
YEAR1985	1451.6	-1.12212
YEAR1986	1461	-1.08635
YEAR1987	1643.7	-0.3911

YEAR1988	2083.4	1.282125
YEAR1989	1961.2	0.817107
YEAR1990	1706.5	-0.15212
YEAR1991	1577.8	-0.64188
YEAR1992	1455.9	-1.10575
YEAR1993	1611.6	-0.51325
YEAR1994	1423.7	-1.22829
YEAR1995	2166.3	1.597591
YEAR1996	1919.4	0.658042
YEAR1997	2262.4	1.963288
YEAR1998	1497	-0.94935
YEAR1999	1540.6	-0.78344
YEAR2000	1985.4	0.909197
YEAR2001	1677.2	-0.26362
YEAR2002	1722.2	-0.09238
YEAR2003	1897.3	0.573943
YEAR2004	1763.7	0.065544
YEAR2005	1760.4	0.052986
YEAR2006	2052.4	1.164158
YEAR2007	1912.1	0.630263
YEAR2008	1737.2	-0.0353
YEAR2009	1632.7	-0.43296
YEAR2010	1716	-0.11597
YEAR2011	1980.6	0.890931
YEAR2012	2086.9	1.295443

Fig 4.21: *least square trend analysis for Enugu.*

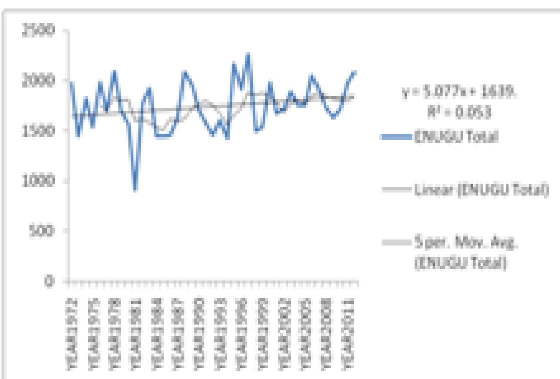


Fig 4.22: *Annual Rainfall fluctuation with respect to SAI for Enugu.*

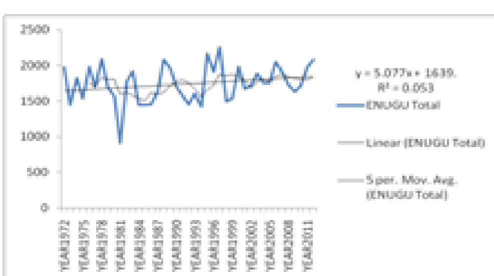


Fig 4.23: *Modeled Annual Rainfall fluctuation with respect to SAI for Enugu.*

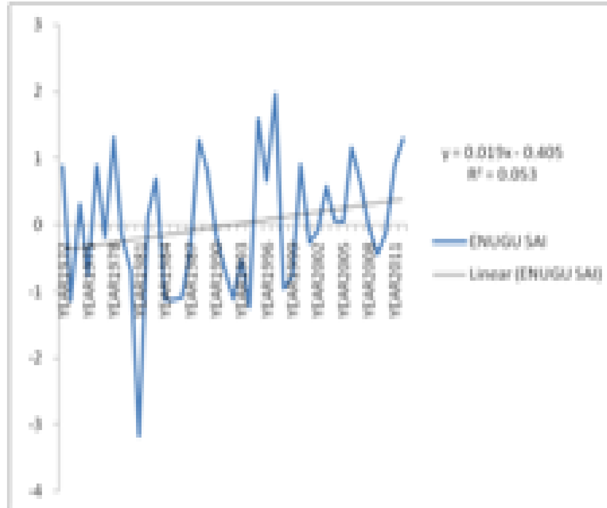
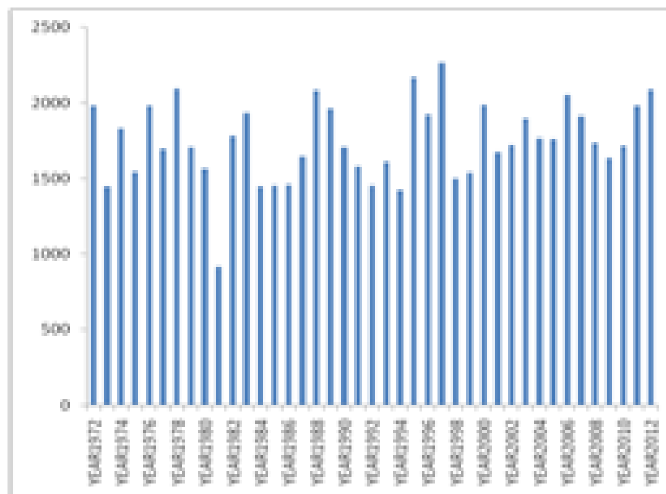


Fig 4.24: *comparative bar chart showing rainfall variation in Enugu*



Fluctuation and trend in Annual Rainfall for Uyo

Fig 4.27 and 4.28, Show the annuals variability of rainfall for Uyo. This reveals that about 38.7 percent of the study period experiences strong negative departure from the mean annual rainfall. This suggests that Uyo experienced dry conditions in these years. 35.5 percent of the period of studies, were year of rainfall enhancement with strong positive departure from the mean annual rainfall. This suggests that it experiences wet condition during these years. 16.13 percent of the study period experience annual rainfall below one standard deviation from the mean annual rainfall and 9.68 experience annual rainfalls above one standard deviation from the mean annual rainfall in Uyo. Fig 4.26 reveals that the running mean was above average from the beginning of the date up to early 1980, where it fell below average. From 1990 the running mean was again above average until late 1990s were it fell below average. The regression equation Y=16.29x + 2062 shows that there is a significant increase in the amount of rainfall of recent in Uyo at the rate of 16.29 mm per year with a coefficient of determination of 0.171. Fig 4.29 reveals that Uyo recorded 3172.9mm as the highest annual rainfall in 2011 and 1562mm as the least in 1983.

Table 4.8** Uyo **Annual Rainfall (mm), Standardized Anomaly Index

UYO		
YEAR	***Annual Rainfall(mm)***	***Standardized anomaly index***
YEAR1981	*2382.2*	*0.165617*
YEAR1982	*2437.4*	*0.3197*
YEAR1983	*1562*	*-2.12385*
YEAR1984	*1832.5*	*-1.36879*
YEAR1985	*2573.7*	*0.700161*
YEAR1986	*1762.9*	*-1.56307*
YEAR1987	*2163.9*	*-0.44374*
YEAR1988	*2238.8*	*-0.23466*
YEAR1989	*2485.9*	*0.45508*
YEAR1990	*2254.2*	*-0.19168*
YEAR1991	*2384.3*	*0.171479*
YEAR1992	*2161.7*	*-0.44988*
YEAR1993	*2209.7*	*-0.31589*
YEAR1994	*2657.6*	*0.934356*
YEAR1995	*2531.1*	*0.58125*
YEAR1996	*2600.3*	*0.774411*
YEAR1997	*2046.4*	*-0.77172*
YEAR1998	*1978.7*	*-0.9607*
YEAR1999	*2313.2*	*-0.02699*
YEAR2000	*2079.5*	*-0.67933*
YEAR2001	*2307.3*	*-0.04346*
YEAR2002	*2315.7*	*-0.02001*
YEAR2003	*2088.1*	*-0.65532*
YEAR2004	*2163.8*	*-0.44402*
YEAR2005	*2828.8*	*1.412236*
YEAR2006	*2554.2*	*0.64573*
YEAR2007	*2587.2*	*0.737845*
YEAR2008	*2293.8*	*-0.08114*
YEAR2009	*1894.7*	*-1.19517*
YEAR2010	*3172.9*	*2.372741*
YEAR2011	*3146.4*	*2.29877*

***Fig 4.26:** least square trend analysis for Uyo*

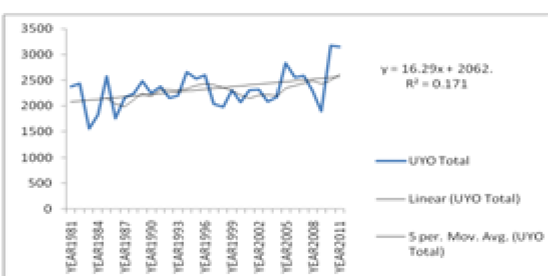


***Fig 4.27:** Annual Rainfall fluctuation with respect to SAI for Uyo*

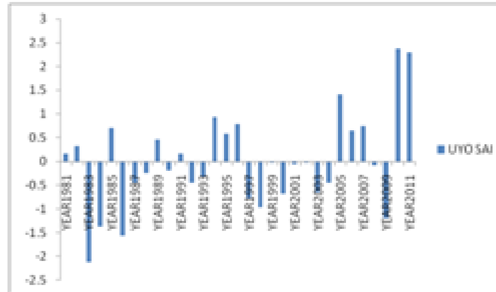


***Fig 4.28:** Modeled Annual Rainfall fluctuation with respect to SAI for Uyo*

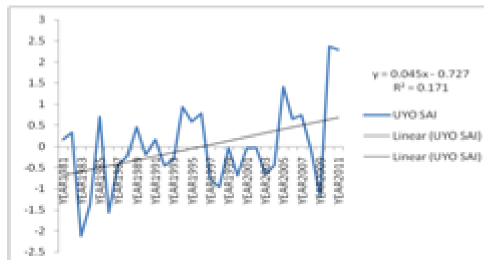
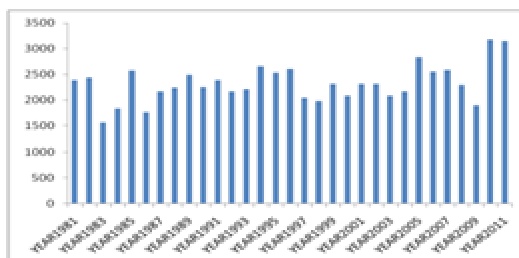


***Fig 4.29:** comparative bar chart showing rainfall variation in Uyo*



CALABAR.	
YEARS	Mean Deviation
YEAR1972	0.05178
YEAR1973	20.89568
YEAR1974	9.759098
YEAR1975	5.865195
YEAR1976	0.894561
YEAR1977	7.546902
YEAR1978	8.292122
YEAR1979	3.539585
YEAR1980	14.57261
YEAR1981	5.346902
YEAR1982	3.588366
YEAR1983	14.85178
YEAR1984	11.23715
YEAR1985	0.261537

YEAR1986	8.449341
YEAR1987	1.306756
YEAR1988	5.676171
YEAR1989	4.646902
YEAR1990	5.55178
YEAR1991	7.176171
YEAR1992	1.45422
YEAR1993	10.84934
YEAR1994	1.256659
YEAR1995	16.91651
YEAR1996	6.32139
YEAR1997	12.94334
YEAR1998	1.088366
YEAR1999	1.155537
YEAR2000	17.25066
YEAR2001	4.240902
YEAR2002	6.300561
YEAR2003	7.27861
YEAR2004	1.707878
YEAR2005	19.87505
YEAR2006	1.52739
YEAR2007	11.51407
YEAR2008	1.688366
YEAR2009	10.46398
YEAR2010	2.818951
YEAR2011	12.96773
YEAR2012	26.98968

Table 4.4: *Deviation of Annual Rainfall from the Mean Annual Rainfall in Percentage*

PORTHACOURT	
YEARS	Mean Deviation
YEAR1972	5.192732
YEAR1973	14.64639
YEAR1974	5.690293
YEAR1975	2.170683
YEAR1976	2.67322
YEAR1977	4.936634
YEAR1978	4.292732
YEAR1979	21.97312
YEAR1980	21.70971
YEAR1981	11.50239
YEAR1982	9.258488
YEAR1983	15.15859
YEAR1984	1.839073
YEAR1985	5.636634
YEAR1986	7.424439
YEAR1987	7.951171
YEAR1988	2.543951
YEAR1989	13.96102
YEAR1990	8.892732
YEAR1991	9.951268
YEAR1992	11.35371
YEAR1993	35.94629
YEAR1994	1.656146
YEAR1995	1.292634
YEAR1996	0.448829
YEAR1997	3.041512
YEAR1998	3.148732
YEAR1999	1.504829
YEAR2000	10.81956
YEAR2001	7.022
YEAR2002	1.436537
YEAR2003	7.319463
YEAR2004	10.93663
YEAR2005	4.141415
YEAR2006	12.75361
YEAR2007	10.44141
YEAR2008	9.463463
YEAR2009	9.860927
YEAR2010	1.836537
YEAR2011	2.939073
YEAR2012	3.726878

OWERRI	
YEARS	Mean Deviation
YEAR1972	11.84512
YEAR1973	14.21488
YEAR1974	8.228049
YEAR1975	17.02073
YEAR1976	7.559756
YEAR1977	12.98902
YEAR1978	5.828049
YEAR1979	10.24268
YEAR1980	12.77927
YEAR1981	7.10122
YEAR1982	3.642683
YEAR1983	11.47683
YEAR1984	21.1939
YEAR1985	13.97439
YEAR1986	21.70366
YEAR1987	5.437805
YEAR1988	0.752439
YEAR1989	3.618293
YEAR1990	8.686585
YEAR1991	11.20366
YEAR1992	2.481707
YEAR1993	6.296341
YEAR1994	10.10366
YEAR1995	13.45244
YEAR1996	10.51585

YEAR1997	2.013415
YEAR1998	1.191463
YEAR1999	3.208537
YEAR2000	2.97439
YEAR2001	2.845122
YEAR2002	10.7622
YEAR2003	6.767073
YEAR2004	5.123171
YEAR2005	1.196341
YEAR2006	2.542683
YEAR2007	5.859756
YEAR2008	13.45732
YEAR2009	0.384146
YEAR2010	17.29634
YEAR2011	23.06707
YEAR2012	11.47439

BENIN	
YEARS	Mean Deviation
YEAR1972	3.966024
YEAR1973	2.743732
YEAR1974	8.080317
YEAR1975	10.84373
YEAR1976	13.99007
YEAR1977	10.41202
YEAR1978	13.94617
YEAR1979	2.924561
YEAR1980	5.914805
YEAR1981	7.397732
YEAR1982	6.736756
YEAR1983	16.3709
YEAR1984	5.168463
YEAR1985	1.846512
YEAR1986	10.98798
YEAR1987	11.10749
YEAR1988	10.04163
YEAR1989	4.409927
YEAR1990	0.912366
YEAR1991	2.116902
YEAR1992	4.468463
YEAR1993	5.656268
YEAR1994	8.119683
YEAR1995	5.055927
YEAR1996	2.770561
YEAR1997	8.316902
YEAR1998	7.748951
YEAR1999	7.285537
YEAR2000	3.080317
YEAR2001	0.214463
YEAR2002	2.880659
YEAR2003	1.248951
YEAR2004	0.643732
YEAR2005	5.055927
YEAR2006	3.436756
YEAR2007	7.743732
YEAR2008	4.904707
YEAR2009	5.355439
YEAR2010	1.336415
YEAR2011	9.631537
YEAR2012	12.38763

ENUGU	
YEARS	Mean Deviation
YEAR1972	5.68839
YEAR1973	7.257951
YEAR1974	2.022537
YEAR1975	4.894537
YEAR1976	5.771317
YEAR1977	1.21161
YEAR1978	8.398146
YEAR1979	1.031122
YEAR1980	4.38722
YEAR1981	20.32624
YEAR1982	0.803024
YEAR1983	4.498146
YEAR1984	7.216488
YEAR1985	7.192098
YEAR1986	6.962829
YEAR1987	2.506732
YEAR1988	8.217659
YEAR1989	5.237171
YEAR1990	0.975024
YEAR1991	4.114049
YEAR1992	7.08722
YEAR1993	3.289659
YEAR1994	7.872585
YEAR1995	10.23961
YEAR1996	4.217659
YEAR1997	12.58351
YEAR1998	6.08478
YEAR1999	5.021366
YEAR2000	5.827415
YEAR2001	1.689659
YEAR2002	0.592098
YEAR2003	3.678634
YEAR2004	0.420098
YEAR2005	0.33961
YEAR2006	7.461561
YEAR2007	4.03961
YEAR2008	0.226244
YEAR2009	2.775024
YEAR2010	0.743317
YEAR2011	5.710341
YEAR2012	8.303024

UYO	
YEAR	Mean Deviation
YEAR1981	1.913935
YEAR1982	3.694581
YEAR1983	24.54413
YEAR1984	15.81832
YEAR1985	8.091355
YEAR1986	18.06348
YEAR1987	5.128
YEAR1988	2.711871
YEAR1989	5.259097
YEAR1990	2.215097
YEAR1991	1.981677
YEAR1992	5.198968
YEAR1993	3.650581
YEAR1994	10.79781
YEAR1995	6.717161
YEAR1996	8.949419
YEAR1997	8.918323
YEAR1998	11.10219
YEAR1999	0.311871
YEAR2000	7.850581
YEAR2001	0.502194
YEAR2002	0.231226
YEAR2003	7.573161
YEAR2004	5.131226
YEAR2005	16.32039
YEAR2006	7.462323
YEAR2007	8.526839
YEAR2008	0.937677
YEAR2009	13.81187
YEAR2010	27.42039
YEAR2011	26.56555

Fig 4.20: *Cumulative Mean Deviation graph for Owerri.*

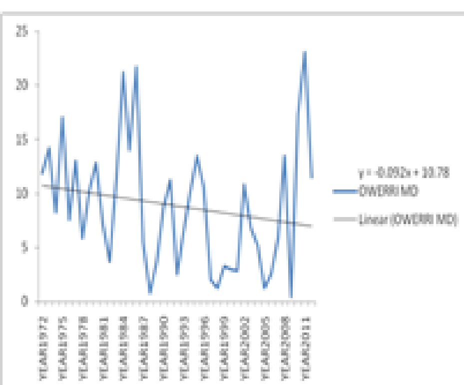


Fig 4.25: *Cumulative Mean Deviation graph for Enugu.*

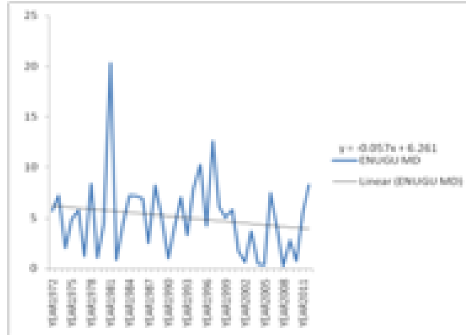


Fig 4.15: *Cumulative Mean Deviation graph for Benin.*

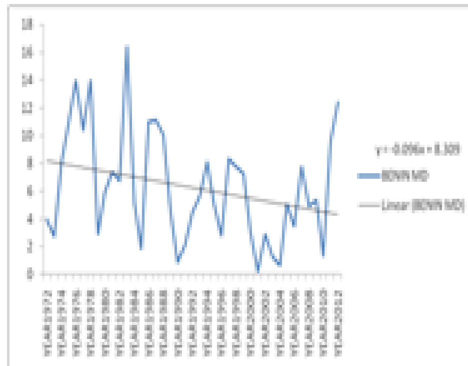


Fig 4.30: *Cumulative Mean Deviation graph for Uyo.*

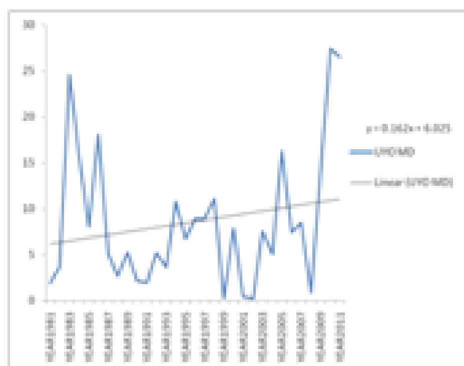


Fig 4.5: *Cumulative Mean Deviation graph for Calabar*

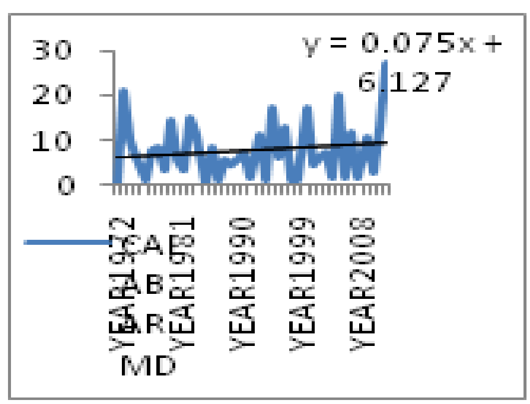


TABLE 4.13: *Summary Of The Pair Wise Descriptive Statistics*

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance Statistic	Coef of Variation (%)
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic		
Benin	41	1244.80	1190.70	2435.50	1861.9068	48.21048	308.69770	95294.269	16.58
Calabar	41	1963.30	2099.40	4062.70	2956.1232	64.75436	414.63023	171918.229	14.03
Enugu	41	1349.30	913.10	2262.40	1746.4756	41.04023	262.78569	69056.317	15.05
Owerri	41	1835.60	1228.40	3064.00	2118.2498	68.88473	441.07747	194549.332	20.82
Port	41	2095.30	1816.40	3911.70	2437.9024	68.31921	437.45639	191368.093	17.94
Uyo	31	1610.90	1562.00	3172.90	2322.8677	64.34340	358.24891	128342.281	15.42

Table 4.14: *Rate Of Change Of Annual Rainfall In The Study Area (Mm/Year)*

Station	Annual rate of change of rainfall (mm/year)
Calabar	15.21
Porthacourt	2.18
Benin	22.23
Owerri	3.25
Enugu	5.08
Uyo	16.29

Table 4.15: *Projected Annual Rainfall for the Study Area (mm)*

year	Calabar	Porthacourt	Benin	Owerri	Enugu	Uyo
2013	3274.82	2483.56	1929.29	2584.66	1852.234	2583.28
2014	3290.03	2485.74	1932.535	2606.89	1857.311	2599.57
2015	3305.24	2487.92	1935.78	2629.12	1862.388	2615.86
2016	3320.45	2490.1	1939.025	2651.35	1867.465	2662.15
2017	3335.66	2492.28	1942.27	2673.58	1872.542	2648.44
2018	3350.87	2494.46	1945.515	2695.81	1877.619	2664.73
2019	3366.08	2496.64	1948.76	2718.04	1882.696	2681.02
2020	3381.29	2498.82	1952.005	2740.27	1887.7	2697.31

CONCLUSIONS: The study has examined recent trends and fluctuations of annual rainfall of southern Nigeria between 1973 and 2012. The temporal pattern suggests a fluctuating and significant increase trend in all the locations. The study concluded that at present, the climate of the region indicates a tendency towards wetter condition rather than the increasing dryness that was a feature of the period from the 1970s to the early 1990s. The implications of the increase in wet conditions rather than increase in dry conditions for Agriculture, water resources, food security, Livelihood and human health will certainly be different. Farmers would take the advantage of the long growing seasons by the adoption of multiple cropping systems. Increase in rainfall means increasing recharge of surface and underground water, creating a favorable condition for irrigation Agriculture. This increase can be harnessed to create adequate water storage against periods of drought.

RECOMMENDATIONS: It is recommended therefore that, follow-up studies aim at identifying other responds stimuli/lus other than the increasing figures are required in other locations that constitute southern Nigeria so as to be able to generalize the findings to the region. Such an approach may lead to a solution to the effects caused by these changes in the earth atmosphere. Thus an integrated impact study to determine the multiple effects of human development on annual rainfall regime is strongly advocated. Besides, providing a scientific management framework through modeling the annual rainfall and predicting, the integrated impact assessment approach will suggests adoption policy option.

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