RAINFALL AND TEMPERATURE ANOMALIES AT SOKOTO 1991-2010

BY

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CERTIFICATION

This is to certify that this research work was carried out by MUSTAPHA IBRAHIM and it is hereby submitted for assessment for the award of B.Sc. Degree in the department of Geography, Usmanu Danfodiyo University, Sokoto.

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External Examiner	Signature	Date

DEDICATION

This research work is wholly dedicated to the Almighty Allah (SWT) for the wisdom and courage granted to me for carrying out this study as part of my academic pursuit, effectively.

I wish also to dedicated this work to my parent Alh. Mustapha Dama Lapai, Mother Hajiya Rabiyatu Mustapha Dama and the entire family members. May God spare our life till death is good for us as a true Muslims. amen. And may God grant us Aljannatul firdausi and the entire Muslims across globe AMEEN.

DECLARATION

I, Mustapha Ibrahim, do here by declare that this title Rainfall and Temperature anomalies at Sokoto between 1991 to 2010 a product of my own research work duly undertaken under the supervision of Dr. A.T. Umar

ACKNOWLEDGEMENTS

I hereby place on record my profound gratitude to all those that have contributed to the success of this work.

First and foremost, I give thanks to the creator of heaven and earth, man and Jinns for giving me the courage, wisdom and understanding for coming all this long.

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I am highly indebted to my mentor the one and the only climatologist in the Department of Geography UDSUS for this thorough supervision of my work. Dr. A.T. Umar. My H.O.D. Alh. Dr. Abdulrahim Maroufdeen and teaching and non teaching staffs in the Department of Geography UDUS and other lecturers for their understanding and useful suggestions.

Although names are too numerous to be included here but I will identify the contribution of my own brother and sisters, cousin both brothers and sisters and friends at large. I thank you all and wish you the best success in all aspect of your live (Ameen).

TABLE OF CONTENTS **PAGE**

CHAPTER TWO

CHAPTER THREE

LISTS OF FIGURES **PAGE**

ABSTRACT

This study examines the rainfall and temperature anomalies at Sokoto for the period 1991-2010. The data on monthly rainfall and temperature of Sokoto were collected from the Nigerian Metrological Agency (NIMET) Sultan Abubakar III International Airport. Sokoto respectively. Simple linear regression and coefficient (r) simple correlation analysis was used to fit the trend in annual rainfall amount, mean monthly temperature (minimum and maximum) for the period of the study. Data analysis was carried out by statistical package of the social science (SPSS) and also Microsoft excel program were used to input and drawing of chart or graph was also used to determine the trend in annual rainfall amount, mean monthly temperature (min and max for the period of the study. The student's 'test was also used to test the significance of the correlation. Detailed analysis of the result showed that there was a downward trend in annual rainfall amount; no significant trend in mean minimum temperature over the period of the study. However, an upward trend was observed in the period 1991-2010. The study recommends that the shelter belt should be planted in cushion the effect of the changing climate in the area. The study suggests that the study on the impact of climatic variability on human welfare should be conducted.

Key words: Annual rainfall, trend, variability, inter tropical discontinuity.

CHAPTER ONE

1.1 BACKGROUND OF THE STUDY

Rainfall in Nigeria is highly seasonal in character with well-marked wet and dry seasons, these are characteristics of the monsoon type of climate. As rainfall decreases from the coast to the interior both in amount and in duration, along the coast to the mean annual total rainfall from 4295mm at bonny in the east to only 5775mm at Lagos in the west. Northwards the annual rainfall decrease in land to less than 700mm in the lake Chad basin (Maiduguri) (Oguntoyimbo, 1978). The latitudinal falling off in rainfall is interrupted by the effects of the relief in the interior. The Niger-Benue trough, lying generally on the leeward side of the eastern upland receives less than average rainfall fort its latitude while north of the trough, the Jos plateau, whose southern wind ward slopes receives season ranges from eight to ten months in the south to less than a months in the extreme north-west (Oguntoyimbo, 1978). Seasonal variation in the rainfall is only attributed to fluctuations of the boundary between the two major air masses which influence the climate of West Africa. These are originated from the Atlantic ocean, and the dry dust laden tropical continental (ITD) air mass, which originated from the Sahara desert. The boundary between these two air masses, the inter-tropical discontinuity ITD (is significant because it separates two distinct term of weather on either side, but unlike the temperate latitudes, it does not give rise to any particular activities associated with the boundary itself. During the northern winter, when the surface location of the ITD lies at about latitude 7^0N across Nigeria, there is only shallow depth on MT air covering the coastal areas, giving rise to occasional showers in the Niger delta between December and February. Most of the interior is then under the desiccating influence of the dust earing CT air mass (Oguntoyimbo, 1978)

The distribution of the total amount of rainfall in the tropics has been examined on different time and spatial scales. Almost every where in the tropics, the annual totals differ widely from year to tear, and in addition, it varies strongly with places as well as the rainfall characteristic, such as its seasonal and diurnal distribution intensity, duration and frequency of raiding. These variations are due to certain factors at both macro and micro levels. Once macro scale, variations of rainfall are caused by a number of factors, usually in combinations. The most important of these is of course, the inter-tropical convergence zone (ITCZ) and the length of its stay over a certain area (Ayoade, 1978).

1.2 AIM AND OBJECTIVE OF THE STUDY

The basic aim of this research work is to examine the anomalies in rainfall and temperature at Sokoto between (1991 - 2010)

1.3 OBJECTIVES OF THIS RESEARCH WORK ARE:

- To determine the rainfall anomaly pattern at Sokoto.
- To determine the temperature anomaly pattern.
- Trend in annual rainfall and temperature (maximum and minimum)

1.4 METHODOLOGY

The data used for this study were monthly and annual rainfall totals and temperature (minimum and maximum) at Sokoto State collected from the Nigerian Meteorological Agency (NIMET) Sultan Abubakar III International Air Port, Sokoto over the period of 1991-2010.

1.5 DATA ANALYSIS

Several statistical tests were used in analyzing the data for this study. These include the simple linear regression analysis, simple correlation (r) and the student “t” test using (SPSS).

The simple regression analysis was used to fit the trend line in the annual rainfall amount, mean monthly temperature (minimum and maximum) for the period (1991-2010). The correlation coefficient (r) was to determine the trend in the analyzed time series for this study. The student “t” test was used to test the significance cause of the correlation.

1.6 DATA PRESENTATION

Tables, graphs and figures were used in analyzing and presenting one data for this work.

1.7 STATEMENT OF RESEARCH PROBLEM

Sokoto is experiencing rainfall anomalies from ongoing climate change, others include desert encroachment, deforestation. This ugly trend is not unconnected with the source of heat waves, drought, diminishing water bodies, epidemics etc. Other negative impact to decline in the amount of rainfall and further increases of temperature, include poverty. Its geographic implications lies in the situation of diminishing bodies, food insecurity, emergence of allergenic poller species and infectious diseases. However, the anomaly in these climatic variation (rainfall and temperature) were not thoroughly examined with respect to Sokoto.

1.8 RESEARCH HYPOTHESIS

Ho - Rainfall and temperature anomaly are not related to the human threat on environment (deforestation) in Sokoto.

1.9 HISTORICAL ANTECEDENT

Sokoto state is a balkanized entity of what used to be part of the Sokoto caliphate founded in 1804 by the great Islamic reformist and scholar, sheikh Usmanu Danfodiyo. The caliphate flourished until the British colonialist conquered it in 1903 and divided it into provinces Sokoto province comprised of Sokoto, Gwandu, Argungu and Yauri emirate. In 1967, with the creation and state in Nigeria Sokoto and Niger merged to form the northwest state. In 1976, the state was bifurcated in to Sokoto and Niger state, Sokoto state as at 1976 comprises of Sokoto, Kebbi and Zamfara states. Following further state creations first kebbi in 1991 and later present form in 1996, Sokoto emerged as a state in its present form. All through these historical developments Sokoto town has remained the capital of the caliphate the province and the state. (Prof. Mohammed Ilya).

1.10 LOCATION

The state is located to the extreme northwest of Nigeria between approximately latitude 12^0N and 13058^0 and longitude 408^1 and 54^1. It shares boundaries with the republic of Niger to the north, Kebbi state to the south west and Zamfara state to the northeast, covering on area of approximately 32,000 sq.km. According to the 2009 national population census the state has a population of 3,702,679 (NPC, 2009). The state is made up of 23 local government areas.

1.11 RELIEF AND DRAINAGE

Sokoto state is dominated by the Sokoto plains, a low land topography with an average height of about 3000 meter above sea level. In a few places, the low land is interrupted by isolated hill and escarpments such as those around age of Kamlambaina. There are two major rivers, the Rima and

Sokoto, and their tributaries the valley of these rivers are wide and constituted one of the most fertile and intensely cultivated dry season farm lands in west Africa and Nigeria.

The drainage system in Sokoto state can be described as radia dominated by the Rima river and its tributaries such as the Sokoto, Gagare and Bunsuru river. Most of the rivers take their source from the south-eastern part of the northern region, especially in Zamfara and Kaduna states. The volume of water in these rivers is understandable low during the dry season and their tributaries are in most cases dry during this period.

1.12 VEGETATION AND SOILs

The vegetation in the state is mostly the Sudan type. It is characterized by mixed woodland and short grasses. The tress are short and have developed a series of drought adaptations mechanism, such as long root systems, leaf shedding during dry season, thin leaves and hard backs. The shrubs are mainly of the acacia species and thorny. Along the river courses, plant density is higher.

Sandy soil and clayed material predominate except along the flood plain of the river valleys (Fadama) where alluvial soils are found. In the northern part of the state,

especially along the Niger-Nigeria border, the plains are covered by acolian or wind deposits from the Sahara desert and the Sahel and these give rise to light sandy soil. By extension, this feature leads to the problems of desert encroachment and desertification that are environmental challenges in the state. (Impact of climate change on Sokoto).

1.13 CLIMATE

The climate of Sokoto state is tropical continental and is dominated by two opposing air masses, the dry tropical continental blowing from the Sahara desert and a moist tropical maritime air masses from the Atlantic ocean. While the former blows from a north easterly direction later comes from a south-westerly direction. These two major air masses result in two major seasons; the wet and dry seasons. While the rainy season commences from mid April and last to the end of September, the dry season extends from early October to May. In between these two major categories there are four (4) other sub-seasonal types as Rani, Bazara, Kaka and Hunturu (Harmattan). The Harmattan period is characterized by a dry, cold and dusty wind experienced in the states between November and February. During this period, the weather is usually cold at night and morning in some cases. Temperatures are highest from late March to May, ranging from 35^0c to 45^0c. Mean annual rainfall is about 600mm with most of it falling in July and august. Over the last fifty years, the rainy season has been characterized by late arrivals of rains, long spell of aridity of up to 21 days and early cassations. This is an indication of climate change.

1.14 ECONOMIC ACTIVITIES

Agriculture has a very unique status in the economy of Sokoto state. It is a mean of subsistence of the people of Sokoto. Its open grassland is suitable for cultivation of varied of crops and animal husbandry. Among the staple crops grown in the state includes sorghum, corn, guinea corn, beans, rice and wheat, some of the cash crop cultivated are; garlic tomatoes, onions, pepper, cotton, tobacco, ginger alligator pepper e.t.c. The grassland provides food to the animals reared. These comprise variety of cows, sheep, goats, camels horses and exotic species of poultry.

A part from subsistence agricultural productions, the state is blessed with abundant human and material resources, since time immemorial, the people of Sokoto state have been engaged in a variety of occupational pursuits notable among these includes, tannery, uphotsory, curving generally weaving, knitting, yinng, black smithy, merchandize and fishing and trading across the sub Saharan trade routes presently, Sokoto is striving with a booming trade benetus and has a potential or variable cottage industrial transformation.

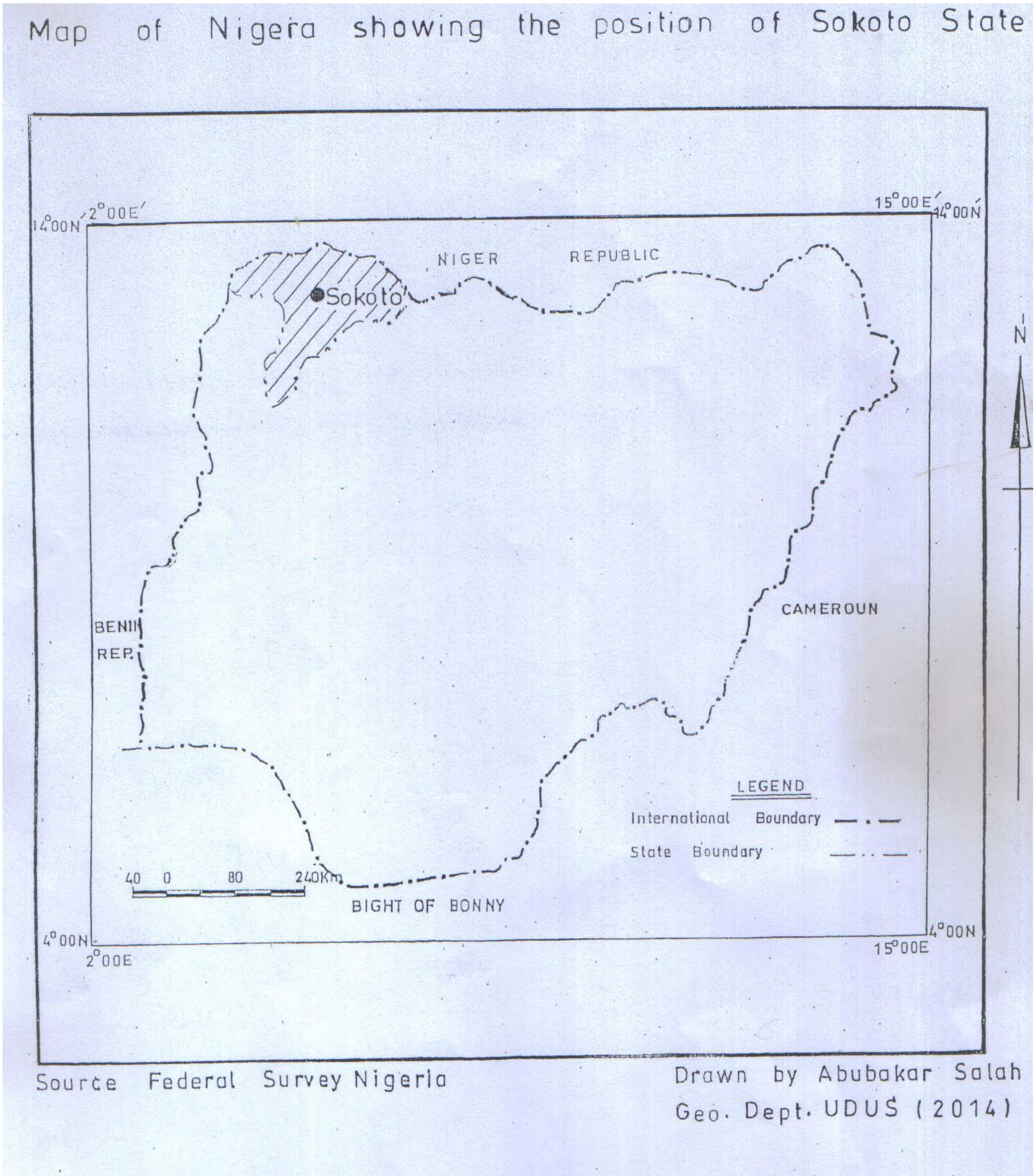


Fig.1 Map of Nigeria Showing Sokoto State

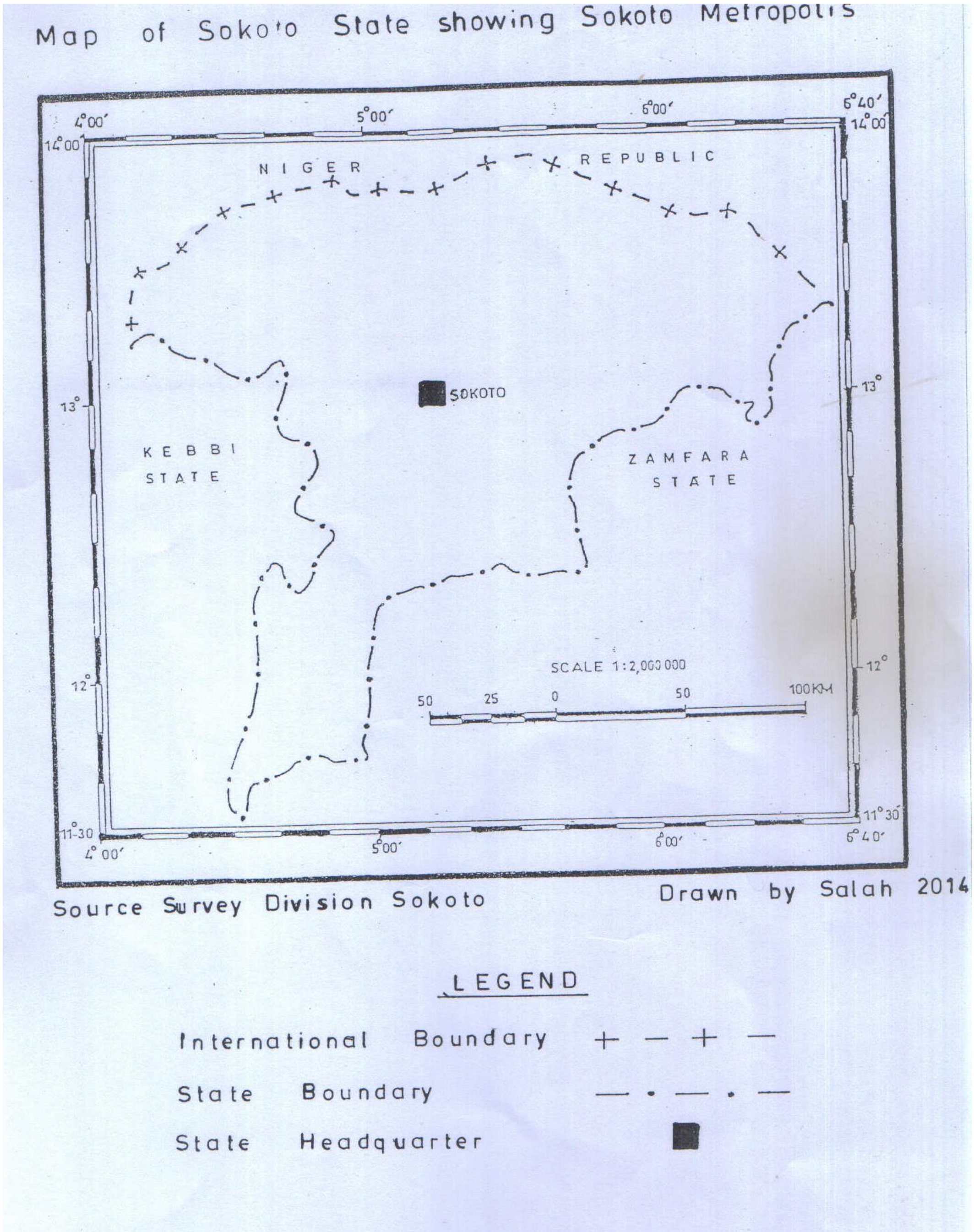


Fig.2 Map of Sokoto State

CHAPTER TWO

2.1 CONCEPTUAL FRAME WORK

The conceptual framework for this study is the ITD. Two major surface air masses influence Nigeria weather and climate. These are the warm moist southwest early air mass originally from the Atlantic ocean and the warm, dry north-easterly air mass originating from the Sahara desert. The boundary zone between these two air masses is devoid of any frontal activity since the two air masses differ little in temperature and the corolious force is low because of our proximity to the equator. This is discontinuity and it is appropriately called the inter-tropical discontinuity (ITD) over the ocean surface where there is evidence of convergence zone (ITCZ). The climate of Nigeria is controlled primarily by the seasonal movement of the ITD and the associated five weather conditions at any place in the country depend largely on its location with respect to the position of the migrating ITD an the associated weather types . the characteristic features of the ITD and the ether types have been extensively described in the literature (see Garnier, 1967, Ayoade 1971). I will only provide a summary here with the aid of fig 3 and table 1

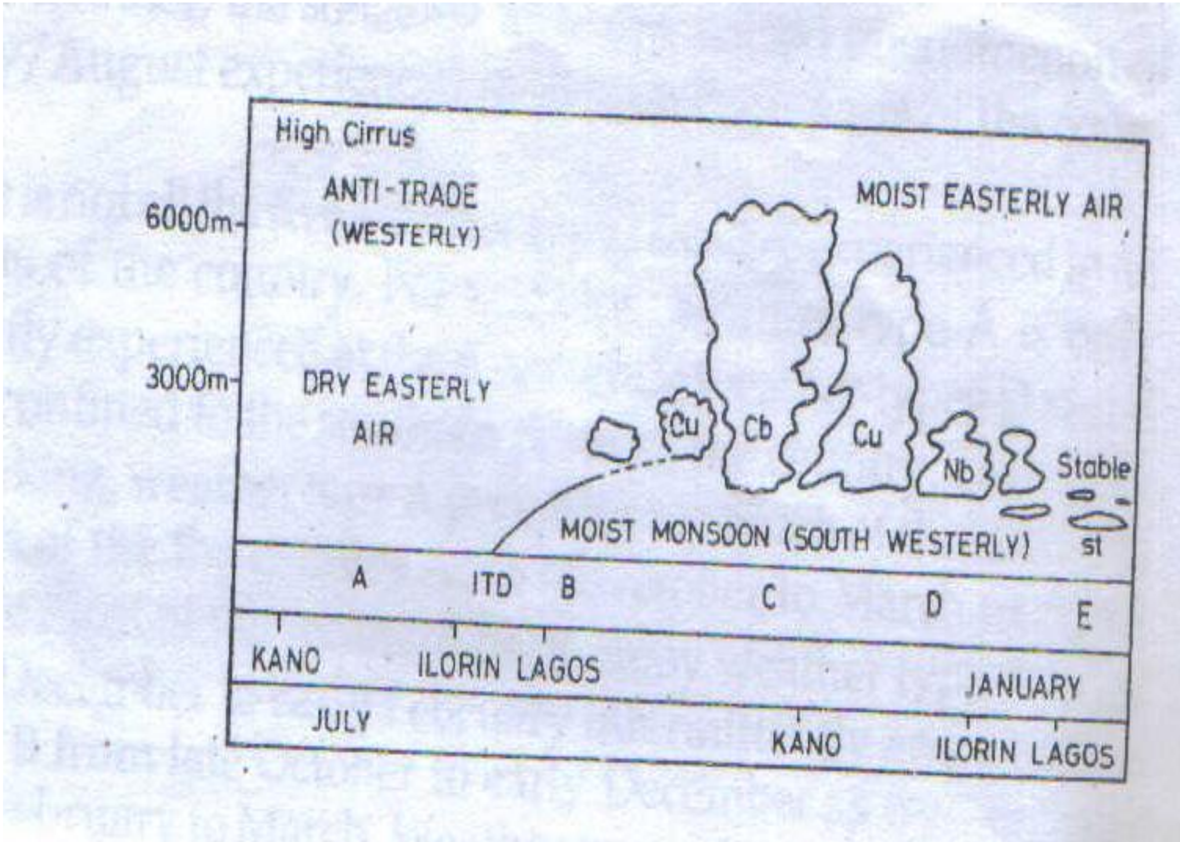


Fig 2.1

Source: (Garnier 1967)

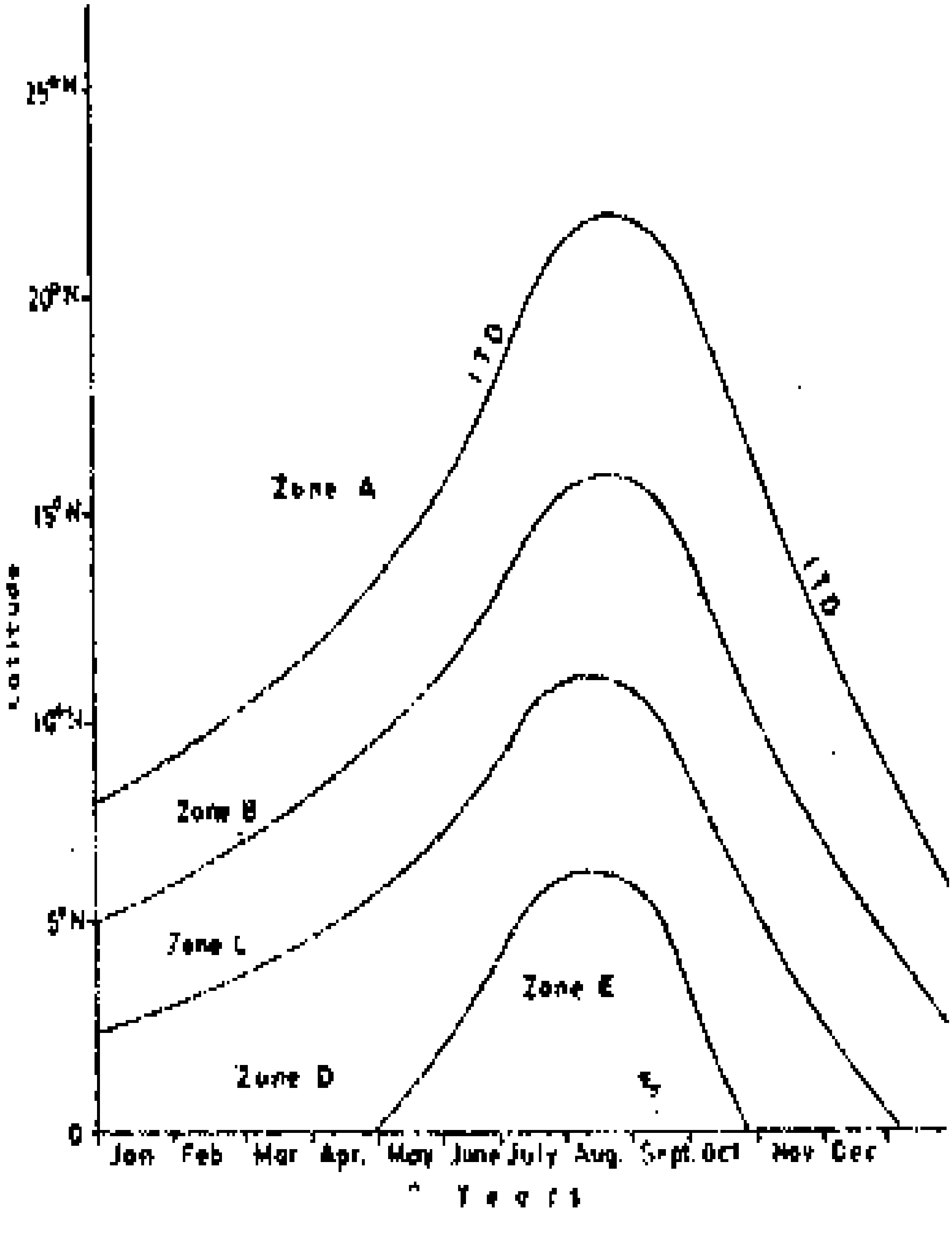


Fig 2.2

Source: (Garnier 1967)

Table 1 major characteristic of the weather types over Nigeria

Weather type	Location	Major characteristic
A harmattan weather	North of surface position of the ITD	Dry north easterly winds maximum temperature 30-35^{0c,} minimum temperature 12-18^{0c} relative humidity is less than 40% , visibility is poor because of dust haze
B dry but humid weather	Up to 300km south of the surface position of ITD	Little rainfall from isolated thunderstorms about 25-50mm per months. wind changes from southwestern lies in the mornings to northeast lies in the afternoons maximum temperature 30-35^{0C,} minimum temperature 18- 24^{0c,} relative humidity is 60-90 percent.
C Disturbace lines weather	300-1300km south of the surface position of the ITD	Moderate to high rainfall from organize lines of thunderstorm known as disturbance lines about 120200 mm per month, maximum temperature 27- 32^{0}c minimum temperature 18-20^{0}c relatively humidity 65-95%
D monsoon rain weather	More than 1600km south of the surface position of the ITD	Heavy monsoon rainfall from monsoon depression 300-350mm per month. Small decimal range of temperature high relative humidity of more than 80%
E little dry season weather	1300-1600km south of the surface position of the ITD	Low to moderates rainfall for stratus and stratocumulus cloud, 125-175mm per month maximum temperature 21-27^{0}c minimum temperature 18-21^{0}c relative humidity 65-95%

Source: Ayoade (1995)

The ITD is at its northern most position at around latitude 20^0N in august while the southernmost is on the average around latitude 7^0N in February. Weather located to north of the surface position of the ITD is characterized by dry Harmattan weather. The other four weather types are located south of the surface position of the ITD. Weather type B is characterized by dry but humid weather while weather type C is associated with disturbance line that give intense rainfall of relatively short duration. Weather type D is the monsoon weather known for its steady rain and drizzles and weather type E is characterized by humid though relatively dry weather, the so called little dry season phenomenal July/august experienced in the southern parts of the country.

It is not all the five weather types that are experienced in all parts of the country. For instance, weather types D and E are confined to the southern parts of the country. Generally speaking, weather type A prevails over much of the northern of the country southern parts enjoy weather type A from late February to March. Weather type C is experienced along the coastal areas particularly the Niger delta area during some of the latter period. From May to October weather types B and C prevail over the northern parts of the country while weather types C D and E prevail over the southern parts in varying durations and frequencies.

The rainfall over Nigeria are controlled by the dynamic climatology of the area. Four main rain producing factors were identified as operating in Nigeria and these were used to explain the pattern of rainfall distribution over Nigeria. The factors are as follows

i. The monsoonal air from the Atlantic ocean
ii. The organized bell of thunderstorms that move from east to west. These are also known as the disturbance lines
iii. The locations of the ITD and

iv. The relief which though strictly speaking is not a meteorological factor, does provide a stringer actions for convections and uplift of air masses.

These factors were operationalized and quantified were then used to explain the pattern of rainfall distribution over Nigeria on annual, seasonal and monthly bases with the aid of the step-wise linear regression model. The results are summarized in tables 2 and 3. For most of the year the ITD accounts for most of the variations in rainfall over the country. But in January, June, July and December the main factor controlling the rainfall distribution pattern is the monsoonal factor while in August it is the disturbance of annual and seasonal rainfall are accounted for mainly by the ITD factor (See tables 2 and 3).

With the exception of the months July and August, the various regression equations obtained provide high levels of explanation of rainfall patters over Nigeria. Even in those months the proportions of variance explained, though 49.2% percent probability level. The relatively low levels of explanation provided by our regression model in the months of July and August is attributable to the anomalous rainfall pattern over the country in those months. The little dry season phenomenon occurs in those months. The little dry season phenomenon occurs in those months in the southern parts of the country particularly south western parts which usually record the lowest rainfall in the country in August. Various hypothesis have been put forward to explain the occurrence of the little dry season phenomenon in late.

Table 2: Regression Analysis of Monthly Rainfall: Percentage of Variance Explained by the Explanatory Factors.

Months	Relief Factor (XI)	Monsoonal Soonal Factor (X2)	ITTD Factor (X3)	Disturbance Line Factor (X4)	All Your Factors
January	10.80	33.07	24.28	8.34	75.77
February	9.62	30.17	43.59	1.05	84.43
March	0.50	8.38	70.41	7.18	86.43
April	5.43	8.29	71.09	4.14	88.95
May	6.40	5.95	68.99	3.58	84.92
June	7.60	38.57	29.16	7.03	82.36
July	9.74	19.31	9.61	10.58	49.24
August	5.50	8.30	4.43	13.21	31.44
September	4.16	-	48.72	11.23	64.11
October	4.08	4.43	75.15	1.06	84.72
November	6.24	26.25	36.46	5.97	74.82
December	8.31	35.54	15.72	7.60	67.17

Table 3: Regression Analysis of Annual and Seasonal Rainfall:

Percentage of Variance Explained by the Explanatory Factors

Months	Relief Factor (XI)	Monsoonal Soonal Factor (X2)	ITTD Factor (X3)	Disturbance Line Factor (X4)	All Your Factors
Wet season	6.20	17.11	36.90	13.01	73.22
Dry season	3.12	18.21	65.79	0.35	87.47
Annual	6.09	17.71	46.42	10.24	80.74

Significance Levels: 5% = 1.36

1% = 2.33

July and August in the southern parts of Nigeria. But time and space will not permit us to discuss these. Suffice it to say that the little dry season phenomenon is more intense and occurs more frequently in the south-west than in the south-eastern parts of the country. Also, the atmosphere over the areas affected is characterized during the period by an inversion layer which prohibits rain-forming processes.

2.2 LITERATURE REVIEW

2.2.1 TEMPERATURE FLUCTUATIONS IN NIGERIA

Temperature is one of the climate elements that have been studied for evidence of climate change. Studies carried out in the low Nigeria (Ojo, 1979, Adebayo (1999), Griffin (1972) have analyzed the trend and variability of temperature in Nigeria and found out that there has been an increase in night temperature (i.e mean minimum temperature). This fact has been confirmed further Baking, Jr. (1992) who carried out his own research in USA.

Over the years climatologists have not fully understood the variations in the past climass and scientists are not sure how the climate of the 21st century is likely be in the absence of the build up of greenhouse gases (Baking Jr, 1992). The issue of climate change cannot be fully understood until the researches carried out to explain the dynamic of changes in the climate.

Global warming is the rise in the average temperature of the earth's atmosphere and oceans since the late 19th century and its projected continuation. Since the early 20th century, earth's mean surface temperature has increased by about 0.8°C (1.4°F), with about two thirds of the increase occurring in 1980. Warming of the climate system is unequivocal and scientists are more than 90% certain that it is primarily caused by increasing concentration of greenhouse gases produced by human activities such as the burning of fossil fuels and deforestation. These findings are recognised by national science academics of all major industrialised nations.

Climate model projections were summarised in 2004 Fourth Assessment Report (AR4) by the Intergovernmental Panel on Climate Change (IPCC). They indicated that during 21st century, the global surface temperature is likely to a increase by 1.1 to 2.9°C (2 to 5.2°F) for their lowest emission scenario and 2.4 to 6.4°C (4.3 to 11.5°F) for their highest. The ranges of these estimates arise from the use of model with differing sensitivity to greenhouse gas concentrations. Future warming and related changes will vary from region to region around the globe. The effects of an increase in global temperature includes a rise in sea levels and a change in the amount and pattern of precipitation, as well as a probable expansion of subtropical deserts. Warming is expected to be strongest in the Arctic region and would be associated with continuing retreat of glaciers, permafrost and sea ice. Other likely effects of the warming include a more frequent occurrence of extreme weather events including heat waves, droughts and heavy rainfall, ocean acidification and species extinctions due to shifting temperature regimes. Effects significant to humans include the threat to food security from decreasing crop yields and the loss of habitat from inundation. Bahtisti, David, Naylor (2009)

2.2.2 RAINFALL VARIATIONS OVER NIGERIA

Nigeria has a tropical climate characterized by two broad season wet and dry whose relative durations vary from the coast to the hinterland- due to he latitudinal stretch of the country and difference in elevation from sea level to over 100 meter above sea level. The country has virtually all the varieties of the tropical climate occurring in the west African sub region.

The climate if Nigeria, as indeed of west Africa is under the influence of two contrasting air masses, the moist tropical maritime (MI) from the sea which flows from the southwest and the northeasterly tropical continental (CT) which originates from the Sahara desert. These two air masses meet along an imaginary line, known as the inter-tropical discontinuity (ITD) or the inter-tropical convergence zone (TTCZ).

The surface locations of the ITD oscillates north and south with the apparent movement of the sun. during the period, October to march, when the sun is in the southern hemisphere, the ITD is displaced toward the south and lies roughly at about latitude 7 degrees north of the equator. This period, the influence of the north easterly air mass is dominant, hence the aridity experienced at this season.

In December to February, the dry and dust laden wind, the Harmattan, blows from the Sahara bringing chilly weather and hazy skies that impede visibility. The influence of the Harmattan now extends right down to the coast unlike in the past when the dense forest vegetation and humid atmosphere of the south limited its influence largely to the interior savannah lands.

During the wet season, mainly between April September, when the overhead sun is in the northern hemisphere, the ITD is displaced northward and reaches latitude 20 degrees north in August. This time the moist southwesterly tropical maritime air mass also referred to as southwest monsoon is then able to penetrate deep in to the country and bring rain to the hinterland.

The movements of ITD north and south within the country are responsible for the spatial variations in the onset and cessation of the rains annually and in the difference in the durations of the wet and dry seasons from one place to another. Generally the wet season decreases and dry season increases corresponding in length from the coast towards the interior.

In the coastal region, rain falls almost every month so that there is no marked dry season period. In the savannah lands the wet season varies from 6 to 8 months while in the extreme northeast the wet season lasts for about 3 months only.

Therefore, the climate types in Nigeria occur broadly in belts running east west across the country in consonance with the pattern determined by the oscillations of the ITD. However, this simple pattern is disrupted in place due to the influences of relief and altitude.

On the Jos plateau and in the eastern borderlands altitudinal influences are responsible for the comparatively higher rainfall and lower temperature levels than usual for their latitudes.

Adekunle, (2010) examined the influence of inter-tropical discontinuity on annual rainfall characteristics in Nigeria between 1970 and 2000. It involved determines the strengths and direction of the relationship between the total annual rainfall in extreme southern and northern part of the country and the total annual rainfall during the period of the little dry season in south western Nigeria and the surface location of the ITD over Nigeria and some other factors that may impacts the ITD characteristic (such as the presume difference between Azores, Libyan and Helena anticyclones and the sea surface temperature of the gulf of guinea).

The result indicates that although the surface locations of ITD significantly account for rainfall inter annual variability in Nigeria, it does so in the northern part of the country only. Pressure difference between the various anticyclones were observed to be another significant factor influencing inter annual rainfall variability in the north. However, the influence of the sea surface temperature of the gulf of guinea on the rainfall characteristic in the northern region is ill defined. It was also noted that the only factor influencing inter-annual variability in little dry season rainfall in the southwest is the sea surface temperature of the gulf of guinea. The result obtained indicated that total annual in the north have significant positive relationship with surface locations of the ITD but significant negative relationship with the pressures differences between the Azores. Libyan and st Hela anticyclones. The little dry season rainfall and total annual rainfalls in the south have significant positive relationships.

The record of rainfall that gives chance to the analysis of temporal variations of rainfall has no long history in Nigeria. Oguntoyin (1978) asserted that the longest established weather station in the country (Nigeria) is in Lagos where recording of rainfall amount began. The variability of rainfall overtime followed the world history as rainfall in the world is changed especially during when all the rain in the world is falling inform of snow not liquid rain (Nadel 1942).

There are evidence of high rainfall in the preset desert due to relic of fluvial laud form in the desert. In Niger (there is evidence of rainfall change over time. High el al. (1973) affirmed that the period 1915-

1935 was known to have been generally one of lower than average rainfall in the south whilst, the north experienced abundant rainfall condition. There followed period of low rainfall and drought about the mid 1930s to about the mid 1950s leading to numerous local famine throughout the country (Nadel, 1942)

Several attempts have been made with limited success, to discern the nature and characteristics of several climatic variability and climatic change in Africa following the great sudan-Sahalian droughts of 1968-75, which ravaged the west African Sahel, and brought to fore the urgency so study the nature and characteristic of climatic variability and climatic change on continent. (Aliyu, 2011). According to IPCC, (2007), climate fluctuations or variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes e.t.c) the climate on all spatial and temporal scales beyond that of individual weather events. Like climate change, variability may be due to natural internal process within the climate system (internal variability), or variations in natural or anthropogenic external forces (external variability). The most crucial things about the concept of climate change is not only the time period involved but also the degree of variability that the change is subjected to as well as the duration and impact of such variability on man and the ecosystem.

The causes of climate change are both natural and anthropogenic as conceptualized and shown in figure 2;1. Climate change is caused by either natural or anthropogenic factors. Researcher have show that for the past few decades, anthropogenic factors like urbanization, deforestations. Populations explosion, industrialization and the release of greenhouse gases are the major contributing factors to the depletion of the ozone layer and its associated global warming and climate change (Buba, 2004; Porbeni, 2004; Deweerdt, 2007 Odjugo, 2007). There have been growing awareness that the earth’s climate is changing at an alarming rate and the fourth assessment report of the intergovernmental panel on climate change (IPCC) affirms that climate change is no longer in doubt but is now unequivocally apparent based on evidence from scientific observations of increases in global average air and ocean temperatures (IPCC, 2007). Although extreme violent weather has occurred throughout history, recent upsurge in climate related hazards is confirming the argument for global warming and climate change (MC Gureure et al .,m 2002; Odjugo and Ikhuoria, 2003; Nwafor, 2006). The evolving climate change coupled with increasing temperature has been observed to plunge some localities into experiencing extreme weather conditions (Olaniran, 2002; Ayoade, 2003; Odjugo, 2005). The on going climate change and its associated global warming are expected to cause distinct climate patterns in different climatic Zonea, which will impact negatively on the ecosystem. That is why Ojo (1991) and clerk (2002) advised that weather and climate should not be taken granted in the pursuit of technological development explorations and processing of environmental resources.

2.2.3 CLIMATE CHANGE IN NIGERIA

Available evidences show that climate change will be global, likewise its impacts, but the biting effects will be felt more by the developing countries especially those in Africa due to their low level of coping capabilities (Mshelia, 2005; Nwafor, 2007; Jagptap, 2007). Nigeria is one of such developing countries. Researchers have shown that Nigeria is already being plagued with diverse ecological problems, which have been directly linked to the ongoing climate change (Adebayo 1998; Odjugo and Ikhouriia, 2007). These studies focused more on climatic impacts. Studies that address climate trends in Nigeria cover either short period or small area (Afiesmama, 1999; Anyadike 1992a; 1992b Cleark 2002; Nkeiruka and Apagu, 2005; Olaniran 2002; Odjugo, 2005; Nnodu et al., 2007), where as singer and a Barry (2007) revealed that it takes at least a century of weather data to evaluate climate trend for a reasonable conclusion to be drawn. There is therefore the need to examine the climatic pattern of Nigeria over a long time as also suggested by Nwafor (2006) so as to capture the long term changes in the climate of Nigeria. It is on this premise that this study examined the climatic pattern of Nigeria between 1901 and 2005 (105 years), using temperature data. Based on these data, the question as to whether there are enough changes in the spatiotemporal pattern of temperature over Nigeria to support the concepts of regional climate change is answered.

Ahmad and Ahmed (2000), IPCC (2001), NEST (2003) and Hengereveld el al. (2005) provided indicators that one could use to assess evidence of climate change in a region. These include increasing temperature, increasing evaporations, decreasing rainfall amount in the continental interiors, increasing rainfall in the coastal areas, increasing disruption in climate patterns and increasing frequency and intensity of unusual or extreme weather related events such as thunderstorms, lighting , landslides, floods, droughts, bush fires, unpredictable rainfall patterns, sea level rise, increase desertification and land degradation, drying up of river and lakes and constant loss forest cover and biodiversity.

While this study reveals that an indicator (increasing temperature) is already present in Nigeria. Recent studies show evidence of those indicators not covered in this study (Chindo and Nyelong, 2005; Ikhile, 2007; Nwafor, 2007; Umoh 2007). This study shows a gradual increasing air temperatures has been observed in Nigeria which fall within the low or medium scenario of global warming of not less than 2.5^0c. Should it continue at the 1971-2005 rate, Nigeria will then be placed among areas that will experience high enenarios of $2.5\text{-}4.5^0$c. Another indicator is the increasing frequency and intensity of unusual or extreme weather related events such as erratic rainfall pattern, floods and sea level rise among others. Although these indicators are outside the scope of this study, recent researchers confirm their existence in Nigeria (Odjugo, 2005; 2009; Molega, 2006; Nnodu et al., Umoh 2007 . Odjugo

(2005) observes decline in rainfall amount in Nigeria. A further support of the evidence of climate change in Nigeria by the two studies is the increase in rainfall amount in the coastal areas since the 1970s, and a constant decline in rainfall amount and duration in the continental interior of the semi arid region of Nigeria. The increasing rainfall in the coastal cities may have been responsible for the increasing floods, devastating the coastal cities of warm, Lagos, port Harcourt and Calabar as observed by (Ogundebi, 2004; Ikhile, 2007; Nwafor 2007; Odjugo, 2010).

The increasing temperature and decreasing rainfall in the semi-arid of Sokoto, Katisna Kano, Nguru and Maiduguri may have resulted in the increasing evapotranspiration, drought and desertification in Nigeria as reported by (Ogunjego and Ikhuria 2003; Adefolalu, 2007). Constant loss of forest cover and biodiversity in Nigeria is linked to global warming and change (NEST, 2003; Ayuba et al., 2007). Available evidence also shows that climate change has impacted on agriculture and health in Nigeria (Mshelia, 2005; Adefolalu, 2007). The decreasing rainfall, increasing temperature and evapotranspiration have resulted in either reduction of water levels or total dry up of some rivers and lakes in northern Nigeria, while lake Chad in Nigeria is reported to be shrinking in size at an alarming rate since the 1970s (Chindo and Nyelong, 2005; Odjugo, 2007). With these factors one can say with a high level of confidence that this study with other related works cited have successfully revealed that Nigeria like most parts of the world,, is experiencing the basic features of climate change.

According to manning (1956) and Ayoade (1983), the variability of rainfall is an important consideration in the tropics where rainfall not only tends to be more variable than in the temperature but is also more seasonal in its incidents within the year. The less variable rainfall is, the more reliable it is. This is because the index of variability is the measure of the degree of likelihood of the mean amount being repeated each year, season or months depending on the period under consideration.

According to Pettersen, (1969), the seasonal distribution of precipitation is as important as the total amount both in the tropics and extra-tropical areas. In many parts of the tropics, precipitation occurs mainly during the summer half of the year and the winter half is relatively dry. The times of start, duration and end of the raining season control agricultural activities in the tropics. The raining season also brings lower temperature and exercises considerable influence on peoples' way of life by limiting outdoor activities because temperature and other climatic elements are much more uniform. The seasonal rainfall distribution forms the basis of most classification or subdivision of tropical climate.

According to Thompson (1957) there are notable variation in precipitation incidence in the course of a day. Although the diurnal rainfall regime is not as important as the seasonal rainfall regime, diurnal variations in precipitation in middle latitudes are not regular than those in lower latitude and therefore rather unpredictable.

CHAPTER THREE

3.0 RESULTS AND DISCUSSION

This chapter is backbone of this work as it comprises the analyzed and the meaningful finding of this research. This shows the rainfall data and Temperature data both maximum and minimum from (1991-2010).

3.1 DISTRIBUTION PATTERN OF RAINFALL AT SOKOTO 1991-2010

From the acquired data, the total amount of rainfall received in Sokoto from the year 1991-2010 is 13810.4mm for the purposes of analysis. The mean amount of rainfall received is 690.52mm. This amount of rainfall is enough for all activities and it's correspondent to known mean rainfall of Sudan savannah which is 1000-1500mm per annum

3.1.1 DISTRIBUTION OF RAINFALL BY THE MONTH

From the analysis of the acquired rainfall of 2.8mm is experienced once in the month of February. February is not a rainy month in Sokoto based on the acquired data. The month May-September are the rainy months in Sokoto as the data indicated. From known climatology of Sokoto, the rainy month in Sokoto started in mid may to late September at most. Month of July is the rainiest with the average amount of 361.6mm and the fairly rain month is May with the average amount of 141.3mm the least rain month is February in which is 2.8mm only in the year1991 and rainfall in it.

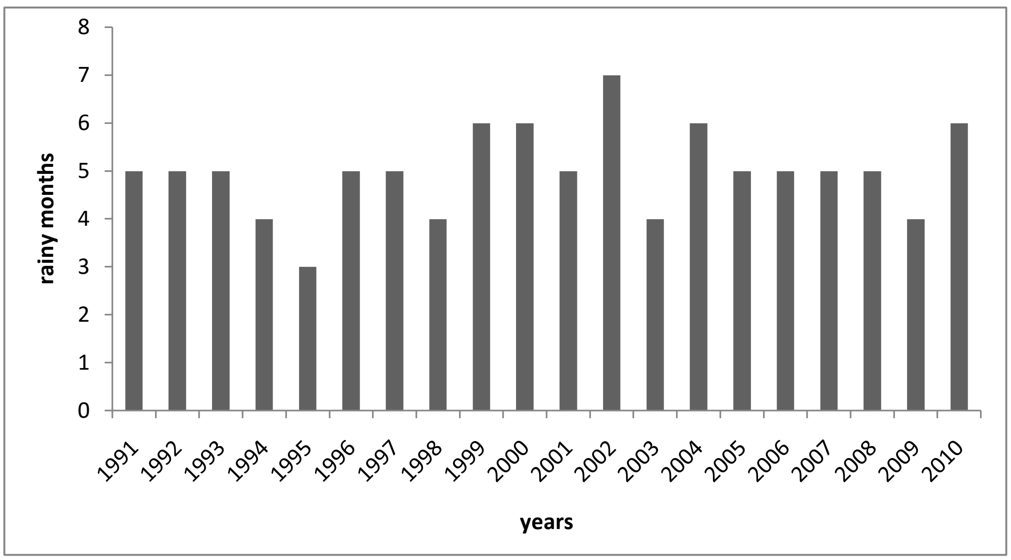


Fig.3.1 Rainy Month at Sokoto Between 1991-2010

3.1.2 DISTRIBUTION OF RAIN BY YEAR

Natural phenomena are in state and causing anomalies in rainfall over time since antiquity. As a result of anomalies in rainfall over the years, some years receive large amount of rainfall while others receive meager amount of rain. In Sokoto from 1991-2010, the year with highest rain is 2010 with the amount of 1146.3mm of rain. Year with the least amount is 1995 which 509.4 of rain received.

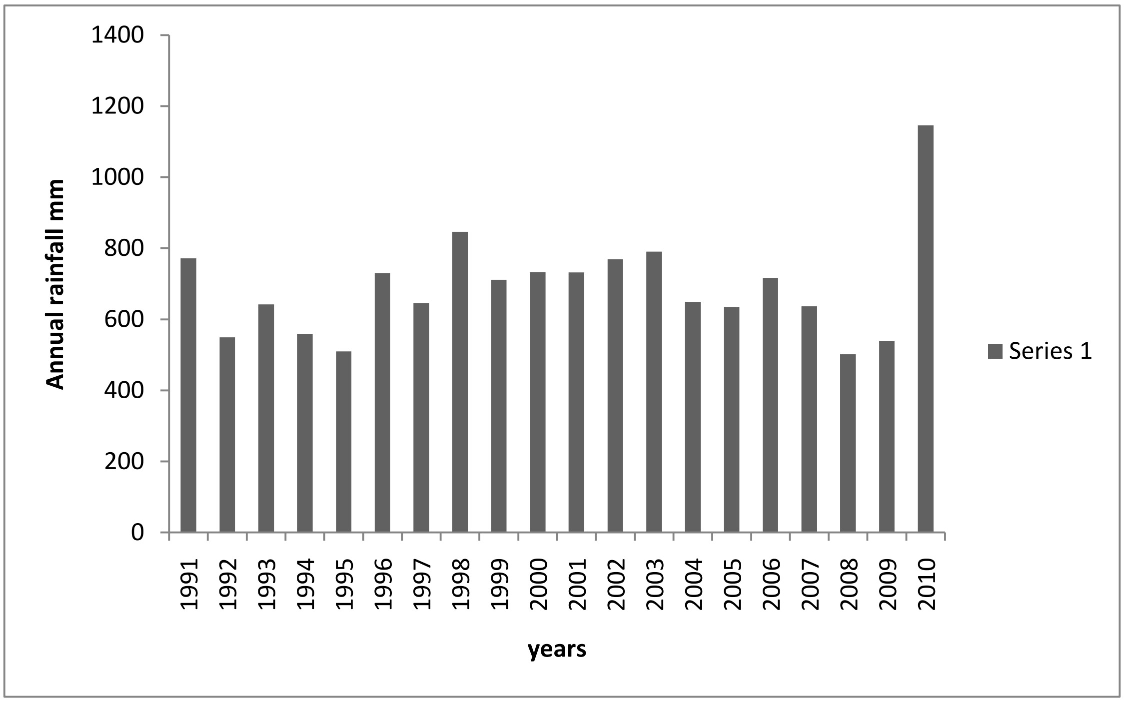


Fig 3.2. Annual rainfall graph at Sokoto1991-2010

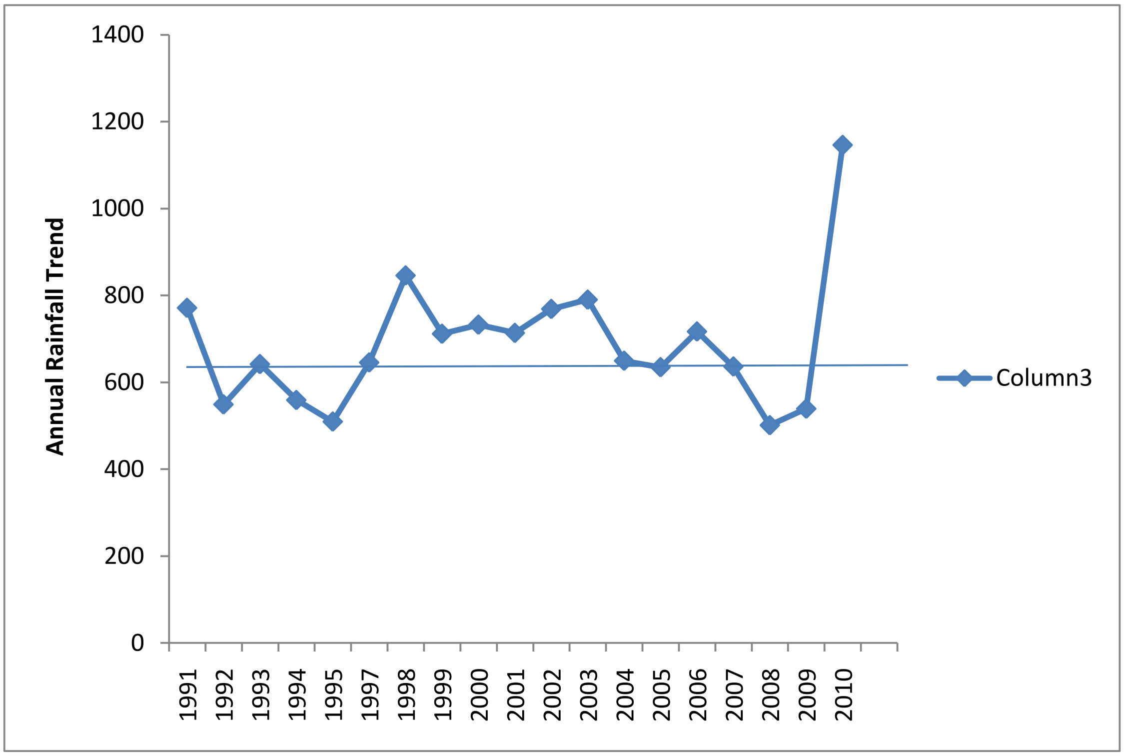


Fig 3,3. Annual Rainfall trend at Sokoto 1991-2010

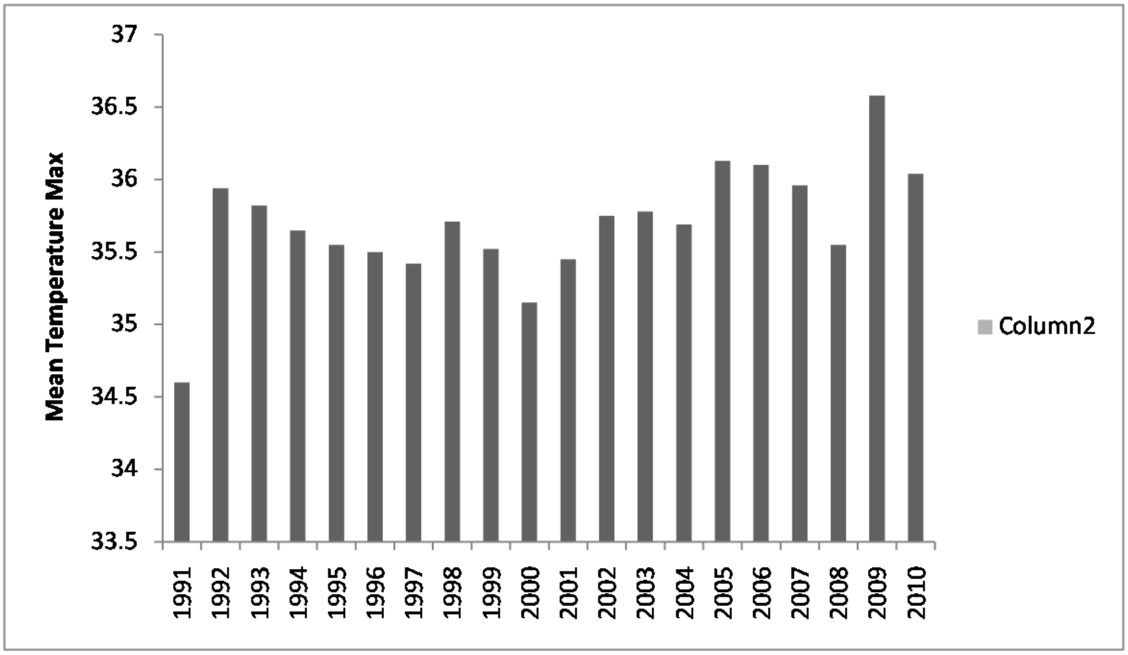


Fig.3.4 Mean Annual Temperature Maximum at Sokoto 1991-2010

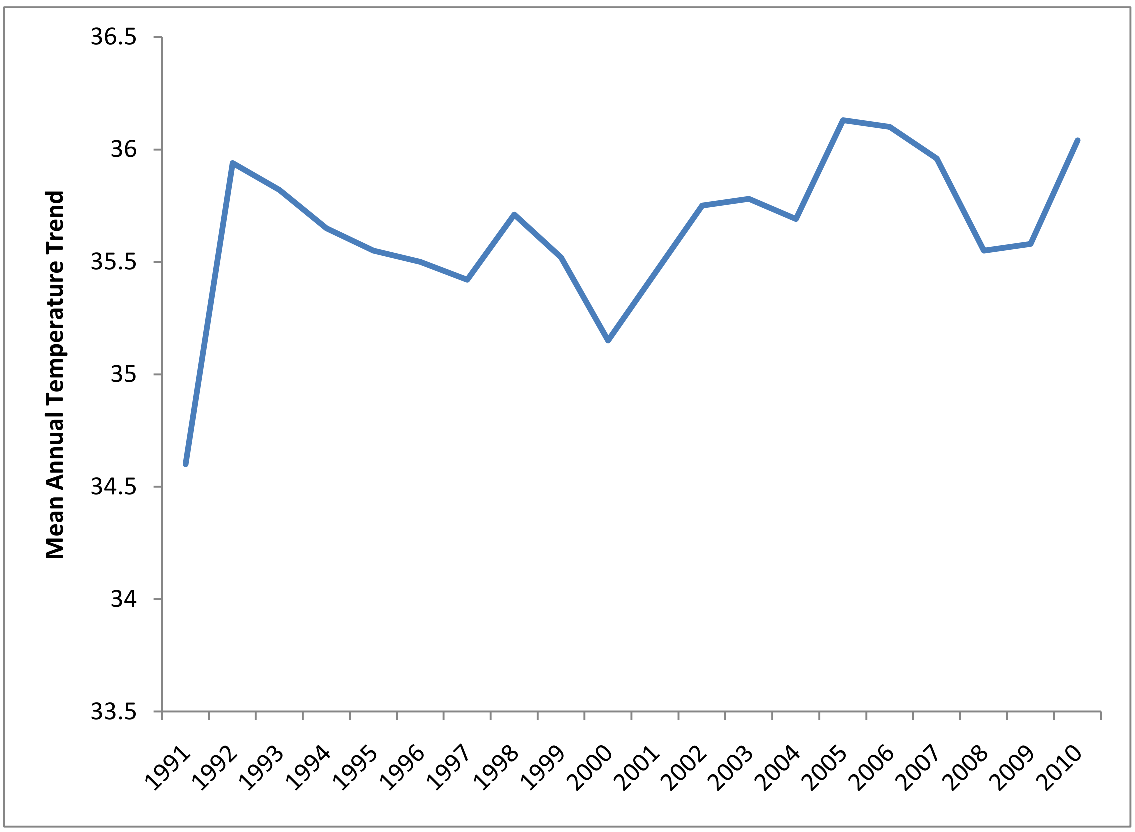


Fig.3.5 Annual Temperature trend Maximum at Sokoto 1991-2010

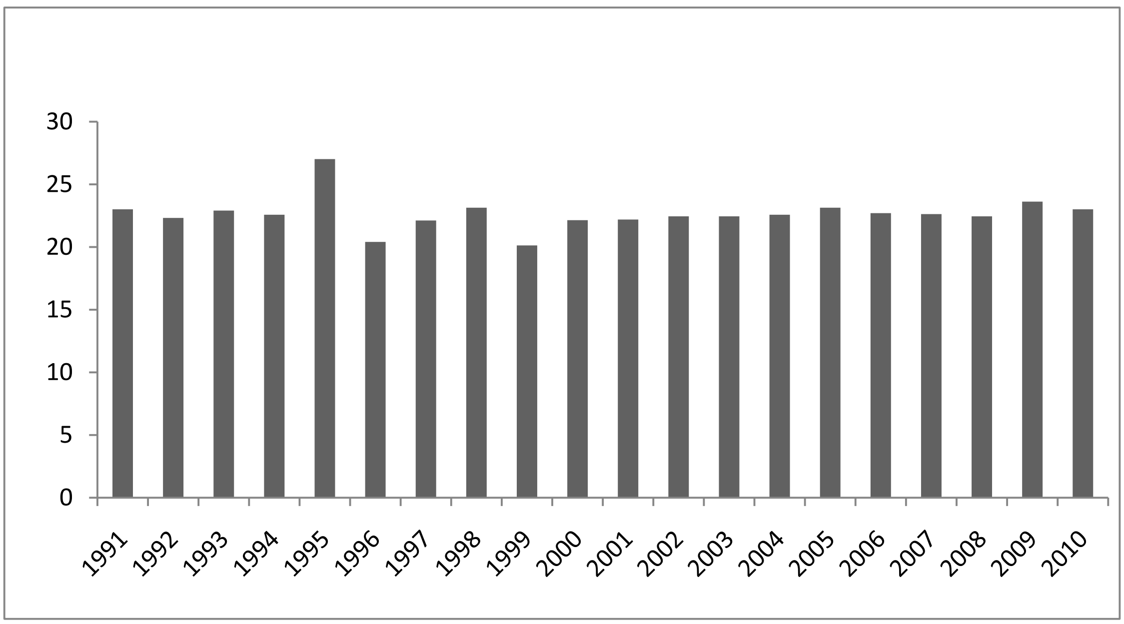


Fig3.6. Annual minimum Temperature graph at Sokoto 1991-2010

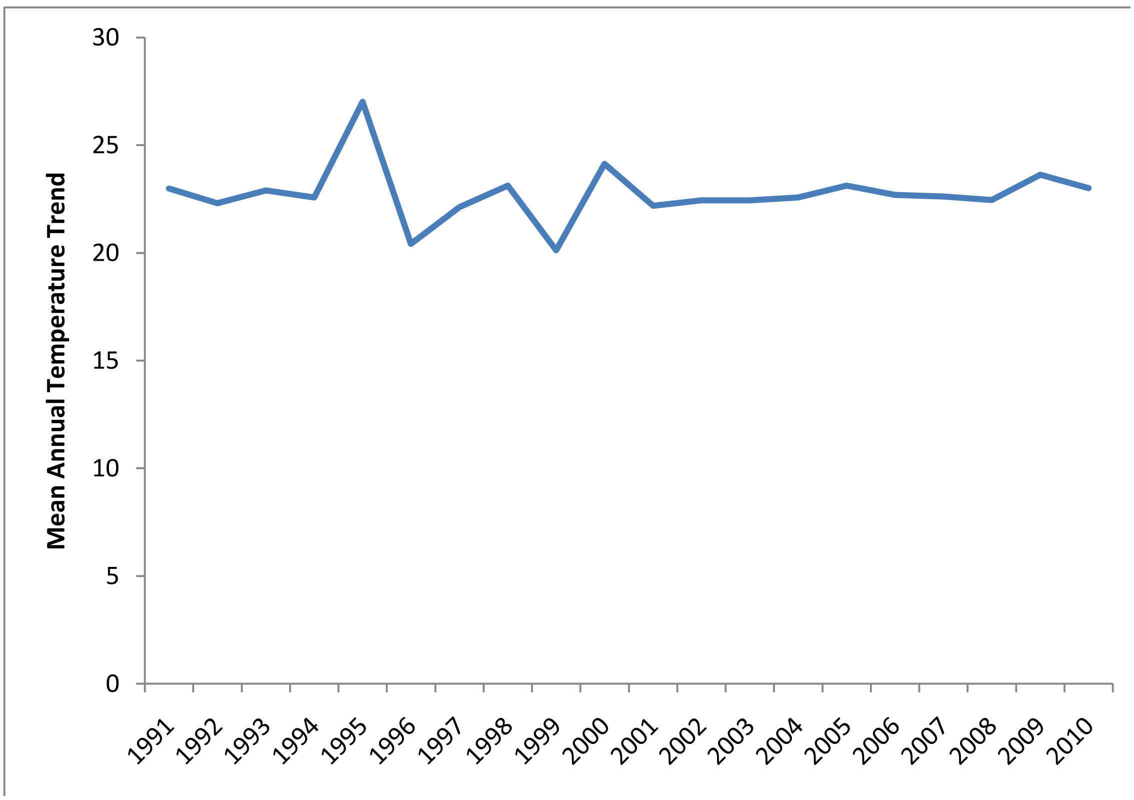


Fig.3.7 Mean Annual Temperature trend Minimum at Sokoto 1991-2010

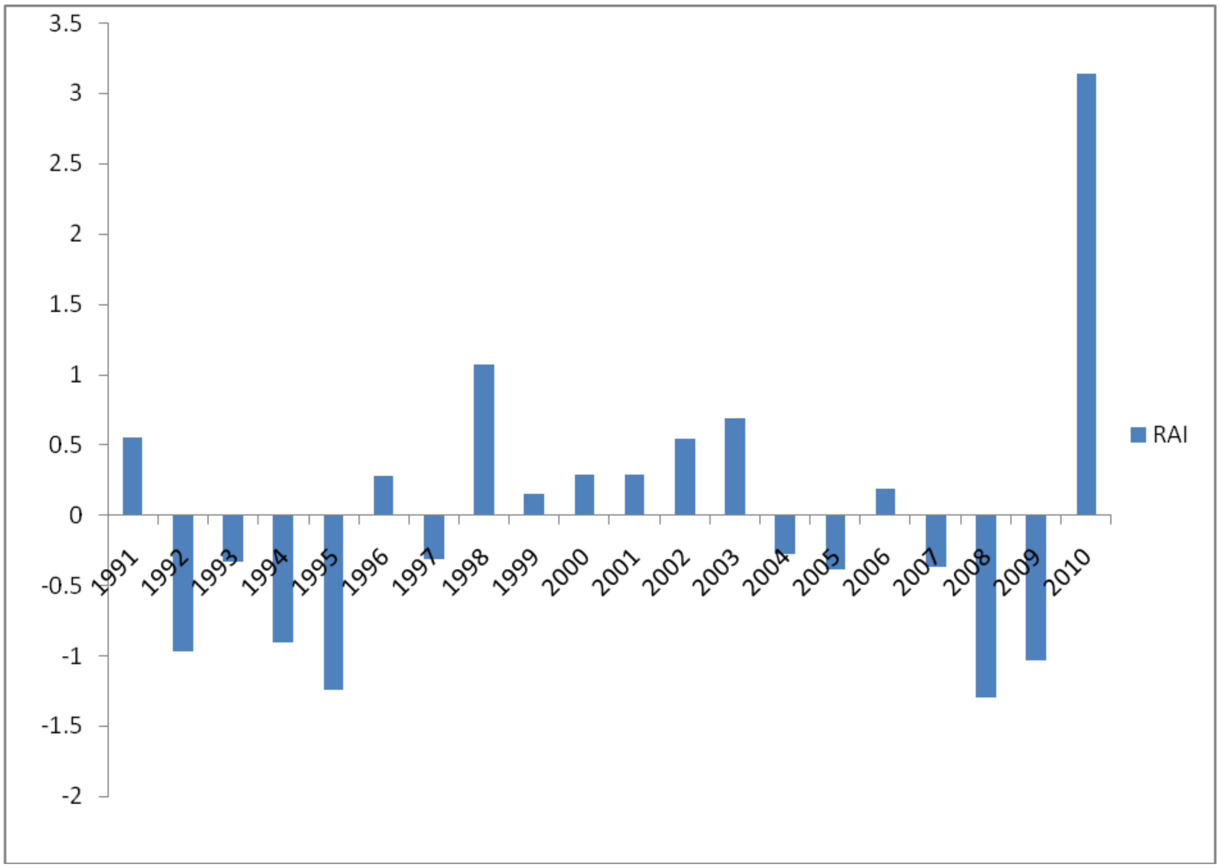


Figure 3.8 Mean annual Rainfall anomalies graph at Sokoto 1991-2010

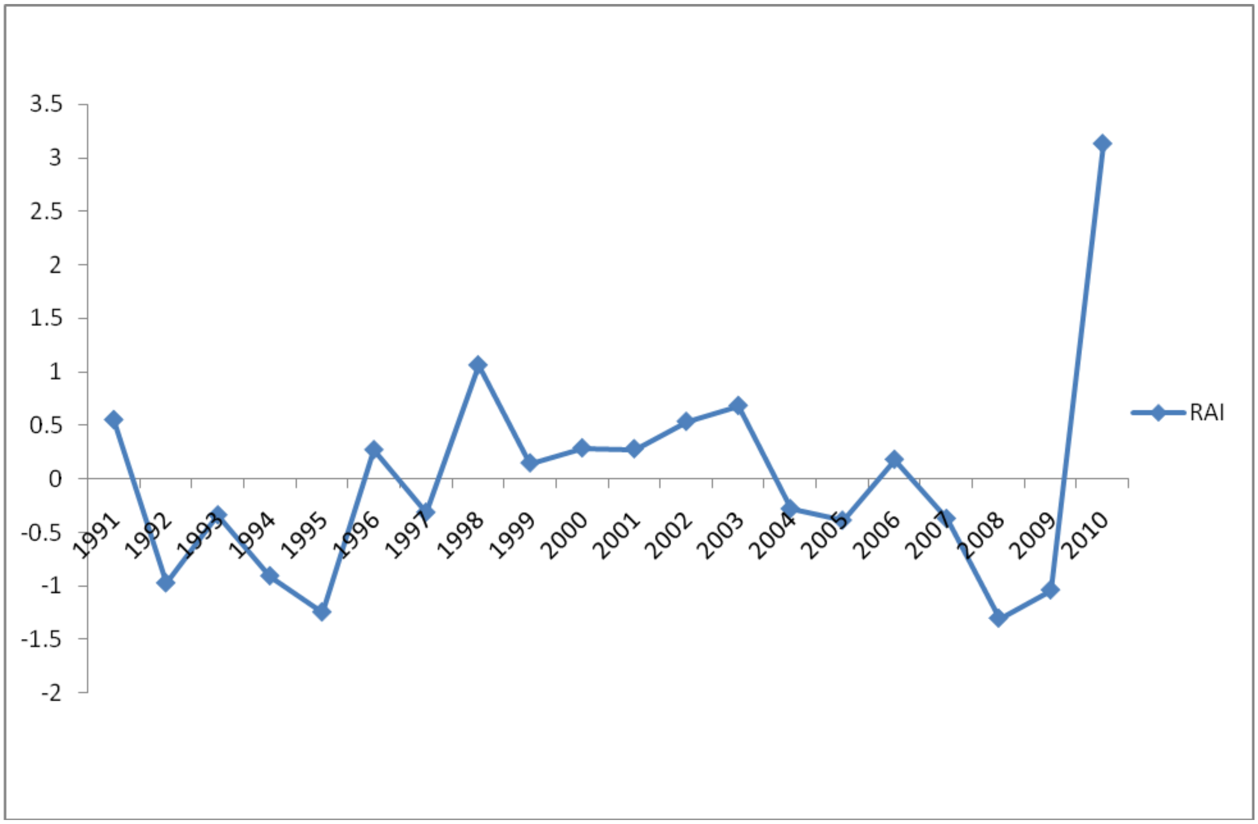


Figure 3.9 Mean Annual Rainfall anomalies Trend at Sokoto 1991-2010

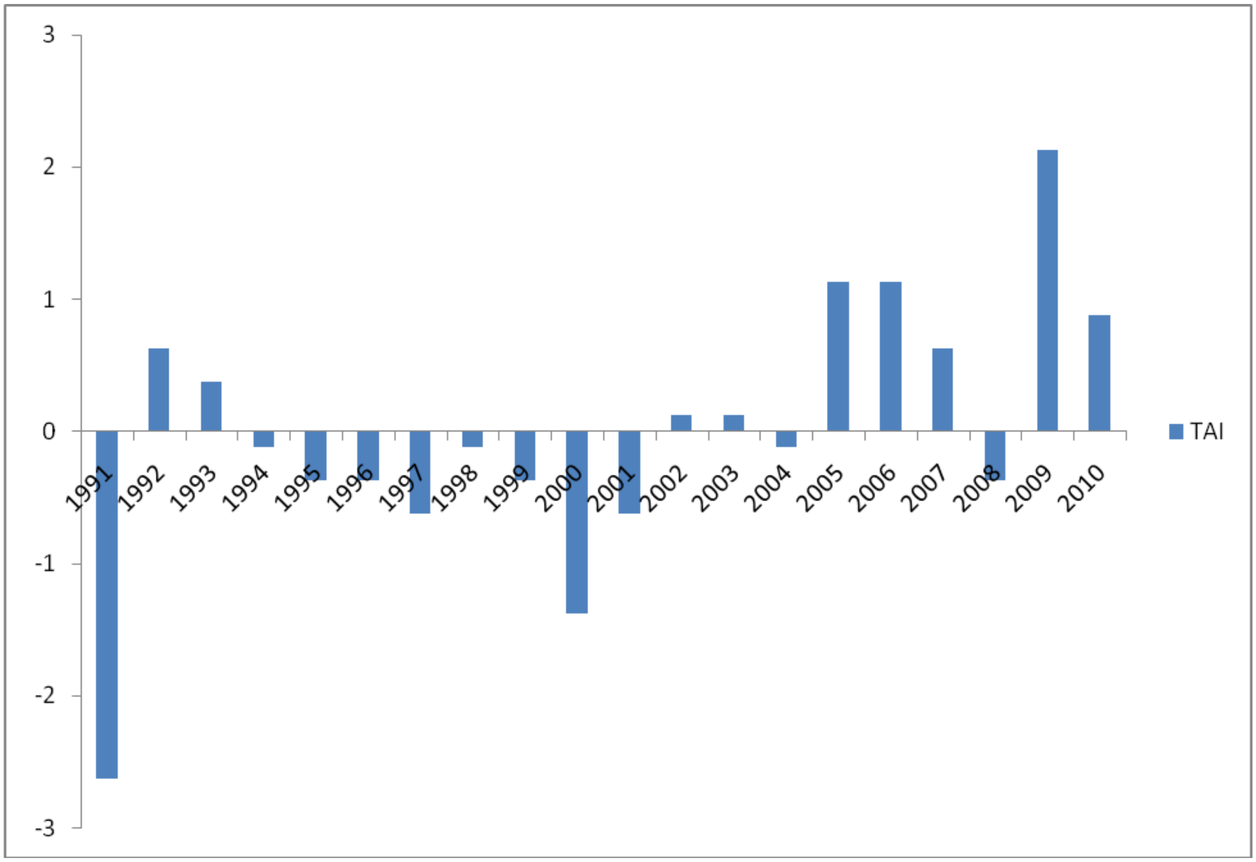


Figure 3.9.1 Mean annual Temperature maximum graph at Sokoto 1991-2010

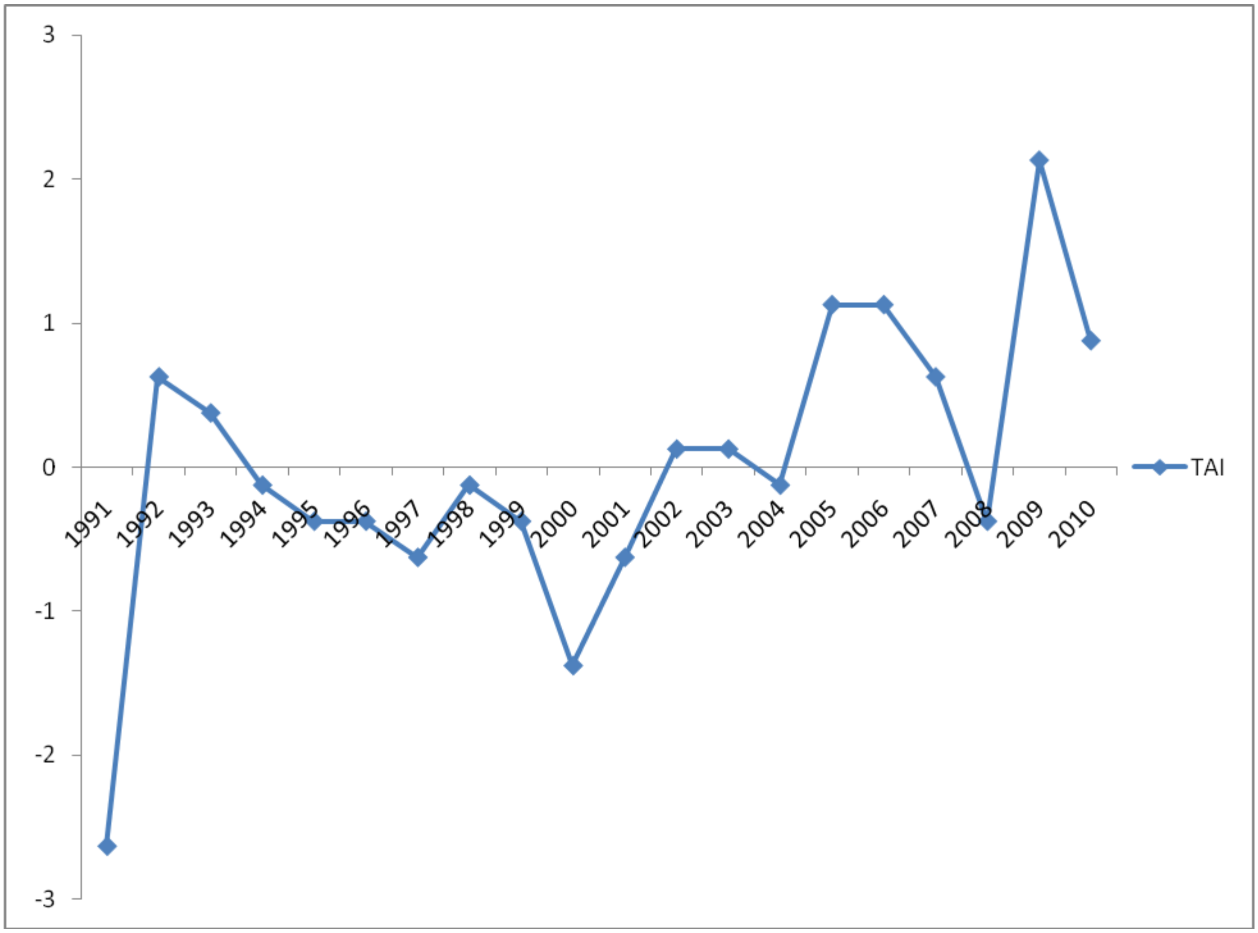


Figure 3.9.2 Mean annual Temperature max. Trend at Sokoto 1991-2010

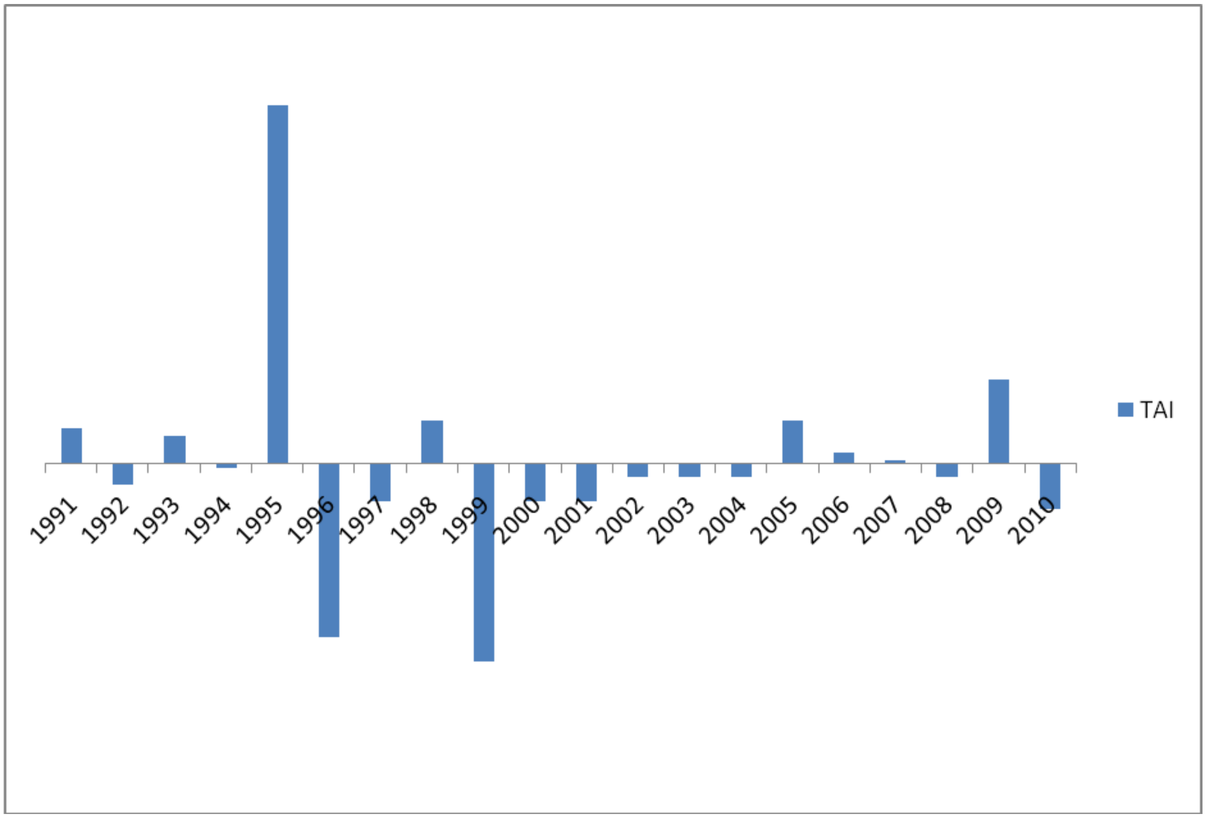


Figure 3.9.3 Mean annual Temperature minimum graph at Sokoto 1991-2010

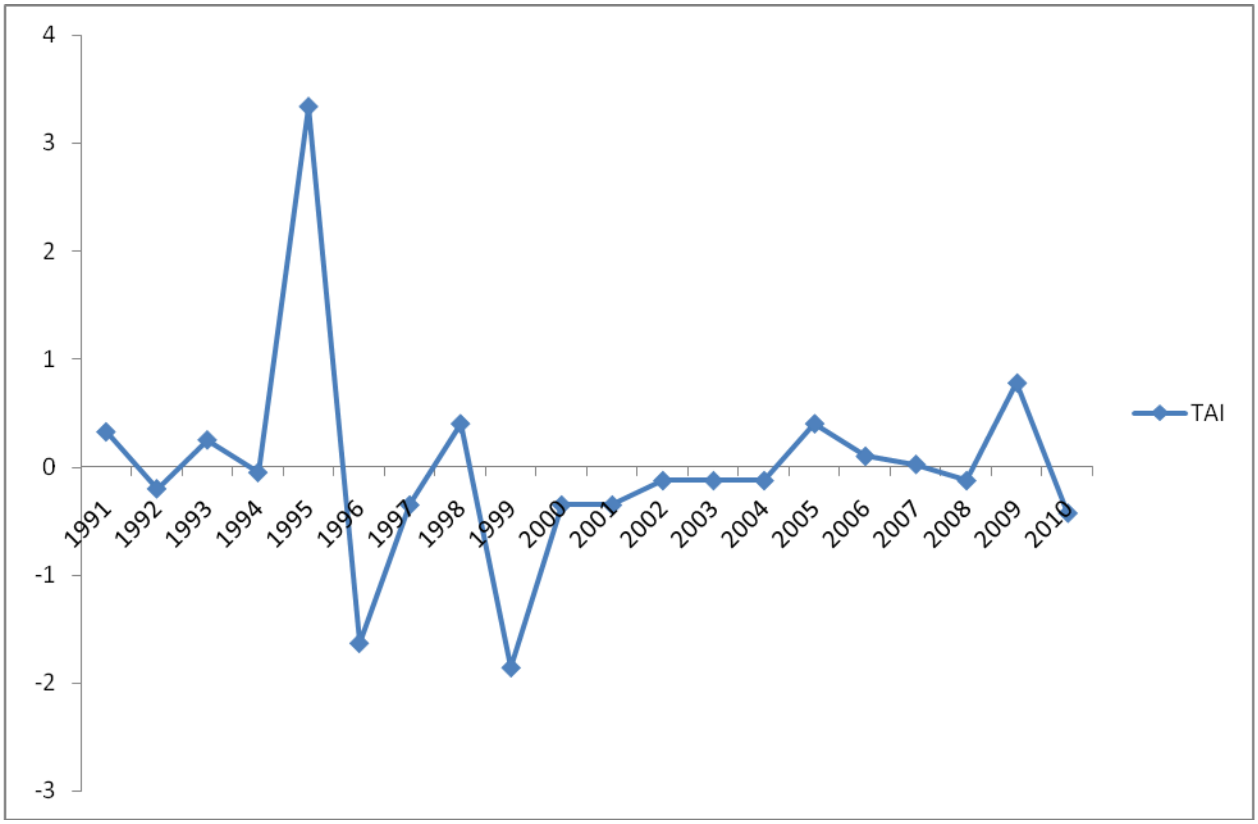


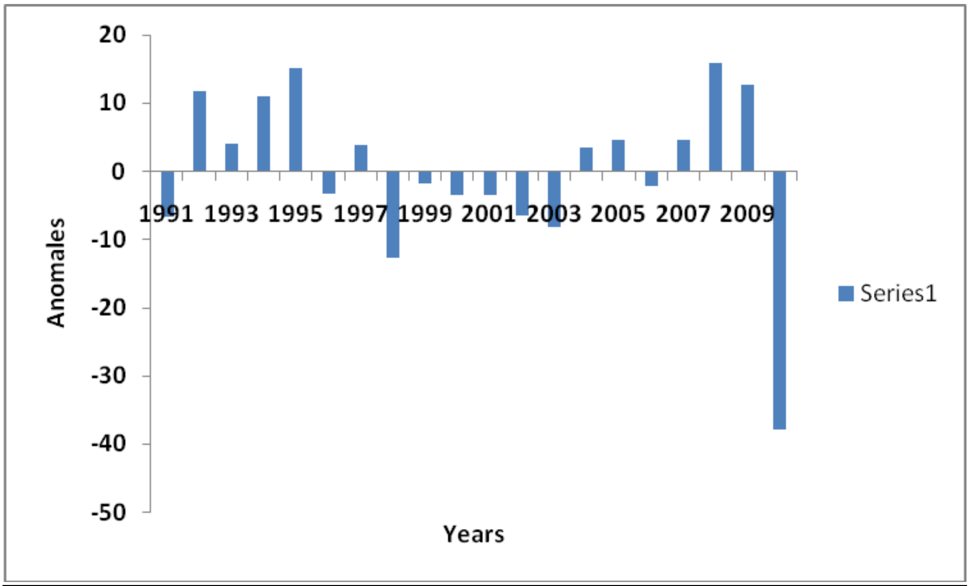
Figure 3.9.2 Mean annual Temperature minimum trend at Sokoto 1991-2010

3.3 ANOMALY AND TRENDS IN ANNUAL RAINFALL AND AT SOKOTO 1991-2010

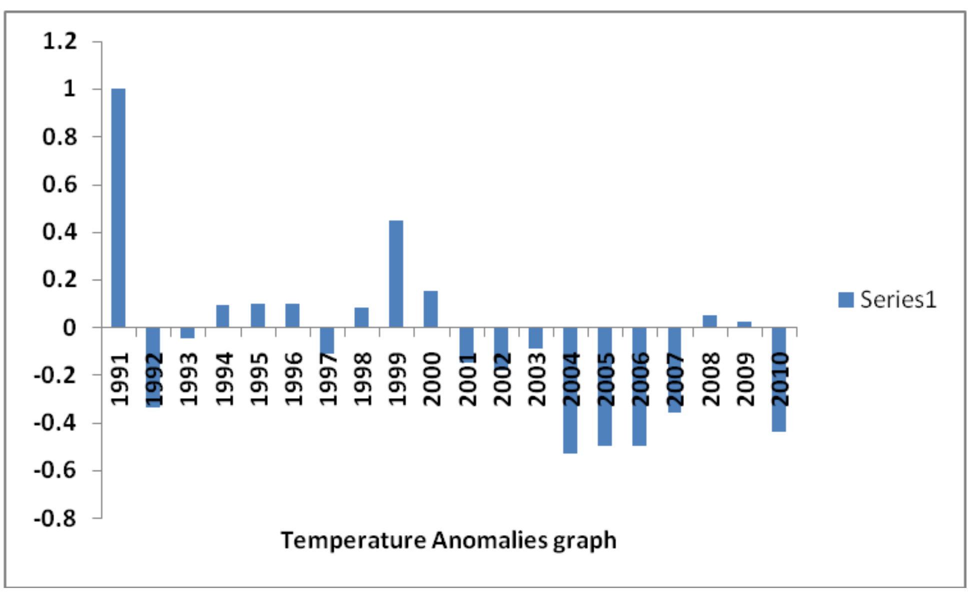
The annual rainfall total were analysed for trend and the result showed an upward trend in the series which indicate a tendency for an increasing annual rainfall at Sokoto. It is interesting to note that despite the observed upward trend in annual rainfall over the period 1991-2010, the annual rainfall showed a progressive decline from early and late as shown in figure 3.1 which was later followed by marked increase throughout 2000's similar result were reported by Umar (2010)

The annual rain days showed a similar result with an upward trend on the annual rain days series However, in the case of annual rain days series, there was a evidence of progressive increase in annual rain days series from late despite the drought of the in the West Africa sub-region and there condition continued through the year 2000's as shown in figure 3.2

In the case of annual rainfall fluctuations analyzed through the 5 years running means and presented in figure 3.3 the annual rainfall series was characterized by the Oscillations and general upward trend during the period under consideration. Annual rainfall continued to increase from late 1980's and become more apparent in the 2000's. Similar results were there reported by E-Tahir (2000)



Source: Author Analysis, 2014.



CHAPTER FOUR

4.0 SUMMARY

Chapter one comprises of introduction, background of the study aim and objectives, methodology of the research, description of the study area. While chapter two compromises literature review and conceptual frame work, then chapter three comprise data presentation and analysis. Chapter four also comprise summary, conclusion and recommendation

4.1 CONCLUSION

The annual rainfall at Sokoto was characterized by oscillation with general upward trend. The trend in time series of annual rainfall annual mean and maximum and minimum at Sokoto, 1991-2010 were examined respectively. The result suggest that the rainfall showed that the rainfall at Sokoto was increasing. However, study that the rainfall pattern over time will also help the agro-climate as a result of the changing pattern of rainfall at Sokoto.

4.2 RECOMMENDATION

This also recommends that the climate information and services should be disseminated particularly to the farmer whose activities were seriously affected by the climate of the region. This will enable farmers to adjust to their farming practice in order to cope with climate change in the region

REFERENCES

Aliyu T. Umar: Evidence of climate change

Griffins, J.E (1972): Climate of Africa, world survey of climatology. (2nd ed)

Ayoade, J.O. (1983): Introduction to climatology for the tropics, John Wily and sons, Chester, UK.

Ayoade J. O. 2003. Climate Change, Vantage Publishers, Ibadan, pp, 45-66

Adefolalu, D.O. 2007. "Climate change and economic sustainability in Nigeria", Paper presented at the International Conference on Climate Change and Economic Sustainability held at Nnamdi Azikiwe University, Enugu, Nigeria. 12-14 June 2007.

Adekunle (2010)examined the influence of in term tropical discontinuity on amend rainfall characteristics in Nigeria between 1870 and 2000.

Aliyu, (2011). According to IPCC, (2007), climate flunctuation or various ability refers to variation in the mean state and other statistics

Anyadike, R.N.C. 1992b, Regional variations in fluctuations of seasonal rainfall over Nigeria Theor. Appl. Climatol. 45.:285-292.

Bahtisti, David, Naylor (2009) "Historical warning of future flood security with unprecedented seasonal head."

Bathig J V (1992) who carried out his own research in U.S.A.

Buba, A. D. 2004. "Climate Change and Water Problems in Chad Republic", J and Environ., 3.2: 42-50

Buba, 2004: Porbeni; 2004, Deweerdt, 2007, Odugo 2007. These researchers have shown that for the past few decades, antheropogenic factors like urbanization, deforestation, population, explosion, industrialization and the release of green house gases are the major contribution to the factors to the depletion of the ozone layer and it associated global warming and climate change.

Clerk, C.R. 2002. "Climate change or climate fluctuation?" J. Arid Environ 1.1:18-33.

DeWeerdt S. 2007. Climate change coming home: Global warming effect on population. World Watch, 2.3: 6-13

Earth observatory.nasa.gov>home>global maps.

Ganier, B. J. (1967): Weather condition in Nigeria, climate research series. No 2.

Hayward, D. F and J. S. Oguntoyinbo (1987): the climatology of west Africa, Hutchison

IPCC Synthesis Report. IPCC AR4 SYR 2007.

Intergovernmental Panel on Climate (IPCC) 2001. The report of working Group 1 of the intergovernmental Panel on climate change, survey for policymakers. Intergovernmental Panel on Climate (IPCC), 2007, "Climate change 2007: Synthesis report. Summary for policy makers", available at: http://www.ipcc-wgl-ucar.edu/wg1/wg1-report.htm,(accessed 26 October 2009).

2009 Ends warmest decade on record Nasa Earth observatory image of the day, 22 January 2010.

Lu, Jian, Vechhi, Gabriel A., Reichler, Thomas (2007). "Expansion of the Hadley cell under global warming"

Nadel (1942) there followed period of low rainfall and drought from about the mid-1930 to above the mid-1950s leading to numerous local famines throughout the country.

Oguntoyinbo, J. S., 1978. Geography of Nigerian Development, University Press, Ibadan

Ojo, O. 1977. Climate of west Africa Heinemann, London

Olaniran, (2002), the evolving climate change coupled with increasing temperature has been observed to plunge some localities in to experiencing extreme weather condition.

Olaniran, O. J. (1990): An analysis of rainfall trends in Nigeria on the international and multi-year time scales vol. 2 Journal climatology

Solomon et al, Technical summary, section TS 5.3 Region scale projection in IPCC AR4 VVGI 2007.

Umar A.T. 2012. Climate change in Nigeria: Evidence from metrological parameters. Usmanu Danfodiyo University, Sokoto

Appendix 1

Date	Year 1991-2010	0.4	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1991		22.4	24.9	27.1	26	25.1	22.8	22.9	23.6	23	20.5	18.1
1992	16.5	18.8	23.9	26.9	26.7	25.5	22.8	22.7	23	23.7	20.3	17
1993	15.8	19.8	23.8	26.2	29.9	25.9	25.4	23.2	22.9	23.6	20.8	17.6
1994	19.2	18.9	20.4	27.4	29.7	28.3	23.6	22.6	21	23.9	19.7	16.2
1995	14.9	17	24.3	26.9	27.7	26.9	23.8	22.5	23.1	23.8	19.9	18.8
1996	17.5	20.7	24.4	26.8	26.4	24.5	23.7	22.6	22.8	22.9	18.5	17
1997	16.9	16.4	22.5	25.9	26.2	24.1	23.7	22.7	23.6	24.7	21.4	18
1998	17	21.4	21.9	28.2	29	26.1	24	23	23.4	24.3	21	18.2
1999	16.8	19.7	23.9	27.1	27.1	26.3	23.3	22.4	22.4	22.4	20.8	16.5
2000	18.9	16.9	21.5	26.6	27.9	25.2	23.5	22.8	23.3	23	19.3	16.6
2001	18.9	17.5	22.4	26.8	27.5	25.6	24.1	22.9	23.1	22.7	20	18.3
2002	16.1	17.8	24.3	27.8	28.3	26.2	24	23.1	23.1	22.2	19.6	16.9
2003	16.5	20.4	22.4	26.9	26.9	25.5	24	22.9	23.3	23.9	20.9	16.7
2004	17.4	19.6	22.3	27	26.4	25	23.4	22.7	23.5	23.1	21.7	18.7
2005	16.6	23.3	26	27.5	27.2	25.2	23.5	23.1	23.4	22.6	20.5	18.3
2006	19.4	21	23.6	25.8	26.7	26.5	24.6	22.8	23	23.3	19.3	16.4
2007	15.7	19.3	22.2	27.9	27.6	25.9	24.2	23	23.1	22.6	21.3	18.7
2008	15.3	18	23.4	26.4	27	26.1	24	23.4	23.9	23.2	19.9	18.8
2009	18.3	22.1	23.7	27.9	27.8	26.5	25.1	23.9	24.2	24.5	21	18.5
2010	17.5	22.5	24.5	28.2	28.3	25.8	23.6	23	23	22.4	20.6	16.7

Appendix II

Monthly Maximum Temperature

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1991	31.5	37.2	38.1	39.7	35.3	34.9	31.4	30.9	33.6	35.9	35.5	31.2
1992	31.8	37.6	40.2	40.7	39.2	35.2	34	31.4	33.8	36.8	37.6	33
1993	32.4	37.8	38.4	41	38.8	34.4	33.6	31.8	34.4	37.2	37.4	32.6
1994	32	37	38.8	40.8	39	34.2	32.8	32	34	37.6	36.8	32.8
1995	31.6	36.6	39.2	41.2	39.6	35	33.2	31.4	33.6	37	36.6	31.6
1996	33.6	32.2	38	40.4	38.2	34.8	33.8	32.6	34	37.4	38	33
1997	34.2	31.6	36.9	40.1	36.8	34.9	33.4	32.6	34.1	37.6	38.4	34.4
1998	32.5	37	36.9	42.1	40.1	36.7	32.6	31.1	31.9	36.7	37.4	33.4
1999	33.5	35.8	41	40.8	39.7	37.4	32.5	29.9	31.8	34.8	36.3	32.7
2000	33.1	31.2	37.1	42.2	40.6	36.3	32.3	31.3	32.9	35.5	36.8	32.5
2001	32.5	33.4	39.5	40.3	38.7	35.7	33.2	31.1	32.9	36.4	36.5	35.2
2002	30.4	34.5	39.5	40.8	40.8	37.1	33.3	31.6	32.9	34.4	36.1	34
2003	33.5	37.3	38.1	40.6	40.8	35.9	33.1	30.7	32.3	36.6	37.2	33.2
2004	33.4	34.6	37.1	41.3	37.5	35.5	32.5	31.1	33.8	38.2	37.4	35.9
2005	31.1	38.8	41.3	42	38.8	34.7	32.9	31.3	33.3	36.6	37.4	35.3
2006	35.9	37.9	40.2	41.8	39.5	37.1	34.7	31.1	31.9	35.3	35.1	32.7
2007	30	36.8	38.8	41.5	39.8	37.1	33.2	30.7	32.7	37.9	38.4	34.7
2008	30	33.2	39.4	41	39.5	37.1	31.9	31.2	33.1	36.9	37.6	35.7
2009	33.7	38.9	40.3	41.9	40.2	37.7	34.2	32.6	33.3	36	34.9	35.2
2010	35	39.2	39.6	41.9	39.9	35.8	32.1	30.8	32.6	34.8	36.8	34

Appendix III

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT Rain.Fall
  /METHOD=ENTER Max.Temp Min.Temp.
```

Regression

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.226[a]	.051	-.061	149.72695

a. Predictors: (Constant), Min.Temp, Max.Temp

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Min.Temp, Max.Temp[b]	.	Enter

a. Dependent Variable: Rain.Fall
b. All requested variables entered.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	20482.861	2	10241.430	.457	.641[b]
	Residual	381108.719	17	22418.160		
	Total	401591.580	19			

a. Dependent Variable: Rain.Fall
b. Predictors: (Constant), Min.Temp, Max.Temp

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1832.538	3015.678		.608	.551
	Max.Temp	-1.422	7.116	-.048	-.200	.844
	Min.Temp	-1.960	2.194	-.214	-.893	.384

a. Dependent Variable: Rainfall