AN INVESTIGATION INTO THE NATURE AND VARIABILITY OF CLIMATE CHANGE-INDUCED RAINFALL OVER AWKA, ANAMBRA STATE

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CERTIFICATION

This is to certify that this work "**AN INVESTIGATION INTO THE NATURE AND VARIABILITY OF CLIMATE CHANGE-INDUCED RAINFALL OVER AWKA, ANAMBRA STATE**" was carried out by **DURU CHINENYE ROYNA** with Registration Number **20134871988** in partial fulfillment of the requirements for the Award of Master of Science (M.Sc.) degree in Pollution Control in the Department of Environmental Technology, School of Environmental Sciences, Federal University of Technology, Owerri (FUTO)

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DEDICATION

This research work is dedicated to God Almighty and to my husband, Julius Okanigbuan.

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ABSTRACT

This thesis investigates the nature and variability of climate change-induced rainfall over Awka, Anambra state. Time series of annual rainfall for Awka, Anambra state was analysed to reveal shifts in rainfall pattern occasioned by ongoing climate change. Past rainfall data over four decades (1975-2014) were collected for the study area for analysis. The series exhibited shifts in bimodal rainfall pattern during annual analysis, however, decadal analysis showed no significant shift. The least rainfall years were 1975 followed by 1983 at average values of 116.4mm and 116.9mm respectively, while the wettest years were 1995 followed by 2009 at average values 206.5mm and 179.8mm respectively, showing that the most recent decades experience higher rainfall, also exceeding the mean of the total mean annual rainfall at 153.8mm. The months of onset and retreat of rainy season was March and October, however, significant rainfall months were April May, June, July, August, September and October. The little dry season/August break experienced shifts in the annual analysis but had no significant shift in the decadal analysis. The total average annual rainfall occurrence throughout the study period is 6150.8mm. The study concludes that variability observed for West Africa rainfall, Awka inclusive has not recently resulted in significant shifts, rather fluctuations in Awka, Anambra state.

CHAPTER ONE

INTRODUCTION

1.1. BACKGROUND OF THE STUDY

The earth's climate is warming; small changes in the average temperature of the planet can translate to large and potentially dangerous shifts in climate and weather. It also implies an alteration in the average weather conditions. The change in climate signifies a lasting transformation in the distribution of weather patterns of a place over periods ranging from decades to thousands of years. The climate of the earth in far from constant; this led to the World Meteorological Organization, (WMO) establishing Climate Observational Stations to monitor the climate system. Data collected through WMO's networks when analyzed, assist policy makers in making informed decisions on the state of the environment so that they are in a better position to prevent its further degradation.

Scientist have observed evidences of variations in the climate system, which may include warming oceans, shrinking ice sheets, sea level rise, global rise in temperature, extreme climatic events, ocean acidification, decreased snow cover and variations in rainfall pattern. Climate model projections were summarized in the 2013 Fifth Assessment Report (AR5) by the Intergovernmental Panel on Climate Change (IPCC). They postulated that during the 21st century, the global surface temperature is likely to rise a further 0.3^0C to 1.7^0C for their lowest emissions scenario using stringent mitigation and 2.6^0C to 4.8^0C for their highest.

Globally, the effects of climate change have become a new reality with deleterious effect which may include disruption of seasonal cycles, ecosystem, agriculture, water needs and food production. It also leads to sea level rise with its attendant consequences, fiercer weather, increased frequency and intensity of storms, floods, hurricane persistent drought, off season rains, dry spells, increased frequency of fires, poverty, malnutrition and series of health and socio economic consequences. Hence, the first world climate conference was held in Geneva, Switzerland to address the impact of climate change. The key objective was to examine the issue of climate variability and change and also the impacts of these variations on humans and their activities. This conference was held following reported abnormal manifestations in many parts of the world including Africa.

In Africa, tropical climate variation patterns particularly over the last 2000 years have been outlined (Grove, 1972). For instance, about 15,000 years ago, rainfall was about one third of the present amount. About 12,000 to 7000 years before now, the climate over most parts of Africa was warmer and wetter than now. The dominant role of agriculture and aquaculture make it obvious that even minor climate variations can cause devastating socioeconomic consequences; even international conflicts have to be expected because climate refugees might not be stopped at inner African boarders. In West Africa, major droughts have occurred at least three times since the beginning of the century. Drought occurred in 1913-1914, 1943-1946 and recently in 1972-1974 (FAO, 2004). The drought of the 1970s that swept most of the Sahel region of Africa left the region, including Nigeria with general water resource issues. Mechanism of rainfall variability in African Sahel received little attention until the severe drought of 1972 and 1973 (Gray, 1992). Infact, in sub-Saharan Africa, incidence of climate variations have been reported by Nicholson (2003) and Nnaji (1999).

Most Northern states of Nigeria have recorded a short rainy season, low agricultural output, limited water supply and inadequate water reserve (Tarhule, 1997). In Nigeria changing rainfall pattern have been observed by researchers such as Anyadike (1993), Nnaji (2001), Ulor (2006) and Bassey (2014). Infact, Nnaji (2001) observed unusual change in the occurrence of wet and dry season regimes in sub-Saharan Africa, while annual decadal and interdecadal variations in rainfall have been reported by Anyadike (1993). Drought related phenomena have persisted, weather patterns have been distorted and the months of occurrence of the "little dry season" or "August break" seem to be varying in the south-east tropical continental climate zone of Nigeria (Nnaji, 2008).

In 1979, the World Meteorological Organization (WMO) hosted the first world climate conference in Geneva, Switzerland, to examine the issue of climate variations and the impacts of these variations on mankind and his activities. This conference came closely after abnormal manifestation of climate in many parts of the world was expressed in terms of floods and drought in the preceding decade. One notable example of such manifestations of climate variations was the drought in the West Africa Sahel, which occurred from the late 1960s to the mid 1970s with disastrous consequence for the economy and people living in the region. Ever since, a variety of studies, more especially numerical modeling have been employed to analyze as well as predict Sahel rainfall (Hastenrath, 1990).

Scientific understanding of the cause of global warming has been increasing. According to World Metrological Organization, the causes of climate change are greenhouse gases, aerosols and land use change. In its fourth assessment (AR4, 2007), the Intergovernmental Panel on Climate Change (IPCC), reported that scientists were more than 90% certain that most of global warming was caused by increasing concentrations of greenhouse gases produced by human activities. Research indicates that natural causes are very unlikely to explain most observed warming, especially warming since the mid-20th century; rather, human activities can very likely explain most of the warming. Against this background, the efforts or rather non-efforts of Nigeria to deal with these problems have to be examined. Most countries are parties to the United Nations Framework Convention on Climate Change (UNFCCC), whose ultimate objective is to prevent dangerous anthropogenic climate change. The UNFCCC have adopted a range of polices designed to reduce greenhouse gas emissions and to assist in adaptation to global warming.

Although, these efforts have better documented variations in Sahel rainfall in recent times, there has been little works on the nature and dynamism of rainfall variability over Awka, Anambra State. Consequently, this project work intends to examine if there are significant fluctuations in key characteristics of rainfall variability namely; frequency, total amount, seasonality in Anambra State, Nigeria over a forty-year period.

1.2. STATEMENT OF THE PROBLEM

Recently, the incidence of unusual weather patterns as they affect wet and dry season regimes have been observed in West Africa including Nigeria (Nnaji, 1999). Most often, some years may experience heavier and prolonged rainfall than usual which may extend into the dry season. However, in some other years; the August break may vary in the month of occurrence or not come at all. According to Iloeje (2004), the rainfall for Ibadan, Nigeria for that year registered 18.9cm in July, 18.8cm in August, 8.5cm in September and 18.5cm in October showing that the "August break" occurred in September. Consequently, the little dry period was altered given the reduction in rainfall season (NIMET, 2014).

The problem addressed in this study is the analysis of the nature of rainfall variability over Anambra State occasioned by the ongoing climate change. Additionally, the study investigates the dynamism of any observed variability, as well as significant rainfall months in Anambra State over the forty-year period.

1.3. SIGNIFICANCE OF THE STUDY

Researchers such as Gray (1987), Lamb (1985), Landsea and Gray (1992) and Nnaji et al (2006) have investigated and analyzed variations in global and sub-regional rainfall. The major challenge, particularly at the local level is insufficient information on the variation in rainfall months. This often results from a lack of awareness of how the climate has changed in the past and how it is expected to change in the future.

There is need to analyse rainfall trends for sectoral application. For instance, rainfall regime and other climatic variations have strong effect on agriculture, air traffic and communication management as well as other socioeconomic activities. For agriculture, which is the main source of livelihood for the majority of the population of Anambra state, it will be of interest to understand how rainfall characteristics are changing. This has implications for crop growth cycle, for example, the start of the rains or frequency and intensity of dry spells and daily rainfall, which can destroy crops if they occur at critical stages of plant growth. Also, in the agricultural sector, proper scheduling of planting dates with the start of the rainfall season is arguably the most important factor that has major impacts on yields. Rainfall is necessary for plant growth and influences the efficiency of water for agricultural purposes. A lack of water and poor water can compromise hygiene and health. Water scarcity encourages people to transport water long distances and store supplies in their homes; this can increase the risk of household water contamination, causing illness.

Rainfall during the day is subject to heavy evaporation losses particularly in low latitudes, high rainfall events can also cause significant environmental degradation. An increase in the intensity and or the frequency of heavy rainfall can wash away topsoil and create major erosion channels. Extreme swings in rainfall pattern combined with projected higher temperatures and decreased rainfall amounts, may lead to even greater impacts on ecosystem than previously expected. Rainfall variations and trends are of great interest to climatologists as well as agriculture in view of the important role of moisture in agriculture. Other rainfall characteristic such as duration, frequency, amount and intensity are equally important to hydrologist and soil scientists concerned with flood forecasting and soil erosion respectively.

The research therefore focuses on determining whether the proportional contribution of each month in the rainy season to the annual rainfall shows any significant trend. Consequently, helping farmers and water resource planners to determine whether current problem of low agricultural yields and water availability are due to the effects of natural climate change and variability or management practices (Mapurisa and Chikodzi, 2014). It is therefore very important that this aspect of precipitation analysis be investigated that may contribute in enhancing the various impact of rainfall in economic growth.

1.4. AIM AND OBJECTIVES OF THE STUDY

The aim of this research is to investigate changes in the rainfall pattern in the study area, focusing on these objectives:

i. assessment of decadal rainfall pattern in Anambra State over a forty-year period.
ii. analysis of the temporal variability of rainfall in the study area by showing year to year fluctuations or variances that exist.
iii. identification of the months of onset and retreat of rainy season in Anambra State and finally,
iv. analysis of the long term mean for the region under study and the means of ten wettest and driest years. The aim is to find which years contribute the most to inter annual variability.

1.5. SCOPE OF THE STUDY

This research is basically on analysis of the bimodal rainfall pattern, rainfall variations and August break phenomenon for the period of forty years. The area of study is Awka, Anambra State.

Awka is the capital of Anambra State, located in the centre of the densely populated Igbo heartland in Southeastern Nigeria. Strategically, Awka is located midway between two major cities in North Igboland, Enugu and Onitsha. Awka is sited in a fertile tropical valley but most of the original rainforest has been lost due to clearing for farming and human settlement.

Awka is in the tropical rainforest zone of Nigeria and experience two distinct seasons brought by the two predominant winds that rule the area: the Southwestern monsoon winds from the Atlantic Ocean and the Northeastern dry winds from across the Sahara desert. The monsoon winds from the Atlantic creates seven months of heavy tropical rains, which is most likely to occur between April and October and are followed by five months of dryness (November-March). Awka is located at coordinates $6^0$12’25”N $7^0$04’04”E. The state covers a total large area of 4,844km^2.

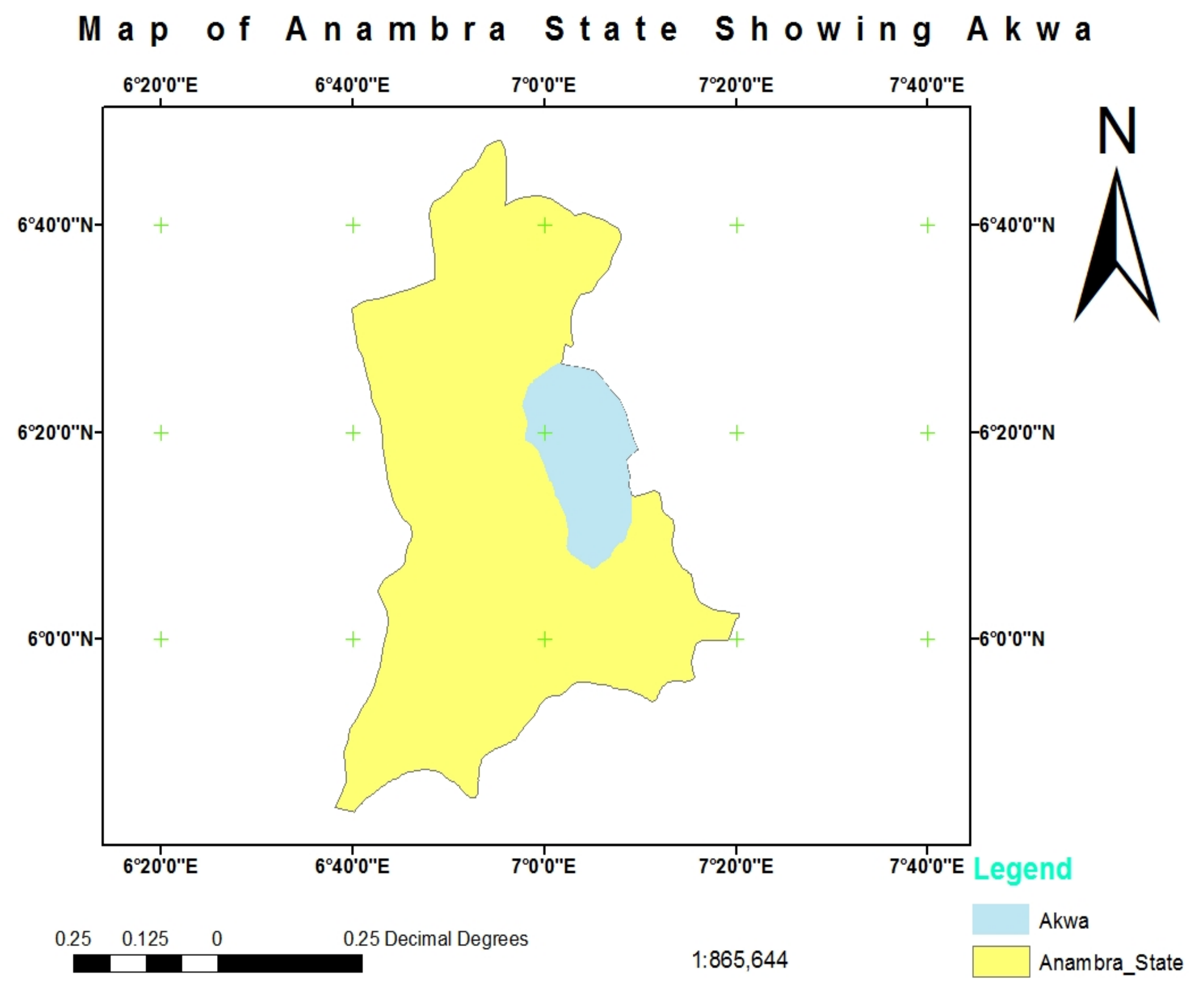

FIGURE 1.1: MAP OF ANAMBRA SHOWING AWKA

1.6. RESEARCH QUESTIONS

The two research questions guiding this study are:

i. Are there changes in rainfall pattern in Awka, Anambra state especially with reference to bimodal pattern of rainfall?

ii. Are there changes in the months of onset and retreat of rainfall in Awka, Anambra state?

1.7. HYPOTHESIS

The research hypothesis is as stated;

i. HO: There is no shift in bimodal pattern of rainfall in the Awka, Anambra state.

   HA: There is shift in bimodal pattern of rainfall in Awka, Anambra state.

1.8. DEFINITION OF TERMS

Rainfall month: refers to any of the twelve months into which the year is divided in which the total amount of prepetition is above 0.3 millimeter per month.

August break: refers to the little dry season or period that usually occur between the long wet season especially within the eighth month of August.

Bimodal rainfall pattern: refers to the two rainfall peaks in a year.

Variability: refers to changes that occur in various elements of weather and climate.

Wet period: refers to a particular length of time during which rainfall is observed in an area.

Synoptic Station: refers to a weather station manned by fulltime trained observers who keep uninterrupted weather watch on weather elements e.g rainfall.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Climate change is a natural dynamics and within recent decades, global climate has witnessed rapid change. Many researchers have investigated climate trends globally and regionally so as to substantiate such trends with scientific evidences Duruji (2006), Orji (2000), Ojo (1988). These investigations came after earlier researchers encouraged studies of long term climate trends and irregular patterns of wet and dry cycle of years (Mabongunje, 1978; Ojo 1988 and Ayoade 1988). The evolving climate change and increasing temperature has been observed to force some localities into experiencing extreme weather conditions (Ayoade 2003, Odjugo 2005). Some scientists such as Fashokun (1995) attribute this to the ongoing global warming which may be contributing to the disappearing ice.

In the article "the days of the ice hunters" which investigated the inconsistency of annual precipitation and climate change over a temperate area, the author observed that Arctic biologists have noted that the entire ecosystem is in collapse, such that if this trend continues, the Arctic ocean could be ice-free each summer by the end of the century

(Ehrlich, 2006). Also Zwingle (2006) in his work titled "Meltdown, the Alps under pressure" observed that global warming is causing the snowfall to be less predictable. Researchers estimate that the Alps have lost half of their glacier ice in the past century. High altitude regions trend to be more sensitive to the global warming and the retreat of glaciers is one sign" says Martin Beniston, a climate specialist at the University of Fribourg, Switzerland.

Many studies have shown that there exists clear inter-annual decadal rainfall variability over sub-Sahara West Africa (Ward *et al*; 1999). Other studies have investigated the inconsistency in annual rainfall and climate change over a temperate region.

In West Africa, during the 1950s, changes in the Sahelian rainfall were particularly dramatic (World Climate Programme, WCP, 1983). Wet conditions prevailed during that decade with averages from 15% above normal in the Southern area to 35%-40% above normal along the Sahelian fringe. Favourable rainfall conditions ended in 1960 and average rainfall deficit from 1968-1973. Deficiency in rainfall was also observed to have occurred in the subsequent years and continued till 1983. The drought that began in 1968 never really ended, though some areas were characterized by Favorable distribution of rainfall throughout the season.

Nicholson (1979) presented normalized annual rainfall departure series from the beginning of the century to 1975 for three regions in the semi-arid West Africa sub-tropics. This was based on a total of 118 stations and exhibited remarkably parallel fluctuation, including a period of well above average rainfall throughout the 1950s and the drier period. The drier period set in during 1960 and culminated in the 1968-1973 Sahel droughts. The analysis presented in the study represents preliminary results of an investigation of recent rainfall fluctuations throughout Africa.

Ahmad and Ahmad (2000), IPCC (2001), NEST (2003), Hengeveld (2005) provided a framework with which to assess the evidence of climate change in a region. These include the temperature rise, according to Marbo (2006) and Ikhile (2009), a rise in temperature could be linked to the effect of climate change and its associated global warming. Others are increasing evapotranspiration, decreasing rainfall amount in the continental interiors, increasing rainfall in the coastal areas, increasing disruption in climate patterns and increased frequency and intensity of unusual or extreme weather related events such as thunderstorm, lightning, landslides, floods, droughts, bushfires, unpredicted rainfall pattern, sea level rise, increased desertification and degradation, drying up of river and lakes and constant loss of forest cover and biodiversity amongst others.

Recently, researchers confirm their existence in Nigeria. Odjugo (2005), Molega (2006), Umoh (2001) observed decline in rainfall pattern in Nigeria. A further support of the evidence of climate change in Nigeria 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 interiors of the semi arid region of Nigeria. The increasing rainfall in the coastal cities of Warri, Lagos, Port-Harcourt, Calabar etc as observed by Ogundebi (2004), Nwafor (2007), Umoh (2007) and Odjugo (2010).

The increasing temperature and decreasing rainfall in the semi arid region of Nigeria such as Sokoto, Kastina, Kano and Maiduguri may have resulted to the increase in evapotranspiration, drought and desertification in Nigeria as reported by Odjugo and Ikhuoria (2003), Adefolalu (2007). The decreasing rainfall, increasing temperature and evapotranspiration have resulted in either reductions of water level or total dry up of some rivers and lakes in the Northern states of Nigeria. Lake Chad is reported to have been shrinking in size at an alarming rate since the 1970s (Chendo and Nyelong, 2005; Odjugo, 2007). In the coastal regions of Nigeria, sea level rise of 0.2m and incursion of salt water into the coastal plain at about 2016-3400km2 was reported (Nest, 2003; Nyelong, 2004; Nwafor, 2006).

In the recent years, there has been incidence of unusual weather pattern and effect on weather condition; these observations are the results of researches done by climatologists such as Duruji (2006), Orji (2000), Ojo (1988) and others. These investigations came after earlier researchers encouraged studies on long-term climatic trends and irregular patterns of wet and dry cycle of the years. (Mabongunje, 1978; Ojo, 1988 and Ayoade, 1988).

Adefolalu (1986) analyzed mean monthly rainfall data of 28 meteorological stations in Nigeria for the period of 69years (1911-1980) to examine trends in precipitation patterns in the country. Results showed some variations which predict a drier environment in the long term.

Anyadike (1992) observed the extent and nature of non-random changes, such as fluctuations, trends and persistence over a 72-year "secular period" (1916-1987). He analysed the time-series of annual rainfall using trend analysis. The findings are that there is tendency towards decreasing seasonal rainfall totals in the entire region though only those for the Northern region and the country as a whole were significant.

According to his evaluation, no significant persistence was evident in any of the regions during this secular period.

Ojo *et al.* (2001) and Udoeka *et al.* (1998) using annual values of some hydro climatological parameters observed climate change and variations as being responsible for the low flow in Kainji reservoir. There was a downward trend of about 2.7 millimeters per year (Gbuyiro *et al.*, 2002).

2.2 CAUSES AND INDICATORS

The causes of climate change are both natural and anthropogenic factors. Although, a large body of evidence supports the conclusion that anthropogenic factors (human activities) is the primary driver of recent warming. These human activities may include urbanization, deforestation, population explosion, industrialization. These evidences have accumulated over several decades and from hundreds of studies. The first line of evidence is our basic physical understanding of how green house gases trap heat, how the climate system responds to increases in greenhouse gases and how other human and natural factors influence the climate. The concentration of CO2 in the atmosphere has increased by roughly 35 percent since the start of industrial revolution. According to Buba (2004), Deweerat (2007) Odjugo (2007), the release of greenhouse gases are the major attributing factors to the depletion of ozone layer and its associated global warming and climate change.

The energy input to earth from the sun varies, for example because of the changes in earths orbital path, changes in tilt angle of the earth, or variations in the energy coming from the sun. These changes occur over long time scales. Another factor that can cause climate fluctuations on yearly to decadal time scales is volcanoes. Volcanic eruption lead to enhancements in stratospheric and tropospheric aerosols which for the most part reflect solar radiation, hence leading to global cooling on a worldwide average. However, regionally, these can lead to warmer conditions by changing atmospheric circulation patterns, especially in the rainy season.

In its recently released fourth Assessment report, the intergovernmental panel on climate change (IPCC), a group of 1,300 independent scientific experts from countries all over the world under the auspices of the United Nations, concluded there’s a more than 90 percent probability that human activities over the past 250 years have warmed out planet. The IPCC also concluded that the atmospheric increase of greenhouse gases mostly result from human activities such as combustion of fossil fuels (coal, oil, natural gas) in industries and deforestation. The industrial activities that our modern civilization depends upon have raised atmospheric carbon dioxide levels from 280 parts per million (ppm) to 390 parts per million (ppm) in the last 150 years. To a lesser extent, the clearing of land for agriculture, industry and other human activities have also increased concentrations of greenhouse gases.

These greenhouse gases may include:

CARBON DIOXIDE (CO_2)

It is an important component of the atmosphere; CO_2 is released through natural process such as respiration and volcanic eruption and through human activities such as deforestation, land use changes and burning of fossil fuels. This is the most important long-lived “forcing” of climate change.

WATER VAPOUR ($H_2O(g)$)

It is the most abundant greenhouse gas, but importantly, it acts as a feedback to the climate. Water vapour increases as the earth atmosphere warms.

METHANE (CH_4)

It is a hydrocarbon gas produced both through natural sources and human activities, include the decomposition of waste in landfills, agriculture and cultivation as well as ruminant digestion and manure management associated with domestic livestock. On a molecule for molecular basis, methane is a far more reactive greenhouse gas than carbon-dioxide but also one which is much less abundant in the atmosphere.

NITROUS OXIDE (N_2O)

This also a powerful greenhouse gas produced by soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production and biomass burning. It occurs in low concentrations relative to carbon dioxide.

CHLOROFLUOROCARBON (CFCS)

These are synthetic compounds entirely of industrial origin. Its largely regulated in production and release to the atmosphere by international agreement for their ability to contribute to the destruction of ozone layer.

TROPOSHERIC OZONE (O_3)

It has a short atmospheric lifetime, and it is a potent greenhouse gas. Chemical reactions create ozone from emissions of nitrogen oxides and volatile organic compounds from automobiles, power plants and other industrial and commercial sources in the presence of sunlight .

Other climate forcers include:

Black carbon

This is a solid particle or aerosol, not a gas, but it also contribute to warming of the atmosphere. Black carbons can directly absorb incoming and reflected sunlight in addition to absorbing infrared radiation. BCs can also deposit on and darken snow and ice, increasing the snow absorption of sunlight and accelerating melt.

Sulphates organic carbon and other aerosol can cause cooling by reflecting sunlight.

Warming and cooling aerosols can interact with clouds, thereby changing a number of cloud attributes such as their information, dissipation, reflectively and precipitation rates. Clouds can contribute both to cooling by reflecting sunlight and warming by trapping out going heat.

According to World Meteorological Organization, the causes of climate change are greenhouse gas, aerosols and land use change.

According to Ayoade (2004), theories of causes of climate change include polar wandering and continental drift, modifications in the earth's topography, variations in atmospheric composition, adjustments in the distribution of land and water surfaces, dissimilarities in snow and ice cover, changes in the cycle of equinoxes, changes in the tilting of the plane of the ecliptic, variations in solar radiation outside the earth's atmosphere including so many other explanations.

This is one reason why no single theory of climate change has been found satisfactory in explaining all the variations that have been known to occur in world climate. Besides, it is believed that various factors operate to bring about a change in climate.

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) also investigated the seasonal rainfall in Guinea savannah part of Nigeria and concluded that rainfall variability continues to be on the increase as an element of climate change.

Okorie *et al*. (2012) noted that climate variation generally occurs at different scales namely: local, regional, national and global scale. Evidence of climate variations is now well documented and the implications are becoming increasingly clear as data accumulates and climate model become increasingly sophisticated. The fluctuations in rainfall and temperature regimes are the atmospheric driving force that is responsible for the climate variations over the Southeastern Nigeria including Anambra state as the case in other parts of the world.

Information on climate risks communicated timely, in clear and relevant terms and through credible sources is essential for mobilizing decision makers across societies to take action that will enhance their capacity and willingness to adapt to climate change. Umunnakwe *et al.* (2004).

An informed public is better able to prepare for a likely occurrence of climate disaster and thus avert or cope with its attendant effects. There is need for climate change adaptation among rural farmers in Anambra state, to determine the socio economic characteristics of the farmers, investigate their knowledge on climate change, identify the sources of their information on climate change, identify their information needs for climate change adaptation and analyze the socio-economic determinants of the farmers. This has adversely affected crop yield.

2.3 CHALLENGES

Among the major challenges facing the African continent and Southeastern Nigeria in particular, water availability is one of the most troubling. In recent years, the sensitivity and exposure of agriculture to climate variations and changes have been a source of concern to the people and governments of the area.

A rise in temperature of between 1.4^{0}C to 5.8^{0}C by 2100 according to the Intergovernmental Panel on Climate Change, IPCC (2007), will have serious negative effects on the socio-economic well being of the country in the following ways:

- Increase in amount of rains and number of rainy days
- Flooding in the coastal areas occuring at shorter intervals.
- Landslide especially in erosion prone areas.
- High temperatures in the North will cause increased health issue such as meningitis, cataracts, yellow fever etc.
- Increase in desertification.
- Drought which encourage locusts and white flies, which in turn will affect food and water supply.
- High cost of construction especially in the coastal areas.
- Deforestation as a result of people's relocation from the flood affected areas of the coast.
- Change in land use in the coast may have drastic effect on agriculture output and hence livelihood.
- Wildlife will also be affected with possible effect on the entire food chain.

There are two extremes of the expected challenges of climate change in Nigeria viz; increase in rainy and dry seasons with each lasting approximately six months on the average that is April to October and October to March respectively.

In Nigeria, the drought of the 1970s that swept most of the Sahel region of Africa left the region, including Nigeria with general water resource issue. The consequences of that are the low agriculture output, limited water supply and inadequate water reserve for power generation which the region is associated with.

Rainfall in North-West of Nigeria has been observed to be shrinking in its mean value; evaporation is increasing while runoff for Kainji reservoir is decreasing. All these have unfavourable implications on the hydroelectric energy generation as less water is available for most part of the area. Since energy, the economy and the environment are interrelated, there is need for proper management in order to attain meaningful sustainable development (Gbuyiro et al: 2002).

Harrison *et al.* (1998) also pointed out that increase in evaporation as a result of higher temperatures together with changes in precipitation patterns might alter the timing and level of river flows. Reduced precipitation would negatively affect the supply of hydro-electrical power generation in Nigeria, which is sensitive to river flow. There might also be problems related to seasonal aspect of river flow as well as a source of water supply in many parts of Africa. The reduced hydro-electrical power production would also impose economic hardships on the people.

In spite of recent technological and scientific advance, weather is still the most important variable in agriculture and determines the adequacy of food supplies in two major ways; one is through weather hazards to crop and the other is through the control exercised by climate on the type of agriculture feasible or viable in a given area. Climatic parameters have huge influence on all stages of the agricultural production and management, harvesting, storage, transport and marketing. This is obvious is the South-eastern Nigeria. Thus, shift in rainfall pattern affect all stages and consequently, food security.

Slowly changing climatic conditions and more frequently extreme events are likely to threaten food security, reduce their access to freshwater and increase vulnerability to water borne diseases. In recent studies, the world health organization indicated that climate change results in an extra 150,000 deaths and 85 million sicknesses each year by increasing spread of malaria, malnutrition and other ailments.

The effects of climate variability and change ripple throughout the environment and society, touching nearly all aspects of human endeavour and environment. These factors should underlie Nigeria meteorological Agency (NIMET) and researchers mission to observe, understand and predict climate variability and change in Nigeria.

2.4 PROSPECTS

Since the early 1970s, sub-Sahara West Africa has suffered from a prolonged drought that had and continues to have large effects on farming, aviation sector, industrial development, health and electricity (hydropower) as currently witnessed by the country's electricity distribution Firm-Power Holding Company of Nigeria (PHCN).

Better predictions of West Africa Monsoon will have large social and economic benefits. Improved predictions require better understanding of the mechanisms behind West Africa rainfall variation (Bader 2004). Hence, there is need for proper management of climatic phenomena in order to attain meaningful sustainable development.

Observations of global climate related activities have made it possible to document and analyze the behaviour of earth's climate. The Intergovernmental Panel on Climate Change (IPCC) periodically updates the state of scientific understanding with regard to climate science.

Hundreds of scientists worldwide participate in the preparation and review of these reports. One of such IPCC report is titled "Climate Change 2001: The Scientific Basis". Also in 2001, the United States National Research Council (NRC) issued a report on "climate change science: An analysis of some key questions".

The United Nations Framework Convention on Climate Change (UNFCCC) and its associated "Kyoto Protocol" is part of an international effort to stabilize the concentration of greenhouse gases in the atmosphere. A further goal of the convention is to promote sustainable development.

Many climate related research has focused on determining whether the human caused increase in greenhouse gases is the cause of the observed changes in the country's climate. As noted in the report of the IPCC (2001), there is new and stronger evidence that most of the warming observed over the last 50 years is attributed to human activities. The 2001 NRC report, also noted that the change observed over the last several decades are likely mostly due to human activities, but we cannot rule out that some significant part of these change is also a reflection of natural variability.

Various researcher, institution and organizations are working toward understanding the current climate trends. Locally, the few climate specialists have carried out some investigations into regional and national trends to prevent adverse consequences. New models and empirical research have begun to address the societal impacts of climate variability such as disease occurrence and variations in crop yield. For example, the Nigeria Meteorological Agency has acquired digital instruments for effective data collection and establishment of more synoptic and climatological network stations to acquire wide weather data. Weather forecasting is becoming more accurate with the help of satellite simulation compared to some decades ago.

Rainfall is a renewable resource, highly variable in space and time and subject to depletion or enhancement due to both natural and anthropogenic causes (Abaje 2010). Climate is, with particular reference to rainfall known to be changing worldwide and there has been growing concern as to the direction and effects of these changes on settlement and infrastructures (Chaponniere and Smokhtin, 2006). Thus, hydrological resources such as streams, rivers and ponds that are mainly rain fed are adversely affected by climate change. Many people, especially in the rural area of Nigeria depend on river, streams, and rainfall harvest for their water supply in the face of infrastructure challenges.

Climate change has caused a shift in the seasonal variability of weather and climate and thus a shift in the normal timing and length of wet and dry seasons and increase in the seasonal fluctuation of the water bodies. In Nigeria, changing rainfall patterns have been observed by researchers such as Anyadike (2006), Nnaji (2001) and Ulor (2006). Infact, Tarhule (1997) observed unusual change in the occurrences of wet and dry season regime in Sub-Saharan Africa, while annual decadal and inter decadal variations in rainfall have been reported by Anyadike (1993) and Ulor (2006).

These reflect the progress made in the recent year in reducing the uncertainties associated with quantifying the factors that influence climate, along with difficulties in distinguishing between human-induced climate change and natural variability. Underlying recent progress are; a longer and more closely studied temperature record; reconstructions of climate data for the past 1,000years; new estimates of the climate response to natural and anthropogenic forcing; better understanding of the driving forces of the global climate both in the tropics and polar regions and new techniques for the detection of change.

One of the key impacts of global temperature change is the shift in seasonal cycle of hydro-climatic variables. This can have significant impacts on water resources management e.g negative impacts on irrigation, non-energy firm, recreation, flood control, and in stream flow for fish (Hamlet and Lettenmaier, 1999). Knowing these shifts in advance can help water resource managers optimize reservoir operations to meet competing demands such as irrigation, environmental needs and power generation.

Shift in the seasonality of Western US precipitation and stream flows have also been observed (Bradley, 1976; Rajagopalan and Lall, 1995; Lins and Michaels, 1994; Dettinger and Cayan, 1995). In an analysis of hydrological impacts of climate change over west-central Canada, Burn (1994) found a strong shift towards the early occurrence of the spring runoff events, especially in the last 30years. Dettinger and Cayan (1995), observed early flows in association with warmer winters in California.

Cayan *et al.* (2002), documented the early onset of spring in the Western US by examining changes in the blooming of plants and the timing of snow-melt runoff pulses

2.5 SUMMARY

Climate change has been confirmed following the release of the 4th IPCC Assessment report. Africa will be worst hit by the effects of climate change which Nigeria a part is of. So many studies have been carried out both on global and local areas to establish correctly the implication of such anomalies. As already noted, rainfall in sub-Sahara West Africa is on the decrease, evaporation is increasing and temperature is becoming warmer.

Climate variability implies variability in temperature and rainfall and various measures and methods have been used to analyse these trends. The prospect of managing the global climatic environment is high but meaningful efforts are yielding results.

2.6 THEORETICAL FRAMEWORK

There are various methods of measuring precipitation variations. The relative variability and the coefficient of variation methods are commonly used in measurement of rainfall variability (Ayoade, 2004). Inter-annual variations in Africa rainfall are examined using rotated Principal Component Analysis (PCA) applied to anomalies from annual mean as well as seasonal anomalies (Janowiak, 1988).

Although choice of methodology depends on the nature of precipitation modeling being undertaken and also the preference of the researcher, this study adopts simple time-series analysis reported by Nnaji, (2000).

The amount of energy entering and escaping from the earth is a determining factor in climate change. Any changes to that balance (either input or output) will cause a directional change in climate (NOAA, 2002).

Observations have conclusively demonstrated that the atmospheric abundance of greenhouse gases has risen dramatically since the onset of the industrial age. Although many theories have been put forward to explain the nature and causes of climate variation, however, such theories can be grouped in three main categories:

- Terrestrial causes
- Astronomical
- Extraterrestrial causes

TERRESTRIAL CAUSES

These causes include;

- Changes in earth topography of land and water
- Changes in atmospheric chemistry
- Changes in snow and ice cover of the earth

There are several theories that have been put forward to explain the changing distribution of the continents and oceans in the geological history. Some of which are the theory of polar wandering and continental drift and the theory of plate tectonics. The theory of continental drift which was popularized by Alfred Wegner in 1915; this theory suggests that the continental masses have changed in their sizes, shapes and relatives. Positions from the geological history form these theories from which we can deduce that the distribution pattern of land and water over the year has changed.

ASTRONOMICAL

These changes results from the change which occur in the earth's geometry and the effect of these on the radiation balance of the earth atmospheric system and hence climate. These theories try to relate climatic variation to the changing parameters of the earth's orbit around the sun. The parameters include;

- Changes in the eccentricity of the earth's orbit.
- Changes in the tilting of the plane of ecliptic.
- Changes in orbital precession.

The consideration of these parameters produce a single astronomical theory of climate variation called "Milankovitch theory".

EXTRATERRESTRIAL CAUSES

These theories postulate changes in the amount of solar radiation the earth receives as a result of the changes in the solar output. These theories try to explain the causes of global and local climate change in their own background. Subsequently, a change in general circulation of the atmosphere on which climate depends, even though climate involves not only the atmosphere rather the hydrosphere, biosphere, the lithosphere and the cryosphere (Ayoade, 2004).

2.7 CLIMATIC CONTROLS OVER SOUTH-EAST NIGERIA

Nigeria is located in the south-eastern part of West Africa between latitude 4^0N and 14^0N and longitude 3^0E and 14^0E.

Nigeria has a tropical climate with variable rainy and dry seasons, depending on the location. The country has a humid tropical climate type because of its location just north of equator. Nigeria climate condition is characterized by hot and wet condition associated with the movement of the inter-tropical convergence zone (ITCZ) north and south of the equator. Udo, (1976) reported that the climate observed in Nigeria and the eastern states is associated with the apparent movement of the air masses over head sun. These air masses include the tropical maritime air masses, the tropical continental air-mass, the equatorial easterlies and to some extent, the land and the sea breeze may be regarded as the fourth and is limited to the coast. Iloeje (1971).

2.8 FACTORS INFLUENCING CLIMATE OF SOUTH EASTERN NIGERIA

2.8.1 Temperature

Nigeria's latitudinal location within the tropics and the low relief supports high temperature all the year round. The major factors that control the temperature distribution over the southern region of Nigeria are; latitude, insulation and cloud cover.

There is however, a considerable variation in time of the day and the season, with mornings and evenings cooler than the afternoon when the sun is directly over head. In January, temperatures are at a minimum due to the cooling effect of north-east wind, however, in July, temperature is higher but increase towards the north due to greater cloud cover along the coast.

2.8.2 Pressure and air mass

There are two anticyclones that dominate pressure patterns in south-east Nigeria, they include; the Azores anticyclone over north Atlantic off the Azores Island and the St. Helena anticyclones off the Namibian coast. In January the Azores high pressure strengthens and extends up the North to the Sahara. It may be split into two large cells called the parent cell and the other one, the Libyan Desert called Libyan anticyclone.

However, because of the nearness of the equator, a small weak low pressure area develops east of cape Palmas. Like temperature, pressure in Nigeria oscillates north and south in tune with the movement of the thermal equator and is influenced by land mass and water bodies. In June/July when the sun is on the tropic of cancer, or close to it, temperatures are high and pressure drops. Hence, we have the Sahara low-pressure belt which fringes northern Nigeria. In December /January, when the sun has moved south to the tropic of Capricorn, both pressure belt and wind system shift south with it. The Sahara becomes a high pressure zone from where a dry and cold wind (CT air mass) blows from where a northern easterly direction to the low pressure belt in the south east). This dry wind drives northern Nigeria about September/October and gains ground bit by bit on the tropical maritime air mass. By January, it moves to southern coastal fringes thus, extending its influence to over 59% of the country. It starts the retreat by March as the sun move north again on it journey to cancer, being push in turn by the tropical maritime air mass. By June, it is completely out of the country.

These two meet along on the starting plane in the atmosphere called the Inter- tropical convergence zone (ITCZ) whose plane moves northwards and southwards. Along this plane, a cool and erratic air mass called

Equatorial easterlies, blow in the upper atmosphere, but dives down occasionally.

2.8.3 Wind

Wind is a powerful determinant of the air temperature and moisture condition of a place. Wind is an agent of transportation. it could be air in motion (vertical or horizontal). Without wind, tropical area would be intolerably hot, areas in higher latitude would be extremely cold and continental areas would be dry.

Wind provides landmass with vapour which is evaporated over the ocean to land with moisture necessary for precipitation. Rainfall distribution over southern region of Nigeria is mostly affected by the atmospheric circulation.

2.8.4 Inter-tropical Convergence Zone (ITCZ)

The inter-tropical convergence zone (ITCZ) is a boundary of convergence of the two air masses from the northern and the southern hemispheres. Inter-tropical discontinuity (ITD) has been used to describe this feature of tropical weather and climate. It is now established that the boundary zone separating the air masses from the northern and southern hemisphere respectively is neither frontal nor always convergent (Ayoade, 2004). The term inter-tropical discontinuity has been proposed by the

World Meteorological Organization, (WMO) to describe the moisture boundary, particularly on land while on the Ocean surface, the term "inter-tropical convergence zone (ITCZ) is used. ITCZ/ITD varies from region to region depending on such factors as topography and distribution of land and water surfaces among others. Over West Africa, the ITCZ takes the form of low-level south westerl.

0ies which converge with north easterlies (Landsea *et al.* 1992). The most dominant feature in causing precipitation over the continent Africa is the (ITCZ). The general fluctuations of the (ITCZ) are such that by March, the presence of the south-west wind begins to be felt in southern parts of Nigeria triggering the onset of raining season. Further northward migration to the ITCZ in June, the south-west wind becomes dominant bringing all northern Nigeria 13-17% annual rainfall.

In September or October, the ITCZ retreats southward at a faster rate than its northward migration (Olaniran and Sumner, 1989) and enables the North-east air mass to gradually prevail over the region thereby reducing the amount of rainfall in August.

The ITD unfortunately does not gradually move at steady rate or even in a constant direction for a long period of time, rather it fluctuates. The average rate of movement of the ITD ranges from 1.90-4 90 latitude per month.

2.8.5 IMPORTANCE OF THE INTER TROPICAL CONVEGENCE ZONE (ITCZ)

The (ITCZ/ITD) is a significant feature of the tropics and provides a framework for following the south–south motions of the rain producing south-west monsoon winds whose depths and motion influence rainfall amount, duration and distribution. All weather activities take place on the equator side of the ITD in areas located some distance away from the surface position.

The regular oscillations of the ITD are responsible for the sudden appearance of the sun and the associated periodic dry conditions in August, a phenomenon called "August break" experienced only at the southern part of the country. This situation therefore accounts for the bimodal rainfall pattern that is in the south-east. The ITD is thus of climatic importance, for its advancement and retreat always determine the advancement and retreat of tropical maritime (the main rain). Also, its seasonal location is the basis on which a synoptic weather type of the region may be grouped; for example in January and July (half of the year). According to Nicholson (1979), the inter-tropical convergence zone (ITCZ) is a prime factor throughout the southern region of Nigeria.

2.9 CLIMATE TYPES FOUND IN NIGERIA

2.9.1 The tropical Rainforest Climate or the Equatorial Moonsoon

This is designated by the köppen climate classification as “AF” and found in the southern part of the country. This climate is influenced by the moonsoons originating from the South Atlantic Ocean, which is brought into the country by the maritime tropical (MT) air mass, a warm moist sea to land seasonal wind. Its warmth and high humidity gives it a strong tendency to ascend and produce copious rainfall, which is a result of the condensation of water vapour in the rapidly rising air.

The tropical rainforest climate has a very small temperature range. These temperature ranges are almost constant throughout the year. The southern parts of Nigeria experiences heavy and abundant rainfall. These storms are usually convectional in nature due to the region proximately, to the equatorial belt. The annual rainfall received in this region is very high, usually above 2,000mm rainfall totals giving for tropical rainforest climate worldwide. The southern region of Nigeria experiences a double rainfall maxima characterized by two high rainfall peaks, with a short dry season and a longer dry season falling between and after each peaks. The first rainy season being around March and last to the end of July with a peak in June, this rainy season is followed by a short dry season lasting for two to three weeks in August. This break is broken by the 'short rainy season' starting around early September and lasting to mid October with a peak period at the end of September. The ending of short rainy season in October is followed by "Dry season". This period start from late October and lasts till early March with peak dry conditions between early December and late February.

2.9.2 The Tropical Savanna Climate or Tropical Wet and Dry Climate

It is extensive in area and covers most of the western Nigeria to central Nigeria beginning from the tropical rainforest climate boundary in southern Nigeria to the central part of Nigeria, where it exerts enormous influence on the region.

This climate exhibits a well marked rainy season and dry season with a single peak known as the "summer maximum" due to its distance from the equator. Temperatures are above 180◦C throughout the year. Abuja, Nigeria's capital city found in central Nigeria has a temperature range of 18.450◦C to 36.90◦C with single rainfall maxima in September.

The single dry season experienced in this climate in central Nigeria beginning from December to March, is hot and dry with the harmattan wind, a continental tropical (CT) air mass laden with dust from the Sahara Desert prevailing throughout this period.

2.9.3 The Sahel Climate and Tropical Dry Climate

This is the predominant climate type in the northern part of Nigeria. Annual rainfall total are low compared to the southern and central parts of Nigeria. Rainy season in the northern part of Nigeria lasts for only three to four months (June-September). The rest of the year is hot and dry with temperatures climbing as high as 400C

2.9.4 Highland climate and mountain climate

This is found on the highland regions in Nigeria. Highlands with the highland climate in Nigeria are well over 1,520 meters above sea level. Due to their location in the tropics, this elevation is high enough to reach the highlands, mountains and the plateau regions standing above this height, a cool mountain climate.

2.10 RAINFALL DISTRIBUTION ACROSS NIGERIA

Rainfall is the determinant factor of a season as well as the key factor of climate variation in Nigeria as with most tropical lands. It varies widely over short distance and from year to year. Rainfall in the coastal belt and south – east is heavy due to the closeness to the equator.

A part of the coast along the Niger Delta, where the rain season is year round, receives more than 4,000 mm of rain each year. Most country's middle belt where the rain season start in April or may and runs through September or October receives somewhat more rain , due to the its higher elevation. In the dry savannah regions, rainfall is especially variable over distance and time. The region along Nigeria's north-eastern border receivers less than 500mm of rain per year, and the rainy season lasts barely three months.

Apart from the orographic rainfall, rain in most parts of Nigeria is conventional. The morning is bright and sunny because the sun heats the land in the morning and early afternoons and causes conventional current to set a motion. The rising of the warm air triggers of the formation of the cumulus cloud or the thunderstorm cloud in the afternoons and evenings, then torrential downpour occur.

The west part of Nigeria is the coastal region of Niger Delta and the mountainous border with Cameroon on the south-east. Here the annual rainfall exceeds 2,500mm as compared with 1,250mm to 1,500mm in almost everywhere and in some places, it is as low as 600mm. Here, the rain season is rather short and dry period is prolonged. Temperature rises very high in the North during the period of March to May before the arrival of the rainy season but the rainy season may be equally unpleasant because of the higher humidity brought by the moist south westerly winds.

On the coast, high humidity and constant high temperature with very little relief makes the weather rather on comfortable throughout the year. In the north, hour of sunshine average from six hours daily during the rainy season to as many as ten in the dry season. Near the coast, they average about three hours daily in the wettest months to six or seven hours during the driest period of the year.

The fact is that recently there has been profound seasonality change accessioned by the ongoing climate change. The resultant climate belt was observed to show pronounced migration across the country in a north-south direction principally influenced by air mass, the tropical continental (CT) air mass and the tropical maritime (MT) air mass. The tropical maritime air mass which is also known as southwest monsoon wind blow into the country from the south to the north, push the ITCZ above the equator in the northern hemisphere to cause rainy season in the country. The season in West Africa is also conditional by the interplay of those two air masses, again these principal air masses influence and determine the different ecological zones through their influence on rainfall occurrence and length as well as temperature and humidity within this region.

Incessant lightning and thunderstorms as well as very humid condition accompany the rainy months of the country. Apart from the predominant air masses of the tropical maritime (MT) and tropical continental (CT), there are less prominent masses known as tropical easterlies that undercut the MT giving rise to disturbance lines with intense thunderstorm of heavy rains of short duration called “squall lines” characteristic of the beginning and end of rainy season in the country.

In the coastal and south-eastern parts of Nigeria, the rainy season usually begins in February or March as moist Atlantic air known as the south west monsoon invades the country. The beginning of the rain is usually marked by the incidence of high winds and heavy but scattered squall. The scattered quality of the stormy rainfall is especially noticeable in the north in dry years when rain may be abundant in some small areas while other areas are completely dry. Further north, it is usually June or July that the rains really commence. The peaks of the rainy season occurs most from the northern part of Nigeria in August when the air from the Atlantic covers the entire country. The northern location received less rainfall than the southern location. The onset period for the northern stations is May/June while the cessations period is September/October. The northern station have only one peak of rainfall which is in August while the southern stations have April as the onset month and October is their cessations month, with two peaks of rainfall (bimodal pattern) in June/July and September. A period when rainfall ceases within the wet season exists in the south and is referred to as “August break”. This period marks the "August dip in precipitation". Although rarely completely dry, this dip (break) in rainfall which is especially marked in the southern stations can be useful agriculturally. This is because it allows a brief dry period for farming activities like grain harvesting.

From September through November, the North West trade winds generally bring a season of clear skies moderate temperature and lower humidity for most of the country. From December through February however, the north east trade winds blow strongly and it brings with them a load of fine dust (Harmattan).

Given the climatological cycle and the size of the country, there is a consideration range in total annual rainfall across Nigeria, both from South to North and in some regions, from East to West. The highest total precipitation is generally in the south-east along the coast around Bonny (south of Port Harcourt), and east of Calabar where mean annual rainfall is more than 4,000mm. Most of the rest of the south-east receives between 2000mm and 3000mm of rain per year, and the south west (lying farther north) receives lower total rainfall, generally between 1,250mm and 2,500mm per year. Mean annual precipitation at Lagos is about 1,900mm; at Ibadan only 140km north from Lagos mean annual rainfall drops to 1,250mm. Moving north from Ibadan, mean annual rainfall in the west is in the range of 1,200mm to 1,300mm (NIMET).

Rainy seasons decline correspondingly in length as one moves north, with Kano having an average rainy period of 120 days to 130 days, Kastina and Sokoto having rainy season 10days to 20 days shorter. Average annual rainfall in the northern is in the range of 500mm to 750mm.

2.11 CLIMATE SEASON IN NIGERIA

The two air masses are the Tropical maritime (TM) and the Tropical continental (TC). The former is associated with the moisture laden south west winds (South westerlies) which blow from the Atlantic Ocean, while the latter is associated with the dry and dusty north east wind (easterlies) which blows from the Sahara desert. When they inter tropical convergence zone (ITCZ), the zone of convergence of the two air masses is to the south equator, the north east wind prevail over Nigeria, thus producing the dry season conditions. Conversely, with the movement of the ITCZ into the Northern Hemisphere, the rain- bearing south westerlies prevail as far inland as possible to bring rainfall during the wet season. The implication is that there is a prolonged rainy season in the far south, while the far north undergoes long dry periods annually. Nigeria therefore, has two major seasons; the dry season and the wet season, the lengths of which vary from North to South.

The seasonal pattern of climate conditions over Nigeria gives rise to four seasons in the south and two in the North.

2.11.1 Southern Nigeria

The four observed season are:

i. The long Rainy Season

This start in March and lasts to the end on July, with a peak period in June over most parts of southern Nigeria. It is a period of thick clouds and is excessively wet particularly in the Niger Delta and coastal lowlands. It is marked by humidity with values hardly below 85% in most part of forested south.

ii. The short dry season

This is experienced in August for 3-4 weeks. However the real dry period known as the “August break” is generally observed in the last two weeks of August in most parts of southern Nigeria.

iii. The short rainy season

This brief wet period follows the “August break” from early September to mid October, with a peak period at the end of September. The rains are not usually as heavy as those in the long rainy season; although the spatial coverage over southern Nigeria is similar. The two periods of rainfall intensity gives the double maxima phenomenon of the rainy season characteristic of southern Nigeria. The short dry season in August between these two rainy periods allows for harvesting and planting of fast growing varieties of grains, such as Maize.

iv. The long dry season

This period start from late October and last to early March with peak dry conditions between early December and late February. The period witnesses the prevailing influences of the dry and dusty north-east winds as well as “Harmattan” conditions. Vegetation growth is generally hamprred, grasses dry and leaves fall from deciduous trees due to reduced moisture.

2.11.2 Northern Nigeria

The climate condition in the Northern part of Nigeria exhibit only two deferent seasons, namely; a short wet season and a prolonged dry season. Temperature during the day remains constantly high while the humidity is relatively low throughout the year with little or no cloud cover. The two observed seasons are;

i. The Long Dry Season

This period extends from October to mid May with the ITCZ in the southern hemisphere, the north-east winds and their associated easterlies over the Sahara prevail over the country bringing dry conditions. The harmattan period during December-January is more intense and longer in the north than in the south. This is the period of little or no cloud cover resulting in wide diurnal range of temperatures.

ii. The Short Wet Season

The wet season covers a relatively short period from June to September. Both the number of rainy days and the total annual rainfall decrease progressively from the south to north. The rains are generally conventional, heavy and short in the duration and often characterized by the frequent storms. This results in flash floods, and in some places sheet or gully erosion.

The few high plateaus of Jos and Biu, and the Adamawa highlands experience climate conditions which are remarkably different from the generalized dry and wet period in northern Nigeria. Temperatures here are 5-10^{O}C lower due to high altitude than in the surrounding areas. Similarly, the annual rainfall figures are higher than in areas around them, particularly on the windward side.

Nigeria can be broadly divided into the following climate regions;

a. The humid sub-equatorial, in the southern lowlands

b. The hot tropical continental, in the far north

c. The moderate sub-temperate in the high plateau and mountain

d. The hot, wet tropical in the hinterland (the middle belt).

2.12 CLIMATIC ANOMALIES

The little dry season

The irregular oscillation of the ITD is responsible for the sudden appearance of the sun and associated dry conditions in August, a phenomenon called "August break" experienced only at the southern parts of country.

This intermediate dry season that occurs between the two rainy seasons is experienced in Anambra state. Obasi (1992), observed a convectively unstable lower half of the troposphere within this region. The reason for the low rainfall at this period include deflation of the southwest Westerlies implying that they blow almost parallel to the coast and bring little rain, extension of St. Helena's anticyclone over the region, the northward extension of the cool Benguala current and inversion in the south westerly winds. (Nnaji, 2008).

Research conducted in Nigeria shows that rainfall increases from the ITCZ southward and peaks about eight to nine degrees latitude south of the ITCZ. There is a sharp decrease in the ITCZ related rainfall at distances over 100 latitude south of the boundary, and this explains the August little dry season in southern region of Nigeria since it is near the Gulf of Guinea (Ilesanmi, 1971). This little dry season is defined by Obasi

(1965) as occurrence of a minimum in total monthly rainfall in the main summer months. He further noted that this occurrence is simultaneous with low temperatures and roughly from the coast to 10◦N. This anomaly occurs for about three to four weeks in August in the southern region of Nigeria.

Analyzing a possible cause of the little dry season Obasi (1963) observed a convectively stable layer imbedded in a convectively unstable lower half of the troposphere during this season. This shows that the vertically integrated total flux of moisture and total flux by mean streamlines are larger in August, as such the occurrence of the little dry season during this period. It follows that this phenomenon may largely be attributed to the south Atlantic sub-tropical Anti-cyclone pushing equator ward during August period.

The result in that moisture continuity equator demand a moisture transport field which is predominantly convergent in June and divergent in August-a situation consistent with the synoptic patterns. In conclusion, the reasons for the low rainfall at this period include;

1. Deflation of the south-west winds to westerly so that they below almost parallel to the coast and thus bring little rain. The southeast

trade winds of the southern hemisphere have no strength enough to acquire a south west direction.

2. The relative coolness of the sea in August because of the north ward extension of the cool Benguala current.

3. Extension of the St. Helena anticyclone over the region through its peaks in August.

4. Inversion in the south westerly winds. This originates from the curve of the anticyclone, the height increases with distance emerging from the centre of the anticyclone, so that the relative height will occur in August when the anticyclone cell is near Nigeria.

5. The effect of the Tropical Eastern jet stream.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

In this research work, analytical methods were employed with indication on its relevance to producing a qualitative research work.

The designs of this research put into consideration the type of data required, its quality, sources and data analysis method to ensure a quality and reliable result. Thus, careful decisions were made in collecting the rainfall data and other information covering Awka, Anambra State in order to maintain the credibility of this research and its subsequent outcome.

This research methodology employed statistical techniques and other quantitative designs and procedures in data analysis to identify the possibility of any shift in rainfall pattern and to examine significant rainfall months in Awka, Anambra State over the period of forty years (1975-2014).

3.2 TYPES OF DATA REQUIRED

Basically, the relevant data needed for this research is the monthly rainfall data for Awka, Anambra State over the period of 40 years (1975-

2014). This data was obtained from the Nigerian Meteorological Agency (NIMET): Anambra State Meteorological Inspectorate, Awka.

This synoptic station was chosen due to its proximity, reliability and availability of adequate data for the study period. The rainfall data is measured in millimeters (mm) and the data was in a digital format for easy manipulation using microsoft excel, a spreadsheet in the Microsoft programme.

Other needful information was collected from materials and sources such as the internet, textbooks, lecture notes, etc which are relevant in relation to the research.

3.3. DATA QUALITY AND UPDATE

The quality of rainfall data used in this research was affirmed by obtaining adequate and continues monthly rainfall values for the period under study. However, a few cases of missing monthly rainfall values were estimated using the estimation method described in chapter 3.3.1.

There were also cases of trace rainfall. According to the Anambra State meteorological inspectorate, Awka, although trace rainfall as low as 0.1mm was measured by the measuring cylinder, rainfall value below 0.3mm was considered trace and only entered for record purposes.

At the NIMET synoptic station, Awka, observations are made at fixed observing hour's intervals. The main synoptic hours internationally agreed upon are 0000 hours (midnight), 0600 hours 1200hours and 1800 hours Greenwich Mean Time (GMT).

These stations are manned by full-time professional observers who maintain continuous weather watch and make hourly instrumental observation of the weather elements on which information is required for the compilation of the synoptic charts or weather forecasting.

NIMET, Awka carries out additional observations at other time between the four main periods often hourly or at three-hour intervals. This data is sent to various centres/stations such as airports for safety and effective flight operations. Thus, there is need for carefulness to guarantee accuracy in data collection.

3.3.1 ESTIMATION OF DATA

The obtained data from NIMET, Awka has three missing data; November 2005, April 2006 and November 2006. The decision to further estimate any missing values is based on three criteria.

i. Any station where the seasonal total for any year has more than one- third missing value or where the gap in record for any given year exceeds two months that year is excluded from the analysis.

The reason is to avoid analysis based on data with high levels of estimated values.

ii. If a given year has two missing monthly values or less, the year average for the respective month is used.

iii. Any further missing value is estimated from the series using the Normal Ratio Method (NR).

This approach was formulated by Paulus and Kohler (1952) and recently used by Gessler (1995), Nnaji (1995) and Okorie (2015)

In this research, a total of three monthly values were missing and a given year had not more than two missing values, thereby making the use of the second approach, "if a given year has two missing monthly values or less the 30-year average for the respective month is used" appropriate. This criterion was then applied in updating observed missing values.

3.4 ANALYTICAL METHOD

In analyzing the rainfall data of Awka over a forty years period, simple statistical techniques such as arithmetic mean was employed to derive mean annual and monthly rainfall, it also enable decadal results to be computed clearly at a glance. Graphs such as line graph were also used to plot rainfall values over time. The analysis was also done to address the stated objectives.

The chi-square was also used to test the hypothesis to check if there was a shift in rainfall pattern. These graphical representations were carried out using the Microsoft Excel.

3.4.1 LINE GRAPH

Line graphs were used in this research to show shifts in rainfall pattern, these line graphs were grouped for easy analysis. The groups include;

i. Annual rainfall line graphs

   The monthly rainfall values in each year for the forty years period were plotted giving rise to a total forty line graph

ii. Decadal annual mean line graphs

   The average rainfall value for each year were plotted decade by giving rise to four line graph

iii. Decadal monthly mean

   The average rainfall values for each of the twelve months in each decade were plotted in four line graphs.

iv. Mean annual rainfall line graph

   The mean rainfall values for each of the forty years were plotted in one line graph.

v. Mean monthly rainfall line graph.

The mean rainfall values for each of the twelve months throughout the forty years period were plotted in one line graph.

vi. Mean of ten wettest and ten driest years.

The mean rainfall values of the ten wettest and ten driest years were plotted in different graphs.

There are a total number of fifty-two (52) line graphs.

3.4.2 THE CHI-SQUARE (X^2)

A chi-square is a non-parametric method used to analyze the observed and expected events such as rainfall. It is used to determine whether there is a significant difference between the expected frequencies and the observed frequencies. It is employed in this research to test the null hypothesis that there is no shift in bimodal rainfall pattern in Awka, Anambra State over a forty year period (1975-2014).

Chi-square, X^2

$$X^2 = \sum \frac{(O_R - E_R)^2}{E_R}$$

Where O_R= the observed rainfall outcomes

E_R= the expected rainfall outcomes

$\sum$ = the sign of summation

For further analysis using the critical value or chi-square tabulated, X^2_t, we deduce

$D_f = (r-1)(C-1)$

Where D_f = degree of freedom

r = the number of rows

c = the number of columns

Alpha (σ) = the level of significance or confidence limit (0.05, 0.01 and 0.001).

If the calculated value of the chi-square is greater than the tabulated (critical) value, the null hypothesis, Ho is rejected and it is concluded that there is no significant shift in rainfall pattern in Awka, Anambra state over the study period.

CHAPTER FOUR

DATA ANALYSIS AND RESULT PRESENTATION

4.1 INTRODUCTION

This chapter deals with data analysis, result presentation and findings. The analysis of data was performed based on the methodology of data analysis dealt in chapter three. Thus, the subsections below include all analysis, observations, findings and result interpretation of the rainfall data with the intention of realizing the aim of the research.

Observation of rainfall pattern was made for shifting seasonality in its bimodal regime, onset and retreat, and the little dry season. This analysis was done bearing in mind the fact that Awka, Anambra State observes four seasons annually, the long rainy season, the short/little dry season, the short rainy season and the long dry season. The two periods of rainfall intensity gave the double maxima phenomenon (bimodal pattern) of the rainy season characteristic of southern Nigeria.

4.2 DATA ANALYSIS

i. **Annual Rainfall Line Graphs:** Here, the monthly rainfall values in each year for the forty years period were plotted giving a total of forty annual rainfall line graphs. These graphs revealed monthly rainfall fluctuations each year, with regards to its bimodal regime, onset and retreat months and a little dry season.

ii. **Decadal Annual Mean Line Graphs:** The forty year period was analyzed in decades giving rise to four decades; 1975-1984, 1985-1994, 1995-2004, 2005-2014.

The average rainfall value for each year was plotted decade by decade giving rise to four line graphs. This revealed the fluctuations of rainfall for each decade.

iii. **Decadal Monthly Mean Line Graphs:** Here, the forty year period was analyzed in decades giving rise to four decades, 1975-1984, 1985-1994, 1995-2004, and 2005-2014. The average rainfall values for each of the twelve months in each decade were plotted, giving rise to four line graphs. This showed rainfall trends in its bimodal regime, onset and retreat months and the little dry season.

iv. **Mean Annual Rainfall Line Graph:** The mean rainfall values for each of the forty years were plotted in one line graph. This graph shows rainfall trend in the average annual rainfall for the forty years.

v. **Mean Monthly Rainfall Line Graph:** The mean rainfall values for each of the twelve months throughout the forty years period were plotted in one line graph. This also revealed seasonality shifts in its bimodal regime, onset and retreat months and the little dry season.

vi. **Mean of Ten Wettest and Ten Driest Years**: The mean rainfall values of the ten wettest and ten driest years were plotted in different graphs. This revealed the years that contributed most to inter annual variability.

There is a total number of fifty-two (52) line graphs which clearly show shifting seasonality over the forty year period.

4.2.1 ANNUAL RAINFALL ANALYSIS

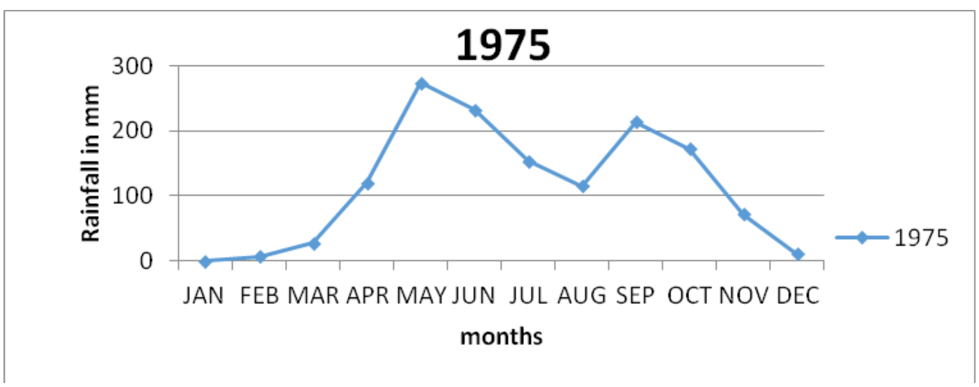

Figure 4.1: Annual rainfall analysis for 1975

Rainfall distribution was observed throughout the year except January at 0; however, its onset was in the month of April with a value of 120.4mm. The month of May had the highest rainfall occurrence in the year at 273.8mm after which there was a decline till August at 115.4mm, which marked the little dry season. The second wet period recorded its peak rainfall in September at 213.5mm, thereafter, there was a downward trend and its retreat was in the month of November with a value of 71.7mm. In this year, there was a clear presence of bimodal regime. February month recorded the lowest rainfall and the total and average rainfall was 1397.1mm and 116.4mm respectively, thus, it's the year with the lowest rainfall throughout the forty year period.

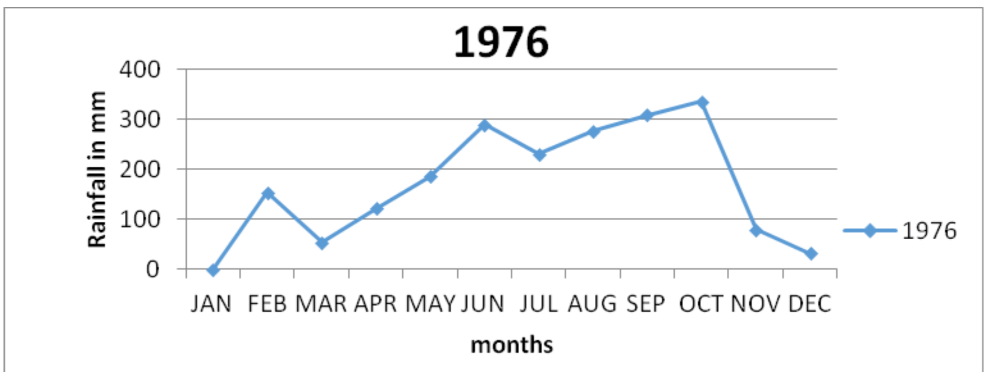

Figure 4.2: Annual rainfall analysis for 1976

There was an increase in the total and average rainfall for the year to 2067.7mm and 172.3mm respectively. The rainfall trend for this year had its onset in the month of February at 153.2mm; it kept on fluctuating until it got to its peak in the month of June at 290.3mm. The little dry season occurred in July at 230.4mm and it kept increasing until it got to the peak of the second wet period at 335.5mm in October, this month recorded the highest rainfall for the year until its retreat in

November at 71.7mm. 1976 recorded the highest February rainfall throughout the forty years period at 153.2mm and the third highest November rainfall at 79.7mm.There was a trimodal regime of rainfall.

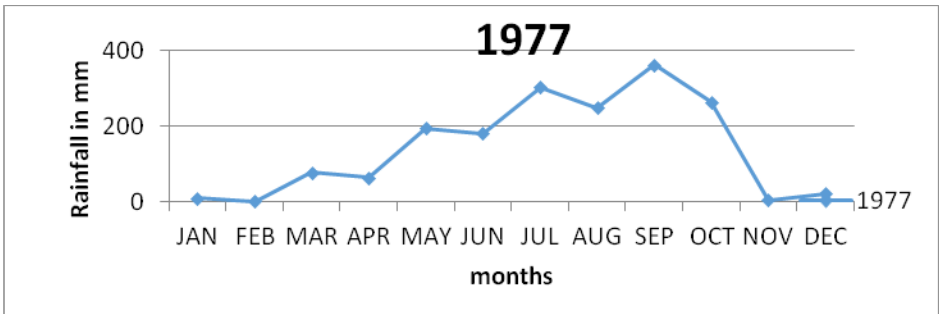

Figure 4.3: Annual rainfall analysis for 1977

From this figure, the distribution of rainfall for this year was not stable; however, the onset of rainfall was in the fifth month, May at 194.1mm. This kept on increasing and decreasing until it got to a peak in the month of July with a value of 303.4mm. There was a declination in August, showing the little dry season at 248.6mm. Hereafter, there was a sharp increase in rainfall at 362.3mm in September giving rise to the highest rainfall occurrence for the year. Rainfall retreat was evident in October at 264.5mm. The total and average rainfall was 1728.9mm and 144.1mm respectively. The regime of rainfall was trimodal

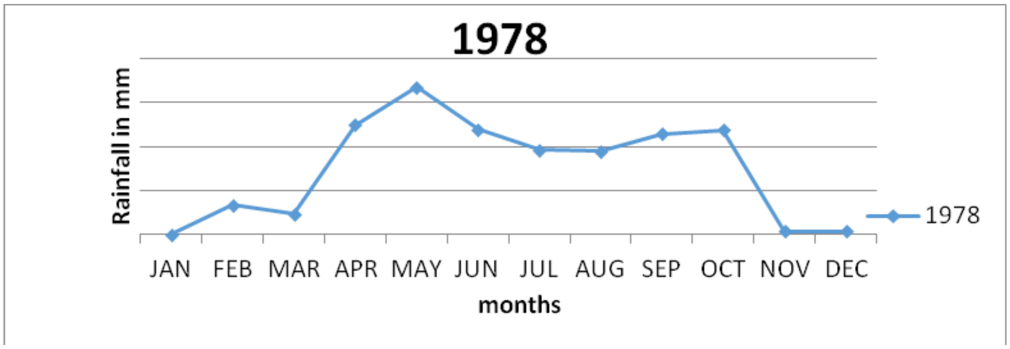

Figure 4.4: Annual rainfall analysis for 1978

The onset of rainfall for this year occurred in April at 248.4mm. The month of May recorded the highest rainfall at 334.9mm, after which the rain declined to the little dry season in August at 189.6mm, rainfall increased weekly to 236.8mm in October which was also the month of retreat. There was a bimodal regime of rainfall even though the second peak was weak. The total and average rainfall for the year increased slightly to 1799.3mm and 149.9mm respectively.

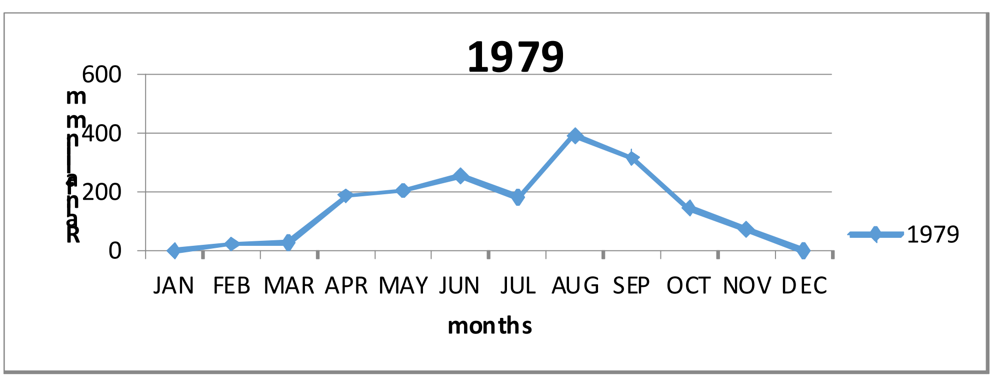

Figure 4.5: Annual rainfall analysis for 1979

The year 1979 had an increased rainfall with total and average values at 1812.7mm and 151.1mm respectively. Its onset was in the month of April at 189.2mm, this increased gradually until there was a decrease in July at 182.5mm which marked the little dry season. A sharp increase occurred in August month at 392.6mm, being the highest rainfall month of the year. Rainfall retreat occurred in October at a value of 146.1mm. This year recorded the third highest August month rainfall at 392.6mm throughout the study period. There was still a bimodal regime of rainfall.

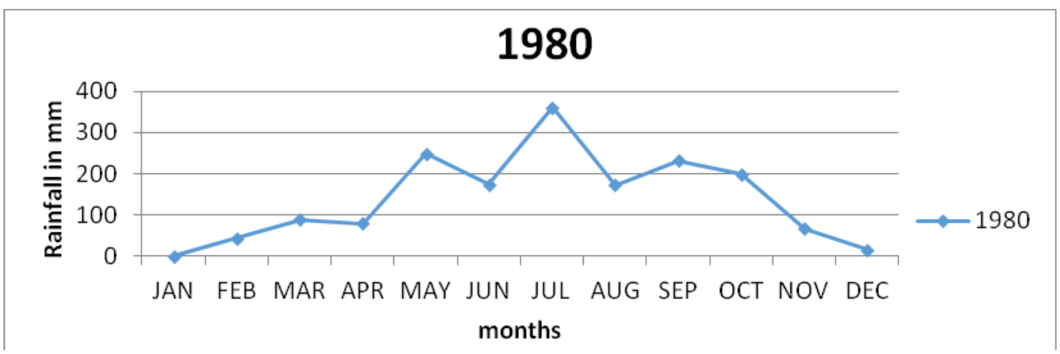

Figure 4.6: Annual rainfall analysis for 1980

The year experienced a drop in rainfall with total and average rainfall at 1683.3mm and 140.3mm respectively. The onset of the rain occurred in the May at 249.3mm; this dropped in June at 174mm and climbed to 361mm in July having the highest rainfall. In August, it dropped again to 173.3mm which marked the little dry season. Rainfall retreat occurred in November at 67.1mm. There was a trimodal regime of rainfall.

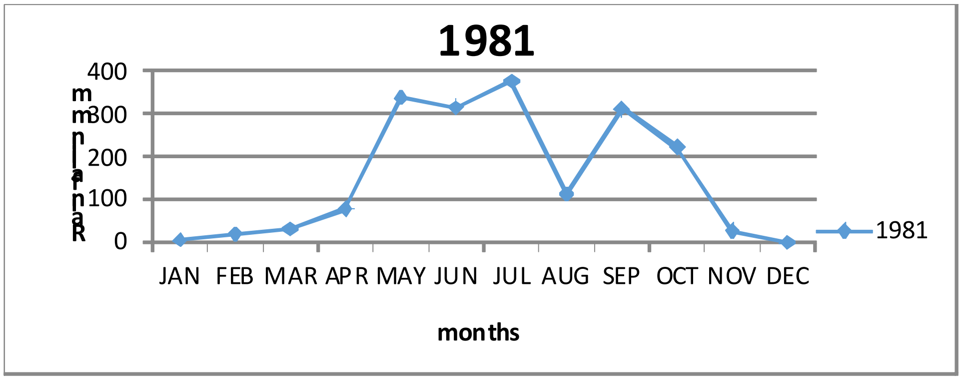

Figure 4.7: Annual rainfall analysis for 1981

From fig 7, the onset of rainfall occurred in May at 337.3mm. July recorded the highest rainfall at 375.7mm after which there was a sharp declination in August which marked the little dry season. This increased to the second wet period in September at 311.8mm. October recorded the month of retreat. This year had the third highest may rainfall in 40years period at 337.3mm. There was a bimodal regime of rainfall. The total and average rainfall increased to 1842.1mm and 153.5mm respectively.

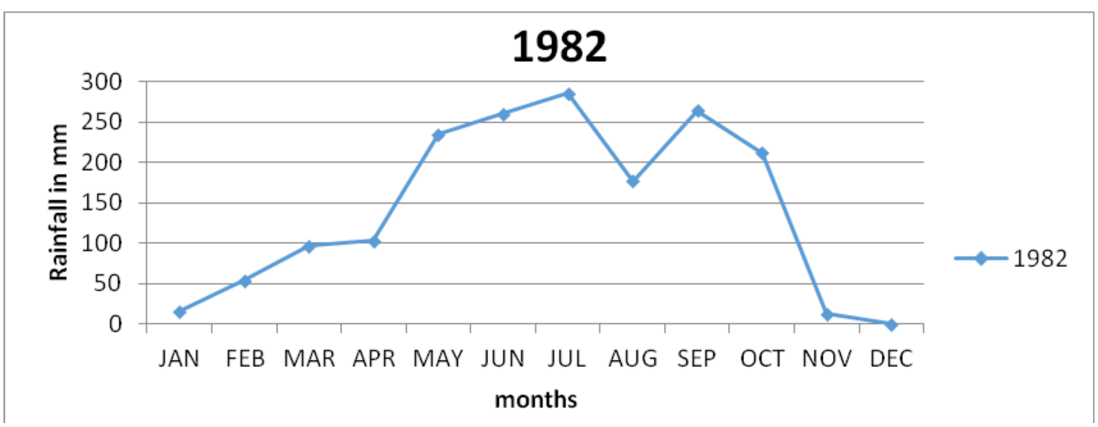

Figure 4.8: Annual rainfall analysis for 1982

In this year, the total and average rainfall was 1715.7mm and 142.8mm respectively. The onset of rainfall for this year occurred in April at 103.1mm, after which it increased progressively to its peak in July with a value of 285.2mm. There was a significant little dry season in August at 177mm and the second wet period began in September at 264.3mm. Rainfall retreat occurred in October at 211.5mm. There was a bimodal regime of rainfall.

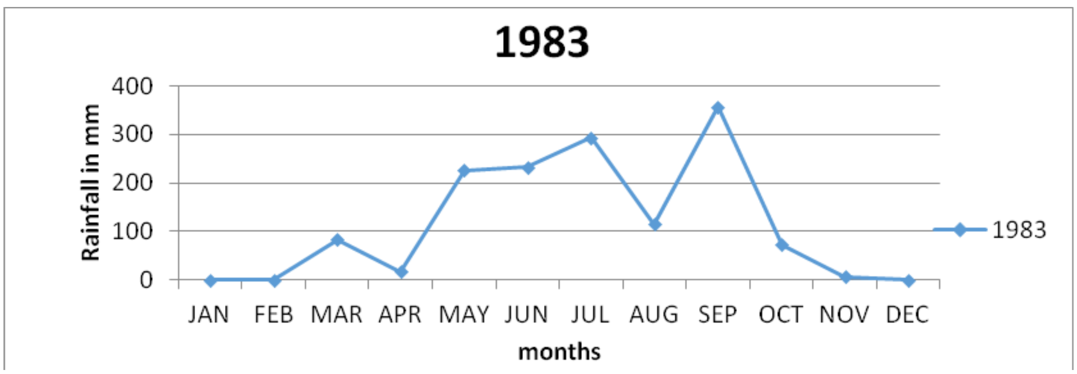

Figure 4.9: Annual rainfall analysis for 1983

This year experienced a decline in rainfall having its total and average at 1403.5mm and 116.9mm respectively. The onset of the rains occurred in May at 225.8mm, this increased slowly and then dropped in August at 114.4mm, this clearly showed the little dry season. In September, there was a rise in rainfall at 357.5mm which was the wettest month, after which rainfall retreats. This year recorded the lowest October rainfall at 72.4mm throughout the period. There was a bimodal regime of rainfall.

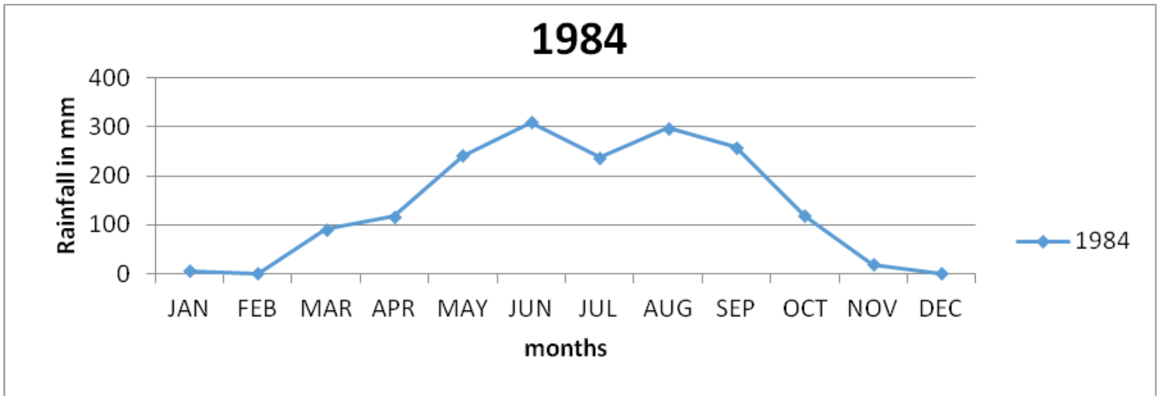

Figure 4.10: Annual rainfall analysis for 1984

In this year, total and average rainfall increased to 1693.3mm and 141.1mm respectively. Onset of rainfall occurred in April at 116.6mm. Rainfall got to its peak in June at309.6mm being the wettest month of the year. July experienced a drop in rainfall at 237.1mm which marked the little dry season. The rain increased in August at 297.4mm which is usually a lower rainfall month. Rainfall retreat occurred in October at 117.9mm. There was a clear evidence of the bimodal regime of rainfall.

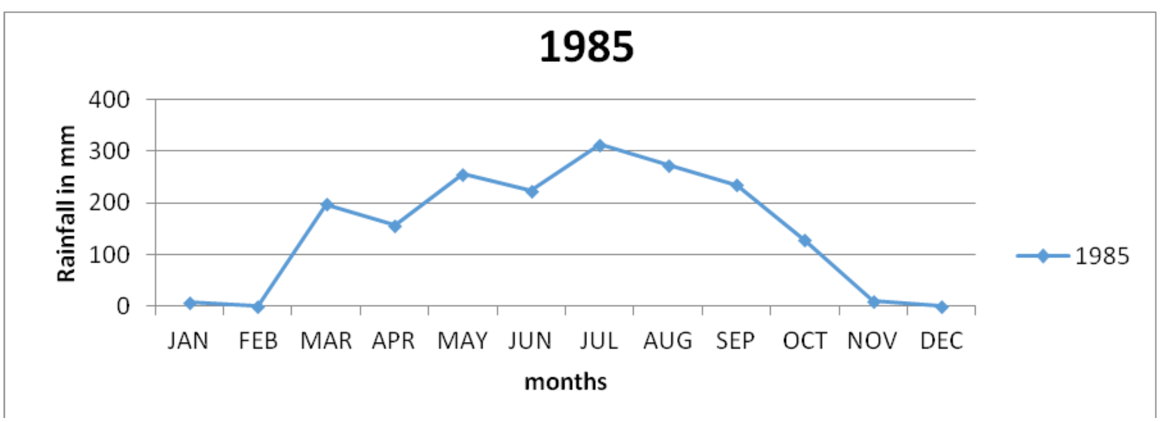

Figure 4.11: Annual rainfall analysis for 1985

In fig.11, rainfall onset occurred in March at 197.3mm in March. It kept dropping and rising until there was a drop which marked the little dry season in June. In July, it climbed to 312.2 mm which was the highest rainfall month. In October, rainfall retreat was experienced at 127.2 mm. This year recorded the highest rainfall value for March throughout the study period at 197.3 mm. There was a trimodal regime of rainfall. The total and average rainfall was 1796.2 mm and 149.7 mm respectively.

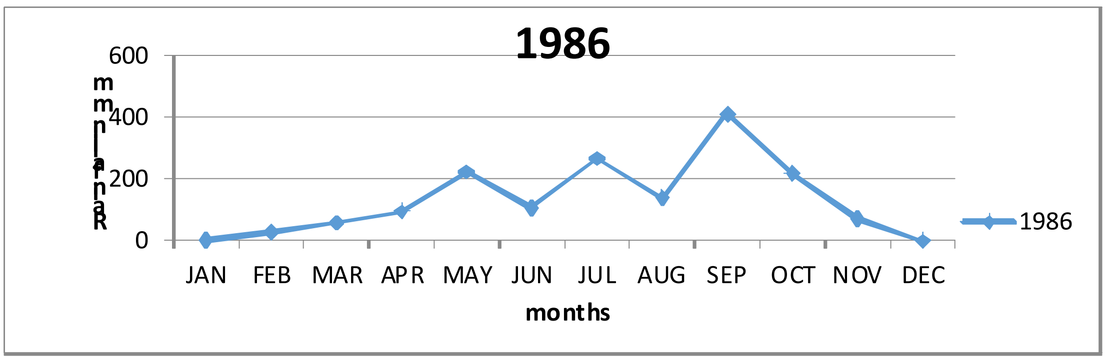

Figure 4.12: Annual rainfall analysis for 1986

In 1986, rainfall distribution was not steady. Its onset occurred in May at 222.7 mm. There were close declines in June and August, but June had the least drop, thus the little dry season. The rain increased in September at 410.2 mm being the wettest month. October experienced rainfall retreat at 216.9 mm. June recorded the lowest rainfall at 107 mm throughout. There was a trimodal regime of rainfall. The total and average rainfall was 1615.3 mm and 134.6 mm respectively.

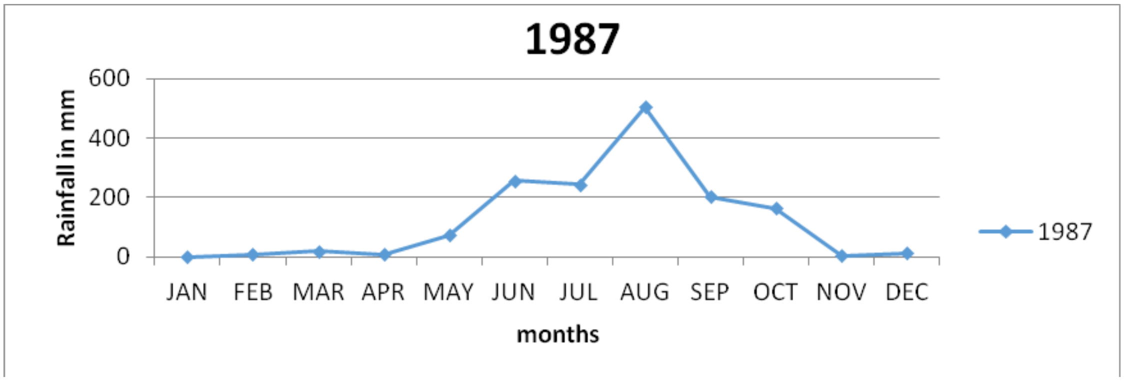

Figure 4.13: Annual rainfall analysis for 1987

From fig. 13, rainfall onset was late in June at 257.2 mm. Its peak occurred in August at 505.4 mm with a clear gap ahead of other months. In September, there was a sharp decrease showing the little dry season. The retreat occurred in October at 163.4 mm. This year had the second highest August rainfall at 505.4 mm, the lowest April rainfall at 8.1 mm and the lowest May rainfall at 72.8 mm. There was a bimodal regime of rainfall even though the first peak was low. Total and average rainfall was 1501.4 mm and 125.1 mm respectively.

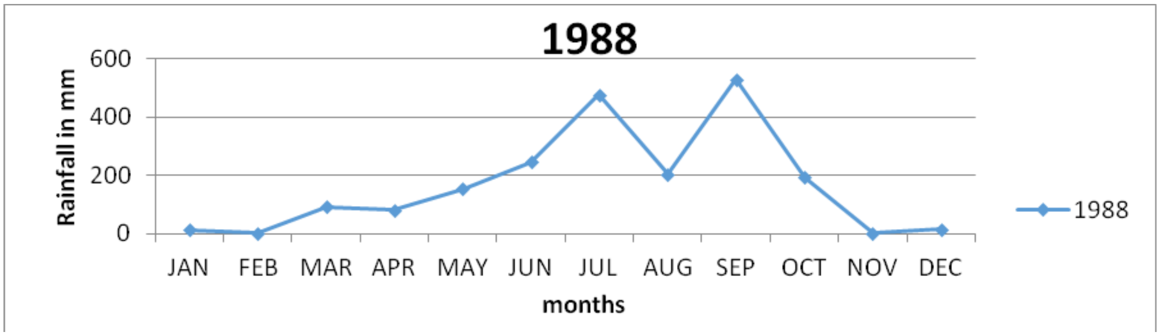

Figure 4.14: Annual rainfall analysis for 1988

In this year, total and average rainfall increased to 2007 mm and 167.25 mm respectively. The onset of rainfall occurred in May at 154.4mm, it declined in August at 204.6 mm which was the little dry season. In September, it increased to 529.7 mm being the wettest month of the year. The retreat of rainfall happened in October at 192.1 mm. This year recorded the highest July rainfall at 478.2 mm and the second highest September rainfall value at 529.7 mm throughout the 40 year period. There was a clear bimodal regime of rainfall.

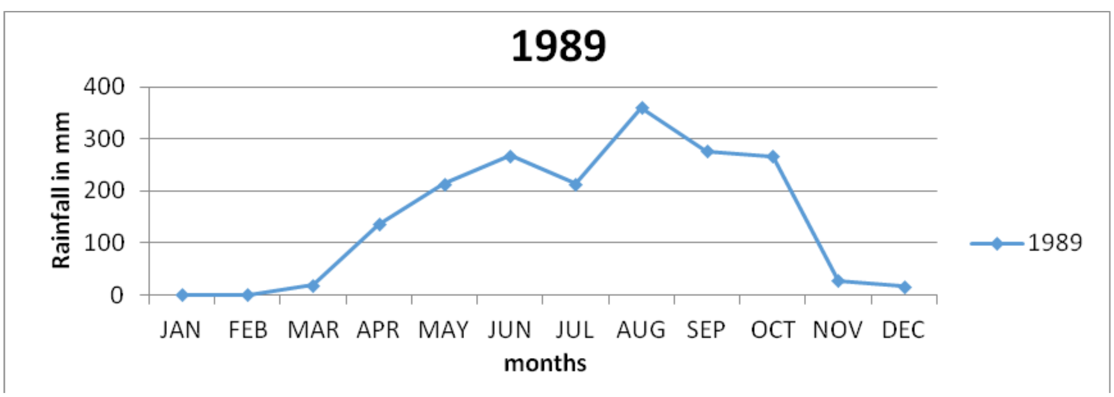

Figure 4.15: Annual rainfall analysis for 1989

From this figure above, rainfall onset occurred in April at 135.8mm, it dropped in July at a value of 213.3mm which marked the little dry season. In August, the rainfall increased sharply to 360.8mm being the highest rainfall month of the year. Its retreat occurred in the month of October at 267.2mm. There was a bimodal regime of rainfall, the total and average rainfall decreased to 1798.4mm and 149.9mm respectively.

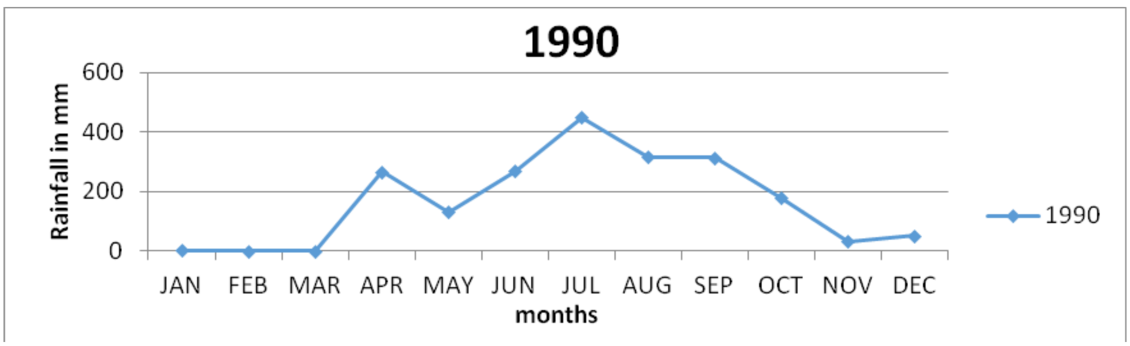

Figure 4.16: Annual rainfall analysis for 1990

From Fig 16, onset of rainfall was quite sudden at 266.6mm in April. It declined in May at 131.9mm which is where the little dry season took place. Afterwards, the rains increased until it got to its peak in July at 449.3mm and it declined. Its retreat was in October at a value of 179.3mm. This year had the highest December rainfall at 52.5mm. Once again, there was a bimodal regime of rainfall. The total and average rainfall for the year increased to 2009.6mm and 167.5mm respectively.

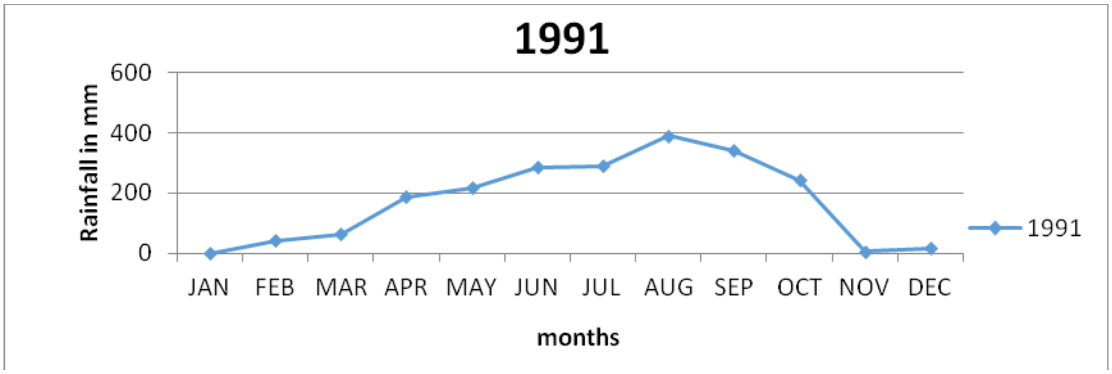

Figure 4.17: Annual rainfall analysis for 1991

In this year, rainfall onset occurred in April at 186.3mm and kept ascending until it got to its peak in August at 390.4mm, this was quite unusual. It declined until its retreat in October at 243.1mm. The presence of the little dry season was not visible, thus, a unimodal rainfall regime and an increase in the total and average rainfall at 2083.4mm and 173.6mm respectively. August recorded the wettest month with a value of 390.4mm.

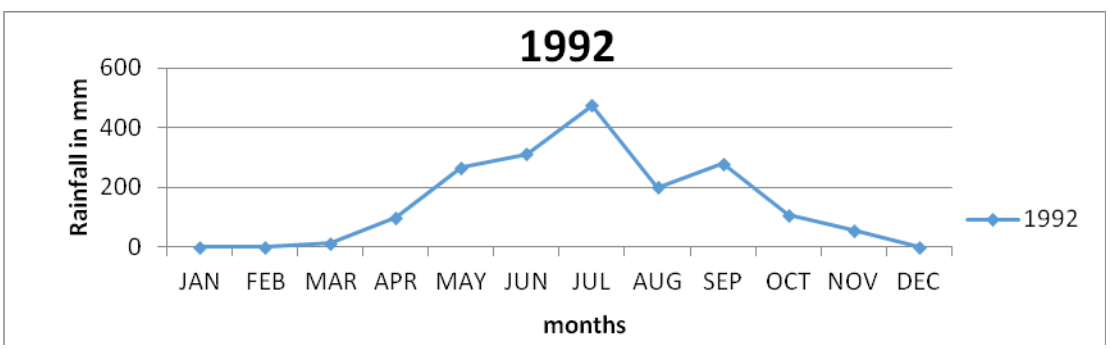

Figure 4.18: Annual rainfall analysis for 1992

Here, total and average rainfall decreased to 1810.9mm and 150.9mm respectively. Its onset was in May at 266mm, it kept rising until it attained its peak in July at 475.6mm and dropped in August at 200.4mm which marked the little dry season. Rainfall retreat occurred in October at 107.9mm. This year recorded the second highest July rainfall at 475.6mm throughout. There was a bimodal regime of rainfall.

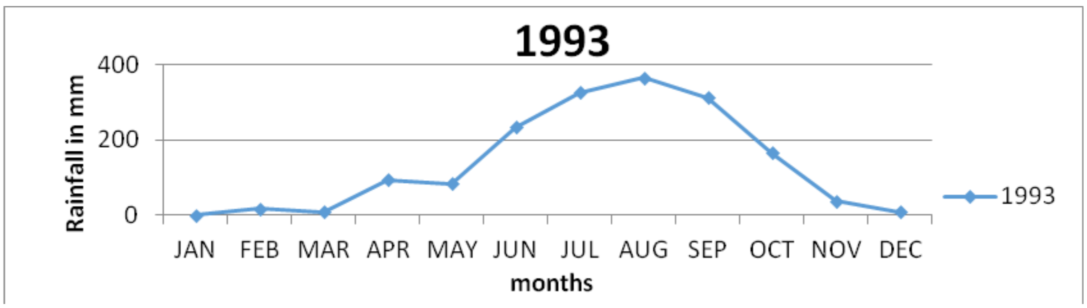

Figure 4.19: Annual rainfall analysis for 1993

The onset of rainfall took place late in June at 234.3mm, this brought about a decrease in the total and average rainfall with at 1654.2mm and 137.9mm respectively. It reached its peak in August at 364.1mm. Its retreat was seen in October at 166.3mm. The regime of rainfall was unimodal, hence there was no little dry season. August recorded the highest rainfall at a value of 304.1mm.

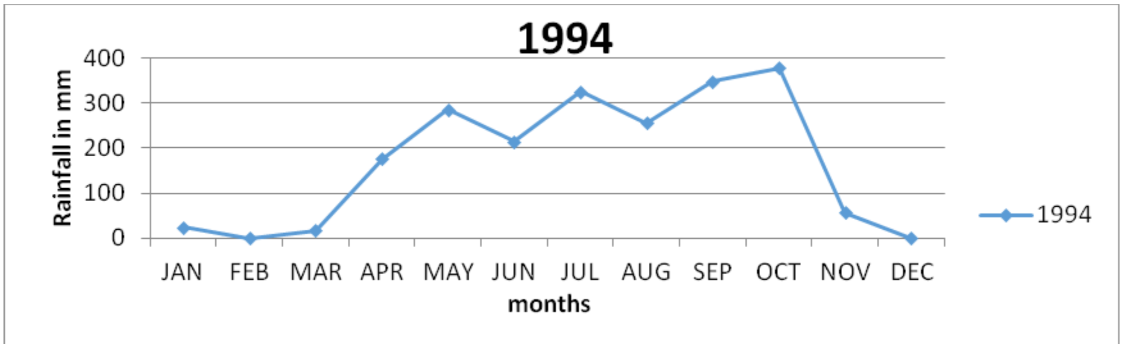

Figure 4.20: Annual rainfall analysis for 1994

This year had an increase in total and average rainfall at 2018.7mm and 173.5mm respectively but its distribution was fluctuating. Onset occurred in April at 175.5mm after which there was rise and falls. There was a little dry season in August at 256mm between the two peaks of rainfall. October was the wettest month of the year at 377.7mm and also the month of retreat. The rainfall regime was trimodal.

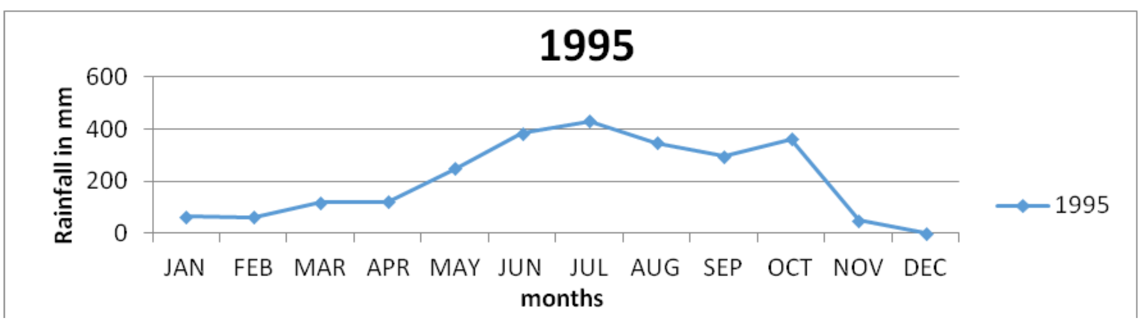

Figure 4.21: Annual rainfall analysis for 1995

1995 had the highest rainfall throughout the forty-year period at total and average rainfall of 2478.5mm and 206.5mm respectively. There was rainfall distribution throughout, but onset was in March at 118mm; its peak was in July at 429.4mm. The little dry season occurred in August at 347.7mm and extended to September, its retreat occurred in October. This year recorded the second highest January and June rainfall at 64.1mm and 382.7mm respectively. The rainfall regime was bimodal.

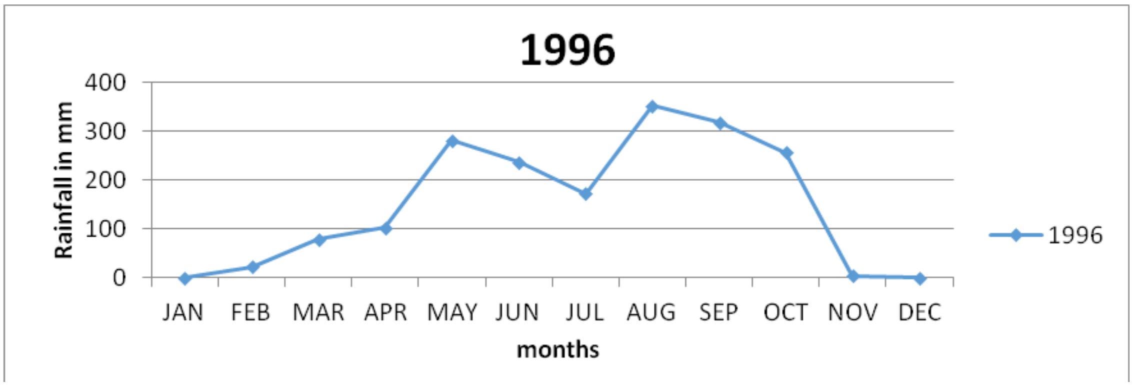

Figure 4.22: Annual rainfall analysis for 1996

This year experienced a reduced rainfall with total and average rainfall at 1826.7mm and 152.2mm respectively. Rainfall increased continuously with its onset in April at 103.1mm. July experienced the little dry season at 171.9mm after which rainfall increased sharply in August at 352.4mm making it the wettest month of the year. Rainfall retreat occurred in October at 256.3mm. There was a clear evidence of bimodal regime of rainfall.

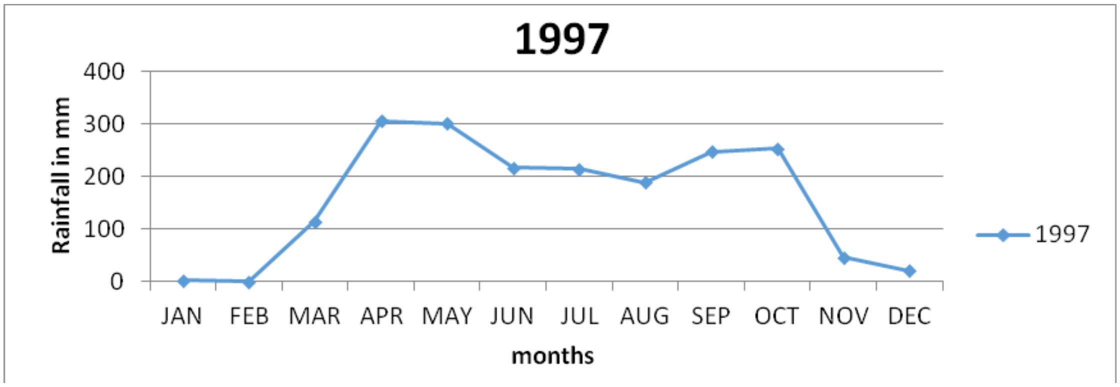

Figure 4.23: Annual rainfall analysis for 1997

In 1997, onset of rainfall occurred in March at 114.2mm and increased to its peak in April at 305.7mm which was quite unusual. This value dropped to 188.5mm in August which marked the little dry season after which the second wet period began. In October at a value of 252.7mm rainfall retreat occurred. This year experienced the second highest April rainfall value at 305.7mm. The rainfall regime was bimodal. Total and average rainfall value was 190.7mm and 158.9mm respectively.

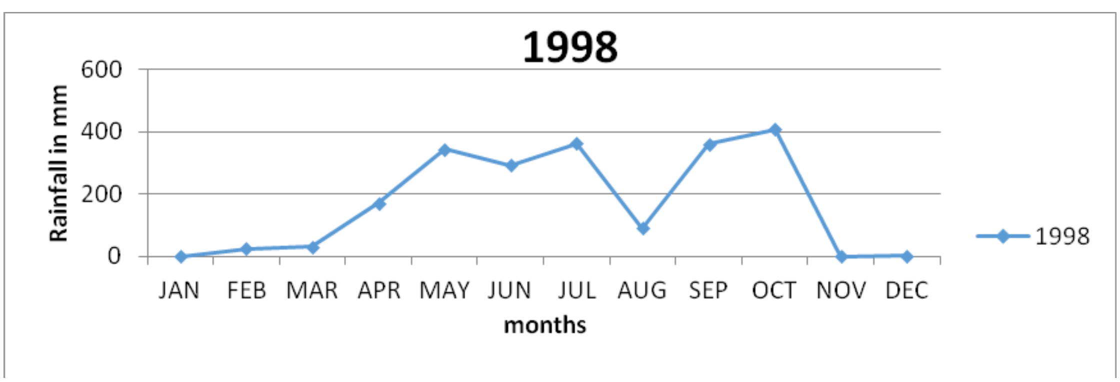

Figure 4.24: Annual rainfall analysis for 1998

This year experienced an increase in rainfall amount. Onset occurred in April at 170.5mm, it declined in August at 91.2mm, which was the lowest August value ever, making the little dry season very obvious. Rainfall peak was in October at 407.1mm; this was the highest October rainfall. This year also recorded the lowest November rainfall at 0.5mm. The total and average rainfall value was 2086.2mm and 173.9mm respectively, the rainfall regime was bimodal.

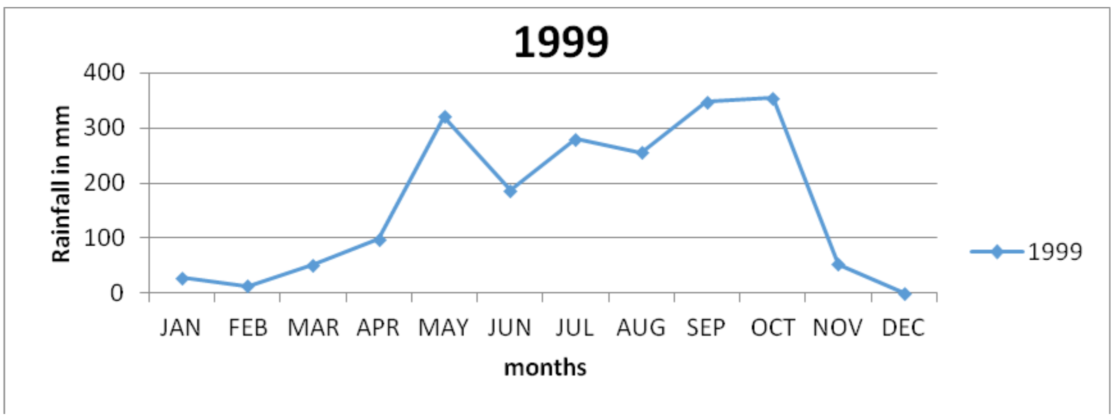

Figure 4.25: Annual rainfall analysis for 1999

From fig. 25, rainfall began early in January but its onset occurred in May at a high value of 320.9mm. The little dry season occurred a little bit early in June with a value of 186.2mm, the second wet period began reaching its peak at 353.9mm in October, which was the wettest month of the year this was also the month of retreat. The total and average rainfall was at 1988.1mm and 165.7mm respectively. The regime of rainfall was bimodal.

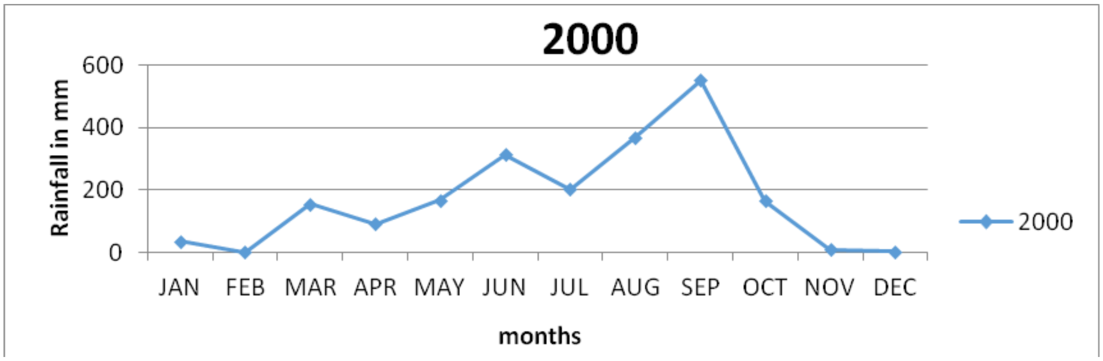

Figure 4.26: Annual rainfall analysis for 2000

Onset of rainfall occurred in March at 155.2mm however, rainfall for this year was not steady. The little dry season was seen in July at 201.2mm, rainfall peak was in September at 550.6mm which was the wettest month throughout the study. Rainfall retreat occurred in October at 109.9mm. This year also had the second highest March rainfall value at 155.2mm. The total and average rainfall was 2060.5mm and 171.7mm respectively while there was a bimodal regime of rainfall.

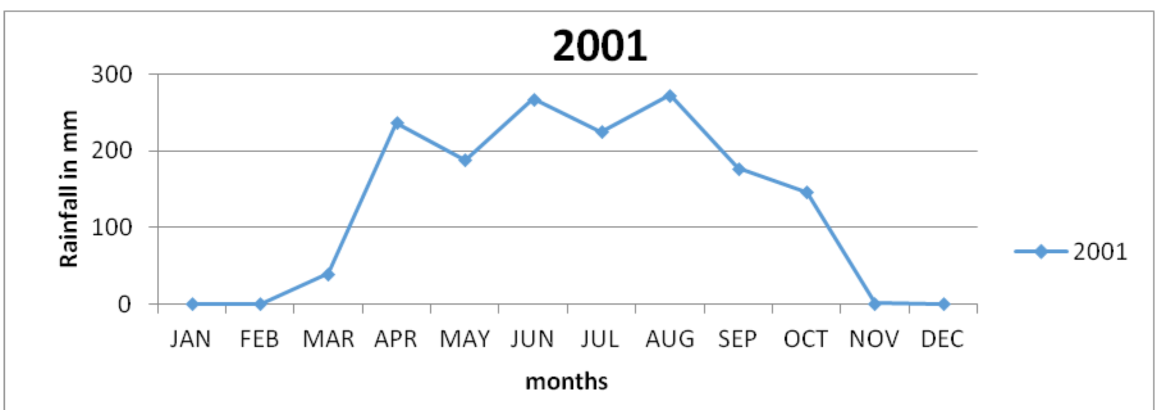

Figure 4.27: Annual rainfall analysis for 2001

The total and average rainfall value decreased to 1556.2mm and 129.2mm respectively. Onset of the rains took place in April at 236.9mm and kept rising and falling until it got to its peak in August at 272.8mm. The little dry season occurred in September at 177.2mm and rainfall retreat was in October at 146.3mm. There was a bimodal regime of rainfall.

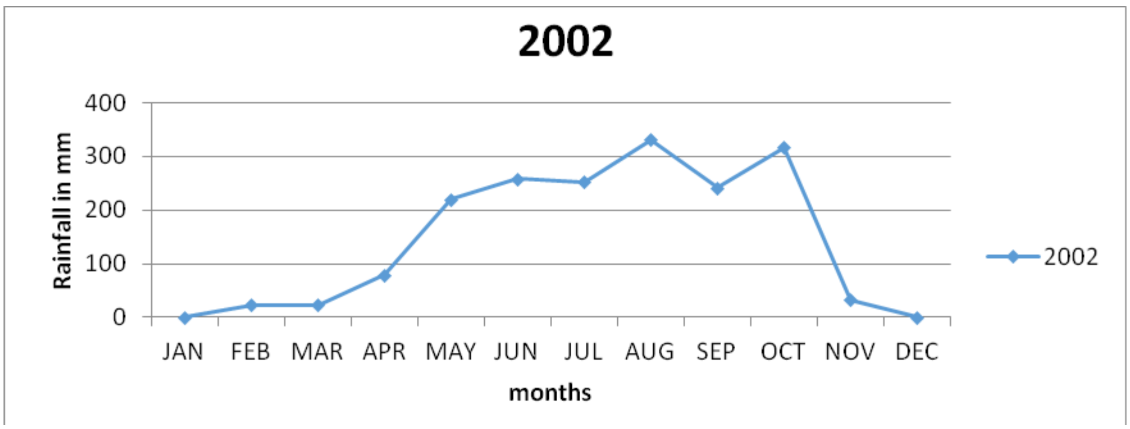

Figure 4.28: Annual rainfall analysis for 2002

In 2002, rainfall distribution increased gradually however, its onset occurred in may at 220.7mm August was the highest rainfall month of the year at 330.9mm and again, the little dry season was seen in the month of September at242.1mm and the second wet period started in October at 316.4mm and also marked the month of rainfall retreat. The total and average rainfall value was 1777.3mm and 148.1mm respectively. There was a bimodal regime of rainfall.

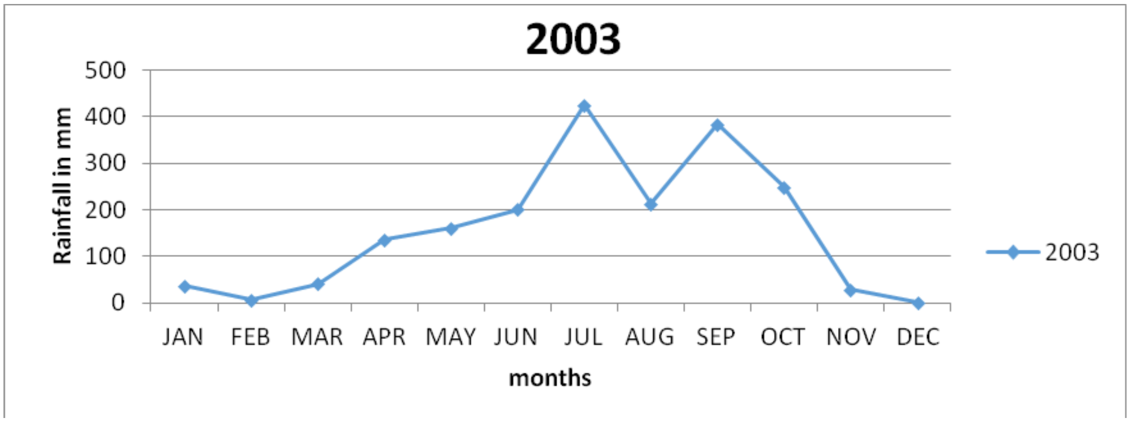

Figure 4.29: Annual rainfall analysis for 2003

There was a general distribution of rainfall throughout the year however, its onset occurred in April at 136.1mm, this increased until it reached its peak in July at 425.4mm this was the wettest month. Rainfall declined in August at 212.5mm which was the little dry season while October was the month of retreat. There was a clear bimodal regime of rainfall. Total and average rainfall was at 1882.4 and 156.9mm respectively.

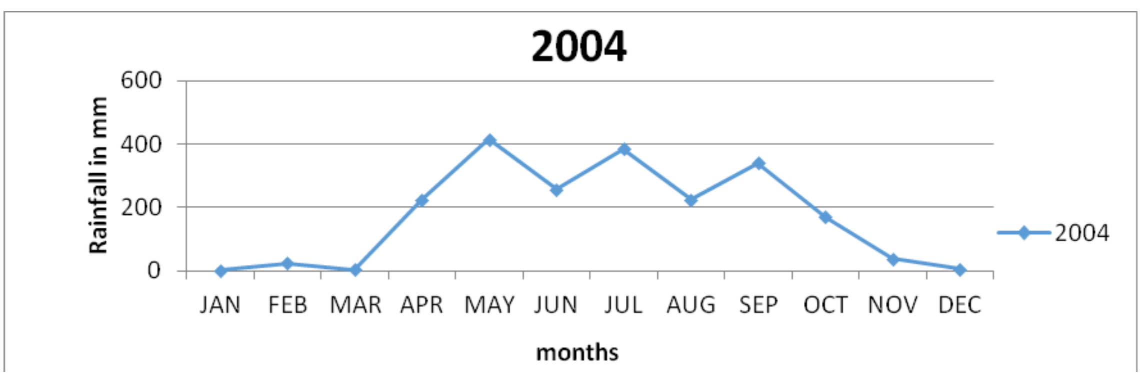

Figure 4.30: Annual rainfall analysis for 2004

From fig. 30, although rainfall was fluctuating, it increased and its onset took place in May at 415.2mm, this was the highest value the month of May ever attained. August month experienced a drop at 223.8mm which marked the little dry season. Its retreat was seen in October at 170.8mm. This year experienced the lowest March rainfall at 3.8mm throughout the study period. The total and average rainfall was at 2089.6mm and 174.1 respectively. The regime of rainfall was trimodal.

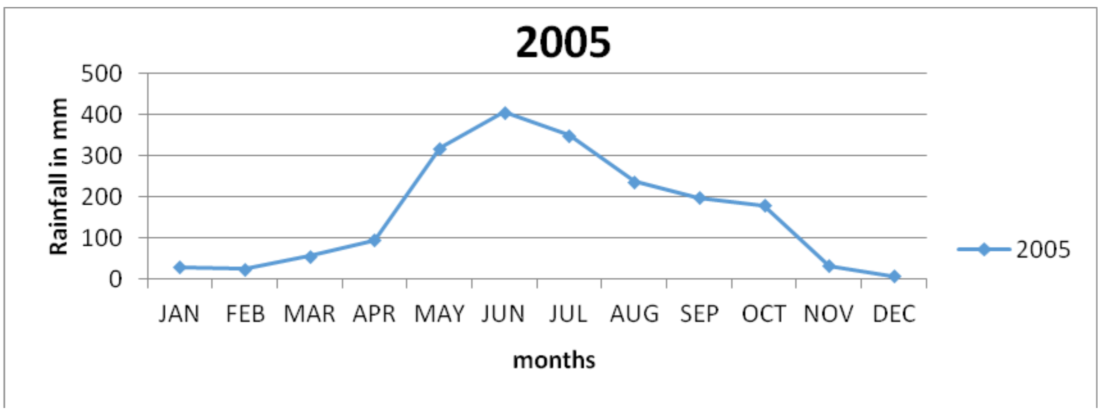

Figure 4.31: Annual rainfall analysis for 2005

Here, Rainfall distribution was throughout the year but, the total and average rainfall value dropped to 1938mm and 161.5mm respectively. Its onset occurred in May at 318.1mm and continued to its peak at 406.5mm in June which was the wettest month. Its retreat was in October at 179.3mm. The little dry season was not visible, thus, the rainfall regime was unimodal. This year recorded the highest June rainfall value at 406.5 mm throughout the study period.

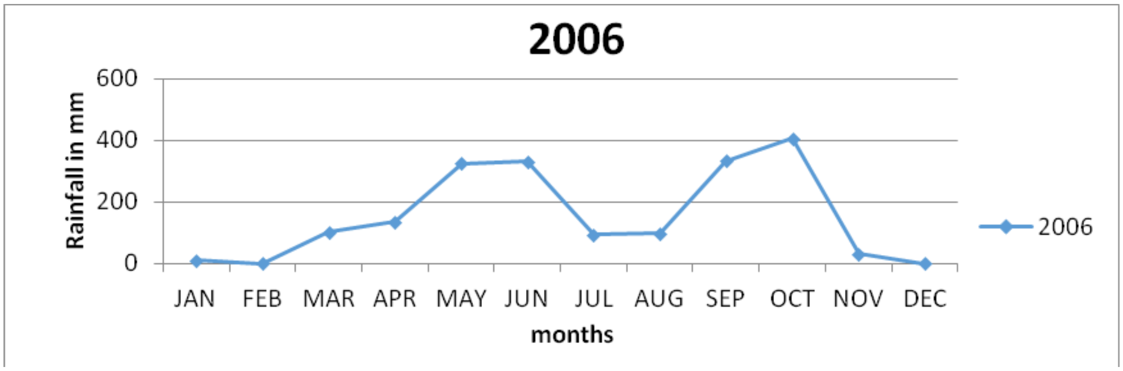

Figure 4.32: Annual rainfall analysis for 2006

In 2006, the onset rainfall occurred in March at 101.7mm; it kept on increasing until a sharp decline in July at 94.5mm, which was the lowest July value. This decline lingered till August, thus there was a prolonged little dry season. Rainfall reached its peak at 406.7mmin October, which was the second highest October rainfall value, rainfall retreat also occurred in this month. The total and average rainfall values were 1839mm and 153.3mm. The rainfall was clearly bimodal.

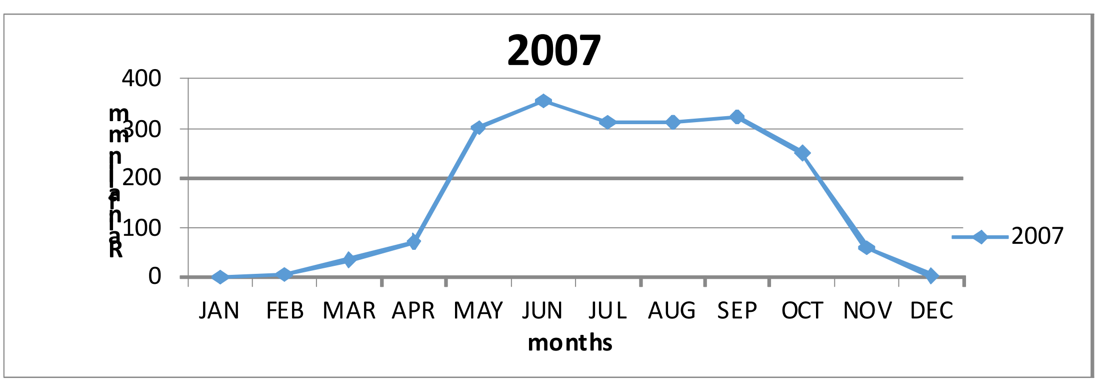

Figure 4.33: Annual rainfall analysis for 2007

Here, the onset of rainfall occurred in May at 301.4mm and it gradually increased to its peak in June at 355.2mm, which was the wettest month of the year. July and August experienced a weak decline with close values of 311.5mm and 312.7mm respectively, after which the rains increased a little in September to 322.7mm. Total and average rainfall increased to 2026.8mm and 168.9mm respectively. There was a bimodal regime of rainfall although the second peak was weak.

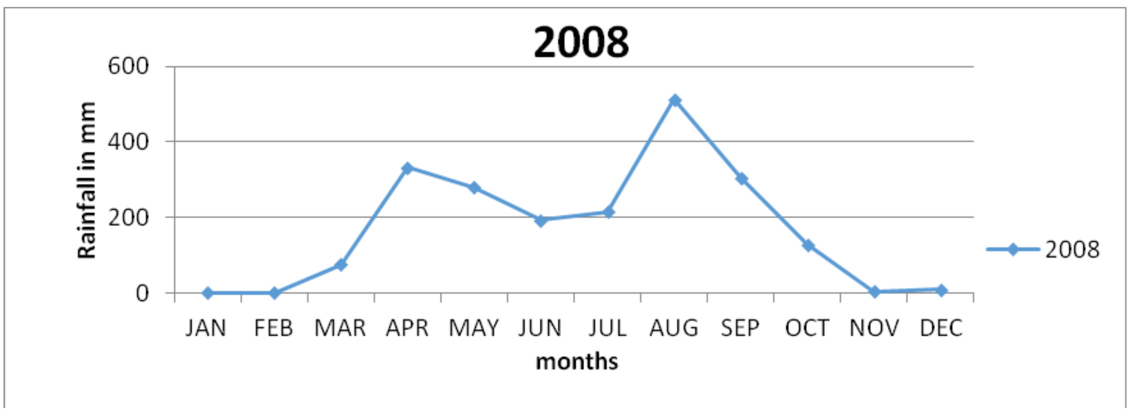

Figure 4.34: Annual rainfall analysis for 2008

In 2008, total and average rainfall increased to 2056.7mm and 171.4mm. Onset of the rains occurred in April at 332mm, this value however, dropped to 193.4mm in June, thus the little dry season which occurred somewhat early. There was a rise in rainfall in August at 513.8mm, this value was the highest August rainfall ever attained. Rainfall retreat occurred in October at 127.7mm. This year also had the highest April rainfall at 332mm. The regime of rainfall was bimodal.

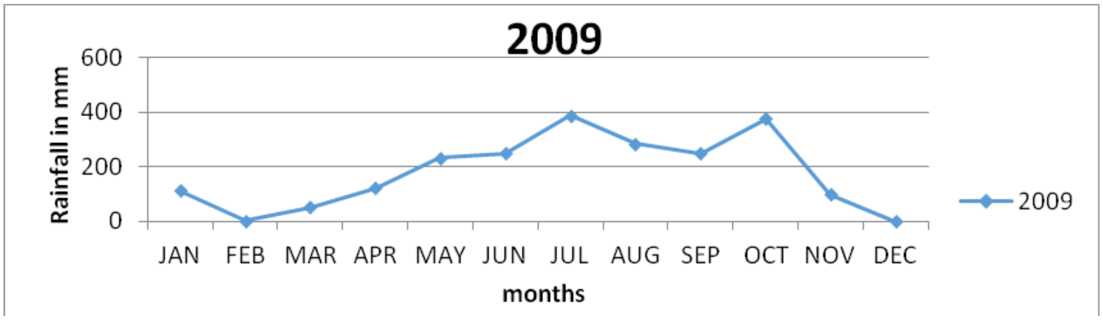

Figure 4.35: Annual rainfall analysis for 2009

2009 had an increased total and average rainfall value at 2157.6mm and 179.8mm respectively, this was the second wettest year throughout. Rainfall onset was unusually in January at 112.2mm which was also the highest January rainfall. It dropped in February and increased continuously till it got to its peak in July at 386.6mm which was the month with the highest rainfall. The little dry season came in September at 249.4mm and the second rainy season began in October and also its retreat. This year recorded the highest November rainfall value at 98.3mm. The rainfall regime was bimodal.

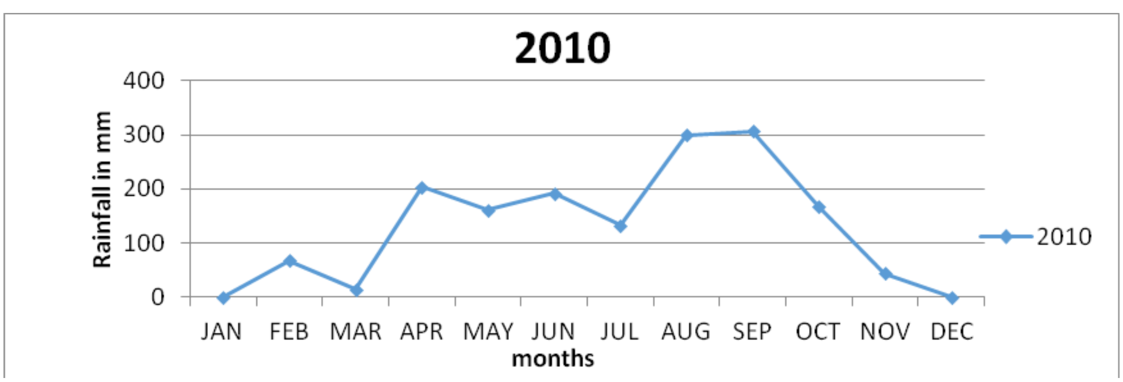

Figure 4.36: Annual rainfall analysis for 2010

In 2010, there was a drop is rainfall amount. Onset of the rains was in April at 203.5mm, it moved in a ziz-zag manner until it reached the little dry season in July at 132.2mm. This value climbed to its peak in September at 306.4mm. Rainfall retreat occurred in October at 166.9mm. This year had the second highest February rainfall at 66.8mm. There was a bimodal regime of rainfall. Total and average rainfall was 1585.9mm and 132.2 respectively.

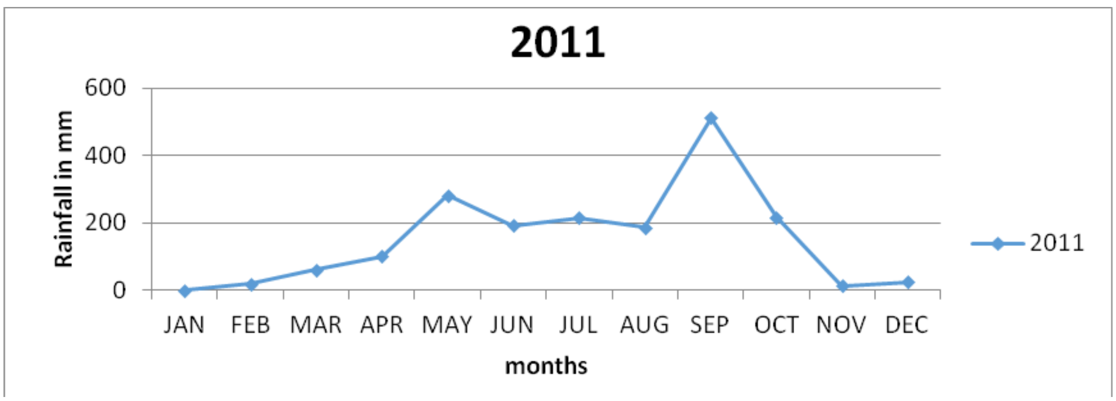

Figure 4.37: Annual rainfall analysis for 2011

In this year, the onset of rainfall occurred in April at 100.7mm, this increased to 281.4mm in May. It is seen that the little dry season actually occurred in August, however, June and July had close values thus, extending this little dry season. In September, the rain reached its peak at 512.1mm; rainfall retreat of rainfall was in October at 216.2mm. The rainfall regime was bimodal, total and average rainfall was 1820.1mm and 151.7mm respectively.

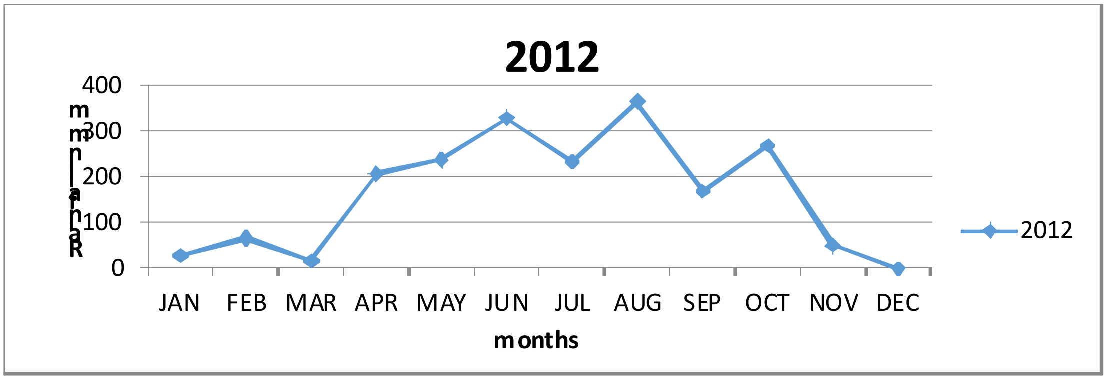

Figure 4.38: Annual rainfall analysis for 2012

From fig. 37, actual onset of rain was in April at 206.3mm, it continued to increase until it declined to 232mm in July; however, this did not mark the little dry season. August had the highest rainfall value at 363.5mm, the little dry season occurred in September at 167.4mm and rainfall retreat occurred in October at 266.7mm. This year experienced the lowest September rainfall value at 167.4mm. The total and average, rainfall values were 1961.5mm and 103.5 mm respectively.

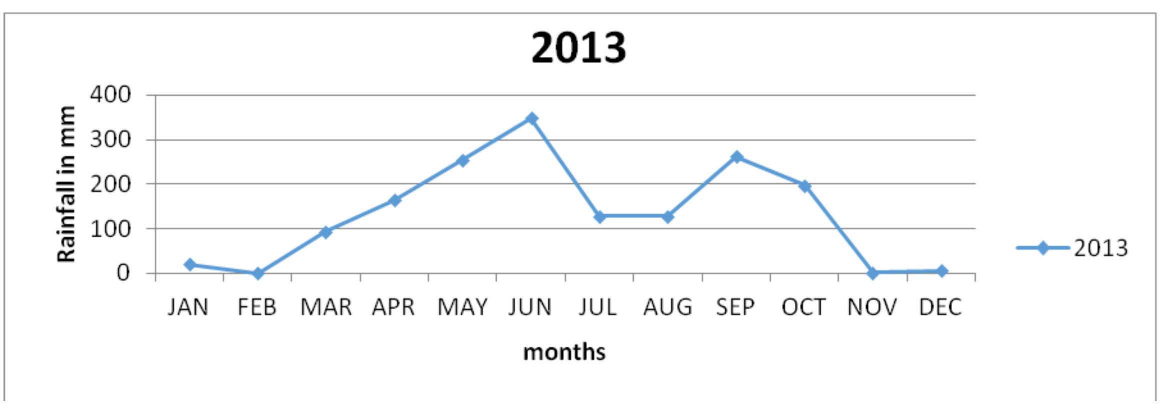

Figure 4.39: Annual rainfall analysis for 2013

In 2013, onset of rain was in April at 164mm, this increased to its peak in June at 348mm and dropped in July at 127.7mm, it may be said that the little dry season occurred here, but August had a close value of 128.2mm therefore, the little dry season was extended. The second rainy season began in September at 261.7 mm and its retreat was in October at 197.3mm. The bimodal regime of rainfall was obvious while the total and the average rainfall were 1603.4mm and 133.6mm respectively.

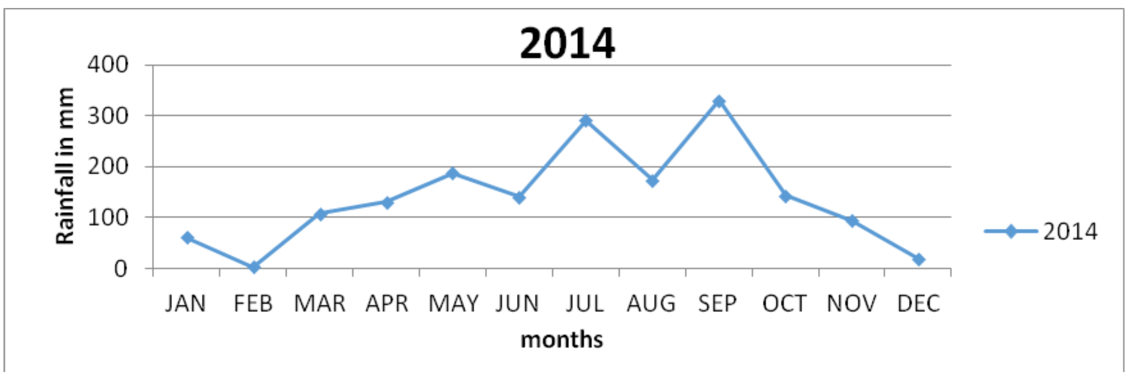

Figure 4.40: Annual rainfall analysis for 2014

The total and average rainfall for 2014 was 1677.7mm and 139.8mm respectively. The onset of rainfall occurred in March at 107.2mm, distribution was not steady. In August, the little dry season occurred at 173.3mm and inclined sharply to a peak of 329.7mm. Retreat of rainfall occurred in October at 142.6mm. The total and average rainfall was 1677.7mm and 139.8mm respectively. The rainfall regime was bimodal.

4.2.2 DECADAL RAINFALL ANALYSIS

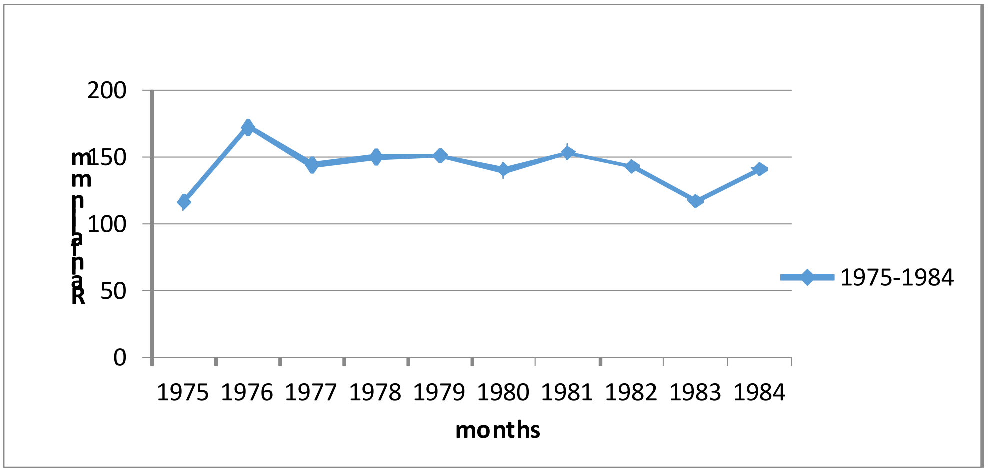

Figure 4.41: Decadal annual mean 1975-1984

Here, 1976 had the highest rainfall at 172.3mm and the lowest rainfall was in 1975 at 116.4mm. From this decadal analysis, average rainfall was between 110mm and 180mm. The rain maintained an almost steady trend. This decade had the least total average rainfall at 1428.7mm.

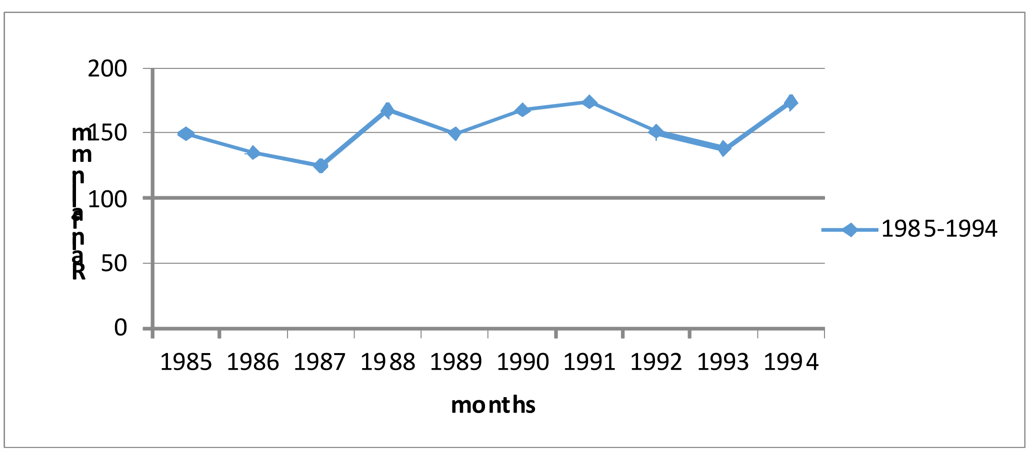

Figure 4.42: Decadal annual mean 1985-1994

In this second decade, there was a near tie between two years of high rainfall, 1991 and 1994 at 173.5mm and 173.6mm respectively. The lowest rainfall occurred in 1987 at 125.1mm. There was a rise and fall in rainfall trend. This decade had the second least total average rainfall with at 1530mm.

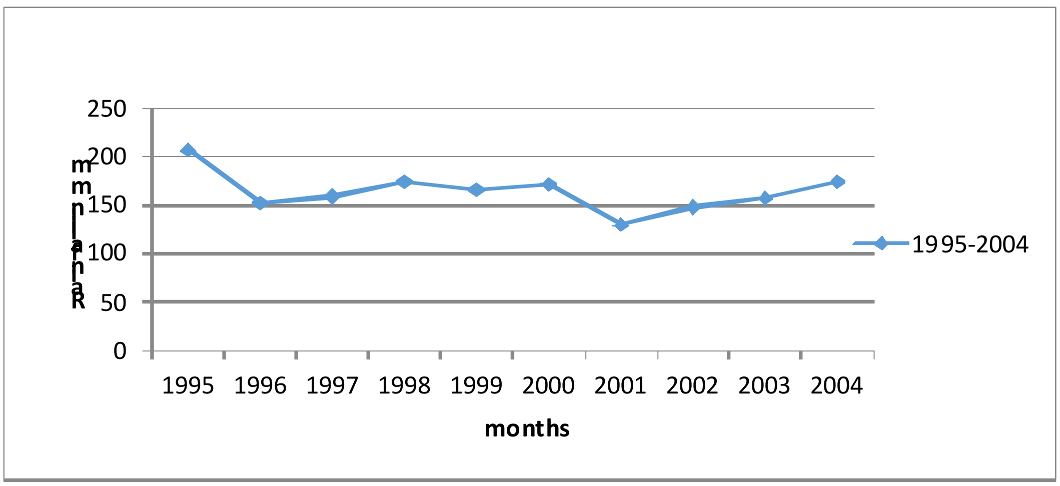

Figure 4.43: Decadal annual mean 1995-2004

From the figure, rainfall started on the high side at an average value of 206.5mm in 1995 which was the wettest year for the decade. 2001 was the least wet year at 129.7mm. This decade had the highest rainfall amount at 1637.7mm

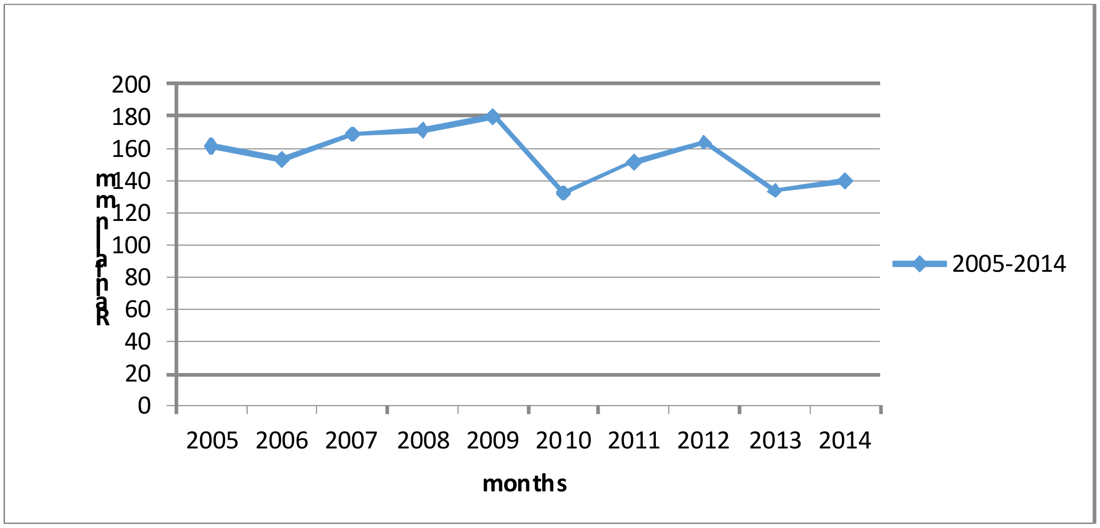

Figure 4.44: Decadal annual mean 2005-2014

In this last decadal, rainfall was increasing gradually from 2006 till 2009 where it reached its peak at 179.8mm and declined quite sharply to 132.2mm in 2010 which was the year with the lowest rainfall value. This was the second wettest decade with a total average of 1555.8mm.

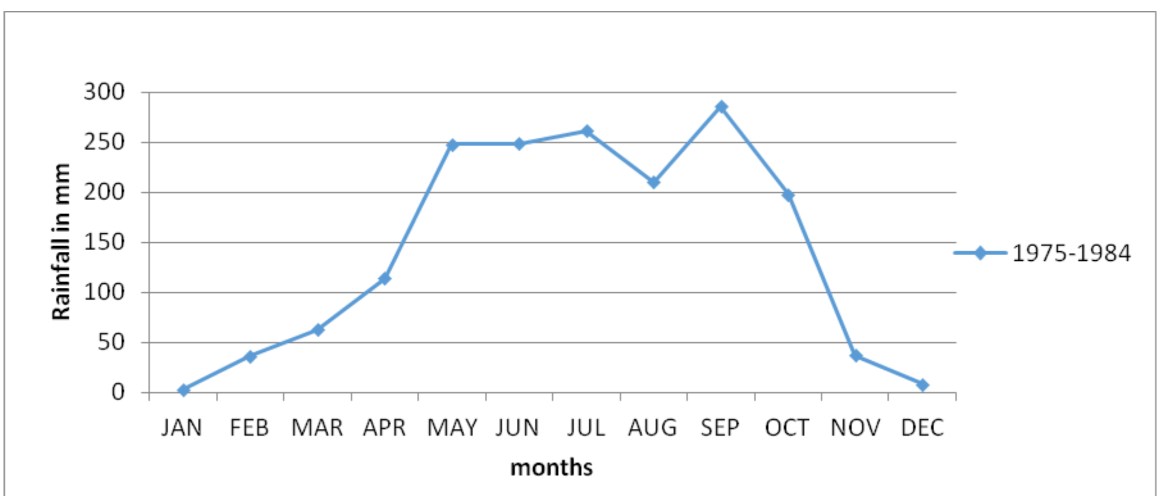

Figure 4.45: Mean monthly rainfall 1975-1984

In the first decade, onset of rainfall was seen in April at113.95mm. The little dry season occurred in August at 209.88mm. September recorded the highest rainfall at 285.48mm and rainfall retreat was in October at 197.88mm. There was a bimodal rainfall regime. Total monthly mean for this decade is 1714.41 which is the least wet decadal month.

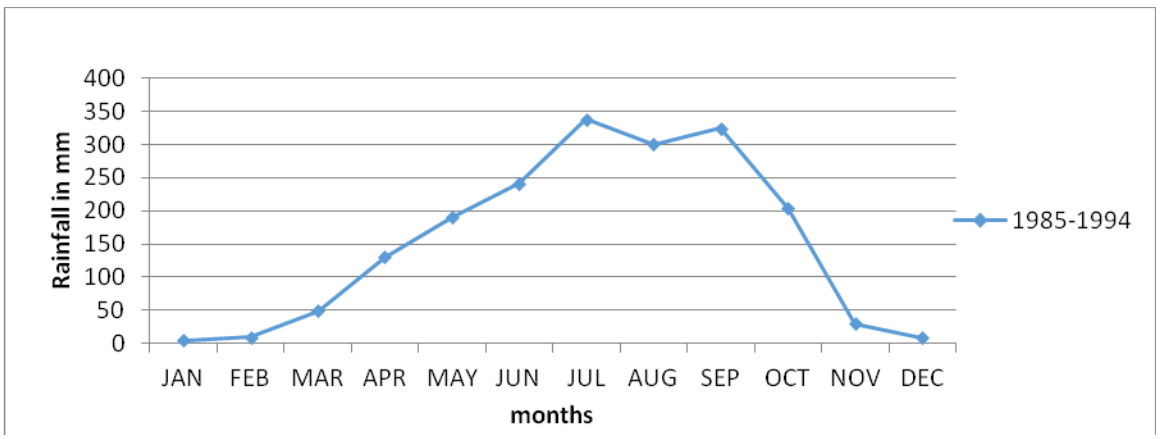

Figure 4.46: Mean monthly rainfall 1985-1994

Here, onset of rainfall occurred in April at 130.01mm the little dry season occurred in August at300.85mm. In this decade, July had the highest rainfall at 338.17mm and rainfall retreat was in October at 204.11mm. Total monthly mean for this decadal is 1835.81mm making it the second least wet decade of the four decades.

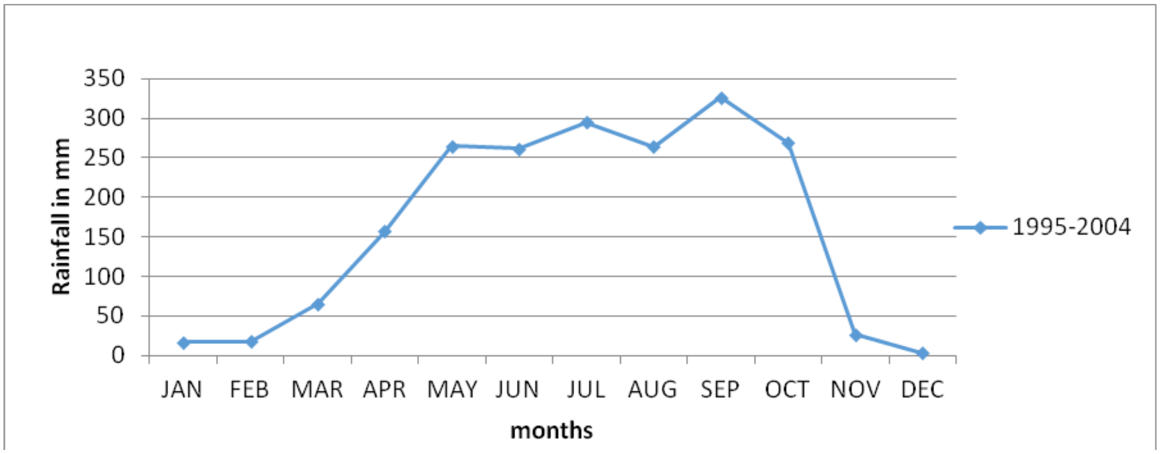

Figure 4.47: Mean monthly rainfall 1995-2004

In the third decade, onset of rainfall was in April at 156.74mm. The little dry season was yet again in August at 264.26mm. September had the highest average rainfall value at 326.06mm. There was a bimodal regime of rainfall. Total monthly mean for the third decade is 1965.25, which made it the wettest of the four decades.

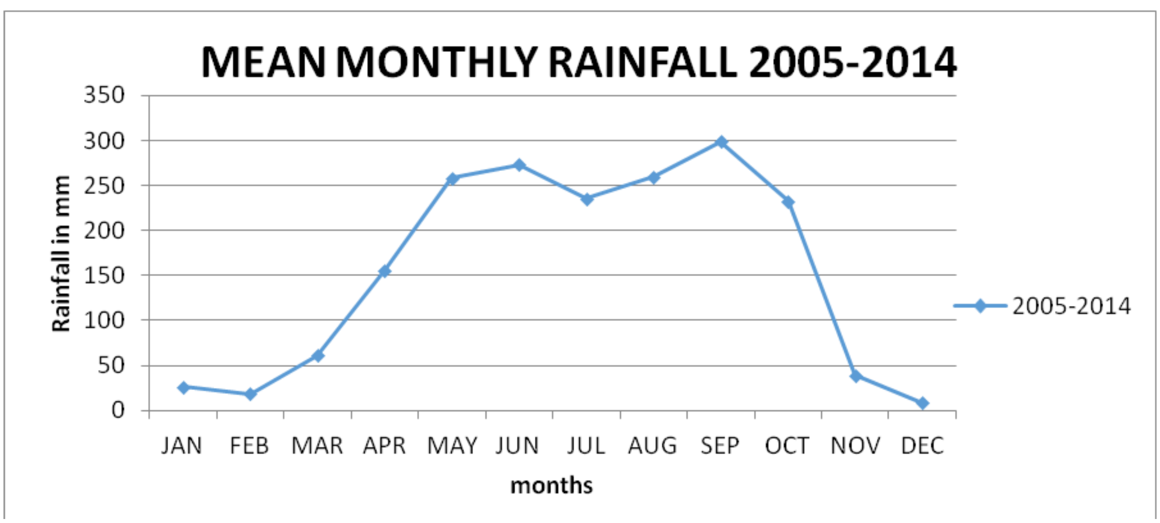

Figure 4.48: Mean monthly rainfall 2005-2014

In this last decade, onset of rainfall was again in April at 156.02mm. The little dry season occurred in July again at 235.6mm. September also had the highest average rainfall value at 293.74mm. There is a clear bimodal regime of rainfall. Total monthly mean for this last decade is 1866.67 making it the second wettest of the four decades

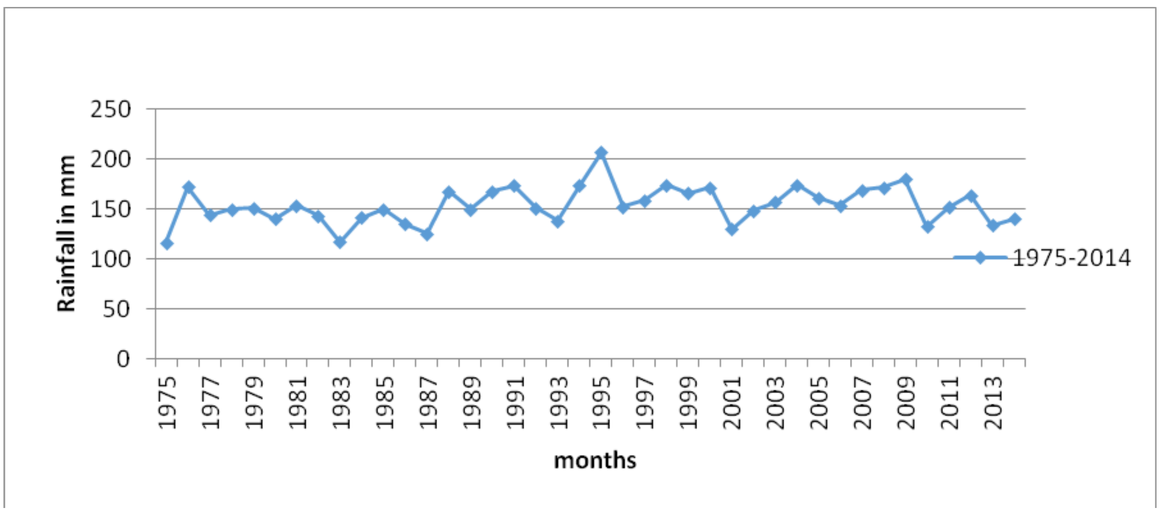

Figure 4.49: Mean annual rainfall 1975-2014

From this graph, rainfall amount was fluctuating throughout the forty-year period. The year 2000 was the wettest year at 206.5mm, followed by the year 2009 at 179.8mm and thirdly, 1998 at 173.9mm. The year1975 experienced the lowest rainfall at 116.4mm, followed by the year 1983 with an average rainfall value of 116.9 and the third lowest rainfall year is 2001 at 129.2mm.

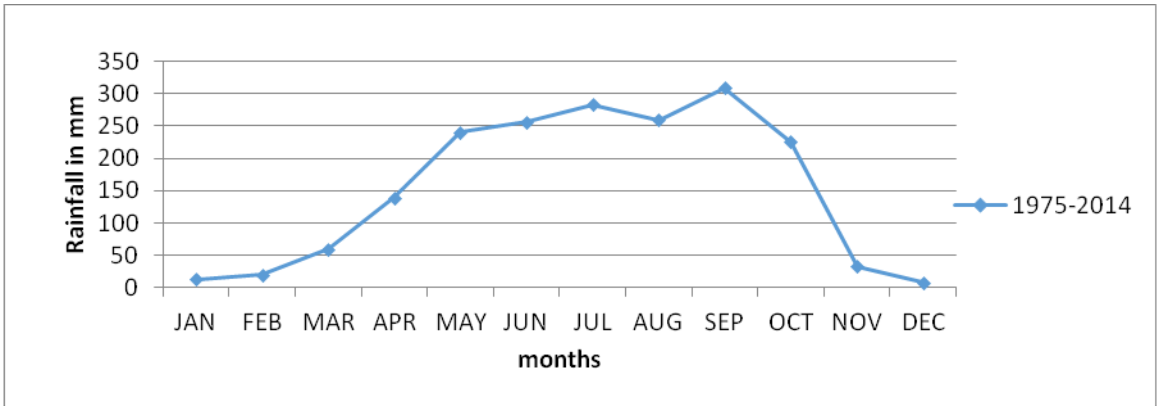

Figure 4.50: Mean monthly rainfall 1975-2014

From the figure, rainfall increased progressively throughout the forty year period. Its onset was in the month of April at 139.2mm. The little dry season occurred in August at 258.7mm, even though August rainfall was not low. September had the highest rainfall at 308.8mm and October marked rainfall retreat at 225.8mm. This graph also showed the bimodal regime of rainfall however; this bimodal regime was not very pronounced.

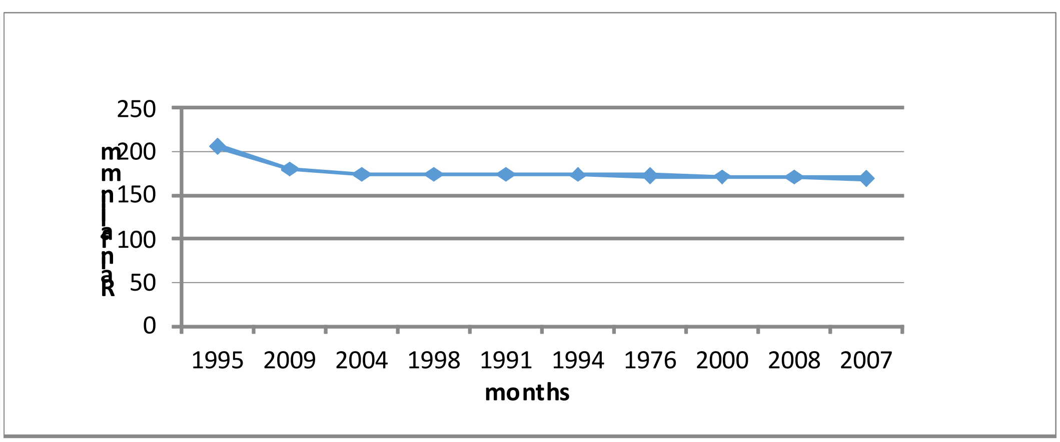

Figure 4.51: Annual rainfall analysis for 10 wettest years

From fig.5.51, the wettest years were 1995, 2009, 2004, 1998, 1991, 1994, 1976, 2000, 2008 and 2007 at values of 206.5mm, 179.8mm, 174.1mm, 173.9mm, 173.6mm, 173.5mm, 172.3mm, 171.7mm, 171.4mm and 168.9mm respectively in a descending order. These values exceeded the mean of the total mean annual rainfall of the forty year period which is 153.8mm. These years contributed to the recent decades being the wettest.

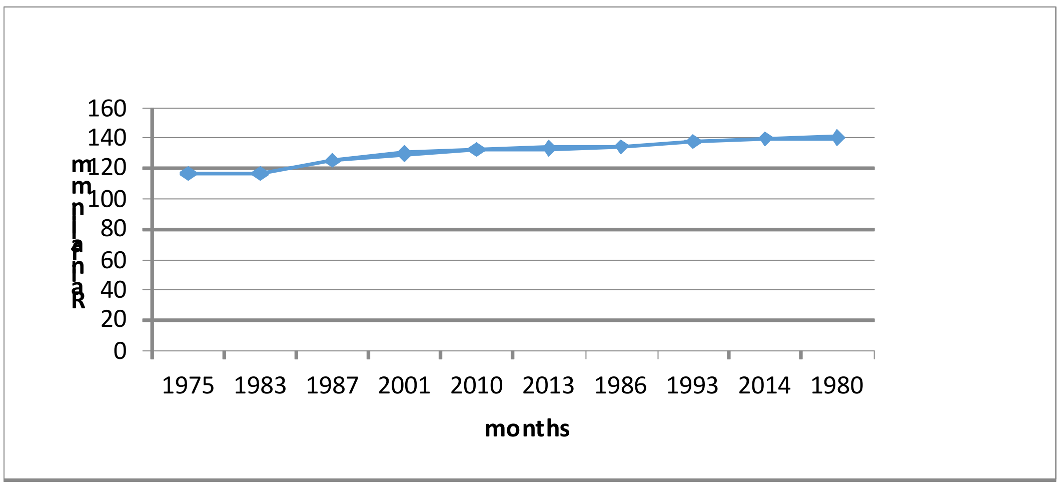

Figure 4.52: Annual rainfall analysis for 10 driest years

From fig.5.52, the ten driest years were 1975, 1983, 1987, 2001, 2010, 2013, 1986, 1993, 2014 and 1980 at values of 116.4mm, 116.9mm, 125.1mm, 129.7mm, 132.2mm, 133.6mm, 134.6mm, 137.9mm, 139.9mm and 140.3mm respectively in an ascending order. These values were less than the mean of the total mean annual rainfall of the forty year period which is 153.8mm.

4.3 VERIFICATION OF RESEARCH HYPOTHESIS

The hypotheses stated in this research are;

1. H_o: There is no shift in bimodal pattern of rainfall in Awka, Anambra state from 1975 - 2014.

   H_A: There is a shift in bimodal pattern of rainfall in Awka, Anambra state from 1975-2014

CHI SQUARE

The observed rainfall values were obtained from the recorded rainfall data while the expected rainfall values were obtained using moving average. This was calculated for the forty year period in four decades.

TABLE 1: CHI SQUARE TABLE FOR DECADE ONE

Year	Observed Rainfall () in mm	Expected rainfall (E_R) in mm	O_R - E_R	$(O_R - E_R)^2$	$\frac{(O_R - E_R)^2}{E_R}$
1975	116.4	142.8	- 26.4	696.96	4.88
1976	172.3	144.3	28	784	5.43
1977	144.1	155.4	-11.3	127.69	0.82
1978	149.9	148.4	1.5	2.25	0.02
1979	151.1	147.1	4.0	16	0.11
1980	140.3	148.3	-8	64	0.43
1981	153.5	145.5	8	64	0.44
1982	142.8	137.7	5.1	26.01	0.19
1983	116.9	133.6	-16.7	278.89	2.09
1984	141.1	142.8	-1.7	2.89	0.02

$$X^2_c = \sum\left(\frac{(O_R - E_R)^2}{E_R}\right) = 14.43$$

TABLE 2: CHI SQUARE TABLE FOR DECADE TWO

Year	Observed rainfall (O_R) in mm	Expected rainfall (E_R) in mm	$O_R - E_R$	$(O_R - E_R)^2$	$\frac{(O_R - E_R)^2}{E_R}$
1985	149.7	153	-3.3	10.89	0.07
1986	134.6	136.5	-1.9	3.61	0.03
1987	125.1	142.3	-17.2	295.84	2.08
1988	167.3	147.4	19.9	396.01	2.69
1989	149.9	161.6	11.7	136.89	0.85
1990	167.5	163.7	3.8	14.44	0.09
1991	173.6	164.0	9.6	92.16	0.56
1992	150.9	154.1	-3.2	10.24	0.07
1993	137.9	154.1	16.2	262.44	1.70
1994	173.5	153	20.5	420.25	2.75

$$X^2_c = \sum\left(\frac{(O_R - E_R)^2}{E_R}\right) = 10.89$$

TABLE 3: CHI SQUARE TABLE FOR DECADE THREE

Year	Observed rainfall (O_2) in mm	Expected rainfall (E_R) in mm	$O_R - E_R$	$(O_R - E_R)^2$	$\frac{(O_R - E_R)^2}{E_R}$
1995	206.5	163.8	42.7	1823.29	11.13
1996	152.2	172.5	-20.3	412.09	2.39
1997	158.9	161.7	-2.8	7.84	0.05
1998	173.9	166.2	7.7	59.29	0.36
1999	165.7	170.4	-4.7	22.09	0.13
2000	171.7	155.7	16	256	1.64
2001	129.7	149.8	-20.1	404.01	2.70
2002	148.1	144.9	3.2	10.24	0.07
2003	156.9	159.7	2.8	7.84	0.05
2004	174.1	163.8	10.3	106.09	0.65

$$X^2_c = \sum\left(\frac{(O_R - E_R)^2}{E_R}\right) = 19.17$$

TABLE 4: CHI SQUARE TABLE FOR DECADE FOUR

Year	Observed rainfall (O_2) in mm	Expected rainfall (E_R) in mm	O_R - E_R	$(O_R - E_R)^2$	$\frac{(O_R - E_R)^2}{E_R}$
2005	161.5	155.6	5.9	34.81	0.22
2006	153.3	161.2	-7.9	62.41	0.39
2007	168.9	164.5	4.4	19.36	0.12
2008	171.4	173.2	-1.8	3.24	0.02
2009	179.8	161.1	18.7	349.69	2.17
20010	132.2	154.6	22.4	501.76	3.25
20011	151.7	149.1	2.6	6.76	0.05
20012	163.5	149.6	13.9	193.21	1.29
20013	133.6	145.6	-12	144	0.99
20014	139.8	155.6	-15.8	249.64	1.60

$$X^2_c = \sum \left(\frac{(O_R - E_R)^2}{E_R} \right) = 10.1$$

For decade 1, X^2_c = 14.43

For decade 2, X^2_c = 10.89

For decade 3, X^2_c = 19.17

For decade 4, X^2_c = 10.1

4.3.1. COMPUTATION FOR CHI SQUARE TABULATED OR CRITICALVALUE

Degree of freedom, Df = (r-1) (c-1)

= (10-1) (2-1)

= (9) (1)

= 9

At confidence limit 0.05 (95%), X^2_t = 16.92

0.05 (99%), X^2_t = 21.67

0.05 (99.9%), X^2_t = 27.88

At all these confidence levels, Chi square calculated value (X^2_c) is less than critical value or Chi square tabulated value (X^2_t) in decade 1, 2, 3 and 4. Therefore, we accept the null hypothesis (H_o) and reject the alternative hypothesis (H_A) to affirm that there is no shift in the bimodal pattern of rainfall in Awka. However, with an exception in the third decade, Chi square calculated value is greater than Chi square tabulated at 0.05 (95%) confidence limit, therefore rejecting the null hypothesis (H_o)

and accepting the alternative hypothesis (Ha) to affirm that there is a shift in the bimodal pattern of rainfall in Awka, Anambra state.

4.4 IMPLICATIONS

Climate change is currently one of the pressing environmental problems in the world with serious threats to human existence. According to Medugu, (2009), Nigeria is one of the countries expected to be most affected by the impacts of climate. The effects of global warming are many and varied; this is so because of its sectorial implications (NEST, 2009). Although, it is difficult to predict precisely the exact impacts of climate change, what is clear is that the climate we are accustomed to is no longer a reliable guide for what to expect in the future. A warming climate will bring change that can affect our Agriculture, water supplies, power and transportation systems, the natural environment and even our own health and safety.

Sectoral Implications

The implications of climate change on agriculture are most important since 40% of the African Gross National Product is obtained in agriculture and 70% of all African labour is employed in this sector. The dominate role of rainfall in agriculture makes it obvious that even minor rainfall variations can cause devastating consequences. Climate change has brought about disruption of farming seasons as a result of inconsistent and erratic rainfall, making agricultural activities more difficult. In Edo state for example, the farming season for this year was disrupted, what ought to have commenced between January and early March did not commence until late April (Daily Sun, 22 July, 2015). This is as a result of the changes in onset and retreat of effective rainfall, thus, making the decision of when to plant and harvest difficult.

Another challenge is the issue of false rains which misleads the farmer and cause delayed growth and harvest or even replanting. Water regulates the temperature of the soil, provides moisture for the crop and microorganisms necessary for soil aeration, it also dissolves soil minerals for crop/plant growth amongst others. Beyond the irregular farming season experienced in many parts of the southern states, Awka inclusive where irrigation is very low, the state experiences a rise in temperature which disturbs the soil, burns crop roots and makes it less of a habitat for microorganisms.

Flooding and erosion is also a big concern here and this problem continues to grow. Floods and erosions have washed away seeds, tubers, crops, nutrients and fertilizers and have increased the loss of biodiversity. It has also disrupted soil structure, Ph, percolation and compatibility thereby causing both agricultural and socioeconomic challenges to the farmer whose food basket is now empty, and some of the people who used to depend on fishing have seen their livelihoods destroyed by the rising waters.

All these result in declining agricultural productivity and subsequent food insecurity. Maize, yam and cassava yield has reduced in Imo state as a result of climate change (Nnaji and Duruji, 1999). This situation if sustained may threaten food security in the state.

Other implications of climate change are in the water resource sector. Irrigational strategies, domestic supply of water, hydro electricity, transportation through water ways and water reserves are all threatened by climate change.

The health sector is not left out as a result of increased incidence of waterborne diseases and food insecurity. High temperature can cause health issue such as meningitis, cataracts, yellow fever. Flooded environment provide habitable environment for malaria vector.

In the socioeconomic sector, climate change has drastic effect on livelihood; high cost of construction, affecting Urban, rural and regional planning, transportation, deforestation as a result of relocation from flood affected areas. Even intranational conflicts have to be expected because of climate refugees' migration.

4.5 SUMMARY

The rainfall trends for Awka, Anambra state over 40-year period (1975-2014) was analyzed in four series /decades; 1975-1984, 1985-1994, 1995-2004 and 2005-2014.

From the graphical illustrations, it is seen that there are two peak periods of rainfall which implies that the bimodal regime of rainfall in Awka, Anambra state still exists in the decadal analysis. However, in the annual analysis, there were 3 cases of unimodal regimes, 9 cases of trimodal regimes and the remaining 28 years were bimodal.

The significant rainfall months include April, May, June, July, August, September and October while the months of onset and retreat of rainfall is April and October respectively.

The "little dry season" or August break remained between June and September in the annual series, however, in the decadal series, the first three decades observed this period in August while the last decade observed it in July.

The month of September had the highest/peak rainfall.

The total average annual rainfall occurrence over the 40 years of study is 6150.8mm.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

The conclusion and recommendations for further research works are stated in this chapter. Furthermore, the implications of this research work are also stated.

5.1 CONCLUSION

The study has shown that the total climatic condition of Awka, Anambra state has been varying both in annual and decadal analysis

Over the past, latter decades have experienced more rainfall than the former.

With reference to rainfall pattern, the two peak periods experienced some variations; however, this bimodal pattern showed no significant shift using the decadal rainfall series but showed some shift using the annual rainfall series.

This research has given some degree of solution to the research problem which sets to identify any shift in bimodal rainfall pattern in Awka, Anambra state.

5.3 RECOMMENDATION

To tackle this global issue, there’s need to internalize our commitments with the international convention on environment , so that it can be fully implemented. The mandate during the last conference was that partners should agree on issues that are legally binding to all countries involved. The issue of reducing emissions was also on the table. The way to achieve this is to mobilize resource and continue to carryout awareness without apportioning blames. According to Nimmoh Bassay, an environmental activist, “Global warming is a global problem, but there are direct implications for every community and nation. Everyone at the smallest political structure has to take action on how to tackle this problem”. He also added “At our local level, one thing Nigeria can do is to immediately stop gas flaring, embark in reforestation project (use of carbon sinks), protect the forests, shift away from fossil energy and move to renewable energy.

The government should improve their financial status towards the solution of findings on this issue. The Nigeria government and all the stakeholders involved in the global phenomenon needs to increase public awareness, promote research and establish a commission that will handle issue related to global warming and climate change.

Although, Nigeria is not a major contributor to global warming, it is really of great concern to the nation since African countries have been identified as the most vulnerable and its implications are evident.

With agriculture being highly dependent upon, its practices in this region are predominantly rain-fed. Thus, farmers should commence planting around March and April since rainfall onset is around this time and early harvest can be done in August or there about and late harvest can be done after the rainy season.

The government should encourage water conservation/storage strategies where rainfall is deficient especially during the dry season. Storage subsurface tanks and reservoirs should be used to store water for irrigation purpose and human/domestic consumption.

Urban, rural and regional planner and other environment managers concerned with construction and related polices should make provision to control surplus water during excessive rainfall. Drainages should be constructed and dredged to allow proper channeling of water into water bodies before significant rainfall months.

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APPENDIX 1: MONTHLY RAINFALL DATA OVER AWKA, ANAMBRA STATE FROM 1975-2014

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	0	7	27.4	120.4	273.8	232	153.5	115.4	213.5	172	71.7	10.4
1976	0	153.2	53.8	121.6	186.1	290.3	230.4	276.8	308.3	335.5	79.7	32
1977	8.7	0.4	77.7	64.1	194.1	180.4	303.4	248.6	362.3	264.5	3.8	20.9
1978	TR	66.4	47.1	248.4	334.9	238.9	192.9	189.6	228.8	236.8	7.9	7.6
1979	0	23.5	28.1	189.2	204.1	254.6	182.5	392.6	316.8	146.1	75.2	0
1980	0	43.1	88.7	79.9	249.3	174	361	173.3	232.4	199.4	67.1	15.6
1981	5.6	20.7	32.9	79.3	337.3	315	375.7	113.7	311.8	222.7	27.4	0
1982	16.1	53.5	96.9	103.1	235	260.3	285.2	177	264.3	211.5	12.8	0
1983	0	0	83.4	16.9	225.8	232.4	294.2	114.4	357.5	72.4	6.5	TR
1984	5.3	0	90.6	116.6	241.1	309.6	237.1	297.4	259.1	117.9	18.6	0
1985	7.8	0	197.3	156.4	255.1	223.4	312.2	273.3	234	127.2	9.5	0
1986	2.6	27.2	57.6	95.5	222.7	107	265.8	138.6	410.2	216.9	71.2	0
1987	TR	9.7	19.1	8.1	72.8	257.2	245	505.4	203.2	163.4	3.7	13.8
1988	11.1	0.4	92.6	81.4	154.4	246.9	478.2	204.6	529.7	192.1	1.8	13.8
1989	0	0	19.2	135.8	213.7	268	213.3	360.8	276.5	267.2	27.5	16.4
1990	1.8	0	0	266.6	131.9	268.5	449.3	314.9	312.8	179.3	32	52.5
1991	TR	42.3	64	186.3	216.4	286.4	290.5	390.4	341.1	243.1	6	16.9
1992	0	0	13.5	99.7	266	311.3	475.6	200.4	280.2	107.9	56.3	0
1993	0	17.2	9	94.7	84.6	234.3	325.7	364.1	311.9	166.3	37.5	8.9
1994	23.6	0	17.2	175.6	285.4	215.2	326.1	256	348.5	377.7	56.4	0
1995	64.1	60.2	118	120.4	249.3	382.7	429.4	347.2	295.4	362.5	49	0.3
1996	1.1	22.3	79	103.1	281.3	236.8	171.9	352.4	317.6	256.3	4.9	0
1997	1.6	0	114.2	305.7	300.1	216.7	214.5	188.5	247.3	252.7	45.9	19.8
1998	0.2	24.6	30.4	170.5	344.3	291.5	362.7	91.2	360.6	407.1	0.5	2.6
1999	27.9	12.9	52.2	98.6	320.9	186.2	279.9	255.6	347	353.9	53	0

2000	36	0.2	155.2	91.6	167.5	313.5	201.2	367.7	550.6	164.9	8.7	3.4
2001	0.1	0.2	40.1	236.9	188	267.8	225.3	272.8	177.2	146.3	1.5	0
2002	0	22.8	22.7	79.2	220.7	258.6	251.9	330.9	242.1	316.4	32	0
2003	37.2	6.8	40.1	136.1	161.2	200.9	425.4	212.5	383.3	249.5	28.1	1.3
2004	1.7	23.6	3.8	225.3	415.2	257.9	384.1	223.8	339.5	170.8	37.9	6
2005	29.5	25.8	56.6	94.9	318.1	406.5	350.4	237.7	199	179.3	XXX	7.8
2006	10.6	TR	101.7	XXX	326.2	331.8	94.5	98.7	333	406.7	XXX	0
2007	0	5	34.7	71.7	301.4	355.2	311.5	312.7	322.7	250.4	59.1	2.4
2008	0	0	75.7	332	279.4	193.4	216	513.8	306	127.7	3.8	8.9
2009	112.2	0.7	50.6	121.1	233.1	248.3	386.6	283.3	249.4	376	96.3	0
2010	0.2	66.8	13.6	203.5	161.3	191.9	132.2	299.9	306.4	166.9	43.2	0
2011	0	18.5	59.9	100.7	281.4	190.9	214.7	186.9	512.1	216.2	13.7	25.1
2012	28.3	66.5	16.5	206.3	236.7	327.8	232	363.5	167.4	266.7	49.8	0
2013	20.2	0	93.3	164	254.1	348.7	127.7	128.2	261.7	197.3	1.9	6.3
2014	61.4	2.6	107.2	130.2	187.5	140.3	290.4	173.3	329.7	142.6	93.5	19