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CLIMATE VARIABILITY IN SELECTED LOCATIONS OF SOUTHEASTERN NIGERIA: AN ANALYSIS OF RAINFALL TRENDS

BY

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Abstract:
This study examined the trends and patterns in the rainfall in selected locations of South Eastern Nigeria. Rainfall data (1983-2014) in Owerri, Umuahia, Onitsha, and Enugu were used for this study. Statistical techniques mainly, mean, standard deviation, coefficient of skewness, coefficient of kurtosis, coefficient of variation, and standardized anomaly index were employed to analyze the data and depict the distribution of rainfall in these stations. The data were analysed using the statistical package for social sciences, SPSS 17, and Minitab 16. The results revealed that the maximum annual rainfall occurred at Warri station (4489.80mm) in the year 2008 and the minimum occurred at Benin (229.10mm) in 2005. Also, Benin has the maximum coefficient of variation of about 26%, while Port Harcourt has the minimum coefficient of variation of about 12%. Warri and Umuahia station are positively skewed indicating that they experience frequent low rainfall values; while Portharcourt and Onitsha are approximately symmetrical skewed. Warri and Umuahia have kurtosis coefficient greater than 5. However, the patterns of rainfall in these areas are random or fluctuating. It is recommended that models built on the perceived decreasing rainfall, such as drainages, dams, have to be reviewed.

Keywords: *Climate, Variability, Analysis, Rainfall, Trends, Nigeria*

1. INTRODUCTION

The trend analysis of rainfall data series is of practical importance for the detection of the gradual trends over time in the face of global climate change. Worldwide interest in global warming and climate change has led to numerous trend detection studies to determine if the values of a random variable generally increase (or decrease) over some period of time in statistical terms (WMO 1966; Luis, et al., 2009; Lana, et al., 2004; Retalis, et al.,1997; WMO 1988; Diodato 2008; and Paturel, et al., 1997). Several authors have analyzed hydro-meteorological time series in West Africa from Niger to Senegal (Carbonnel, et al.,1985, 1987, 1989 and Snijders, 1986). They pointed out the non-stationarity of the series and a climate jump down between 1965 and 1972; the majority of the shifts appearing between 1969 and 1970. All these studies suggest the possibility of a worldwide new climatic phase since the start of the 70's. A climate change can occur abruptly (step change) or gradually (trend) or may take more complex form. Climate change is often reorganized as a progressive trend. The existence of a trend in a hydrological time series is detected by statistical test. There is no best forecasting procedure as the choice is essentially dependent on the objective of the forecast, degree of accuracy, and the properties of the time series (Aribisala, 2005). However, rainfall has more significant effect on inter-annual changes in crop yield in a tropical environment as it determines the supplies of water to plants (Adejuwon, 2010). Moreover, rainfall is the major limiting climatic factor in the growth and production of crops (Falkenmark, 1989), as it is particularly very sensitive to water deficit. Climate variability and change has become a topical issue in recent times because of its largely detrimental impacts on natural and human systems. It is based on this information that this study was carried out to provide information on rainfall trends (variations) to the farmers of the selected study areas because almost every farmer is interested in what the expected rainfall would be, more than any other climatic element as it determines the success or failure of crops. The general objective of the study is to analyze the rainfall trends (variations) and patterns in Selected Locations, to examine the annual (yearly) variability of rainfall of the selected locations in South Eastern Nigeria over the years.

2. MATERIALS and METHOD

The study area is situated in the tropical rain forest zone of Nigeria with latitudes $4° 47^{I} 35^{II}$ N and $7° 7^{I} 44^{II}$ N, longitudes $7° 54^{I} 26^{II}$ E and $8° 27^{I} 10^{II}$ E. According to Ezemonye and Emeribe (2012), the area has mean maximum temperature of 27 °C and total annual rainfall exceeding 2500mm. Early rainfall occurs in January and February with full commencement of rainy season in March and stopping in November of each year. The dry season lasts between four to five months. The highest rainfall is recorded from July to October with little break in rainfall in August popularly described as "August break". South Eastern Nigeria comprises Abia, Anambra, Enugu, Imo, and Ebonyi States. The relative location is bounded in the north west by Kogi and Benue States, in the northeast by Cross River State, in the South by Akwa Ibom and Rivers States, and finally in the West by Delta State, as shown on Figure 1. The area is well drained. The notable lakes, rivers, and streams that are found draining the area in this zone include Rivers Niger, Imo, Nike Lake, Anambra, Idemili, Njaba, Oguta Lake, Nkisi, Ezu, Oji, etc.

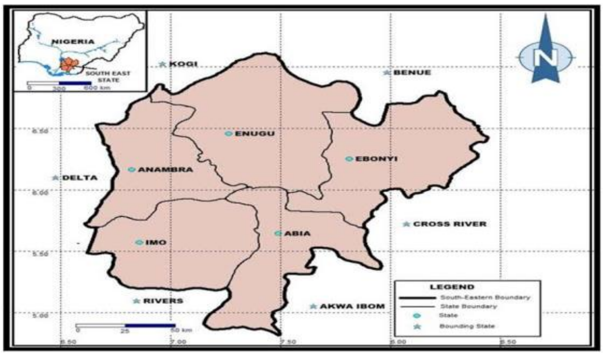

Figure 2.1: Map of the southeast region of Nigeria showing the two-component states. (FDLAR, 1990)

2.1 Data Collection

The relevant data needed for the research are monthly rainfall data of the various study areas (Owerri, Umuahia, Onitsha, and Enugu). These were obtained from the Nigerian Meteorological Agency (NIMET) in the various study areas (Owerri, Umuahia, Onitsha, and Enugu,). The data covered a period of thirty years from 1983-2014.

These data are monthly rainfall records spread over the time frame of the study. The rainfall data are measured in millimeters. The data were collected in an electronic format to enable effective analysis in Microsoft Excel version 2010.

2.2 Data Analysis

In analyzing the required data, descriptive statistical techniques/tools were used. They include Mean yearly (Annual) rainfall for each study areas, Yearly rainfall standard deviation for each study areas, Standard coefficient of skewness, Coefficient of variation, Standardized anomaly index (SAI), and Graphical plots

2.2.1 Mean Yearly (Annual) Rainfall

This is a measure of central tendency. Mathematically, it is denoted as $\bar{X}$ and computed as:

$$\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad (1)$$

Where $\bar{X}$ = mean yearly rainfall

x_i = yearly rainfall values (mm)

N = total number of observations.

2.2.2 Yearly Rainfall Standard Deviation

This is a measure of dispersion. The standard deviation measured the absolute dispersion for variability. The greater the standard deviation, the greater will be the magnitude of the deviation of the yearly rainfall values from the mean yearly rainfall for the periods.

A small standard deviation means a high degree of uniformity of the yearly rainfall values.

Computationally, it is denoted as σ and given by

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{X})^2}{n-1}} \qquad (2)$$

Where: x_i= annual rainfall for the year

$\bar{X}$ = mean annual rainfall

N = total number of observation

σ = standard deviation

2.2.3 Standard Coefficient of Skewness

To measure the co-efficient of skewness, the Karl Pearson's co-efficient of skewness which is based upon the difference between mean and mode was used. The difference value is divided by the standard deviation to give the relative measure. This is obtained using the formulae:

$$\text{Co-eff. Of Skewness} = \frac{Mean - Mode}{Standard\ deviation} \qquad (3)$$

When skew > 0: Right skewed distribution that is most values are concentrated on left of the mean with extreme values to the right.

Skew < 0: Left skewed distribution that is most values are concentrated on the right of the mean, with extreme values to the left.

Skew = 0: Mean = Mode = Median; and distribution is symmetrical.

2.2.4 Standard Coefficient of Kurtosis

It refers to the degree of flatness or peakness. When a distribution is normal or symmetrical, the coefficient of kurtosis is equal to 3. When it is more than 3, it is more peaked than the normal and when it is less than 3, it is less peaked than the normal.

Mathematically,

Kurt (x) $= \frac{\mu^4}{\sigma^4}$ (4)

Where μ^4 = fourth moment about the mean

σ = standard deviation

2.2.5 Coefficient of Variation

This is measure of relative variation. It is used when we want to compare the variability of two or more than two series. That series for which the coefficient of variation is greater is said to be less consistent or less uniform or less stable. On the other hand, a series which has less coefficient of variation is more consistent and more stable.

Mathematically,

Coeff. of variation, C. V $= \frac{\sigma}{\bar{X}} x\, 100$ (5)

Where,

σ = yearly rainfall standard deviation

$\bar{X}$ = mean annual rainfall

It is clear from above that dispersion (variation) measures the extent to which the observations vary from some central value like the mean. They served as a basis for the control of the variability in the yearly data (Gupta, 2011).

2.2.6 Standardized Anomaly index (S.A.I)

It is used in the analysis of rainfall variability. It is given as

SAI (Z-scores) = $\frac{x_{i-}\bar{X}}{\sigma}$, *i*= 1, 2,…0. (6)

Where x_i= yearly observations

$\bar{X}$ = mean annual rainfall

σ = yearly rainfall standard deviation.

2.2.7 Graphical Plots

Graphical plots were used to plot annual rainfall values. These clearly are used to reveal trends (variations) and patterns in rainfall over the thirty-year period for each study area. These graphical representations were carried out using statistical package for social sciences, SPSS 17, and Minitab 16. All the rainfall data in this study were analyzed using statistical package for social sciences, SPSS 17, and Minitab 16.

3. RESULTS AND DISCUSSION

The results of the analysis are shown in tables 1 to 2 and figures 1 to 20:

Table 3.1: Annual Series of Rainfall from 1983-2014.

YEAR	OWERRI	ONITSHA	ENUGU	UMUAHIA
1983	1694	1417.6	917.1	1511.4
1984	2223.4	1683.9	1781.1	2650.8
1985	2437.3	1799.6	1939.9	2342.2
1986	2036.2	1617.9	1450.6	4137.6
1987	2057.2	1503.7	1467.3	1884.2
1988	2675.3	2008	1532.4	2362
1989	2601.3	1782	1643.7	2197.3
1990	2743.2	2025.6	2083.4	1788
1991	2537.7	2095.4	1961.9	1958.8
1992	2479.1	1804.9	1706.5	2190.8
1993	2172.2	1654.1	1577.7	1980.9
1994	2650.1	2081.7	1663.1	2141.9
1995	2613.9	2478.5	2170.9	2625.3
1996	2803.7	1826.7	1919.4	2751.9
1997	2126.7	1907	2284.6	4190.9
1998	1815.5	2086.2	1496.1	1975.9
1999	2306.4	1966.1	1623.1	2701.3
2000	2538.6	2057.1	904	1680.6
2001	2180.3	2014.5	1677.2	2190.2
2002	2227.1	1777.3	1725.8	2251.4

2003	1850.8	1868	1891	2181.3
2004	1805.1	2083.8	1770.8	1911.4
2005	2498.6	1920.7	1716.5	1808.6
2006	2631.9	1910.3	2084.3	1938.3
2007	1762.5	2026.8	1867.6	2420.7
2008	1793.8	2056.2	1626.5	2395.6
2009	1802.4	2157.6	1978.3	2060.8
2010	1798.6	1582.9	1879.3	1916.1
2011	2471.2	1565.1	2012.7	2226.4
2012	2365.7	1528.7	1957.1	1933.4
2013	1671.5	1313.9	2072.6	2161.7
2014	2516.4	1654.7	1962.6	2069.4

Table 3.2: Descriptive Statistics of Annual Rainfall of Study Areas.

Yearly Rainfall (mm)	No of Years	Minimum	Maximum	Mean	Standard Deviation	Skewness Coefficient	Kurtosis	CV
Owerri	32	1671.50	2803.70	2246.49	354.42	-0.22	-1.37	15.78
Onitsha	32	1313.90	2478.50	1851.77	247.62	0.07	-0.05	13.37
Enugu	32	904.00	2284.60	1760.78	302.93	-1.13	2.01	17.20
Umuahia	32	1511.40	4190.90	2266.78	567.90	2.30	6.13	25.05

3.1.1 Discussion on Descriptive Statistics of Annual Rainfall for Owerri

From table 3.2; between 1983 ─ 2014 Owerri recorded 2246.49 mm, 2803.70 mm, and 1671.50 mm as its mean, maximum and minimum annual rainfall respectively. Owerri experienced frequently high annual rainfall with negative skewness coefficient of -0.22. There is however slight variation in annual rainfall values in Owerri with its coefficient of variation recorded as 15.78 %. Its kurtosis value is -1.37 indicating that it is light-tailed, which means that the rainfall experiences platykurtic distribution.

3.1.2 Discussion on Descriptive Statistics of Annual Rainfall for Onitsha

From table 3.2, the mean, maximum and minimum rainfall values from 1983 ─ 2014 for Onitsha are 1851.77 mm, 2478.50 mm, and 1313.90 mm respectively. The maximum and minimum rainfall values occurred in the years 1995 and 2013 respectively. Onitsha recorded steady annual rainfall above 1500 mm for the 32 years studied, except for 1983 and 2013 with annual rainfalls of 1417.6 mm and 1313.90 mm. Onitsha experiences a mesokurtic distributin , with skewness coefficient value of 0.07, which is close to normal distribution. The kurtosis value for Onitsha is -0.05, wish showed that it is light-tailed with platykurtic distribution.

3.1.3 Discussion on Descriptive Statistics of Annual Rainfall for Enugu

The mean, maximum and minimum rainfall values from 1983 ─ 2014 as shown in table 3.2 Enugu are 1760.78 mm, 2284.60 mm, and 904.00 mm respectively. Maximum and minimum annual rainfalls were recorded in the years 1997 and 2000 respectively. Enugu rainfall distribution is highly skewed with skewness coefficient of -1.13 and the state experiences leptokurtic rainfall distribution with kurtosis value recorded as 2.01. The coefficient of variation for rainfall values in Enugu is 17.20 %. This shows that there is less variation in rainfall variability in Enugu when compared to Umuahia, Calabar, and Benin.

3.1.4 Discussion on Descriptive Statistics of Annual Rainfall for Umuahia

The values for mean, maximum, and minimum annual rainfalls between the years 1983 ─ 2014 for Umuahia as shown in table 3.2 are 2266.78 mm, 4190.90 mm, and 1511.40 mm respectively. The maximum and minimum annual rainfalls occurred in the years 1997 and 1983 respectively. The annual rainfall values are highly skewed with skewness coefficient of 2.30. The annual rainfall values here are heavier tailed distribution with kurtosis of 6.13 and are also said to experience platykurtic distribution. Umuahia experienced highest variability in annual rainfall among the studied locations with coefficient of variation of 25.05%.

3.2 Results of the Standardized Anomaly Index for Owerri

The result of the standardized anomaly index for Owerri is shown in figures 3.1

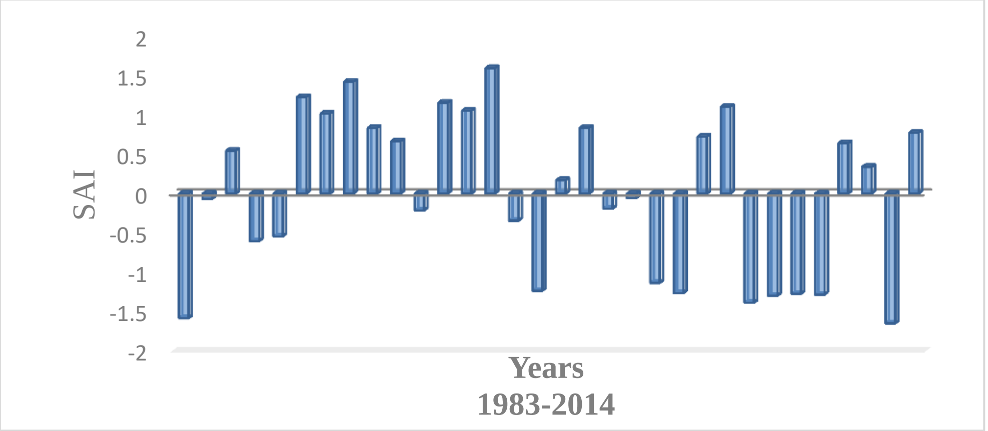

Figure 3.1: Standardized Anomaly Index for Annual Total Rainfall at Owerri

The annual rainfall standardized anomaly index for Owerri is shown in figure 3.1 Owerri was marked with above long averages between 1983 and 1996 with 5 respites of negative rainfall anomaly index below average indicating period of low rainfall years at Owerri. After 1996, there was a low annual rainfall period with strong negative departure with 7 respites of positive annual rainfall anomaly index above average until 2014. Owerri had the highest positive rainfall anomaly index above average in the year 1996 and the lowest negative rainfall anomaly index above average in the year 1983

3.2.1 Standardized Anomaly Index for Onitsha

The result of the standardized anomaly index for Onitsha is shown in figures 3.2

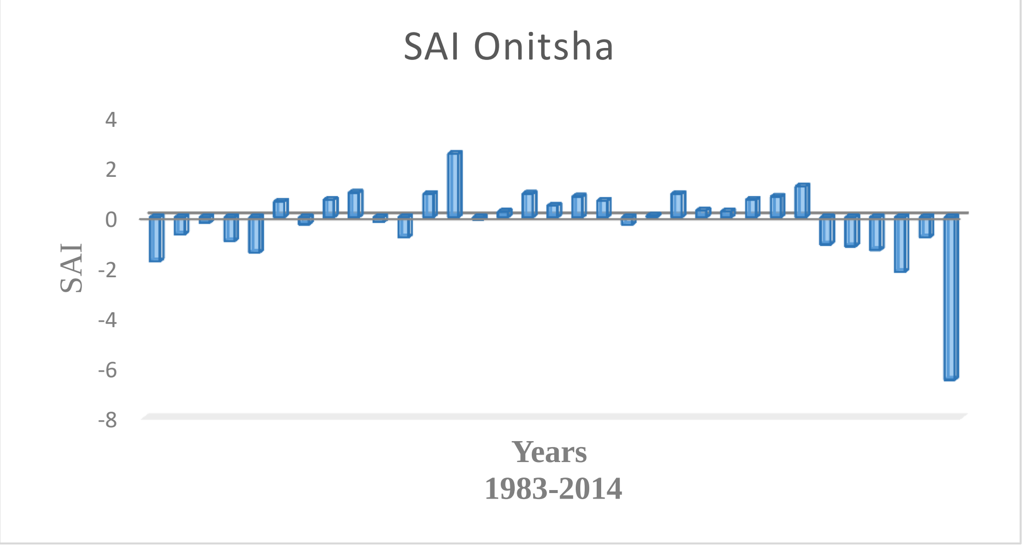

Figure 3.2: Standardized Anomaly Index for Annual Total Rainfall at Onitsha

Figure 3.2 shows standardized anomaly index for annual rainfall at Onitsha. Below long-term averages of annual rainfall anomaly index persisted during the period spanning 1983 -1987. From the year 1988 to 2009 positive long-term annual rainfall anomaly index above averages occurred with 4 respites of negative anomaly index below average indicating period of high rainfall years at Calabar. From the year 2010, there was long-term negative anomaly index of annual rainfall below aver until the year 2014. The highest positive annual rainfall anomaly index above average was recorded in 1995.

3.2.2 Standardized Anomaly Index for Enugu

The result of the standardized anomaly index for Enugu is shown in figures 3.3

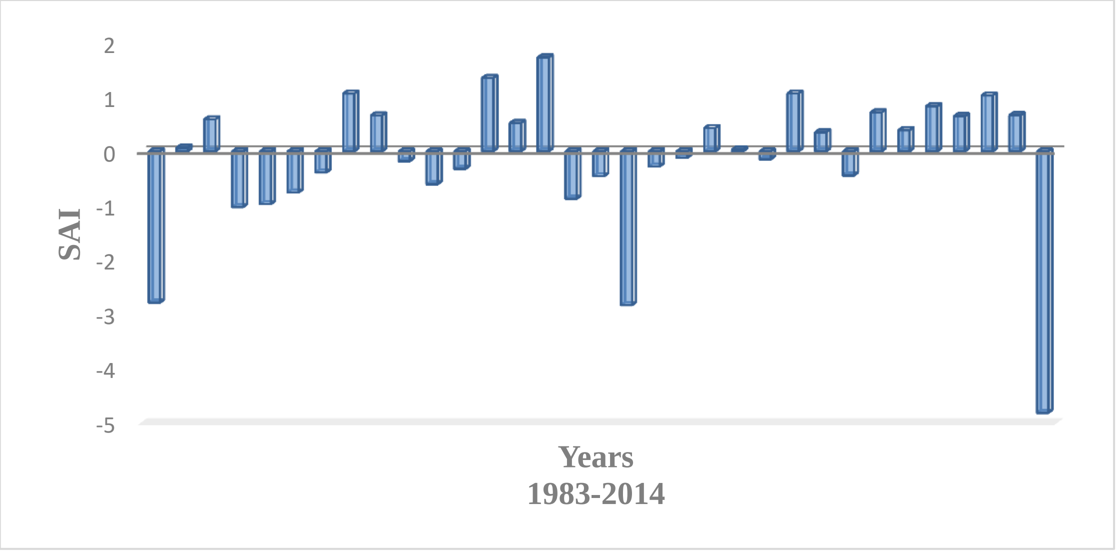

Figure 3.3: Standardized Anomaly Index for Annual Total Rainfall at Enugu

Figure 3.3 shows the standardized anomaly index of annual rainfall for Enugu. Below long-term averages, annual rainfall persisted during the period spanning 1983 to 2000, with 6 respites of positive anomaly index average years. Long-term average annual rainfall continued during the period spanning 2001 – 2014 with 5 respites of negative anomaly index below average years. Highest positive annual rainfall anomaly index above average was recorded in 1997, while the lowest negative rainfall anomaly index below average was recorded in 2000.

3.2.3 Standardized Anomaly Index for Umuahia

The result of the standardized anomaly index for Umuahia is shown in figures 3.4

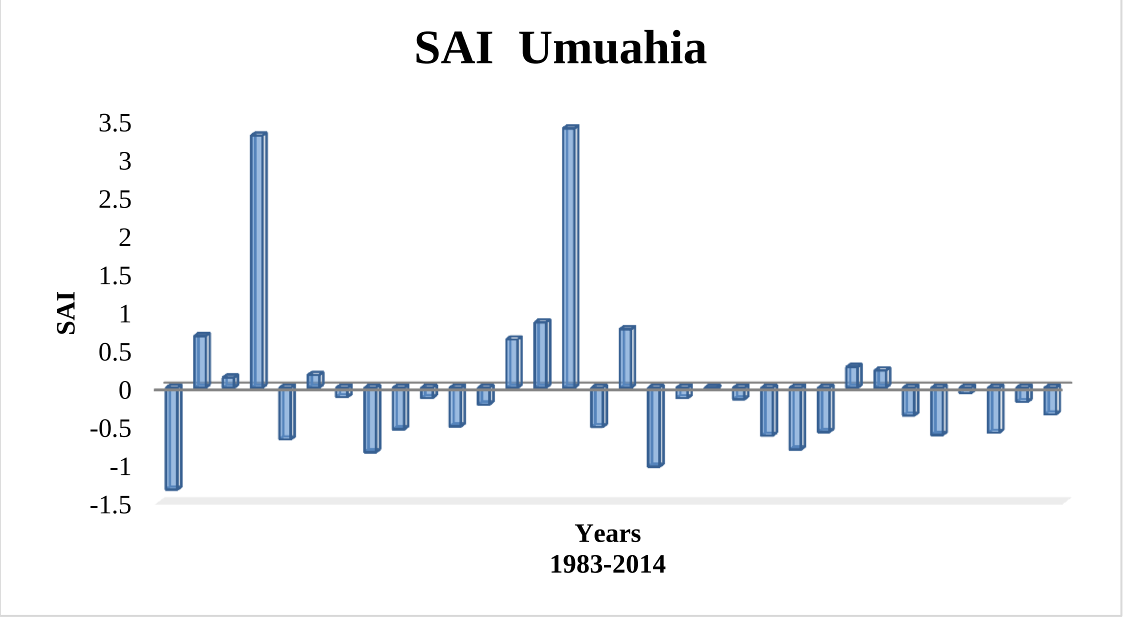

Figure 3.4: Standardized Anomaly Index for Annual Total Rainfall at Umuahia

The annual rainfall standardized anomaly index for Umuahia is shown in figure 3.4, Umuahia below long-term averages annual rainfall persisted during the period spanning 1983 – 2014 with 10 respites of positive anomaly index above average years. The highest positive rainfall anomaly index above average was recorded in 1997 and the lowest negative rainfall anomaly index below average was recorded in 1983.

3.3 Results on Trend Plots of Annual Rainfall for Owerri

Result of trend plots of annual rainfall for Owerri city is shown in figures 3.5 below.

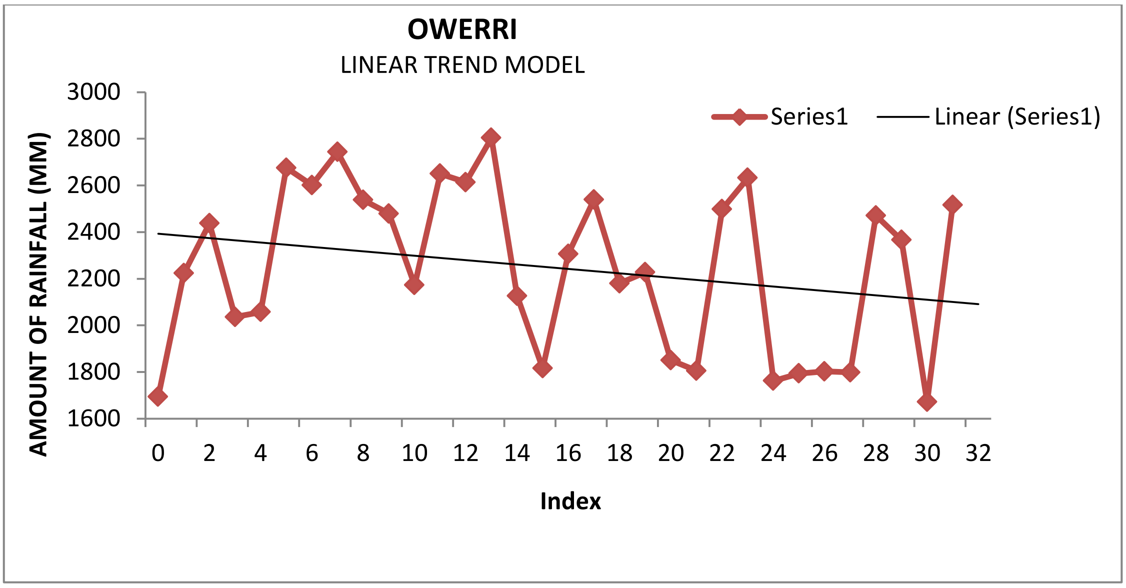

Figure 3.5: Trend Plot of annual Rainfall in Owerri

The trend of annual rainfall in Owerri city for the study period of 1983 – 2014 is shown in figure 3.5. From figure 3.1, the year 2013 recorded the lowest annual rainfall of 1671.50mm, while the year 1996 recorded the highest rainfall of 2803.70mm. The mean annual rainfall for the study period is 2246.49mm. Years 1983, 1984, 1986, 1987, 1993,1997 ,1998, 2001, 2002, 2003, 2004, 2007, 2008, 2009, 2010, and 2013 experienced annual rainfall below the mean value, while the years 1985, 1988, 1989, 1990, 1991,1992, 1994, 1995, 1996, 1999, 2000, 2005 ,2006, 2011, 2012 and 2014 experienced annual rainfall above the mean value. From the graph, the trend in rainfall shows a decrease in rainfall as indicated by the decreasing linear trend line. This means that rainfall amount decreases as the years went by.

3.3.1 Trend Plots of Annual Rainfall for Onitsha

Result of trend plots of annual rainfall for Onitsha city is shown in figures 3.6.

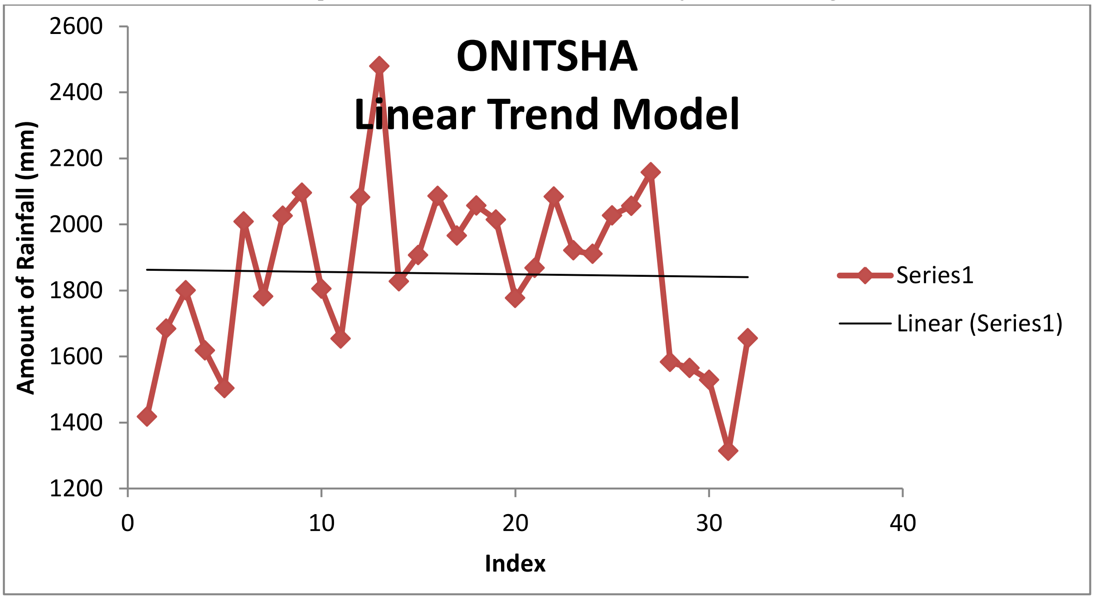

Figure 3.6: Trend Plot of annual Rainfall in Onitsha

Figure 3.6 shows the trend of annual rainfall in Onitsha city for the study period of 1983 – 2014. From figure 3.1, it is evident that the year 2013 recorded the lowest annual rainfall of 1313.90, while the year 1995 recorded the highest rainfall of 2478.50mm. The mean annual rainfall for the study period is 1851.77mm. Years 1983, 1984, 1985, 1986, 1987, 1989, 1992, 1993 1996, 2002, 2010, 2011, 2012, 2013 and 2014 experienced annual rainfall below the mean value, while the years 1988,1990, 1991, 1994, 1995, 1997, 1998, 1999, 2000, 2001, 2003, 2004, 2005, 2007, 2008 and 2009 experienced annual rainfall above the mean value.

3.3.2 Trend Plots of Annual Rainfall for Enugu

Result of trend plots of annual rainfall for Enugu city is shown in figures 3.7.

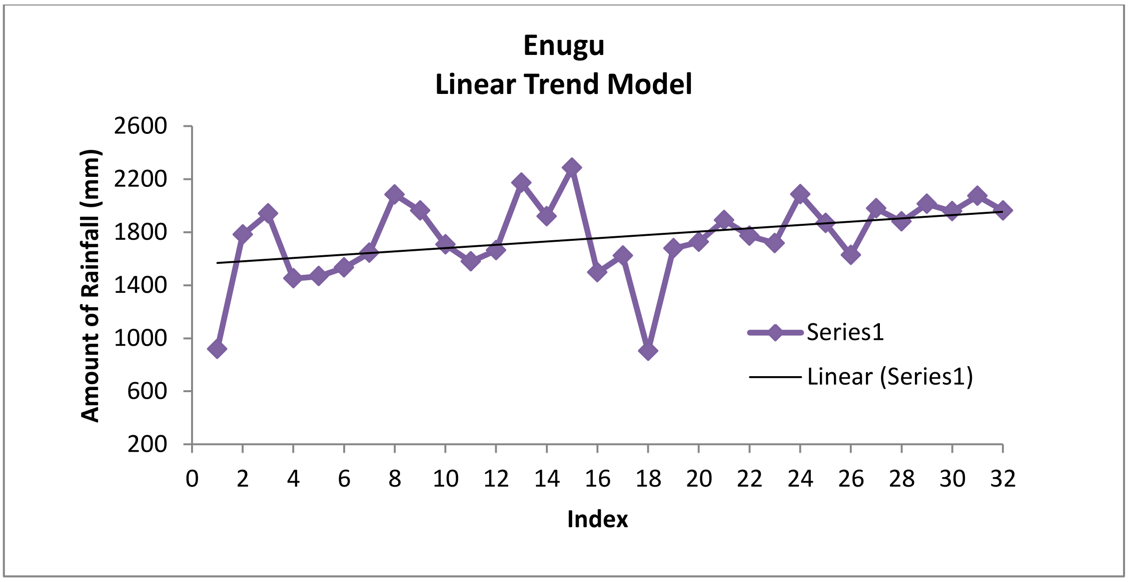

Figure 3.7: Trend Plot of annual Rainfall in Enugu

Figure 3.7 shows the trend of annual rainfall in Enugu city for the study period of 1983 – 2014. From figure 3.1, it is evident that the year 2000 recorded the lowest annual rainfall of 904.00mm, while the year 1997 recorded the highest rainfall of 2284.60mm. The mean annual rainfall for the study period is 1760.78 mm. Years 1983, 1986, 1987, 1988, 1989, 1992, 1993, 1994, 1998, 1999, 2000, 2001, 2002, 2005 and 2008 experienced annual rainfall below the mean value, while the years 1984, 1985, 1990, 1991, 1995, 1996, 1997, 1998, 2003, 2004, 2006, 2007, 2009, 2010, 2011, 2012, 2013 and 2014 experienced annual rainfall above the mean value. From the graph the linear trend line is positive, indicating a progressive increase in the annual rainfall during the period of study in the study region.

3.3.3 Trend Plots of Annual Rainfall for Umuahia

Result of trend plots of annual rainfall for Umuahia city is shown in figures 3.8 below.

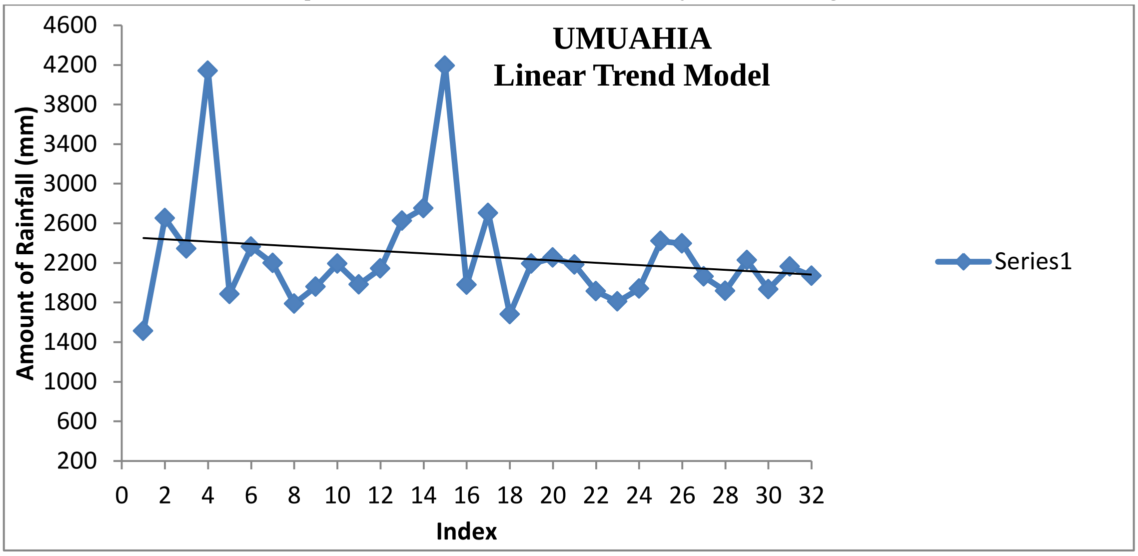

Figure 3.8: Trend Plot of annual Rainfall in Umuahia

Figure 3.8 shows the trend of annual rainfall in Ibadan city for the study period of 1983 – 2014. From figure 3.1, it is evident that the year 1983 recorded the lowest annual rainfall of 1511.40mm, while the year 1997 recorded the highest rainfall of 4190.90mm. The mean annual rainfall for the study period is 2266.78mm. Years 1983, 1987, 1989, 1990, 1991, 1992, 1993, 1994,1998, 2000, 2001, 2003, 2004, 2005, 2006 , 2009, 2010, 2012, 2013,and 2014 experienced annual rainfall below the mean value, while the years 1984, 1985, 1986, 1988, 1995, 1996, 1997, 1999, 2002, 2007, 2008, and 2011 experienced annual rainfall above the mean value. From the graph, the trend in rainfall shows a decrease in rainfall as indicated by the decreasing linear trend line. This means that rainfall amount decreases as the years went by.

4. CONCLUSION

The study examined the rainfall trends and patterns in selected locations of South Eastern Nigeria for the period 1983-2014. It was observed that among these locations, two locations, namely Enugu and Umuahia showed an increase in trend of annual rainfall while the other two locations (Owerri and Onitsha) showed a decrease. As expected all annual rainfall patterns show randomness and are fluctuating each year. There are risks and opportunities of the increasing trends and fluctuating patterns. Risk is possible loss, and opportunity is possible gain. The risks and opportunities of an increasing trend and fluctuating pattern of annual rainfall in the study areas for agriculture, grazing lands, water resources, ecological systems, food security, livelihoods, and human health will certainly be different. Increasing trend in rainfall totals may trigger floods and erosion of the topsoil. Flooding will results to washing away of top soils/farmlands, disruption of socio-economic activities, overflowing/damage to reservoirs and other infrastructure, and the loss of life and property. The implications on infrastructure are that models built on the perceived decreasing rainfall, such as drainages, dams, etc., have to be reviewed. This will lead to an increase burden of the recurrent cost of repair/replacement and increased cost of community services. Increasing rainfall means increasing recharge of surface and underground water resources, which can be harnessed to create adequate water storage against periods of shortage. It will be recommended that the following should be adhered to;

1.0 Since rainfall distributions in the locations have no definite pattern, it, therefore, becomes imperative that water resource development should be focused on efficient utilization of agricultural land. This calls for stern government policy on harnessing and controlling of the water resources.

2. The models built on the perceived decreasing rainfall, such as drainages, dams, should be reviewed in order to prevent possible flooding in some areas also, opportunities should be provided by the government for professionals to study and develop realistic methods for utilization of surplus water.

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