# DECADAL RAINFALL VARIABILITY IN NORTHERN NIGERIA

# (1901-2009)

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**BEING AN M.Sc.DISSERTATION SUBMITTED TO THE DEPARTMENT OF GEOGRAPHY,BAYERO UNIVERSITY, KANO, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN GEOGRAPHY (M.SC. GEOGRAPHY)**

**OCT, 2015**

## DECLARATION

I hereby declare that this work is the product of my own research efforts; undertaken under the supervision of Dr. M.M. Badamasi and has not been presented and will not be presented elsewhere for the award a degree or certificate. All sources have been duly acknowledged.

**……**

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## CERTIFICATION

This is to certify that the research work for this thesis and subsequent preparation of this thesis by (ALIYU UMAR ALIYUSPS/11/MGE/00044)were carried out under my supervision.

**……**

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**(Supervisor)**

## APPROVAL

I certify that the thesis has been examined and approved for the award of the degree of MASTER OF SCIENCE, GEOGRAPHY (Environmental Management)

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## ACKNOWLEDGEMENT

All praise and glory be to Allah Almighty, the beneficent, the merciful for giving me the life and health to undertake the M.sc Geography programme up to this thesis work. Alhamdulillah, Indeed.

Special appreciation to my supervisor Dr. M. M. Badamasi for the sound guidance, tireless attention, and encouragement he rendered to me, without which this work would not have seen the light of the day. Only Allah Almighty that can reward his indefatigable effort.

My sincere gratitude and appreciation to my parents Hon. Umar Aliyu Fama, Hajiya Hafsat Muzakkar and Hajiya Halimatu Abubakar Lema for the prayers, discipline and guidance you gave to me. May your final abode be Jannatil Firdous.

I also thank all my M.sc Geography colleagues for the advice, well-wishes, encouragement and prayers offered to me in the process of this thesis. My special appreciation goes to the entire non-teaching staff of Geography and my able Lecturers and Mentors in person of: Professor J. Afolabi Falola, Professor Kabiru Ahmed, Mal Aliyu D. Maiwada, Mal Muhammad A. Liman, Professor Adamu I. Tanko, Professor Yusuf M. Adamu, Dr. Ahmed M. Ibrahim, Professor Maharazu A. Yusuf, Dr Salisu Mohammed, Dr Ibrahim B. Yakubu, Mal Ishaq, Mahmud Abba Yusuf, Dr. Adnan and the rest of teaching staff that I could not mention. Thanks for the positive influence you gave me.

My special appreciation to Dr. L.F. Buba for the fatherly guidance and attendance rendered to me. Thank you very much Sir. I must appreciate Nura Ibrahim Hassan for the elderly guidance and help he offered to me.

Thank you so much my office colleagues for the prayers and well-wishes rendered to me. My special appreciation goes to my wife Maryam Umar Bala and our children Halimatu Aliyu Umar (Walida), Abubakar and Hafsat (Iman).

I cannot conclude this acknowledgement without mentioning Bala Muhammad, Abdullahi Ahmad Dala as well as Muhammad Ahmad Jafar for their immense and unquantifiable contributions right from the scratch of the work up to the point of conclusion. May Almighty Allah reward them.

## DEDICATION

I dedicate this work to my parents.

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## ABSTRACT

Area studied covers Northern Nigeria from latitude 9-14$^{o}$N and longitude 3-15$^{o}$E enclosing 18 states namely Kaduna, Kano, Katsina, Bauchi, Sokoto,Niger, Plateau, Borno, Yobe, Gombe, Adamawa, Zamfara, Jigawa and Kebbi. Rainfall data were downloaded Global Precipitation Climatology Center. The data set is composed of monthly 0.5$^{o}$latitude/longitude gridded series of precipitation over the periods 1901-2009 for the entire world. Data used for the study area was extracted using GIS software. The research has analysed the variability of rainfall that occurs on decadal basis spatio-temporally within the study area and time. The generated co-efficient of variability image covering the study time series were derived from the data andshows increasing variability of rainfall with increasing latitude. It also revealed that 1901-1910 decade shows wet condition at all stations slightly falling from 1911-1920, from where the wet decades continued up to 1970s. From 1970s a sharp decline in SPI value indicating dry decades was noticed up to the year 2009, this was noticed all stations studied.

# CHAPTER ONE

# GENERAL INTRODUCTION

## 1.0 INTRODUCTION

The knowledge of climate variability over the period of instrumental records on different temporal and spatial scale is important to understand the nature of different climate systems and their impact on the environment and society (Oguntunde et al. 2012). The global climate has changed rapidly with the global mean temperature increasing by $0.7^{O}C$ within the last century. However, the rates of change are significantly different among the regions (IPCC, 2007).

Globally, it has been observed that changes are occurring in the amount, intensity, frequency and type of rainfall. In Africa, rainfall exhibits high spatial and temporal variability. Mean annual rainfall ranges from as low as 10mm in the innermost core of the Sahara region to more than 2000mm in part of the equatorial region. The coefficient of rainfall variability in African deserts is above 200%, about 40% in the most semi-arid regions and between 5% and 20% in the wettest areas (Watson, Zinyowera, Moses and Dokken, 2001).

Evaluation of changes in the spatial and temporal pattern of rainfall is very important to the future development and sustainable management of water resources of a given region or country. Rainfall is a principal element of the hydrological cycle, so understanding its behavior may be of magnificent socio-economic significance. Understanding of climate change could be through the detection of trends and oscillations in rainfall time series. However, changes in rainfall are hard to measure, because rainfall is not uniform and varies considerably from place to place and time to time even over small areas.

Oladipo (2008) concluded that, in Nigeria climate change is one of the most serious threat to poverty eradication and sustainable development. This is because the country has large rural population that is directly depending on the natural resources for their livelihood which are climate sensitive. Climate change seems to be the foremost global challenge facing human and environment at the moment. One of the indicators of climate change is rainfall (Adger et al., 2003; Frich et al., 2002; Novotny and Stefen, 2007).

The geographic variation in seasonal rainfall trends has tremendous agricultural significance since there are indications that the reliability of the season is decreasing from the humid forest zone with the positive seasonal trends to arid/semi-arid savanna with significant negative seasonal trends (Amissah and Jagtap, 1999). Rainfall analyses in Nigeria have been more during the 20th century. Example (Anyedibe,2006) examine rainfall trends for a period of 72 years (1916-1987) in which monthly as well as annual rainfall variations over southern, middle-belt and northern regions of Nigeria as well as the country as a whole was studied. Trends analysis showed a tendency toward decreasing annual rainfall totals in all the regions, with the rate of decrease being greatest after 1961 in the southern region. All the regions experienced the reverse of the trend during the 1931-1960 periods. (Adefolalu, 1986; Hess et al., 1995; Olaniran, 1990, 1991, 2002; Olaniran and Summer, 1990; Bello, 1998; Ati et al., 2009; Alli, 2010; Oguntunde et al., 2011) have all analyzed rainfall during 20th century. Adefolalu (1986) analyzed rainfall data between 1911 and 1980 from 28 meteorological stations to examine trends in precipitation patterns, a general decrease of dry season rainfall was observed. Oguntunde et al, (2011) examined the existence of trend in annual and monthly rainfall of Nigeria over 1901-2000. Results showed that rainfall spatial distribution was highly latitudinal dependent ($r^2 > 0.90$) and

had no clearly linear relations with the longitude. Rainfall variability index showed that 1950's was the wettest decade (+0.84) while 1980's was the driest (-1.19), with the two decades between 1970 and 1990 being drier than any other comparable period in the century. There was a sharp difference between changes in rainfalls in 1931-1960 and 1961-1990 periods. Annual precipitation reduced by 7% between the two periods. While more than 90% of the landscape showed no significant rainfall change in the first period, about 57% of Nigeria showed decrease in the second period.

## 1.1 RESEARCH PROBLEM

Climate change is brought about by human activities on the environment; it leads to the global warming. Climate change may lead to the decline in rainfall amount, change in frequency and duration of the rain season which may eventually lead to the change of rainfall pattern over time. Therefore, need to investigate the trends of rainfall pattern is required in order to compare what was obtained in the past and what is obtainable now. Also for us to detect a climate change, study of rainfall over a long period of time for a vast area is needed. That is why the study of decadal rainfall variability in northern Nigeria from the year 1901 to 2009 was conducted.

## 1.2 RESEARCH QUESTIONS

This research will address the following questions:

I. Can satellite rainfall data be used for exploring rainfall trends in northern Nigeria?

II. What is the spatio-temporal distribution of rainfall in the study area over the period of study?

III. What is the pattern of decadalvariability of rainfall over the period of study?

IV. What is the trend of rainfall within the period of study?

## 1.3 AIM AND OBJECTIVES

The aim of this study is to examine the decadal variability of rainfall over Northern Nigeria from 1901-2009 periods.

This can be achieved through the following objectives:

i. To determine the validity of satellite rainfall data use in modeling rainfall for the study.
ii. To identify the spatial and temporal distribution of rainfall in the study area.
iii. To examine the trend of rainfall pattern within the study area.
iv. Toexamine the decadal variability of rainfall in Northern Nigeria.
v. To make recommendations based on the findings of the result..

## 1.4 SIGNIFICANCE OF THE RESEARCH

Continuous rainfall studies is important in Nigeria because global climatic change could have effects on various environmental variables rainfall included and continuous human activities on the environment over time causes climatic variations which directly or indirectly affects rainfall trends.

## 1.5 JUSTIFICATION OF THE RESEARCH

Although a number of studies in rainfall trends were undertaken by quiet a number of researchers/scholars within and outside the country as seen in the study background. Nevertheless, Nigeria with over 70% of its citizens engaged in irrigation or rain-fed cultivation, animal rearing, poultry keeping and other activities both agricultural and non- agricultural that requires water, especially Northern Nigeria. Rainfall is the most important climatic variable. So

continuous studies into rainfall dynamisms over the whole country or a portion of it, is quiet needed for proper agricultural planning and other purposes. That is why a study of rainfall trends over a century and beyond for Northern Nigeria as a hub of agricultural cultivation will be conducted.

## 1.6 SCOPE OF THE RESEARCH

The spatial scope of the study is Northern Nigeria which approximately falls within Latitude $9^{o}$-$14^{o}$N and Longitude $3^{o}$–$15^{o}$E. Temporal scale ranges from the year 1901–2009 and the variables considered in the study are rainfall amount, latitude, longitude and altitude.

## 1.7 STUDY AREA

### 1.7.1 Location

Northern Nigeria which is the study area is located within Latitude $9^{o}$–$14^{o}$N and Longitude $3^{o}$–$15^{o}$E and enclosed about 17 States of Northern Nigeria which includes: Borno, Yobe, Jigawa, Kano, Katsina, Zamfara, Sokoto, Kebbi, Niger, Bauchi, Gombe, Adamawa, Taraba, Kaduna, parts of Kwara,Nassarawa and FCT Abuja. The area shares boarder with Niger Republic to the North, Benin Republic to the West and Cameroon Republic to the East.

### 1.7.2 Climate

The climatic conditions of the study area Northern part of Nigeriaexhibit only two different seasons, namely, a short wet season and a prolonged dry season i.e. the area is the tropical wet and dry climate, classified by koppen as Aw. Temperatures during the day remain constantly high while humidity is relatively low throughout the year with little or no cloud cover. There are however, wide diurnal ranges in temperature (between nights and days) particularly in the very hot months. The mean monthly temperature during the day exceeds $36^{o}$C while the mean monthly temperatures at night fall most times to below $22^{o}$C.

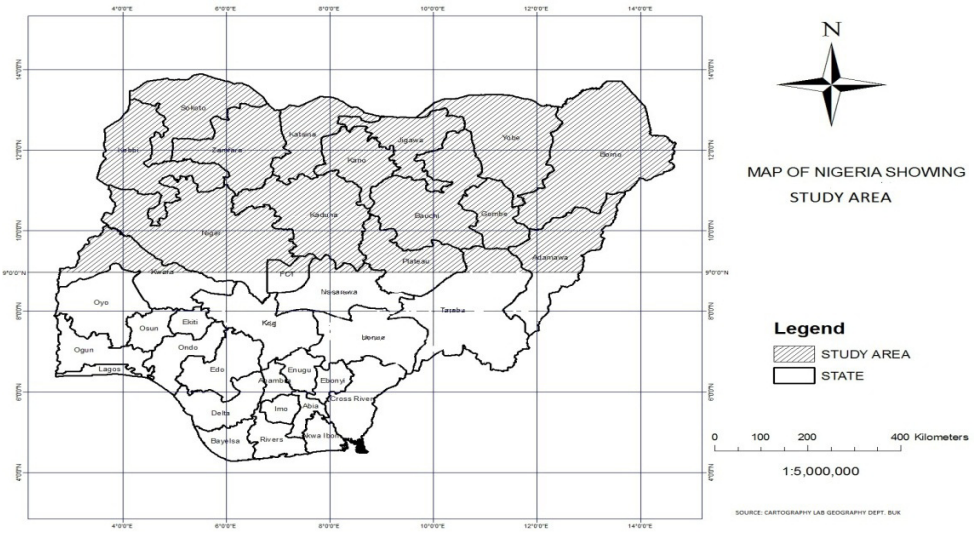


**Figure 1: The Study Area**

The few high plateaus of Jos and Biu, and Adamawa highlands experienced climatic conditions which are markedly different from generalized dry and wet period in Northern Nigeria.Temperatures are 5–10$^{o}$C lower due to high altitude than in surrounding areas. Similarly, the annual rainfall figures are higher than in areas around them, particularly on the windward site (www.cometonigeria.com).

The climate highly varied across the study area and is dominated by the influence of three main winds currents. These are the Tropical Continental (cT) air mass, the Tropical Maritime (mT) air

mass and the Equatorial Easterlies (Ojo, 1977). Tropical Maritime air mass originates from the southern high pressure belt located off the Namibian coast, and along its way picks up moisture from over the Atlantic Ocean and thus wet. The Tropical Continental air mass (cT) has the high pressure belt north of the Tropic of Cancer as its origin. This air mass is always dry as a result of little moisture it picks along its way. Tropical Maritime and Tropical Continental air masses meet along a starting surface called the Inter-Tropical Discontinuity (ITD). The third air mass (Equatorial Easterlies) is a somehow erratic cool air mass, which comes from the east and flow in the upper atmosphere along ITD. This air mass penetrates occasionally to actively undercut the Tropical Maritime and Tropical Continental and give rise to squall lines or dust devils (Iloeje, 2001). Nigeria is a country of marked ecological diversity and climatic contrasts. The ecological zones of the country are broadly grouped into six, Mangrove, Fresh Water Swamp, Rain Forest, Tall Grass Savanna, Short Grass Savanna and Marginal Savanna. But only three ecological zones fall under the study area viz: Tall Grass Savanna, Short Grass Savanna and Marginal Savanna

### 1.7.3 Vegetation

Apart from small areas in the high plateaus which support a montane vegetation and relict forest in the low lying ground along the southern boundary, the whole of northern Nigeria is covered by savanna vegetation which has been subdivided into four zones (see figure 1) running roughly parallel across the region. Passing northwards from savanna forest mosaic in the south they are: the Derived savanna, Guinea savanna, Sudan savanna and Sahel savanna.

The vegetation of the derived Savanna consists of thick-barked trees up to 12 to 15 metres high with tall grasses (1.5 – 3m). It covers an area of about 93,130 square kilometers. However, only the northern tips of this belt fall within the study area. The typical vegetation of the Sahel Savanna is open thorn-tree with Acacia The Guinea Savanna is similar in appearance to the derived Savanna, except that the grass growth is shorter and consists mostly of Hyperrhenia/Andropogon. The main trees are Isoberlinia which characteristically flushes during

the middle of the dry season. This zone extends for roughly 123,710 square kilometers. Large areas in the Sudan Savanna are almost continuously cultivated, and little trace remains of the natural vegetation. Combretum, Acacia and Commiphora are the most common trees and Andropogon gayanus is the dominant grass of the area. This zone provides the most favorable conditions for the production of grains and livestock. It covers an area of 129,270 square and Commiphora being dominant. The area of coverage amounts to about 11,120 square kilometers.

### 1.7.4 Rainfall

Annual rainfall is not uniform. For example, at the southern boundary of the study area annual rainfall may be as much as 1500mm and the length of growing season about 260 days. At the northern boundary the rainfall is 250mm and growing season of only 55 days. These climatic differences enhance in rainfall variability with latitude affect the nature of vegetation and economic activities especially agriculture (Buba, 1995). The annual rainfall figures are higher in and around the areas of highland especially at the windward site.

### 1.7.5 Soils

The soil types of Nigeria correspond closely with vegetation belts, except for the highland areas. The soil types in the study area ranges from Tropical Lateritic Soil at the extreme south of the study area through Semi-arid Brown Soil to Sub-Desert Soil at the extreme north of the area. Tropical Lateritic Soils are mainly in Savannah and impervious. Semi-arid Brown Soils contains more organic matter and are better developed because of chemical and biological actions. Sub-Desert Soils contain very little organic matter.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 CONCEPT OF CLIMATE CHANGE

Fourth assessment report of the intergovernmental panel on climate change (IPCC, 2007) concluded that climate change is already happening with multi-dimensional effects on human societies and environment. IPCC (2007) defines climate change as a change in the state of the

climate that can be identified (e.g. by using statistical tests) by changes in the mean and/ or the variability of its properties, and that persists for an extended period typically decades or longer. Although the length of time it takes the changes to manifest matters, the level of deviation from the normal and its impacts on the ecology are the most paramount.

The coupled atmosphere-ocean system has a preferred mode of behavior known as EL-NINO, and similarly the atmosphere is known to have preferred patterns of behavior, such as Northern Atlantic Oscillation (NAO). There is evidence that NAO, which affects the severity of winter temperatures and precipitation in Europe and eastern north-America, and EL-NINO, which has a large regional effect around the world, are behaving in unusual ways that appear to be linked to global warming.

## 2.2 CAUSES OF CLIMATE CHANGE

Climate change is primarily caused by two basic factors, which include natural processes (bio geographical) and human activities (anthropogenic). The natural processes are the astronomical and extraterrestrial factors. The astronomical factors include the changes in the eccentricity of the earth's orbit, changes in the obliquity of the plane of ecliptic and changes in orbital procession while the extraterrestrial factors are solar radiation quantity and quality among others. On the other hand, the anthropogenic factor in climate change involves human activities that either emit large amount of greenhouse gases into the atmosphere that depletes the ozone layer or activities that reduced the amount of carbon absorbed from the atmosphere. The human factors that emit large amount of greenhouse gases include industrialization, burning of fossil fuel, gas flaring, urbanization and agriculture. On the other hand, human activities that reduce the amount

of carbon sinks are deforestation, alteration in land use, water pollution and agricultural practices. Human factors have been proven by the Intergovernmental Panel on Climate Change (2007) to be responsible for the climate change. The emitted greenhouse gases are carbon dioxide ($CO_2$), chlorofluorocarbons (CFCs), Methane ($CH_4$) and nitrous oxide ($N_20$) among others. Currently, $CO_2$ contributes the highest rate of greenhouse gases.

## 2.3 IMPACT OF CLIMATE CHANGE

Increasing temperature (global warming) and decreasing precipitation in most part of the world are the greatest impacts of climate change. These bring about either negative or positive ecological impacts in different parts of the world. The increasing temperature has led to the increased land-based ice instability and its melting. The thawing of the arctic, cool and temperate ice, the increasing rainfall in some parts of the world and expansion of the ocean as water warm s has started impacting on the sea level rise, coastal inundation and erosion. The current global estimate of sea level rise is 0.2m and it has projected to increase to 1m by the year 2100 (Hengeveld et al. 2002; Hengeveld et al. 2005). The implication is that the present 0.2m sea level rise has inundated 3,400 $km^2$of the coastal region of Nigeria, and if the sea level rise attained the projected 1m on or before 2100 then 18,400 $km^2$ of the coastal region may be inundated (NEST 2003).

Climate change will alter all aspect of hydrological cycle ranging from evaporation through precipitation, runoff and discharge (Mcguire et al, 2002). The global warming and decreasing rainfall together with the erratic pattern of rainfall produce a minimal recharge of ground water resources, wells, lakes and rivers in most part of the world. In Nigeria, many rivers have reported

to have dried up or are becoming more seasonally navigable while Lake Chad shrunk in area from 22,902 $km^2$ in 1963 to a mere 1303 $km^2$ in 2000. This shows that what is left of Lake Chad in the year 2000 is just 5.7% of 1963. Increasing temperature and decreasing rainfall have led frequent drought and desertification (Odjugo and Ikhuoria 2003). The IPCC warns: 'Climate change and variability are likely to impose additional pressures on water availability and water demand in Africa' (Boko *et al.,* 2007:435).

## 2.4 RAINFALL TRENDS AND VARIABILITY IN AFRICA

Kassie *et al.*,. 2014 analyses temporal variability and extreme values of selected rainfall and temperature indices in Central Rift Valley of Ethiopia which showed that in the short rainy season (March to May), total mean rainfall varies spatially from 178 to 358mm with co efficient of variation of 32-50%. In the main (long) rainy season (June-September) total mean rainfall ranges between 420-680mm with a coefficient of variation of 15-40%. During the period 1977-2007, total rainfall decreased. There was also a large inter annual variability of the length of growing season, ranging from76 to 239 days.Oduro and Adukpo, 2006 studied time series of annual mean rainfall of Ghana for the period 1961-1998 and the result revealed a number of periodicities. A periodicity of 5.6 years was detected to be highly significant, that of 2.7 years was of borderline significance and the rest were insignificant.

The variability of rainfall, defined as the average deviation from the mean, is enormous, sometimes up to 40- 80% and increases with decreasing annual rainfall totals. Especially in the marginal areas, such as Sahara Desert, the Sahel and sub-humid Sudan zones rainfall unpredictably poses enormous threats to food security (ASC, 1999). Sharon (1992) found out that anomalous rainfall has prevailed on African continent during the 1980s, with negative mean

anomaly for decade except in low latitudes and in small sectors on the northern and southern extremes of the continents.

## 2.5 RAINFALL TRENDS AND VARIABILITY IN NIGERIA

Akinsanola and Ogunjobi (2014) analysis of rainfall and temperature variability over Nigeria from 25 synoptic stations from 1971-2000 (30years), find that there is rainfall anomaly over all the stations, in which some dry years were mixed with wet years and vice versa and this occur in all seasons in all stations. It was observed that rainfall decreases from the coast (Warri, Calabar) to the Sahel (Nguru, Katsina, Kano, Maiduguri) at all seasons. Decadal anomaly of rainfall in Nigeria showed that in the first decade of 1971-2000, there was an increase in the rainfall amount in cities like Jos, Enugu, Kaduna, Nguru, Minna and Katsina. A decline in rain amount was noted in larger part of the south-west and north eastern Nigeria. Analyses of long time trends and decadal trends in time series revealed continuous alternately decreasing and increasing trends in mean annual precipitation and air temperature in Nigeria during the study period.

Adefolalu (1986), in his study of rainfall trends for periods of 1911 – 1980 over 28 meteorological stations in Nigeria there was an appearance of declining rainfall for 40years. Also in his study Buba (2000) concluded that over most Northern Nigeria there has been a substantial decrease of rainfall between 1931-1960 and 1961-1990.

Analysis of climate of North-western Nigeria for the period of 1915-2008 confirms that the rainfall of the region has fluctuated substantially which affect both inter-annual and intra-annual rainfall patterns. The study further shown that inter-annual rainfall of (1967-2007) has fluctuated hugely not only in terms of total amount receives, but also in the dates of rainfall onset and cessation, as well as in the length of rainy season (Ekpoh and Ekpenyong, 2010). Also Eludoyin

et al. (2009) studied monthly rainfall distribution in Nigeria between 1985-1994 and 1995-2004 and noticed some fluctuations in most months within the decades. Ayansina et al. (2009) investigated the seasonal rainfall variability in Guinea savannah part of Nigeria and concluded that rainfall variability continues to be on the increase as an element of climate change.

The West African region has experienced a marked decline in rainfall from 15-30% depending on the area. The pattern of rainfall in Northern Nigeria is highly variable in spatial and temporal dimensions with inter-annual variability of between 15-20% (Abaje et al. 2010). Oguntunde et al. (2010) study of rainfall trends in Nigeria, 1900-2000 found that rainfall decreased with increasing latitude. Its value ranged from about 400mm per year around the Lake Chad in the northeast corner to over 2500mm per year in the south around the Niger Delta area. Spatial pattern of the coefficient of variation (%) showed a reverse latitudinal trend as rains become more varied northwards. The temporal pattern showed a general decline in rainfall over Nigeria in the last century. Obot et al. (2007) evaluated rainfall trends in Nigeria for 30 years (1978-2007) and concluded that the total amount of rainfall across six geopolitical zones of Nigeria at selected locations within the zone from Mann Kendall test reveals an increasing trend in only one out of the six stations. Ifibiyi, (2013) study of rainfall trends in the Sudano- Sahelian Ecological Zone of Nigeria over 50 years concluded that there was a downward trend in rainfall amount in the 1970's and 1980's which was responsible for the flood episodes in Northern Nigeria during that decade.

Rainfall is a climatic parameter that affects the way and manner man lives. Every facet of ecological system, flora and fauna is affected by rainfall. Hence, the study of rainfall is important and cannot be over emphasized (Obot and Onyeukwu, 2010). T.M. Hess et al (1995) analyzed

daily rainfall records for 1961-1990 for Nguru (12.53$^{o}$N, 10.28$^{o}$E, Alt 343m), Potiskum (11.42$^{o}$N, 11.02$^{o}$E, Alt 415m), Maiduguri (11.51$^{o}$N, 13.05$^{o}$E, Alt 354m) and Maine Soroa (13.13$^{o}$N, 11.58$^{o}$E, Alt 339m) in Niger to described any change in season duration, rain-days per season and rainfall amount per rain day. They discovered that there was a constant decrease in annual rainfall of 8mm per year at all four stations and majority of this reduction occurred in august and September.

Anyadike, (2006) examined monthly and annual rainfall variations over southern, middle-belt and northern regions of Nigeria as well as the country as a whole over a 72 year period (1916-1987). Changes such as fluctuations and trends were investigated using Gaussian low-pass filter. Trend analysis showed a tendency toward decreasing annual rainfall totals in all the regions, with rates of decrease being greatest after 1961 in the southern region. All regions experienced the reverse of the trend during the 1931-1960 periods. Power Spectrum analysis revealed the significant oscillations in the rainfall totals. Temi (2006) studied changes in rainfall characteristics and their implication for flood frequency in Makurdi for 77 years (1927-2004). Data on daily rainfall were collected and annual rainfall trends were analyzed using Spearman rank correlation coefficient, and annual rainfall variability analyzed using standard rainfall anomaly index while recurrence intervals were analyzed using Gumbell probability theory. The result of the analysis shows among other things that there was a remarkable continuous downward trend in annual rainfall amounts; that the period of 1996-2001 witnessed the highest frequencies of extreme rainfall events and flood frequencies.

Oladipo and Kyari (1993) used simple water balance method to compute the dates of the onset and termination and length of the growing season from long-term rainfall series in Northern Nigeria. The result shows a progressive decrease in the length of growing season from a mean of about 200 days in the south to less than 155 days in the extreme northern part. While there is no statistically significant trend in the onset dates, there is some evidence for statistically significant decreasing trend in the termination dates and the length of the growing season over the region. The results also indicate that recent trends in the length of growing season are more sensitive to large inter annual fluctuations in the start of rains than to variations in the cessation dates. Olaniran and Summer, (1990) studied changes in the variations of annual and growing season rainfall series for the period 1919-1985 in Nigeria on a regional basis, using Power Spectral and low pass filter techniques, and the mean-kendall rank statistics. Four regions are coastal zone, the guinea savanna zone, the midland area and the Sahel, are used in the investigation of rainfall variation from south to north across the country. Evidence emerges of a progressive decline in annual and growing season rainfall for northern Nigeria, north of $9^{o}$N latitude, for the period 1939-1985. Ati *et al*., (2009) study rainfall data spanning a period of 50 years (1953-2002) for 9 stations in northern Nigeria to determine the trend in annual rainfall. The evidence from the nine stations considered shows that there is significant increase in annual rainfall amount in the last decade of the study.

Amissah and Jagtap (1999), analyses variation in the season (April to September) rainfall from 23 stations across Nigeria over 30- year period, 1960-1990. Regression analyses were used to examine long-term trends. Principal components and cluster analyses were used to group stations with similar trends in standardized seasonal rainfall. Mean accumulated standardized seasonal

rainfall were used to examine short- and medium term trends for each of the groups identified. Significant decreases in rainy season rainfall were found at 8-stations mostly in the Guinea and arid/semi-arid savannas of northern Nigeria, whereas no station showed significant increases. Examination of the monthly (April through September) rainfall showed that only three stations Kano,Sokoto and Potiskum in the arid/semi-arid savanna of the 23 stations used in the analysis had declining rainfall trends for each of the months April to September and subsequently declining seasonal rainfall trends. However, 12-15 stations had consistently declining rainfall trends in at least some but not all growing season months. However, a similar pattern was not the case in term of increasing rainfall trends, where only one to three stations had consistently increasing rainfall trends in some but not all of the months from April to September. Stations that showed increasing rainfall trends were in the southern parts of Nigeria. Six groups with similar patterns in standardized seasonal rainfall were identified by principal components and cluster analyses. For most of the groups, the period from 1967-1973 was that of consistently below average seasonal rainfall. However, the timing and extent of decline varied with location. Common to stations in four of the six groups was a negative trend in seasonal rainfall for the period considered.

Result of the research conducted by Buba (2008) indicated that variability in annual rainfall totals over northern Nigeria is lower than those of the monthly totals; there is also tendency for variability of annual totals to increase as the totals decrease and there has been a trend toward aridity in the most of the stations studied. The study further revealed regional variation in terms of rainfall fluctuations and precipitation over the study area has declined over the period of 1943-2000.

Analysis of the climate of north-western Nigeria for the period 1915-2008 revealed that rainfall of the region has fluctuated substantially. Such fluctuations affect both inter-annual and intra-annual rainfall patterns. The study further shown that rainfall between 1967 to2007 have fluctuated enormously, not only in terms of total receipts, but also in the dates of rainfall onset and cessation as well as in the length of the rainy season (Ekpoh and Ekpenyong, 2010).

Isma'il and Oke (2012) concluded that there is a significant downward trend in the yearly total and mean rainfalls at Birnin-Kebbi in the last three decades, which can be attributed to climate change.

Abaje, Ndabula and Garba (2014) found that, Kano has been experiencing decreasing number of dry conditions and consequently, increasing wetness over the recent years. The in the annual rainfall yield in the recent periods is predominantly as a result of the increased in the June, July and August rainfall.

Odjugo (2010) revealed that, there is increasing temperature and decreasing rainfall amount and duration in Nigeria between 1901 and 2005. Temperature increase of 1.1$^{o}$C was observed in Nigeria for 105 years while rainfall amount dropped by 81mm. The rainfall amount is generally decreasing in Nigeria; the coastal region of the country has been experiencing slightly increasing rainfall since early 1970s. In their findings, Oguntunde, Babatunde and Gunner (2011), rainfall varied mostly in the north (marginal savannah) also there is decreasing rainfall with increasing altitude. The study further revealed that temporal pattern showed a general decline in rainfall over Nigeria in the last century; as less than10% of the entire Nigeria landscape experience about

500mm per year of rainfall, 60% experience about 1300mm per year while about 10% of the southern part of the landscape experience heavy storm above 2000mm per year.

Adakayi (2012) described the rainfall in northern Nigeria as quasi-periodic because of the perceptible distribution between 1970s and 1980s and 1990s to 2005. The study further forecast that, 2007- 2030 rain continues to decline until 2019 and increases from 2020 till 2030. Also the southern parts of the study area have higher rainfall and lower temperatures compared to the northern parts. Time series analysis showed that there have been more rainfalls lower than the mean values than that of over the mean values. The most uneven distributions were found in 1984, 1985, 1995 and 2006. The years 1991 and 1972 have the highest number of rain days followed by 1984, 1982 then 1978. However, 1996, 1983 and 1977 have the least number of rain days. Generally, the number of rain days has increased since the 1990's

Annual land precipitation has continued to increase in the middle and high latitudes of the northern Hemisphere (very likely to be 0.5% to 1% per decade), except over eastern Asia. Over sun-tropics ($10^{o}$N to 30 $^{o}$N), land surface rainfall has decreased on average (likely to be about 0.3% per decade), although this has shown signs of recovery in recent years (Mohammed, 2005). Abaje *et al* (2012) examined recent trends and annual fluctuations of annual of the South Sahel Ecological Zone (SSEZ) of Nigeria between 1949 and 2008. The study concluded that, at present, the climate of the region indicates a tendency towards a wetter condition rather than increasing dryness that was a feature of the period from 1960s to 1980s.

Drastic changes were observed in the trends of rainfall in the twenty locations covered in Nigeria. The results showed Akure and Maiduguri stations were decreasing in trends of rainfall with magnitude of return period at an average of 2 years. On the other hand, Osogbo, Port Harcourt, Sokoto, Warri and Yelwa stations experienced upward trends of rainfall on annual basis. Stations that experienced downward trends of rainfall are Abuja, Benin, Calaber, Lagos and Yola. Abeokuta, Enugu, Ikeja and Iseyin experienced upward trends in rainfall, while Minna and Bauchi stations experienced no change in trends. Alli et al (2012). Temidayo and Emmanual (2014) studied 100 years of rainfall in Northern Nigeria subdivided into ten (10) decades, using ILWIS GIS software; the results were presented on a spatial digitized map of Northern Nigeria. The result of the analysis revealed that there were several drought years in the study period. Analysis further revealed that decades 7 to decade 9 (i.e. 1967-1976, 1977-1986 and 1987-1996) witnessed persistent drought in Northern Nigeria. The SPI analysis revealed distinct period of negative and positive values in which negative values indicate occurrence of drought and positive indicate there is no drought.

Akinyemi *et.al* (2013) found that there is significant change in the distribution and characteristics off rainfall such as occurrence and intensity in the monthly and annual rainfalls in Ekiti state. The results of the Standardized Anomaly, Moving Average and Trend Line shows that there are fluctuations in the annual rainfall even though the positive and negative deviations are evenly distributed.

Rainfall variability and changeshas been widely researched by a quiet number of scientists that spatio-temporal rainfall variability is real. Analyses of long time trends and decadal trends in the rainfall long term time series suggest a sequence of alternately decreasing and increasing trends in mean annual precipitation in Nigeria (Akinsanola and Ogunjobi, 2014). There was a sharp

difference between changes in rainfalls in 1931-1960 and 1961-1990 periods. Annual precipitation reduced by 7% between the two periods (Oguntunde et al. 2010).In response to the above researches, this research used gridded rainfall data documented by Global Precipitation Climatology Center (GPCC) to further investigate the variations and trends in rainfall Northern Nigeria from latitude $9^{o}$-$15^{o}$N and longitude $3^{o}$-$15^{o}$E for the period 1901-2009.

## CHAPTER THREE

## MATERIALS AND METHOD

This chapter discussed in detail the process of data generation, processing and tools of data analysis.

### 3.1SOURCES OF DATA

Data used in this study involves a gridded world precipitation data covering the period 1901-2009 downloaded from www.gpcc.dwd.deGlobal Precipitation Climatology Centre. The precipitation value was in millimeter per month per grid that is gridded at spatial resolution $0.5^{o}$ latitude by $0.5^{o}$ longitude.

Alsoannual rainfall data for ten 10 stations within the study area was obtained from the archives of the Nigerian Meteorological Agency (NIMET). The stations are Katsina, Zaria, Yelwa, Gusau, Nguru and Potiskum. The period data covered vary

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