

ISSN 1118-2083

ENVIRONMENTAL ISSUES

Volume 7, No. 1, 2017

**Published by:
Department of Geography
and Environmental Management
Faculty of Social Sciences
University of Ilorin,
Ilorin, Nigeria**

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ISSN 1118-2083

Printed by:
Unilorin Press
University of Ilorin

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Assessment of Climate Variability in Southwestern Nigeria Using Rainfall Trends

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Abstract *This study was carried out in the Southwestern region of Nigeria. Its main aim was to assess the Climate scenario in the area using prevailing rainfall trends. Rainfall records for 35years (1975 - 2010) were obtained from the Nigerian Meteorological station (NIMET) at its headquarters in Oshodi, Lagos. The data were obtained for five stations which are Ikeja, Abeokuta, Akure, Ibadan and Osogbo. These data were analyzed in order to obtain the rainfall trend and consequently the climate variability/change scenario. The Simple linear regression analysis and the Runs test were used to identify the trends in rainfall for each of the stations and the whole region. The t-test and correlation analysis were also employed in determining the significance and strength of the trend gotten. Microsoft excel and SPSS were both used to "run" the analyses. The results obtained showed an increasing trend in rainfall for all the stations. However, this trend was found to be insignificant for four of the five stations. Only Abeokuta showed statistical significance in its rainfall trend. It had the largest rate of increase in rainfall with 9.106mm/year for the 35 years period. For the whole Southwestern region, a weak insignificant trend in rainfall was found although there was increasing rainfall in the region with an average rate of 5.250mm/year. The study concluded that the minimal climate variability scenario in this part of the country will intensify with time and recommends combating, controlling and mitigating the climate change propelled rainfall extremes, floods and drought through systematic use of climate information in planning and decision making at all levels, use of climate-informed technologies that reduce vulnerability to weather variability and uncertainty, as well as climate-informed policy and market-based interventions that transfer risk from vulnerable populations.*

Keywords: Climate, Climate Variability, Rainfall, Trend, South-Western Nigeria

Background of study

Climate variability is a global phenomenon occurring from region to region but the effects are more devastating in countries where flooding or drought has occurred. The impact of climate variability is felt majorly in terms of rainfall and temperature. Climate variability is a general term used to describe the inherent variability or variation of climate on various temporal scales. It is used to explain the way climatic variables (such as temperature and precipitation) depart from some average state, either above or below the average value (Okorie et al,2012).

Climate change, the significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years (IPCC, 2007), is no longer a hypothesis. Never in the history of man has the issue of climate

change been so topical at national and international levels (Ayoade, 2003a). It has been the leading cause of controversy over issues relating to climate and has been on the front burner of world leading researches in environmental science and climatology. Climate change is a phenomenon of nature, that the world over has accepted as a fact of life. So important is climate change that it has been described as "the greatest crises ever faced collectively by mankind" (Foley, 1991). Climate variability and change is already apparent and will get worse than previous forecast had suggested". Now, there is a strong consensus that the global climate is warming and will continue to warm. There is however less agreement on just how much it will warm or what the impact of the warming will have on humans (Thomas et al, 2003).

One important factor accounts for the prominence now given to the issue of

climate variability and change in the global scene: the frequency of occurrence of extreme weather events such as flood, drought, heat and cold waves. These are experienced in different parts of the world in recent years and have devastating effect on human lives and properties as well as national economies (Ayoade, 2003b). Changes in climate either long or short term changes, can alter significantly the hydrological behavior of catchments, rainfall in particular. Floods and drought are product of too much and too little rainfall (Chaulagain, 2006) which in turn is an effect of changing rainfall trends.

Rainfall is perhaps the single most important process in the hydrologic system. The hydrologic system, which consist of the circulation of water from the ocean to air and back to the ocean is in turn an integral part of the global climate system (Critchfield, 2002; Ayoade, 2003b; Olaniran, 2002; Chaulagain, 2006). Therefore, any change in the hydrologic system cause changes in the climatic system. Rainfall, being a major process in the hydrologic system will consequently be affected by these changes to the climate system. Changes in rainfall will therefore be one of the most critical factors in assessing the overall impact of climate change (Met office, 2011). Arnell, (1993) also estimated that climatic changes would result in changes in rainfall patterns and trends. Rainfall trends may however be increasing, decreasing or non-coherent (static).

In Nigeria, it is well known that climate has varied in time and space, and that it will continue to vary in future. Climate variability has induced erratic rainfall events in many parts of the world, Nigeria inclusive. It has reported that variations in rainfall intensified for the different climatic regions and individual locations in Nigeria in the last three

decades of the last century (Okorie et al, 2012). The unique location of the Southwestern Nigeria, with the Atlantic Ocean to the south and the prevailing Tropical maritime, has made it one of the wettest regions in the country. In the last few years however, this region has witnessed several cases of flooding. The flood event in Ibadan - a major southwest city - that generated headlines, claiming hundreds of lives and damaging properties worth millions is a case in point. This sudden abrupt change in rainfall intensity is linked to changing rainfall trends and may be accounted for by climate variability. Indeed, signal of climate change may be obtained from a changed seasonal rainfall regime (Olaniran, 2002).

Rainfall is a climate parameter that affects the way and manner man lives. It affects every facet of the ecological system, flora and fauna inclusive (Obot and Onyeukwu, 2010). Rainfall varies from year to year and over decades and changes in amount, intensity, and frequency affecting the environment and society. There is increasing evidence that human induced climate is changing the rainfall and hydrological cycle, especially the extremes (Trenberth, 2005). Although some historical changes in climate have resulted from natural causes and variations, the strengths of the trends and the patterns of change that have emerged in recent decades indicate that human influences, resulting primarily from increased emission of CO₂ and other green house gases, have now become the dominant factor. The rate and amount of these changes, their consequences on temporal and spatial patterns, are at present source of major concern to atmospheric scientists and allied researchers. (Okorie et al, 2012)

Both decreasing and increasing rainfall trends have culminating effects of drought and flood respectively. Low-

productive rain-fed agriculture is dominant in the southwest; consequently, the importance of the timing and amount of rainfall that occurs cannot be overstated. It is generally known that agriculture employs a large number of people in this region. The reliance on agriculture is even more acute in rural areas. Given such a heavy dependence on rainfall, it should come as no surprise that climate extremes such as drought and flood could pose significant economic, social and health threats to the entire region. FAO, (2005) estimated that by 2080 an increase in drought may lead to 11 percent decrease in land suitable for rain-fed agriculture. Even if crops do not fail, the vagaries can still cause variation in yield (Olaniran, 1990).

Apart from the impact on agriculture, other natural hazards such as mudslides, landslides and gullies may also ensue from climate change induced change in rainfall trend. It is therefore crucial to understand trend and variability in rainfall, its relation to climate change, possible impacts on environmental, economic and social aspects, as well as identify adaptation options to minimize potential hazard on a regional scale. Therefore, this research seeks to address the present trend of rainfall in Southwestern Nigeria, the overall trend over a period of 35 years, the consequent climate change scenario and predict the likely climate change scenario in the study area for future years using identified rainfall trends.

Study area

Southwestern Nigeria stretches from Latitude 6°N to 10°N and from Longitude 2°30'E to 6°E. It is separated from the other regions by the upper and lower Niger River that empties into the ocean via a deltaic mouth. Southwestern Nigeria occupies Nigeria's western border with Benin Republic. It is however

bounded to the South by the Atlantic Ocean on Lagos' coast. Politically, Southwestern Nigeria, one of the six geo-political zones, comprises six states which are Lagos state, Ogun state, Ondo state, Osun state, Ekiti state; and Oyo State.

There is a general lessening of equatorial and sub-equatorial climate conditions and a corresponding increase in wet tropical climate condition as one move from the southern end to the northern fringes of the region. The sub-equatorial climate has an annual rainfall of over 1500mm with one or two months of dry season and double maxima rainfall. The rainfall annual total for the wet tropical climate ranges between 1000 and 1500mm. The rainfall here is double maxima but dry season may stretch for four months. A mean annual temperature of 27°C is fairly constant for the whole region and mean annual temperature range is between 4°C and 5°C. In general, the region is characterized by alternating dry and wet season with relative humidity of 70%. The dry season lasts from November to March while the wet season starts in April and ends in October (Iwena, 2007). The southwesterly wind and the northeast trade winds blow in the rainy and dry (Harmattan) seasons respectively.

The region is densely populated with a high level of urbanization with the highest in the country. Soil and climate favour cash crop production such as cocoa, rubber, palm trees, kolanuts, orange, and tobacco among others. Cocoa is particularly extensively grown. Most of the kola nuts produce in the country are grown here (Emielu, 2008). Local craft industries still feature prominently in the economy of this region. They include: cloth weaving in Oyo and Iseyin; cloth dyeing in Abeokuta and Osobgo; pottery as well as wood and calabash carving in Oyo town.

The total population of Southwestern Nigeria according to the 2006 National population census was put at 27,721,832. The six states had the following population: Lagos state- 9,113,605; Ogun state-3,751,140; Oyo state - 5,580,894; Ondo state -3,460,877; Ekiti state- 2,398,357; Osun state- 3,416,959. Large scale manufacturing industries abound in this region such as pulp and wood industry in Ondo state; food and drink industry in Oyo, Ogun, and Lagos

state; Cement industry in Ewekoro and Shagamu; car assembly plant in Lagos among others. Marble is quarried in Igbeti in north Oyo state, gold is mined at Ilesha and limestone at Ewekoro and Shagamu. These minerals have associated industries (Abegunde et al, 2007). Lagos, with about 10% of Nigeria's population, accounts for approximately 25% of Nigeria's retailing, 40% of its wholesaling, 40% of its external trade, and 70% of its industrial capacity (Paul et al, 2007).

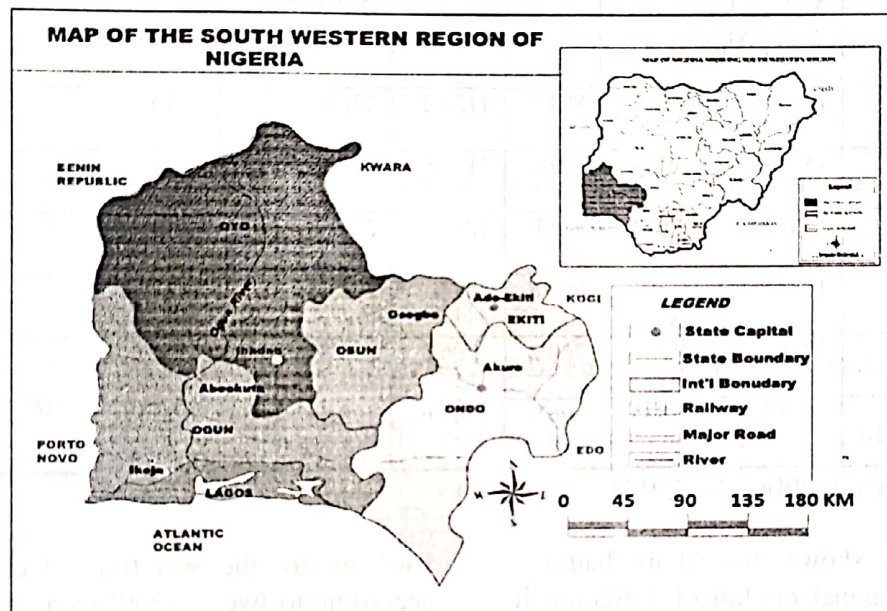


Fig 1. Map of Southwestern Nigeria (inset: Map of Nigeria showing the Southwest)
Source: Adapted from Google Map

Methodology

Data for this study were obtained mainly through secondary sources. Rainfall data for 35 years were sourced from the archival records of the Nigerian Meteorological Agency (NIMET) at its headquarters in Oshodi; Lagos. NIMET is the agency responsible for the measurement, control, and storage of Hydro-meteorological data in Nigeria

(Olofintoye and Sule, 2010). This data is gotten through the measurement of rainfall depth in millimeters (mm) collated for twelve months of the year. The rainfall data spanned thirty-five years between 1975 and 2010 for each stations located in the southwestern states. They are Ikeja, Abeokuta, Ibadan, Osogbo and Akure. Descriptive and inferential statistics were used in this study to analyze the data

collected. The major descriptive method used to summarize the data was mean, standard deviation, variance, coefficient of variability, and coefficient of skewness

while the inferential methods used were trend analysis (Run test and simple linear regression) and correlation Analysis.

Results and Discussion

Descriptive Analysis of Rainfall in Southwestern Nigeria

The mean annual rainfall for some selected stations in Southwestern Nigeria, their range, standard deviation, skewness and variability are shown in the table below.

Table 1: Descriptive Statistical Analysis of Rainfall in Southwestern Nigeria (1975 - 2010).

S/ N	STATION	MEAN ANNUAL RAINFAL L (mm)	MAX	MIN	RANG E	STANDARD DEVIATION	COEFFICIENT OF SKEWNESS	COEFFICIE NT OF VARIATIO N (%)
1	IKEJA	1461.9	2019.9	894.7	1125.2	270.04	-0.163	18.47
2	ABEOKOUT A	1578.2	2135.5	1028.9	1106.6	266.88	-0.062	16.91
3	AKURE	1662.3	2542.3	1257.5	1284	276.80	1.174	16.65
4	OSOGBO	1334.8	1691.8	802.8	889.0	202.93	-0.248	15.20
5	IBADAN	1295.4	1966.4	760.2	1206.2	276.55	0.263	21.35
6	WHOLE REGION	1465.9	1835.9	1061.5	774.36	195.85	-0.470	13.36

Source: Author's Fieldwork. (2013)

Table 1 shows that Akure had the highest mean annual rainfall of 1662mm. It also recorded the maximum rainfall for the entire region over the 35 year period. On the other hand, Ibadan had the lowest mean annual rainfall in the region. A possible explanation for this is their respective proximities to the sea. Emielu (2008) noted that rainfall amounts tend to decrease with increasing distance from the sea. Fig 2 shows clearly that Ibadan is the farthest from the Sea while Akure is the closest and most southerly. Ikeja, Abeokuta, and Osogbo had mean annual rainfall of 1461.9mm, 1578.2mm and 1344.7mm respectively. For the entire region, a mean annual rainfall of

1461mm for the Wet tropical climate type according to Iwena, (2007) was found. Fig 2 shows the distribution of mean annual rainfall by stations.

Furthermore, deviation from the mean annual rainfall seemed highest in Akure and least in the region as a whole. Rainfall variability was also low for all the stations. Overall, rainfall was homogenous for the entire region ($C.V < 33\%$). Ideally, in most of the stations, the rainfall did not follow a normal distribution but were found to be negatively skewed as shown in the coefficient of skewness. This concurred with Viessman and Lewis (1996) that rainfall data are usually markedly negatively skewed.

However, the rainfall for Ibadan and Akure showed positive skewness. This deviation occurred probably because precipitation

records are more sensitive to exposure, aspect, surface roughness and surface heating than temperature records (Ayoade, 2004).



Fig 2: Map showing Mean Annual Rainfall by States in the Southwestern Nigeria (1975 - 2010).
Source: Author's Fieldwork (2013)

Trend Analysis Of Rainfall For Each Station In The Southwestern Nigeria And Consequent Climate Change Scenario

The mean annual rainfall data of all the five stations were analyzed for likely trend using first, the Runs test.

Table 2: Runs test to Detect Presence (or absence) and Strength of Trend

S/ N	STATION	CASES <TEST VALUE	CASES> TEST VALUE	RUNS TEST		Z	RUNS TEST PERCENT AGE OF RUNS	LEVEL OF SIGNIFIC ANCE	REMARK
				TOTA L CASE S	NO OF RUNS				
1	IKEJA	18	18	36	17	- 0.507	47.2	0.612	WEAK TREND
2	ABEOKUT A	17	17	34	14	- 1.219	41.18	0.223	WEAK TREND
3	AKURE	18	18	36	17	- 0.507	47.2	0.612	WEAK TREND
4	OSOGBO	18	18	36	20	0.169	55.6	0.866	CLEAR OSCILLATION
5	IBADAN	18	18	36	22	- 0.845	61.1	0.398	CLEAR OSCILLATION

Test Value = Rainfall in median year

Source: Author's Fieldwork. (2013)

In Table 2 above, the runs test revealed weak trend for Ikeja, Abeokuta and Akure with Z-score values of -0.507, -1.219, -0.507 respectively while Osogbo and Ibadan revealed clear oscillation with Z-score of 0.168 and -0.845 respectively. Ikeja had 17 runs which was just below 50% of the total cases. This represents only a weak trend, with a Z score of -0.507, at the 0.612 level of significance. Also, rainfall records in Akure showed a weak trend because the number of runs was lower than 50% of the total cases. Furthermore, Abeokuta and Ibadan were

stations with the least and most number of runs respectively. Abeokuta had just 41% of runs to the total cases. This makes it comparatively the station with the strongest trend and consequently the highest climate change scenario. Conversely, Ibadan with 61% runs (too many runs) had no trend in its rainfall record. Similarly, the rainfall records for Osogbo showed oscillation, with a significance level of 0.866, as the number of runs was 55% of the cases. Hence for Ibadan and Osogbo, the climate change scenario is most probably too subtle to notice.

Simple Linear Regression Analysis.

The trends, their confidence limits and the errors on estimation for all the stations were calculated by a simple linear regression analysis.

Table 3: Analysis of Trends in Mean Annual Rainfall in Southwestern Nigeria Stations (1975 - 2010).

S/N	Station	Mean Annual Rainfall (mm)	TREND DETECTION				r	R ²	t-Test	Trend Significance at $\alpha = 0.05$
			a (intercept)	Trends (mm/year)	Regression equation	Std Error (mm)				
1	IKEJA	1461.9*	1320.4**	7.648	$Y = 1320.4 + 7.648x$	4.196	0.298	0.08	1.803	Not Significant
2	ABEOKUTA	1578.2*	1418.3**	9.106	$Y = 1418.3 + 9.106x$	4.403	0.343	0.12	2.068	Significant
3	AKURE	1662.33*	1620.1**	2.285	$Y = 1620.1 + 2.285x$	4.489	0.087	0.01	0.509	Not Significant
4	OSOGBO	1334.8*	1217.4**	6.344	$Y = 1217.4 + 6.344x$	3.119	0.329	0.11	2.03	Not Significant
5	IBADAN	1295.4*	1247.2**	2.608	$Y = 1247.2 + 2.608x$	4.479	0.099	0.01	0.582	Not Significant

Source: Author's Fieldwork. (2013)

The findings show that all the stations had increasing trend in rainfall that varied among them for the 35 years period. Correlation analysis also showed a positive but weak correlation between rainfall and time for all the stations. Also, for 4 out of the 5 stations, the t - test revealed that the trends were not significant at the 5% confidence limit. Only Abeokuta showed statistical significance in its increasing rainfall trend. Rainfall in Abeokuta was found to be increasing at an average rate of 9.106mm/year. A correlation coefficient of 0.343 revealed a comparatively high correlation between its rainfall and time.

This is seen clearly in the sharp rise in trend from 1975 to 2010 in Fig 4.

In contrast, the analysis revealed that Akure had the least rate of increase with 2.284mm/year as well as the second lowest correlation between rainfall and time (0.087). This increase was of course not significant (it was the least significant) at $\alpha = 0.05$, with a t - test score of 0.509 significant at 0.614. Similarly, Ibadan showed the second lowest increasing trend in rainfall (2.607mm/year) which was found to be insignificant. On the other hand, Ikeja had the second highest rate of increase in rainfall with an increase of 7.648mm/year. But with a t-test value of 1.803, the increase was found to be too

subtle to be significant at the 5% confidence limit. This shows a minimal climate variability scenario.

Lastly, the analysis revealed a relatively high increase in rainfall per year and the second highest correlation of rainfall and time in Osogbo. Again, this increase was

not large enough to be significant. Most of the findings in the Simple linear regression analysis concurred with those of the Runs test in terms of trend and significance. The charts for the linear trend of annual rainfall for all the stations are shown below.

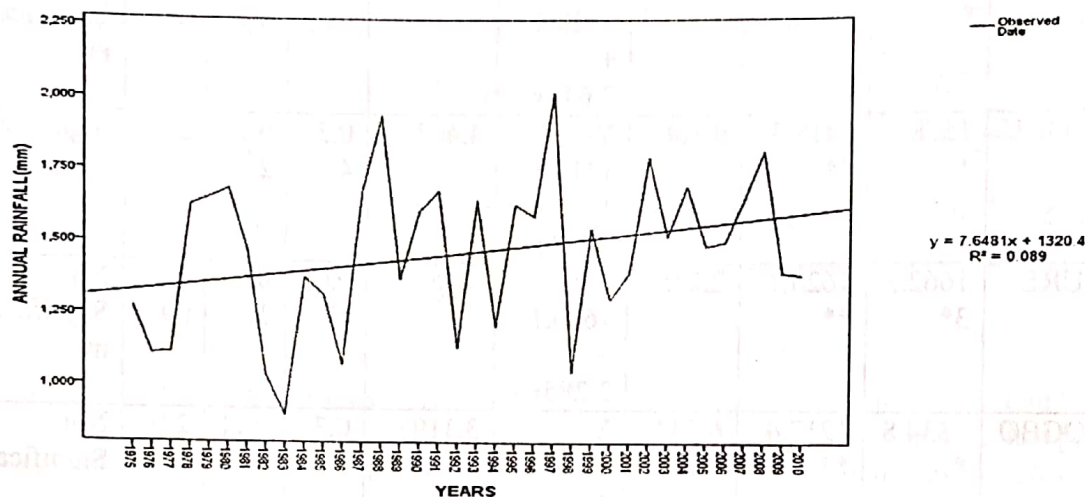


Fig 3: Chart of Linear Trend of Annual Rainfall in Ikeja (1975 - 2010).

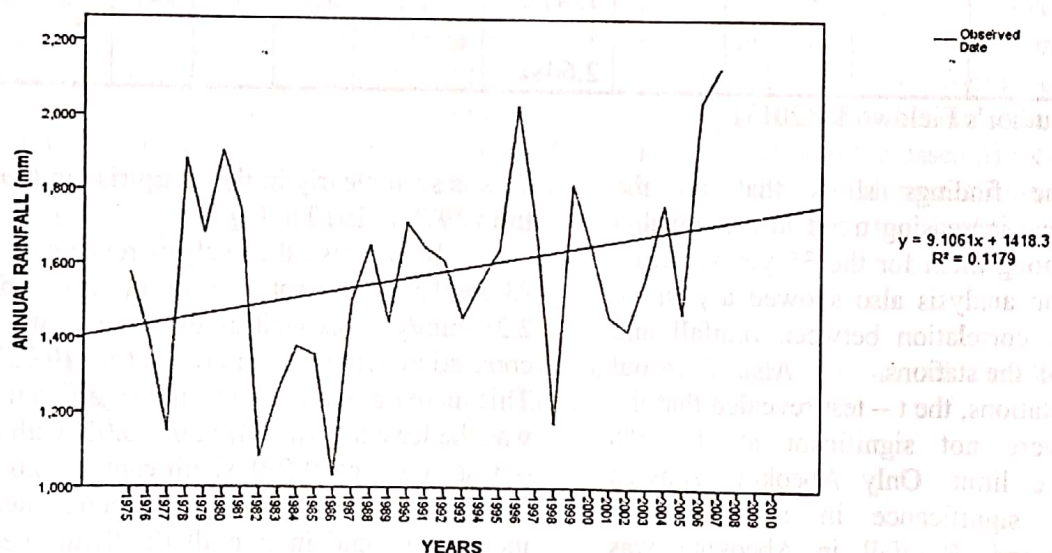


Fig 4: Chart of Linear Trend of Annual Rainfall in Abeokuta (1975 - 2010).

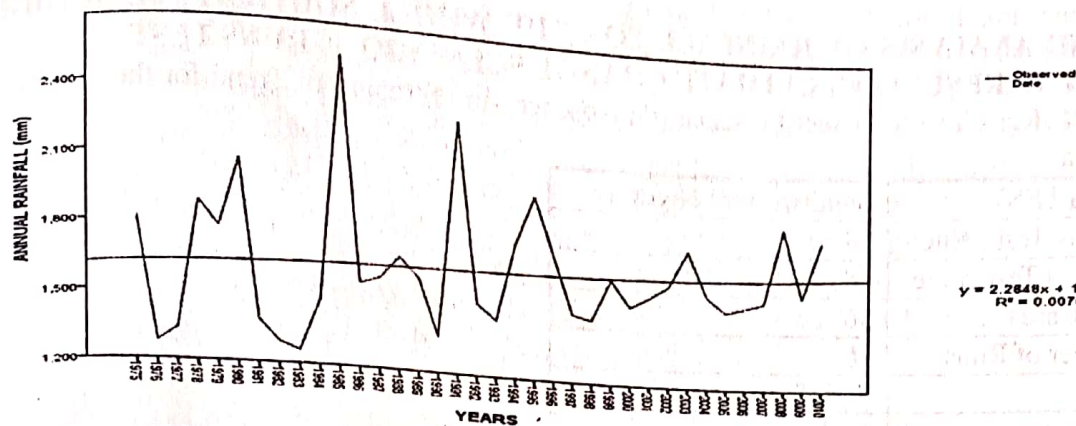


Fig 5: Chart of Linear Trend of Annual Rainfall in Akure (1975 - 2010).

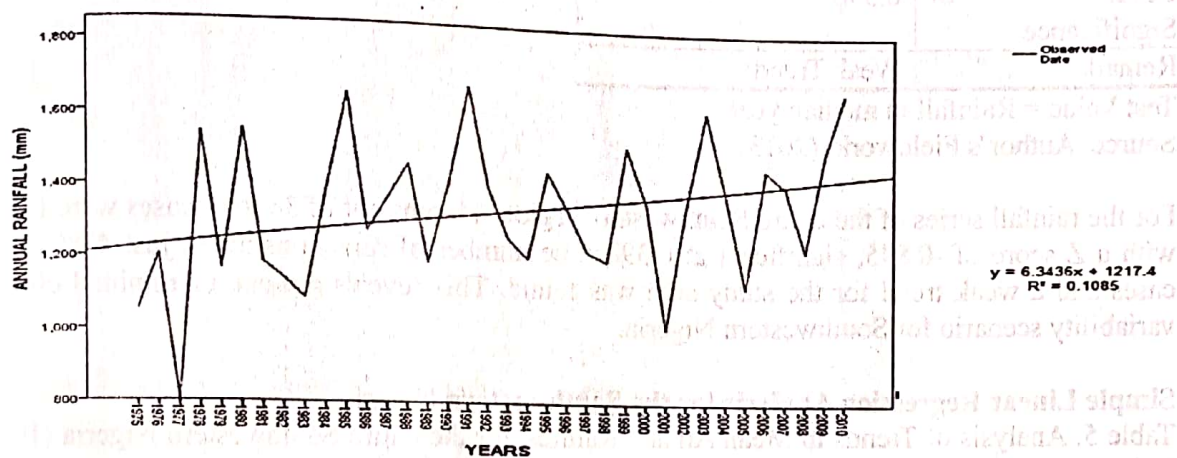


Fig 6: Chart of Linear Trend of Annual Rainfall in Osogbo (1975 - 2010).

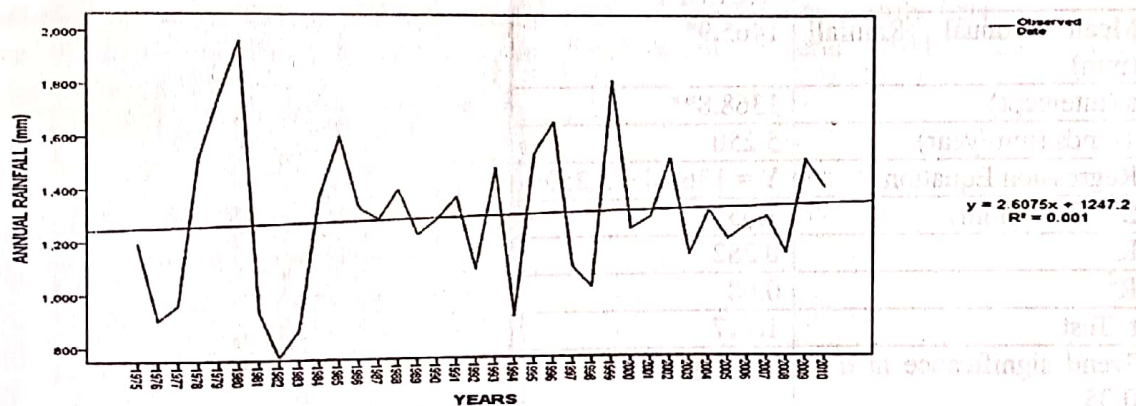


Fig 7: Chart of Linear Trend of Annual Rainfall in Ibadan (1975 - 2010).

TREND ANALYSIS OF RAINFALL FOR THE WHOLE SOUTHWESTERN NIGERIA AND THE RESULTING CLIMATE CHANGE SCENARIO RUNS TEST

Table 4: Runs Test to Detect Presence (Or Absence) and Strength of Trend for the Southwestern Nigeria.

RUNS TEST	Southwestern Nigeria
Cases < Test value	18
Cases > Test value	18
Total Cases	36
Number of Runs	16
Z	-0.845
Percentage of Runs(%)	44.4
Level of Significance	0.398
Remark	Weak Trend

Test Value = Rainfall in median year

Source: Author's Fieldwork. (2013)

For the rainfall series of the entire Southwestern region, 16 runs out of 36 total cases were found, with a Z score of -0.845, significant at 0.398. The number of runs constituted just 44% of the cases and a weak trend for the study area was found. This reveals a weak or minimal climate variability scenario for Southwestern Nigeria.

Simple Linear Regression Analysis for the Southwestern Nigeria

Table 5: Analysis of Trends in Mean Annual Rainfall for the entire Southwestern Nigeria (1975-2010)

TREND ANALYSIS	SOUTHWESTERN NIGERIA
Mean Annual Rainfall (mm)	1465.9*
a (intercept)	1368.8**
Trends (mm/year)	5.250
Regression Equation	$Y = 1368.8 + 5.250x$
Std Error (mm)	3.058
R	0.282
R^2	0.08
t- Test	1.717
Trend significance at $\alpha = 0.05$	Not Significant

Source: Author's Fieldwork (2013)

The simple linear regression analysis revealed an increasing trend in the rainfall record for the whole study area.

Rainfall was found to be increasing at an average rate of 5.250mm/year. This increase will lead consequentially to

occurrences such as flooding, erosion. In line with Oriola,(1994), Increasing flood risk is now being recognized as the most important sectoral threat from climate change in most parts of the region which has prompted public debate on the apparent increased frequency of extreme, and in particular, on perceived increase in rainfall intensities. The correlation analysis showed a weak but positive correlation between

rainfall and time. A correlation coefficient of 0.08 in itself explains that rainfall is actually increasing but at a slow (insignificant) rate. The t – test value was however not up to the critical value at which a trend will be considered significant. The simple linear regression analysis, as with the runs test, also shows minimal climate variability scenario in the area.

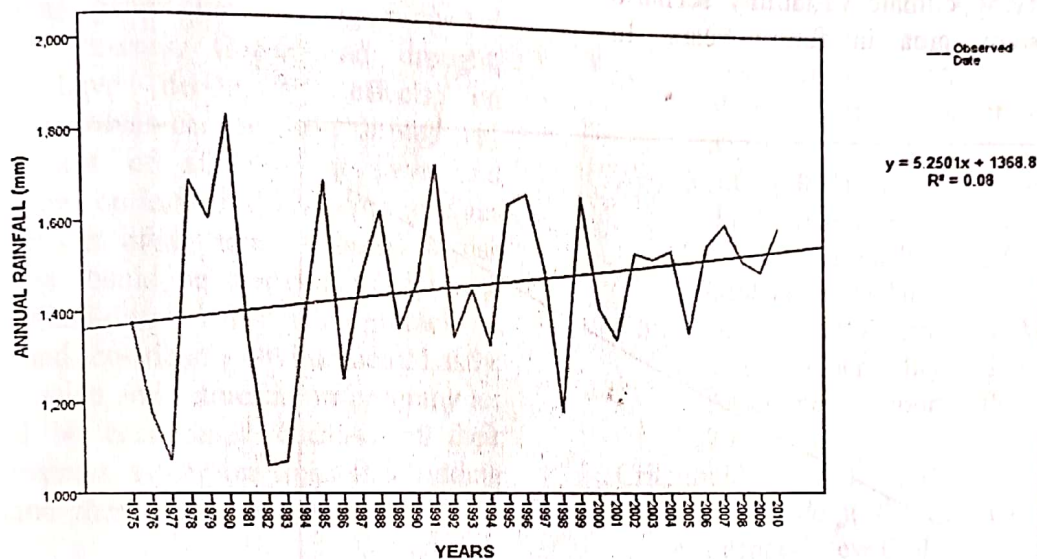


Fig 8: Chart of Linear Trend of Annual Rainfall in the entire Southwestern Nigeria (1975 - 2010).

Prediction of Future Climate Change Scenario (2011 - 2060) for the Study Area.

Table 6: Predicted Rainfall increases for Southwestern Nigeria (2011 - 2060) Using Predetermined Rainfall trend.

Year	Predicted Annual Rainfall (mm)	Percentage increase from base year (%)
2011	1563.1	
2020	1610.3	3
2030	1662.6	6.4
2040	1715.3	9.7
2050	1767.8	13.1
2060	1820.3	16.5

Source: Author's Fieldwork (2013)

The forecast of annual rainfall using trend line equation from simple regression

analysis showed a continuous rise in rainfall. The forecast is based on the linear regression

equation gotten from the trend analysis of the rainfall for the southwestern region, $Y = 1368.8 + 5.250x$. Going by this equation, rainfall for the study area is expected to increase at an average rate of 5.250mm/year. By 2030, annual rainfall total would have increased by 6.4% from that in 2011. Also, based on the forecast, annual rainfall totals in 2060 would be 1820.3mm, a 16.5% increase from that in 2011. These of course points to an intensifying climate variability scenario for the study area in future years. In

assessing the relationship between the intensity of Climate change and time scale, Edward and James (2001) asserted that oscillations that take place over longer periods typically have greater magnitudes than those occurring on shorter time scales. Hence, the minimal climate change observed over the past 35 years may become severe in the next 50 or more years. Figure 9 below shows the chart for the forecast of annual rainfall in the southwestern region.

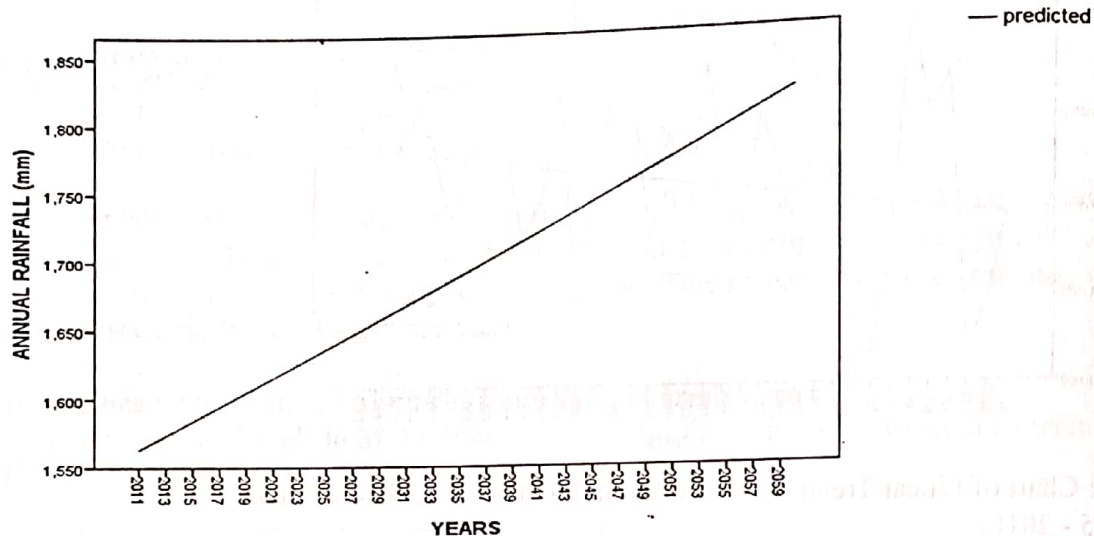


Fig 9: Chart of Predicted Annual Rainfall totals for the whole Southwestern Nigeria (2011 - 2060).

Conclusions and Recommendations

The insignificant increasing trend in rainfall showed that climate variability is not driving any systematic trend in rainfall in the Southwestern Nigeria. There is little evidence of climate change in the annual rainfall series of the Southwestern Nigeria i.e. climate change in the region is minimal and subtle. Abeokuta was however an exception: The rainfall in Abeokuta demonstrated significant increasing trend with correlation values of 0.343 between its rainfall and time. Thus, the study concludes

that there is significant evidence of Climate variability at the stations which can be generalized for the state. The minimal climate variability scenario in this part of the country will intensify with time. Long term unmitigated Climate variability will likely cause more rainfall in annual totals and consequently reinforce present increasing trends – exceeding the capacity of people and the natural environment to adapt. This is in line with Olaniran (2002) and Adefolalu et al (2001) submission that contrary to the long-term decline in rainfall widely reported for the 1970s and 1980s for

subtropical West Africa, some areas of Nigeria have experienced a progressive increase in rainfall activities during certain periods. This is the situation over Southern Nigeria (Coastal and Guinea Savanna belts), which experienced progressive increase in August rainfall amount without a corresponding increase in rainfall frequency.

Based on the findings in this study, it recommends combating, controlling and mitigating against climate change propelled rainfall extremes, floods and drought, which have debilitating effects on agriculture. This can be done through reinforcement of all relevant laws and regulations on industrial and domestic gas emissions in urban areas. Urban land use practices should be made to conform to already-laid-down rules that promote a green and eco-friendly environment. Lastly, afforestation and reforestation programmes should be encouraged because of their effectiveness as carbon sinks that ridding the atmosphere of heat trapping gases.

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