CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Climate is a subject of interest to scientists in diverse fields like meteorology, agriculture, water resources, human biology, etc. because of its impacts on all human endeavours including human health (World Health Organization [WHO], 1993). For many centuries, humanity has managed to adapt and reduced the impacts of climate by adjusting shelter, food production, energy provision and lifestyles in order to be healthy (World Meteorological Organization [WMO], 2009). This is because studies have shown that climatological factors influence disease occurrence directly by affecting the agents and the host of diseases, and indirectly by their influence on the biologic and socioeconomic environments. The link between climate and health had been on the studies since the existence of mankind. Hippocrates 2,500years ago wrote about regional differences in climate and their relationship to states of health (McMichael and Sari Kovates, 1999). Hufeland was the first to establish a link between mortality rates and climatic phenomena, in the second half of the 19th Century (May, 1958). It has been established that climate and weather influences all kinds of illness, including mental disorders (Golovina and Trubina, 1999).

According to Fox, Hall and Elveback (1970), climatic elements such as rainfall, temperature, humidity and radiation, are directly important in the survival of microbial agents in the "free state" and in the life cycles and reservoir mechanisms of many microbes and higher parasites that affect man. In most direct sense, unduly low barometric pressure at high altitudes or excessively high pressure in the depths of the sea, extremes of heat, cold, or sunlight; and the powerful lightning bolt are in themselves physical agents of disease. Skin cancer is more common in areas that have high and intense ultraviolet rays from solar radiation. Eye disorders such as cataract are more prevalent in areas of high exposure to sunshine rich in ultraviolet radiation (WHO, 1996). Climatic elememts influence the emergence and reemergence of infectious diseases, in addition to multiple human, biological, and ecological determinants (Patz *et al.*, 1996). It is well established that climate is an important determinant of the spatial and temporal distribution of vectors and pathogens. In theory, a change in climate would be expected to cause changes in the geographical range, seasonality (intra-annual variability), and in the incidence rate (with or without changes in geographical or seasonal patterns) of vectors and pathogens (Kovats *et al.*, 2001). Most vector-borne diseases exhibit a distinct seasonal pattern, which clearly suggests that they are weather sensitive. Rainfall, temperature, and other weather variables affect in many ways both the vectors and the pathogens they transmit. For example, high temperatures can increase or reduce survival rate, depending on the vector, its behaviour, ecology, and many other factors. (Gubler *et al.*, 2001).

Several examples may be given on how climate affects human disease indirectly. Climate variability and extremes of weather as well as climatic events such as droughts, desertification, floods, and storms *etc.*, also indirectly influence the distribution and abundance of disease vectors and their intermediate host species. Indeed, it is the weather extremes and climatic events that have the most devastating effects on human health and well-being (Epstein *et al.*, 1998). For example, during periods of water shortage, which normally accompanies drought conditions, water is mostly rationed to the detriment of personal hygiene. At such times, risks of faecal-oral diseases (primarily diarrhoea) and water-washed diseases (such as tracoma, scabies *etc.)* are also common (Ojo & Ojofeyitimi, 2002).

In a warm, tropical climate like Nigeria, difficulty in dissipating internally generated heat results in depression of body functions, lowering of vitality, and a predisposition to infection.

In temperate climates, the facility of heat loss is presumed to stimulate vitality and quicken body function (Fox *et al*., 1970). However, over the last decades, population growth, increased energy usage and industrial development have contributed to the climatic variability and exacerbated disease proliferation in the world in general and Nigeria in particular (WMO, 2009). In view of anticipated global climate change, Patz *et al.*, (2001), noted that global climate change might expand the distribution of vector-borne pathogens in both time and space, thereby exposing host populations to longer transmission seasons, and immunologically naive populations to newly introduced pathogens. Global assessment of the potential impacts of anthropogenic ally-induced climate change on vector-borne diseases suggests an increase in extent of the geographical areas susceptible to transmission of malarial Plasmodium parasites, dengue Flavivirus and Schistosoma worms (Martens, Theo and Focks 1997). Climate change will have an important impact on the length of the transmission season in many areas, and this has implications for the burden of disease. Possible decreases in rainfall indicate some areas that currently experience year-round transmission may experience only seasonal transmission in the future. Estimates of future populations at risk of malaria differ significantly between regions and between climate scenarios (Martens *et al.*, 1999). In Australia, Models of climate change predict increases in rainfall, tides and temperature for parts of Australia, and such changes have the potential to increase the risk of arbovirus transmission by increasing the distribution and abundance of vectors, and duration of mosquito and arbovirus seasons (Russell, 1998). Consequently, climate variations and change have a significant impacts on diseases and its characteristics.

1.2 Statement of Research Problem

The impacts of climate on health are already serious in many parts of the world. In view of the projected increases in climatic extremes, impacts of climate variability on health are expected to be more serious than they are at present (Abiodun *et al*., 2012). The universal aspiration of any nation is good health and well-being of her citizenry. Achieving this goal has been a herculean task for a developing country like Nigeria. Nigeria's overall health system performance was ranked 187th among the 191 member states by the World Health Organization in 2000 (FMH, 2005). Diseases such as malaria, measles, tuberculosis, and other infectious diseases remains prevalent despite numerous programmes and efforts to combat them (ICSU, 2008). Disease programme, such as Malaria, Measles, Tuberculosis and other programmes are currently being implemented within a weak health system and have had little impact. The routine immunization coverage rate that had reached over 80% in the early 1990's has nosedived to an all time low by year 2000. Avery high proportion of primary health care facilities serve only about 5-10% of their potential patient load, due to consumer's loss of confidence in them among other causes. Our secondary health care facilities are in a prostrate condition. Diagnostic and investigative equipment in tertiary health institutions are outdated. The referral system between various types of health facilities is either non-functional or ineffective. Erratic supply and non-availability of essential drugs and related materials is a common feature. Public expenditure on health is less than $8 per capita, compared to the $34 recommended internationally (FMH, 2005). Partnerships between the public and private sectors are either non-existence or ineffective. Consumer's health knowledge, comprising information, education and communication, and their level of awareness of their rights to quality health care are low; so also is awareness of their health obligations. Donors and other development partners are poorly coordinated. Even, after Abuja's declaration decades ago, most African country including Nigeria are not yet on track to achieve the health Millennium Development Goals (MDG's), (WHO, 2011). In her bid to provide the entire population with adequate access not only to primary health care but also to secondary and tertiary services through a well-functioning referral system. The government have instituted a comprehensive national health system, health system based on primary health care, an integrated and coordinated national health care system, voluntary agencies and private sector, community involvement and many programme to achieve the MDG's.

Understanding climate variations in any society is critical to development, especially as it relates to health and diseases (Connor *et al*., 2008). Some of the most virulent infectious are highly sensitive to climate conditions. For example, temperature, rainfall, and humidity have strong influence on the reproduction, survival and biting rates of the mosquitoes that transmit malaria, and temperature affects the life cycle of the infectious agents themselves. Hot, dry conditions favour meningococcal meningitis. In Nigeria only few existing studies on climate provides features and characteristics on different geographic locations and they are without clear linkages that depict its absolute and relative variations. Despite the relationship between human health and climate elements, not too many studies on diseases have investigated the extent of the synergy. This is in spite of the common knowledge that a good understanding of the impacts of climate on diseases could form a basis for understanding the seasonal occurrence and trend of diseases. One of the important challenges for control of all these diseases is to understand and, where possible, predict their distribution in time and space, to allow control programmes to target interventions and to anticipate and predict epidemics.

In general, the relationships between diseases and climate variations are also not evaluated in both spatial and temporal dimensions for a meaningful interpretation that could aid preparedness and better planning process. Rather, analysis on climate-diseases relationship in Nigeria focuses on mere weather conditions and occurrences of diseases. However, studies in other countries, such as in the People's Republic of China, have established links between climate variations and diseases. Hsia (1978) established that attacks of bronchial asthma always occur in spring and highest in autumn when the average temperature is about 21°C

(Hsia, 1978). In Rwanda, increase in malaria incidence and distribution are typically in wet weather (Loevinsohn, 1994). In Pakistan, fluctuations in falciparum malaria intensity were correlated with variations in climate variables such as temperature and precipitation (Carcavallo, 1995). An in-depth analysis and understanding of these linkages between climate and diseases has supported the prevention of these diseases in certain areas. Thus, it is important to understand the depth of the relationships between climatic elements and diseases.

1.3 Research Questions

The research questions for this study are:

(i) What are the spatial and temporal characteristics of the selected climatic elements in Nigeria?

(ii) What are the spatial and temporal variations of the selected diseases?

(iii) Are there any cycles in the epidemic occurrences of the diseases (i.e. times when the diseases result in massive occurrence and/or death in their interannual occurrences)?

(iv) In what ways are the selected diseases related to the selected climatic elements of temperature, relative humidity, solar energy and rainfall on both temporal and spatial scales?

(v) Are there significant shifting patterns in the dynamics of the selected diseases and climatic elements, particularly of rainfall and temperature?

1.4 Objectives of Study

The main objective of the research is to examine the impact of climatic variations on the distributional patterns of Malaria, Measles, Pneumonia, Cerebro-Spinal-Meningitis, and Tuberculosis in Nigeria.

The specific objectives of the study include:

(1) Examining the nature of climate variation in Nigeria;

(2) Identifying the spatial and temporal distribution of the selected diseases in Nigeria;

(3) Investigating the relationships between climatic variations and the prevalence of selected diseases occurrence in the different ecological zones of Nigeria.

1.5 Significance of the Study

Climate is a key variable in managing the overall burden of diseases, particularly in developing countries like Nigeria where the ability to control climate-sensitive diseases constrain the prospects of achieving the United Nations Millennium Development Goals (WMO, 2008). To mitigate climate's adverse effects, the health sector needs to understand and quantify the specific effect of climate variability and change, both on the overall disease burden and on opportunities and effectiveness in the public health response. For example an accurate assessment of the impact of a bed net programme for malaria control depends on knowing the climatic trend during the assessment period. In the absence of any intervention, increasing wet years may well increase the mosquito population, resulting in a higher incidence of malaria while, conversely, the period of drought may well decrease mosquito population and reduce the incidences of malaria (Ghebreyesus, 2008). It is axiomatic that there is a good public health intervention strategy to cope with climate-sensitive diseases. This strategy must consider the role of climate, as well as other factors affecting disease incidence and preventive health care. Lack of understanding of the relationship between climate and disease often results in health services discounting its importance (WMO, 2008). By working with disease control programmes, climate services can help to identify where their information can be applied most effectively. Short term observation of local rainfall to provide an alert for epidemics of malaria, or gridded maps of routinely collected temperature and humidity data to generate maps of suitably for meningitis or malaria transmission in order to improve targeting and efficiency of diseases surveillance and control.

The significance of the impact of climate on health has increased in recent years. In 1989, for example, the US Environmental Protection Agency (USEPA) submitted a report addressing the relationship between climate and diseases to US Congress (USEPA, 1989). In Europe, the European Charter on Environment and Health (1987) directed their attention to this relationship. The awareness is not limited to developed countries, as many developing countries have also been conducting scientific assessments of the relationships between climate variability/change and health (WMO, 1996). Therefore, there is every need to assess these relationships for Nigeria in order to provide adequate information for effective early warning systems. However, studies that are available, especially from epidemiologists only refer to the influence of environmental factors on human health, mostly on local scale and mainly from the epidemiological point of view. But meteorological variables are the most important environmental factors in the transmission of malaria globally (Rasha and Ayman, 2011). The significance of this study, therefore, will be to know the impacts of climatic variation on the selected diseases as well as understanding the complex interrelationships.

1.6 Scope and Delimitation of the Study

This research focuses on climatic elements and their impacts on diseases. Rainfall and Temperature (maximum and minimum) were used. The choice of these elements appears significant and important due to limited detailed empirical work done in this area. Others considered but not to details include radiation, relative humidity, and surface wind speed. This study looks at the relationships between selected diseases and climatic elements at National, State and Ecological levels. The selected diseases are (a) Malaria (b) Measles (c) Pneumonia (d) Cerebro-Spinal-Meningitis (CSM) and (e)Tuberculosis (TB). The selection of the diseases was based on the following criteria and assumptions:

- The most prevalent disease (Malaria) based on the available data and information

- The diseases associated with the highest maternal and infant mortality rates, (Malaria, Measles).
- Those that have consistency in data availability and attracting international attention (Malaria, Measles) and
- Diseases that are most sensitive to climatic parameters (Pneumonia, CSM, TB)

1.7 Research Hypotheses

H_o: Null Hypothesis

1. There is no significant trend in the variations of the climatic elements over the study region
2. There is no significant shift in the spatial occurrences of selected diseases over the period of study
3. There is no significant relationship between selected climatic elements and disease incidence

1.8 Operational Definition of Terms

***Climate* -** Climate is defined as the average meteorological conditions experienced in particular areas, over a specified time period, such as thirty years.

Climate System – This is defined as the totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions.

Climate variability - Climate variability in this study refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events.

Disease – is defined as a process, which disturbs the structure or functions of the body, it is mainly caused by the pathogens or illness of the body, of the mind or of plants, caused by infection or internal disorder.

Ecosystem - This refers to mutually interrelated communities of species and abiotic components, existing as a system with specific interactions and exchange of matter, energy, and information.

Rainfall anomaly-is a deviation from typical or normal conditions of rainfall.

Incidence - This refers to number of cases of a disease commencing, or of persons falling ill, during a given period of time in a specified population.

Morbidity- This is the rate of occurrence of disease or other health disorder within a population, taking account of the age-specific morbidity rates

Prevalence - This refers to the number of events, (e.g. instances of a given disease or other conditions), in a given population at a designated time.

Vector - An organism that acts as an essential intermediate host or definite host for a human pathogen and which plays an active role in its transmission.

1.9 The Study Area

1.9.1 Location and Size

Nigeria lies approximately between longitude 3^{o} and 15^{o} E and latitude 4^{o} and 14^{o} N. It is bordered on the north by the Niger Republic, on the east by the Republic of Cameroon and on the west by Benin republic. The Gulf of Guinea, an arm of the Atlantic Ocean forms the southern boundary (Fig.1.1). The greatest distance from east to west is approximately 1,300 km, and from north to south is about 1,100km. The total length of the coastline of the country is about 853km while the area of Nigeria is about 923,300 sq. km. Nigeria is the most

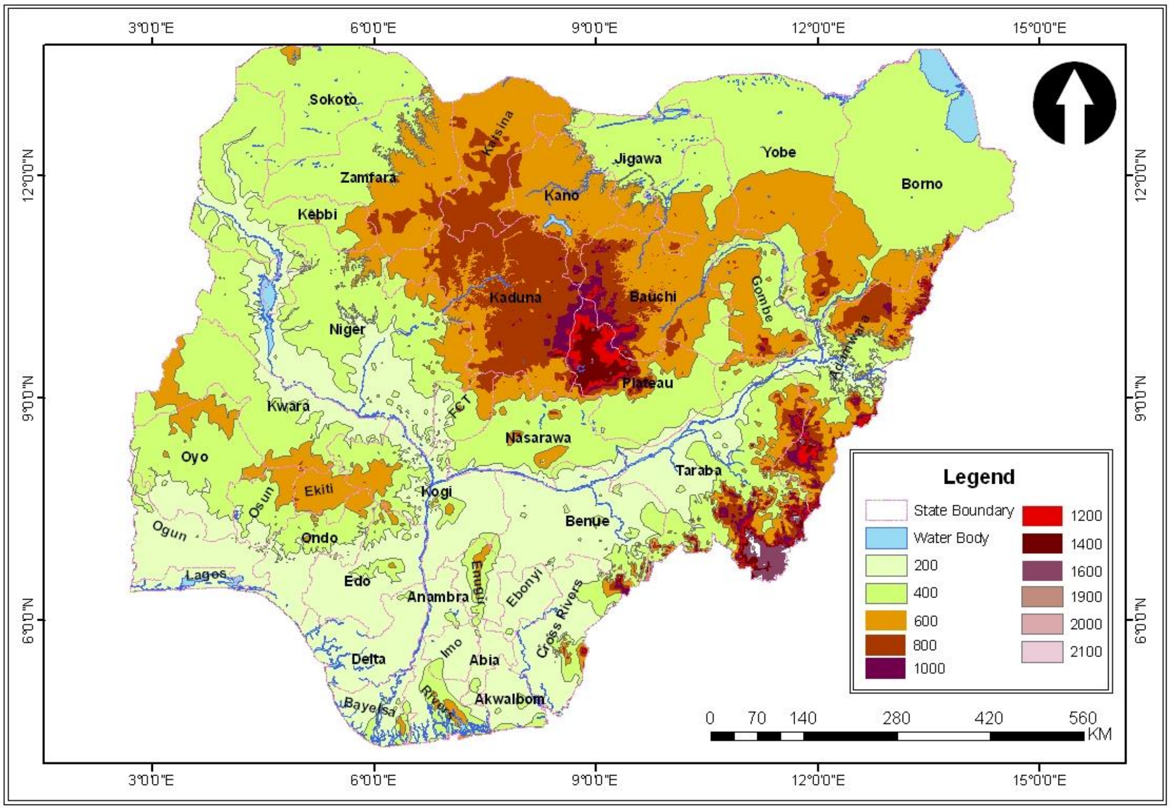

Fig. 1.1: Geo-Political Distribution of Nigeria States

populous country in Africa with a population of over 140million (NPC, 2006). A population of approximately one person out of every five Africans (Barbour *et al*, 1982).

1.9.2 Physical Features

1.9.2.1 Geology

Nigeria is composed mostly of metamorphic rocks of the basement complex, which outcrop in many parts and are overlain to the north by continental sedimentary of tertiary rocks. The Chad formation is to the north - east, while the Gundumi and Gwandu formations are to the north - west (Barbour *et al*, 1982). The earlier marine sedimentary of Lower and Upper Cretaceous age are deposited along the Niger - Benue - Gongola troughs and to the southern parts of the country. The relatively younger volcanic rocks of the tertiary era can be found on

The Biu and Jos plateau, which are major areas of extensive lava flow. The coastal area and the Niger Delta, have extensive alluvial deposits, which mask the underlying geological structure. The Niger enters the country from the northwest, the Benue from the northeast; they join at the city of Lokoja in the south central region and continue south, where they empty into the Atlantic at the Niger Delta. Together, they form the shape of a *Y* (Barbour *et al*, 1982).

1.9.3 Vegetation and Soils

1.9.3.1 Vegetation

In general, Nigeria has two major vegetation types. These include the forests to the south and the savannahs to the north. There are two types of forests namely the swamp forests and tropical rain forests. The swamp forests are found in many parts of the coast especially in parts of the Niger Delta, Lagos, Badagry and Calabar areas. Mangrove swamp vegetation occurs in areas permanently occupied by the brackish and tidal waters while fresh - water swamp forests are found in parts of Niger Delta and also along river valleys subjected to annual floods. Raphia palm is one of the useful trees found in fresh water swamps. The rain Forests are situated to the north of the swamp forests. They are found in areas with mean annual rainfall of at least 1500mm, and not more than three months in the year with less than 25mm of rain. Tall trees, masses of creepers and almost impenetrable undergrowth characterise the rain forests. The trees commonly found in the rain forests include Iroko, Obeche, Mahogany, and Sapele (Barbour *et al*, 1982).

There are three main types of savannah found in Nigeria. They include (a) The Guinea savannah, (b) the Sudan savannah and (c) the Sahel savannah. The Guinea savannah is the most southerly of the three savannah zones. It is characterised by a relatively short dry season of about four months and a relatively long rainy season of about eight months. There are many trees and tall grasses, which often attain a height of four meters or more. During the dry season, the grasses become seared while the trees shed their leaves.

The Sudan savannah is located to the south of Sahel savannah. It occurs in areas, which have mean annual rainfall of about 600-1000mm and a dry season of about six to seven months. Grasses averaging only one or one and half meters (1-1½m) in height are found here. Trees are generally scattered and include such species as fan - palm and dum. The Sahel savannah is the most northerly of the three savannah zones. It occurs in areas which have a mean annual rainfall of about 250 - 600mm and a dry season of up to nine months. The vegetation consists mainly of small thorny bushes with several species of Acacia found almost everywhere. Grasses are usually less than one meter in height (Barbour *et al*, 1982).

The mountain vegetation is found on the Adamawa highlands, as well as the Jos and the Biu plateaux. The grasses here are shorter while the trees are fewer than those in the Guinea or Sudan savannahs.

1.9.3.2 Soils

Two main types of soils can be found in Nigeria. These include the ferruginous soils and the ferrallitic soils. The ferruginous soils are mainly associated with the savannah vegetation. They are neither deeply weathered as ferrallitic soils nor do they contain free aluminium.

The ferrallitic soils, on the other hand, are mainly associated with the rain forests. The soils are deeply weathered and contain iron and aluminium. Soils rich in plant foods; permeable, fertile and derived from volcanic rocks are found on the Jos plateau

Alluvial soils are found on flood plains of the Niger Delta and along the coastal plains. These soils are formed from recent water deposits. The soils along the Niger and the Benue valleys are good examples of alluvial soils (Barbour *et al*, 1982).

1.9.4 Relief and Drainage

1.9.4.1 Relief

The relief of Nigeria can generally be divided into highlands and lowlands. The highland areas cover much of Northern Nigeria from Kaduna State to the eastern border of the Country through Plateau, Kano and Bauchi States. The highlands are also extensive over much of eastern Nigeria particularly along the boundary between Nigeria and the Republic of Cameroon. The major lowlands include the valley of the Sokoto River, the low plains to the northeast, the valleys of Rivers Niger and Benue, the coastal plains and the Niger Delta.

In general, nine relief regions may be distinguished in Nigeria. They include the Northern High Plains or the High Plains of Hausa lands, the Eastern Mountains, the Western Uplands, the South - Eastern lowlands and the Enugu scarp lands, the Western coastland, the Niger Delta, the Niger-Benue valley, the Sokoto Plains and the Chad Basin (Udo, 1978).

The northern high plains generally consist of plateaus with series of broad steps (Pediments) across which rivers meander widely in valleys of extreme old age. The Jos Plateau is the highest of these pediments.

The western uplands ran in a broad zone from the Benin Republic border eastwards toward the Niger. These uplands are broadest to the west where parts rise to more than 600 meters above sea level. They are narrower and are more dissected to the east. The uplands have several steep-sided hills known as Inselbergs, examples of which are the Idanre and the Aseke hills. To the south of western uplands lie immediately the Western coastlands. They include the coastal fresh - water swamps, which face the coastal Lagoon, that stretch from the Republic of Benin to the Niger Delta. The eastern mountains are located along the eastern frontiers of Nigeria and consist of the Mandara mountains and the Biu plateau. The mountains generally run from north to south and are over 800 meters high in some areas (Udo, 1978).

The Niger - Delta is a fan - shaped region of muddy creeks and brackish swamps with only occasional patches of slightly drier ground. The Delta has a coastline of about 320km with an area of 16,000km^2. The Sokoto plains have heights that average between 200 and 500 meters and lie to the northwest of Nigeria. The Sokoto River and its tributaries drain the Sokoto plains. The Chad Basin is an area of sedimentary rocks occupying the north east of Nigeria with Lake Chad, which has an average depth of less than three meters. The lake occupies the lowest part of the basin (Udo, 1978).

1.9.4.2 Drainage

The drainage pattern of Nigeria reflects the climate as well as the relief of the country. The most important river is the River Niger with Benue River as its main tributary. The northern tributaries of rivers Niger and Benue rise from the northern high plains. These include rivers Gongola, and Kaduna and the rivers that flow northeastwards to Lake Chad. Rivers such as Ogun, Osun, Osse flow southwards from the western uplands while the Cross river also flows southwards from eastern mountains to the Atlantic Ocean. Many rivers, which include the Shari, Lagone, Yedseram and Hadeija, also flow into Lake Chad (Udo, 1978).

1.9.5 Climate

The climate of Nigeria is largely determined by the characteristics of two major air masses - the moist maritime (equatorial) air-mass (mT air) originating from the Atlantic Ocean and the dry tropical (cT) air-mass originating from the Sahara desert (Adejokun, 1964; Ojo, 1977). The quasi-stationary boundary zone between these two air masses is called the Inter- Tropical Discontinuity (ITD) (Adejokun, 1964). The adoption of the term "ITD" follows the tradition of the Nigerian Meteorological Agency which in turn follows the concept as defined by the World Meteorological Organisation (WMO). According to the WMO definition, the ITD can be defined as the discontinuity separating the very hot and dry continental air from the cooler moister air from the Atlantic Ocean.

The rainy season in Nigeria is mainly linked to the northwards and southwards movement of the ITD, which is associated with the migratory pattern of the apparent movement of the sun, although with some time lag of about two weeks. In general, the characteristics of the rainfall patterns which result from the influence of the movement of the ITD, and the weather and climate systems consist of two equinoctial maxima in the forest area located along the coast, and one single maximum in the central parts and in areas to the north. Rainfall over the forest regions tends to be spread over many months, while inland from the coastal areas, and especially towards the northern parts of the country, rainfall becomes more concentrated within three to four months. In addition to the short rainy season to the north, the rainfall characteristics also include relatively low annual rainfall high variability and unreliability in rainfall (Ojo, 1977).

The Climate of Nigeria is also influenced by factors other than ITD. Such factors include atmospheric disturbances and medium to large-scale fluctuations in the atmospheric and oceanic circulation, land and sea breezes and relief. These factors are especially significant for sustainable environment and resources management because of their impacts on regional and local space scales. For example, the coastal areas are impacted locally and regionally by the characteristics of the coastal waters and land and sea breezes while relief factors play significant roles to influence the climates of the Adamawa highlands and the Jos Plateau (Ojo and Ojofehintimi, (2002).

The wind system that dominates the dry season in Nigeria is the north-easterly trade wind, originating from the Sahara desert. It always comes with the characteristics of dryness and is dust laden. Harmattan dust haze is a weather phenomenon that generally occurs north of the Inter-Tropical Discontinuity (ITD) during the Northern Hemispheric winter. Dust haze, one of the atmospheric pollutants affecting Nigeria during the dry season occurs during the month of November to March, but occasionally during the months of October to May over the northern parts of the country (Oyebande and Oguntoyinbo, 1970). It has been defined as very fine and opalescent particles which are so minute that they can remain airborne for a considerable length of time. The presence of these Harmattan dust particles constitutes a dusty atmosphere and act as obstruction to vision with visibility reduced to less than 1km by natural dust. Apart from the low visibility recorded during the dust haze period that disturbs flight operations in the aviation industry, it also constitutes a health hazard to people. The dry winds during the Harmattan dust haze spells causes the skin to dry to a degree that gives a sensation of razor – sharp cuts being inflicted on the body when one bends over. It also causes the irritation of the throat and eyes as if affected by diffused spray of “tears gas”. Coughing and running noses associated with bronchitis may be aggravated too. (Adefolalu, 1984). Some diseases such as Asthma, Cerebro-Spinal-Meningitis (SMS), and other respiratory diseases are commonly associated with the harmattan wind.

1.9.6 Population and Socio-Economic Characteristics

The National Population Census (NPC) conducted in 2006 put Nigeria population to be 140,003,542. According to UNDP (2012) the total population for Nigeria is projected to be about 166 million people in 2012, comprising about 250 ethnic groups, accounting for approximately one-quarter of West Africa's population. More than 20% of Nigerians are urban dwellers and at least 24 cities have population of more than 100,000. However, the population is expected to have risen to about 255.6million by the year 2025 at a growth rate of 2.8%. Poverty rate is about 62.6%, Per Capita Income is $1280; Human Development Index is 0.47% (UNDP, 2012). Total expenditure on health per Capita (Intl $207, 2013). Life expectancy is about 54years (2013 est.), (female is 55 yrs. and male is 54 yrs.), (WHO, 2013).

Agriculture is the main stay of the economy, with about 70 percent of the people engaged in farming or agriculture related activities. Agriculture, including farming and herding, accounts for 23 percent of Nigeria’s GDP and engages 3 percent of the economically active population. Agriculture contributed more than 75 percent of export earnings before 1970. Since then, however, agriculture has stagnated, partly due to government neglect and poor investment, and partly due to ecological factors such as drought, disease, and reduction in soil fertility. By the mid-1990s, agriculture’s share of exports had declined to less than 5 percent. Once an exporter of food to nearby countries, Nigeria now must import food to meet domestic demand. Nigeria’s major crops include palms (used to produce palm oil), cacao, rubber, and cotton, all of which were once exported but are now sold mostly locally. Also grown are sorghum, millet, maize (corn), yams, and cassava, all formerly used as food for growers but now widely sold for cash. Nigeria is rich in deposits of variety of minerals including petroleum, iron ore, diamond, gold, bauxite, natural gas, tin, columbite, coal limestone, lead, zinc etc. Manufacturing products are food and brewed beverages, refined petroleum, iron and steel, motor vehicles, textiles, foot wear, pulp and paper etc. Major exports are Petroleum, Cocoa, rubber and groundnuts etc. While major imports are Machinery and transportation equipment, manufactured good etc.

CHAPTER TWO

2.0 CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 Theoretical Framework

Climate and the many natural processes influenced by climate are a fundamental component of the earth's life supporting mechanisms. Consequently it is axiomatic that the characteristics of climate and climatic variations have significant impacts on the health and the survival of humanity and the ecosystems. The impacts of climate on health are already serious in many parts of the world and in view of the projected impacts of climate change, many of the health impacts are expected to be more serious than at present. The major impacts of climate variations and possible impacts of climate change are shown in Table 2.1, while Table 2.2 shows the relative impacts of climatic variations on health.

In general, the characteristics of climate and their impacts on human health are determined by the processes and feedbacks in the climate system which essentially is related to, and interact with the components of the environment. Indeed, the sustained health of the human populations depends upon the continued characteristics and processes of the climate system which sometimes can be equated to the climate-environmental systems.

It is probably important to emphasize that climate is a global concept, which is normally seen as the average state of the atmosphere or of weather conditions observed for a relatively long period of time of about 30 years or more. But in recent times, climate is not only defined by mean state, but the definition has been extended to measures of extremes and variability over periods of decades. While weather prediction very much depends on the accuracy of atmospheric observations, the reality of the characteristics of climate is essentially determined by the understanding of the processes and feedbacks in the climate-environment systems which involves the interactions of the various components of the environment (Fig.2.1).

Table 2.1. Possible major types of impacts of climate change on human health

TEMPERATURE AND WEATHER CHANGES

Mediating process	Health outcomes
Direct Impacts	
Exposure to thermal extremes	Altered rates of heat – and cold-related illness and death
Altered frequency and /or intensity of other extreme weather events	Deaths, injuries, psychological disorders; damage to public health infrastructure
Indirect Impacts	
DISTURBANCES OF ECOLOGICAL SYSTEMS Effects on range and activity of vectors and infective parasites	Changes in geographic ranges and incidence of vector-borne diseases
Altered local ecology of waterborne and foodborne infective agents	Changed incidence of diarrhoeal and other infectious diseases
Altered food (especially crop) productivity, due to changes in climate, weather events, and associated pests and diseases	Malnutrition and hunger, and consequent impairment of child growth and development
Sea level rise, with population displacement and damage to infrastructure	Increased risk of infectious diseases, psychological disorders
Levels and biological impacts of air pollution, including pollens and spores	Asthma and allergic disorders; other acute and chronic respiratory disorders and deaths
Social, economic and demographic dislocations due to effects on economy, infrastructure, and resource supply	Wide range of public health consequences: mental health and nutritional impairment, Infectious diseases, civil strife

Source: Modified after WHO, 1996

Table 2.2. Relative impacts of climatic variations with reference to significant climatic parameters -Temperature, Rainfall, Relative Humidity, Solar Radiation and Wind (*modified after WHO, 1996*)

Aspects of climate variations/change

Health Outcomes	Variations in Mean Climatic Parameter					
	Temperature	Rainfall	Relative Humidity	Radiation	Wind	Extreme Events (flood and drought)
Heat-related deaths and illness						+++
Physical and psychological trauma due to disasters		+++				++++
Vector-borne diseases	+++	++++	+	+	+	++
Non-vector-borne infectious diseases	+	+	++		+	+
Food availability and hunger	++	++++	+++			+
Consequences of sea level rise	++	+++				++
Respiratory effects: - air pollutants - pollens	 + ++	 +		 ++ ++	 +++ +++	 ++
population displacement	++					+

++++ = very great effects; +++ = great effects; ++ = fairly great effects + = just recognizable effects; empty cells indicate no known relationship.

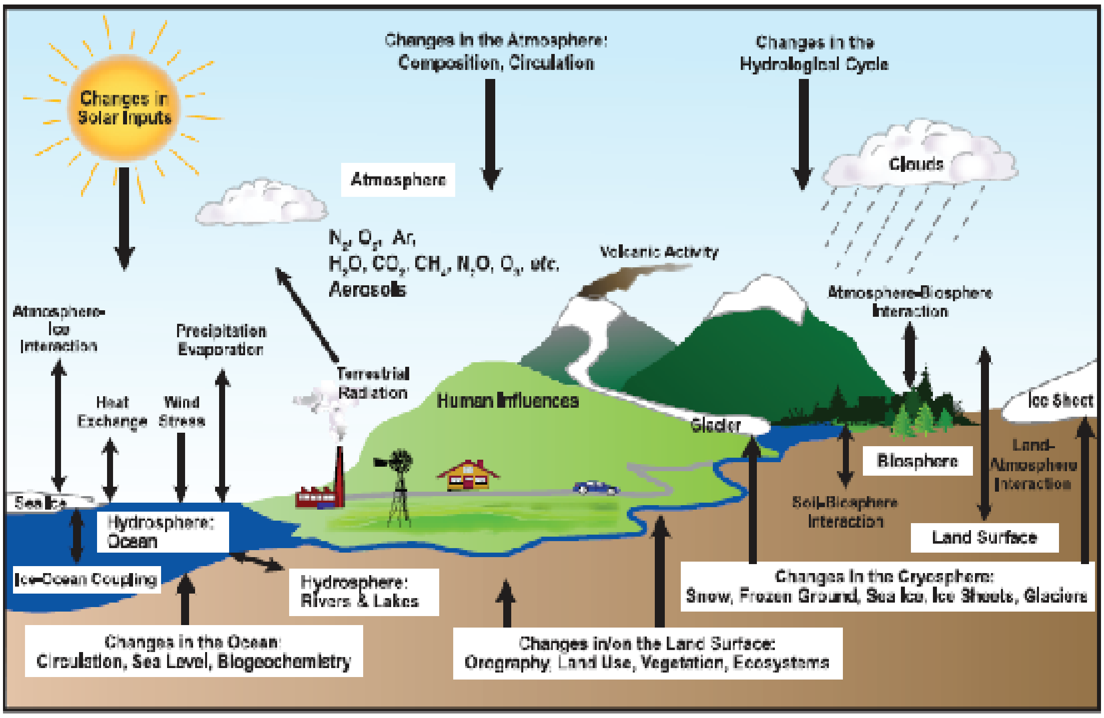

Fig. 2:1 Schematic view of the components of the climate system, their processes and interactions. Source: IPCC, 2007

The atmosphere, hydrosphere, cryosphere, biosphere, land surface and human beings are part of the components of the climate-environment systems. Climate system and atmospheric processes are strongly affected by, or "coupled to" the components of the climate – environmental systems.

In general, climate is the result of complex interactions between the different subsystems shown in Fig. 2.1. The oceans, the land surface, and the ice-coverage of land and oceans, together form the climate system. Atmospheric processes are strongly affected by or “coupled to” the various entities of these systems. As for the atmosphere, many of its properties are influenced by its gaseous composition, which itself is influenced by human beings and plant life on Earth. For example, human activities directly affect the atmospheric concentration of gases such as nitrogen and oxygen, and of trace gases such as water vapour, CO_2, methane

(CH_4) and nitrous oxide (N_2O). Although trace gases account for only 0.3% of atmospheric mass, they play a major role in relation to both the natural and the human-induced greenhouse effect.

2.1.2 Disease Interaction and the Environment

Health is best visualized as an equilibrium state in which multiple and diverse factors are balanced. Disease occurs when the balance is disturbed by change in the force with which one or more factors operate. Three classes of contributing factors are commonly recognized, the agent, the host, and the environment. The "agent" is synonymous with the primary or true cause without which a specific disease cannot occur. Agent factors derive from those innate properties of agents which help determine mechanism of transmission and reservoir and ability to cause disease in man. For microbial agents, these contributing factors include: (1) ability to survive in the free state (to resist temperature, sunlight, and other environmental influences): (2) the capability and requirements for multiplication outside the human host (bacteria can multiply in non-living media such as food or milk, whereas viruses can multiply only within living cells of vertebrate or arthropod host): and (3) the capacity to cause disease (pathogenicity), an attribute that may vary from strain to strain of the same microbial species.

The term "host" refers to man and, more specifically, the particular man or group of men of immediate concern. Host factors are biologic (age, sex, race, specific immunity and other attributes that relate to susceptibility or resistance) or behavioural (as governed by habits and customs). Environment embraces all that is external to the agent and the human host(s) immediately in question including fellow men. Environmental factors, thus, are very numerous and are commonly sub divided into three classes which relate, respectively, to the physical, biologic, and socio-economic segments of the environment.

To illustrate graphically the interaction of agent, host, and environmental factors, Dr. John Cordon has employed the analogy of a lever balanced over a fulcrum (the environment) by weights at either end representing respectively the agent, and the host (Fig. 2.2). When the system is in balance (the equilibrium state), good health prevails. When any of the forces changes, the balance is disturbed and disease increases.

For example increase in the weight of the agent could result from the emergence of a mutant strain of influenza virus with its antigenic character so altered that pre-existing host immunity becomes ineffective. The weight of the host could increase as the result of gradual population turnover owing to births and deaths or more rapid change in composition as a result of war - motivated population shifts. Either of these changes would increase the proportion of persons susceptible to specific microbial agents. The leverage of the agent also would be increased by an environmental change that facilitates agent spread. Finally, an environmental change which alters host susceptibility would increase the leverage of the host. This can be illustrated by the increasingly common phenomenon in industrial urban areas of the sudden build-up of air pollutants during atmospheric inversions to levels which are believed to increase the susceptibility of the human respiratory tract to infection.

Modern fundamental concepts in climatic variation and diseases are many and include the following:

- The Concept of Normal Climate
- Climate System Concept
- Ecological System (man-environment relation)
- Epidemiology of diseases

Objectively, the complex interactions between concept of normal climate, climate system, ecological conditions over a specified time (usually 30 years or more). Which may include information about the frequency and intensity of extreme events and other statistical characteristics of weather (WMO, 2003). Climate varies naturally over a wide range of spatial and temporal scales (NRC, 2001). Spatial climate variability include well-known latitudinal and altitudinal temperature gradients. For example, typical temperature value over Jos Plateau in Nigeria is lower that the latitudinal coverage in the area. Its orographic nature makes her rainfall pattern higher than its location (Ojo , 2008).

Interannual variations in the mean annual surface air temperature at specific locations are typically on the order of a degree Celsius (NRC, 2001). Interannual variations in rainfall can also be substantial. Apart from these, there exists a patterns or modes of climate variability (WMO, 2013). The best known of these modes is the El Nino / Southern Oscillation (ENSO) cycle. Others include the Pacific North America Oscillation and North Atlantic Oscillation (NAO). These modes have a degree of impacts on the climate variability of each location.

The concept of climate system elucidate the highly complex system consisting of five major components; the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere and the interaction between them (IPCC, 2007). The climate system evolves in time under the influence of its own internal dynamics and because of external forcing such as volcanic eruptions, solar variations and anthropogenic forcing such as the changing composition of the atmosphere and land use changes. Land –use and Land-cover changes can exert a profound influence on the distribution of infectious diseases. For instance, malaria vectors tend to be concentrated on land that is exposed to sunlight and that contains pool of water, thus land - cover changes that impact the amount of sunlight in vector breeding sites can alter the dynamics of malaria transmission (Walsh *et al*., 1993; Kovats *et al.*, 2001). Emerging diseases may be caused by a variety of pathogens that are considered to be undergoing changes in particular ways. Diseases emergence can be due to a variety of causes, including increasing global traffic of goods and people. Changes in human behaviour and demographics, or a breakdown in public health measures. Other frequently identified factor in diseases emergence (especially in outbreaks of previously unrecognized diseases) are climatic or ecological changes that place people in contact with a natural reservoir or host of an infection, by either increasing proximity or creating conditions that favour an increased population of the microbe or its natural host (NRC, 2001). The ecological approach examines the impact of human activities on the environment and the resultant effects on man within an ecosystem in order to safeguard human's term of health (Oyebande, 1995; Olorunfemi and Jimoh, 2000). The characteristics of climate and their impacts on human health are determined by the processes and feedbacks in the climate system which essentially is related to, and interact with the components of the environment. In general, climate is the result of complex interactions between the different subsystems shown in Fig. 2.3. Indeed, the sustained health of the human populations depends upon the continued characteristics and processes of the climate system which sometime can be equated to the climate-environmental systems (IPCC, 2007). Most infectious diseases can be classified as either anthroponotic or zoonotic. Anthroponitic diseases are caused by microorganism that normally exist in a transmission cycle involving only humans. Zoonotic diseases occur when microbes that are normally transmitted among non-human hosts are transferred to humans. Anthroponoses involves two components (microbial agent, human host) and are spread among people through contact or close association. Direct transmission of microbes such as tuberculosis or measles, for example, occurs via aerosolized droplets, fecal material, fomites, or other particulates. Indirectly transmitted anthroponoses involve three components (agent, vector, and human. A good examples include many widespread diseases caused by microbes that are transmitted via arthropod vectors such as dengue and malaria, which are transmitted by

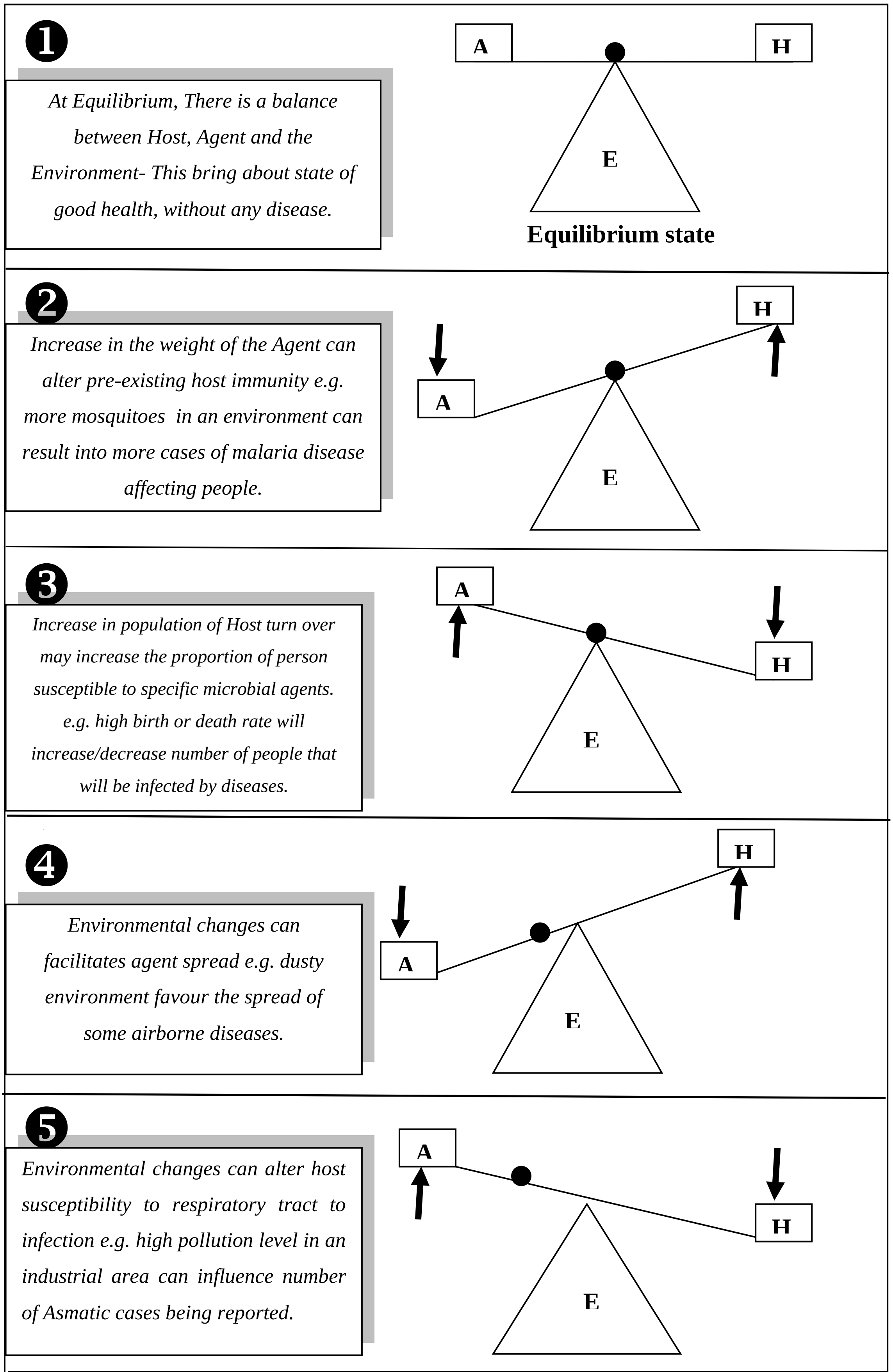

Fig.2.2: Illustrates the Interaction of Agent, Host, and Environment factors:
A= agent; **H**= host/man; **E**= environment (*adapted from Fox et al, 1970)*

mosquitos. Direct transmission zoonoses involve three components (agent, reservoir, and human) and are spread by aerosolized particles or body fluids. Indirectly transmitted zoonoses, involve four components (agent, vector, reservoir, and human) infect humans via water, soil, feces, or arthropod vectors. Finally, there are several infectious diseases that are not communicable but that are acquired from the environment, such as tetanus, and coccidioidomycosis (NRC, 2001).

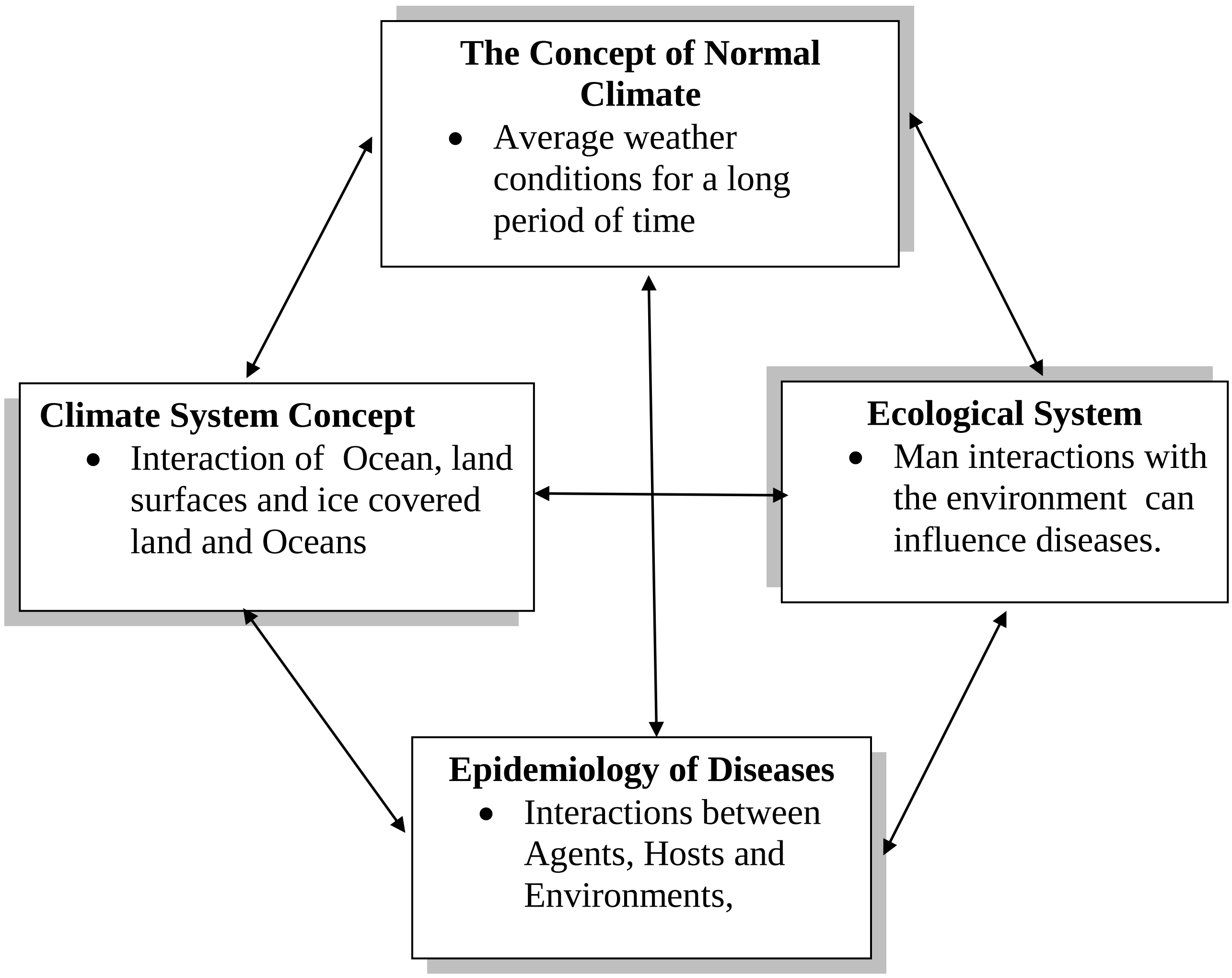

Fig. 2.3: An Idealised complex interactions between Global Concepts, Climate System, Ecological System and Epidemiology of Diseases (*modified after* NRC, 2001)

Human curiosity is the fundamental motivation of epidemiology, curiosity that centres on the causation of disease in human populations (Melnick, 2002). Epidemiologic problems are concerned with explaining the occurrence of diseases in human populations and with exploiting explanations discovered for the development of methods to protect man against disease. Epidemics occur when the conditions supporting the balance between the human, parasite and vector populations are disturbed in favour of the latter. This change in equilibrium is often brought about by climate anomalies which temporarily allow sufficient mosquito survival and parasite development.

2.2 Literature Review

In this thesis, the literature review is carried out under the following topics.

(i) Nature of Climate Variations.

(ii) Spatial and Temporal distribution of diseases in Nigeria.

(iii) The relationships between Climate variations and Diseases.

(iv) Characteristics of Diseases used in this study

2.2.1 Nature of Climate Variations

The world meteorological organization has defined climate as an average meteorological conditions over a specified time period (usually at least a month) which may include information about the frequency and intensity of extreme events and other statistical characteristics of the weather (NRC, 2001). Climate varies naturally over a wide range of spatial and temporal scales. In Nigeria, the spatial climate variability manifest by the humid climate in the south with annual rainfall over 2,000mm and semi-arid in the north with annual rainfall less than 600mm. (Ojo, 2008). Spatial climate variability include well-known latitudinal and altitudinal temperature gradients. For example, the topography of Jos plateau also plays a significant role in the spatial distribution of the climate of Nigeria, (Abiodun *et al.,* 2012). Temporal climate variations are mostly obviously recognised in ‘normal’ diurnal and seasonal variations (NRC, 2001). There are generally two seasons in the year, the wet and the dry seasons. The climate also characterized by double maxima in the south, with the first maxima in June and the second maximum in September. Cross- equatorial tropical Atlantic SST patterns influence the monsoon flow and moistening of boundary layer so that a colder northern tropical Atlantic induces negative rainfall anomalies (Xue *et al.,* 2010; Rowell, 2011) such negative rainfall anomalies manifest in Nigeria as short dry season. Climate varies on all time scales, from one year to the next, as well as from one decade, century or millennium to the next. (Michael, 2002). Variations in the Earth’s climate over time are caused by natural internal processes, such as El Nino as well as changes in external influence. These external influences can be natural in origin, such as Volcanic activity and variations in Solar output or caused by human activity, such as greenhouse gas emissions, human sourced aerosols, ozone depletion and land use changes (IPCC, 2007). Regional climates are strongly influenced by modes of climate variability. Modes and regimes provide a simplified description of variations in the climate systems (IPCC, 2013). Regional climates in different locations may vary out of place, owing to the action of teleconnections which modulate the location and strength of the storm tracks and poleward fluxes of heat, moisture and momentum. Understanding the nature of teleconnections and changes in their behaviour is central to understanding regional climate variability and change. Such seasonal and longer time-scale anomalies have direct impacts on humans, as they are often associated with droughts, floods, heat waves and cold waves and other changes that can severely disrupt agriculture, water supply and fisheries, can modulate air quality, fire risk, energy demand and supply and human health (IPCC, 2007). Several authors have studied climate variations and variability (IPCC, 2001; 2007; and 2013). For example, monsoons are the dominant modes of annual variation in the tropics (Trenberth, Stepaniak & Cannon, 2000); Wang and Ding, 2008), and affect weather climate in numerous regions. Variations in mean climate, seasonal cycle, intraseasonal and inter annual variability are modes of climates (Sperber and Kim, 2012), Atmospheric processes over Africa (Zheng and Braconnot, 2013). For example, rainfall exhibits notable spatial and temporal variability (e.g. Hulme *et al*., 2005). According to IPCC, 2007, analysis of atmospheric and climatic variability has shown that a significant component of it can be described in terms of fluctuations in the amplitude and sign of indices of relatively small number of preferred patterns of variability. Some of the best known of these are: El Nino-Southern Oscillation (ENSO), North Atlantic Oscillation (NAO), Northern Annular Mode (NAM), Southern Annular Mode (SAM), Pacific-North American (PNA) Pattern, and Pacific Decadal Oscillation (PDO). In all these the most relevant and have significant impacts on weather and climate of Nigeria is the El Nino Southern Oscillation (ENSO). Interannual rainfall variability is large over most of African countries, according to Nicholson *et al*., 2000; Chappell and Agnew, (2004), annual rainfall declines has been observed since the end of the 1960s with a decrease of 20 to 40% noted between the period 1931-1960 and 1968-1990. In other regions, such as southern Africa, no long-term trend has been noted (Dia *et al*., 2004). But in Angola, Zambia, Mozambique, Malawi and Zambia, a significant increase in heavy rainfall events has also been observed (Usman and Reason, 2004), including evidence of changes in seasonality and weather extremes (Tadross *et al*., 2005a; New *et al.*, 2006). During recent decades, eastern Africa has been experiencing an intensifying dipole rainfall pattern on the decadal time-scale. The dipole is characterized by increasing rainfall over the northern sector and declining amounts over the southern sector (Schreck and Semazzi, 2004).

Variation is also noted in temperature across the continent. For instance, decadal warming rate of 0.29C in the African tropical forests (Malhi and Wright, 2004) and 0.1 to 0.3C in South Africa (Krunger and Shongwe, 2004) have been observed. There has been an increase in the number of warm spells over Southern and West Africa between 1961 and 2000, according to New *et al*., (2006).

2.2.2 Spatial and Temporal distribution of diseases

Diseases distribution have been studied by several authors. Ratmanov *et al*., (2013), study the geographic distribution and geospatial characteristics of vector borne diseases in West Africa. He highlighted the great potential for the use of Geographical Information Systems and Remote Sensing (GIS/RS) technologies in the surveillance, prevention and control of vector borne and other infectious diseases in West Africa. (Olajuyigbe, Alinaitwe, Adegboyega & Salubi, 2012), also used GIS techniques to analyse factors responsible for incidence of water borne diseases in Ile-Ife, Nigeria. They noted poor environmental factors and topography were responsible for high incidence of waterborne diseases in their study areas.

An assessment of the spatial pattern of malaria infection was also studied by Onwuemele *et al.*, (2014). Seasonality variations was noted to have played a significant roles in malaria infections in Nigeria. Molesworth, Cuevas, Connor, Morse & Thomson, (2003), also studied the geographical distribution of meningitis in West Africa and found it to be attributable to environmental change driven by both changes in land use and regional climate change. Akinbobola and Omothso (2007, 2009), also used five to twelve years data to study the effect of weather on some common diseases in three stations in Nigeria. They found that malaria and pneumonia are associated with the rainy season while measles, chicken pox and CSM are common during the hot dry season. Other researchers that have investigated spatial and temporal distribution of malaria and tuberculosis were: (Afolabi, Adepeju & Osomo, (2013);

Idowu, Okoronkwo & Adagunoho, 2009; Tamb *et al.*, 2012; Da-Silva and Marshall, 2012; Oloyede & Akinbogun, 2013).

2.2.3 The relationships between Climate Variations and Diseases

The impacts of the weather and climate on health outside Africa have been studied extensively especially during the last fifty years. For example, Hsia (1978) and his colleagues have been engaged in investigations on the effects of weather and climate on respiratory diseases in the People's Republic of China. The results show that attacks of bronchial asthma always occur in spring and autumn but the attacks are more frequent in autumn than in spring, and this is usually highest when the average daily temperature is about 21^{o} C. Also, the study of the influence of weather and climate on rheumatic diseases was carried out by Tromp (1977) in the central area of West Germany. In this study Tromp (1977) found significant correlations between advection of warm or cold air mass, weather conditions carried by the advection, and upper air and vertical turbulent moisture on one hand and some selected diseases on the other. Wise (1977) also noted in his studies, that variations in diabetes prevalence between different geographic areas were dependent on both environmental and genetic factors, with food intake. Also, Jendritzky and Winkler (1978) found that anticyclone weather with moderate cold air has decreasing effects on blood-glucose.

Cox (1978), highlighted observations made during the last decades concerning the survival and spread of micro organism by aerosols. He found that the ability of a given micro-organism to survive and to remain infective in the airborne state depends to a large extent upon environmental factors. Simpson (1978) studied the influence of season upon type A influenza and noted two simple types of evidence that show that the disease is influenced by seasons. Annual fluctuations in *falciparum* malaria intensity in northeast Pakistan during the

1980s were correlated with variations in annual temperature and precipitation (Bouma, Sonclorp & Varder Kaay: (1994), 1995). Carcavallo *et al.,* (1995) noted that temperature, precipitation, and extreme weather events can also have effects on the viability and geographical distribution of the *anophelius* mosquitoes that transmit malaria. In particular, he noted that some higher latitude species were able to survive in sheltered places during cold spells, but most *anophelius* mosquito activity comes to a halt when the temperature drops below 23°C.

Several other authors have also studied the effects of weather and climate on malaria. (see for example MacDonald (1957), Slooff (1961), Pampana (1963), Bouma (1995), Rosedaal (1990), Suthersh (1993); Matsuoka *et al.*, (1994); Martin *et al.,* (1995), Martens, Niessen, Rotman, Jetten & Macmicheal, (1994), (1995), Tayse *et al.,* (1986), Haines, Epstein McMichael, (1993). For example Macdonald (1957) studied the incubation cycle of the *plasmodium* parasite of malaria. He found out that sensitivity to temperature is an important factor in the disease transmission. Also Slooff (1961) in his studies of malaria in Indo – Australia area, noted that breeding sites of *Anopheles punctulatus* group are closely associated with daily precipitation.

Khaw and Woodhouse (1995) and Pan *et al.,* (1995) noted the effects of high temperature on mortality. In their studies of heat waves, they were able to link the effect of extreme temperatures to the excess deaths from cardiovascular, cerebrovascular and respiratory conditions. Michelozzi *et al.*, (1999) in their recent studies of weather conditions and elderly mortality in Rome during summer found that increases of weather temperature and humidity are associated with an increase in daily mortality among older people. Also, De and Muchopdlyay (1998) carried out a study during 1998 heat wave of May and June in India, They concluded that about 1550 lives were lost. Gubler (1998) studied some of the factors that are responsible for determining the incidence and geographical distribution of vector borne diseases. He noted the importance of climatic factor as well as societal factor as being responsible.

In a study of reported cases of foodborne illness in the UK for the period of 1982-1991. It was found that there was a clear-cut overall increase in reported cases occurred, but that more cases had been in late summer months than in colder months (Bentham & Langford, 1995). Also in diarrhoeal diseases studies, it has long been observed that bacterial diarrhoea often peaks during hot and wet seasons and that this phenomenon is most pronounced in poor, temperate climate countries (Drass, Tomkins & Feacham 1981). The effects of El-Nino on diseases have also been investigated. For example, Bouma *et al.,* (1996) noted that the increase in malaria occurrence can be attributed to observed El-Nino phenomenon for Pakistan. Studies of the impacts of weather and climate variations and change on health have not been restricted to outside Africa. For example Loevinsohn (1994) noted a marked increase in the incidence and distribution of malaria during a typically hot wet weather in Rwanda in 1987. Studies carried out in Nairobi, Kenya and Harare in Zimbabwe by Martens *et al*., (1995) show that with climate change, large urban highland population that fall outside areas of stable endemic malaria and that are currently essentially malaria free area would be affected by malaria. According to Golovina and Trubina (1999), Denis Birkett made the unusual discovery that lymphoma of the Jaw, which is widespread among children in Central Africa is found only in a few areas with particular climate conditions, i.e. in places where annual precipitation is > 500mm and air temperature is usually > 15°C. The disease is caused by a breakdown in the immune system of the children, who often suffer from malaria in those areas. In their work, Taylor and Mutambu (1986) reviewed the malaria situation in Zimbabwe with special reference to 1972 – 1981, and noted that transmission of malaria begins to increase with the onset of the rains in November. Rogers and Williams (1993) attempted to map the geographical distribution of *G. morsitans (*tsetse fly*),* a vector of African trypanosomiasis (Sleeping sickness). Using climate and vegetation indices obtained through satellite remote sensing they found a correlation between the predicted distribution of the vector and human infections. Rogers and Packer (1993), found out that there was a difference in mean temperature between areas where *G. Morsistans (*tsetse fly*)*does and does not occur, thus indicating that a small change in temperature may significantly affect the distribution of African trypanosomiasis disease in Kenya and Tanzania. The effects of El Nino on diseases have also been investigated. According to Loevinsohn (1994), increase in malaria can be attributed to observed El Nino – associated warming in the highlands of Rwanda.

Also in Uganda, Lindblade, Walker, Onapa, Katungu &Wilson, (1999) found that an increase in rainfall/sometimes associated with El Nino, trigger highland epidemics. But Lindsay, Bodker, Malina, Masanzeni & Kisinzia, (2000) found a reduction to malaria infection in Tanzania associated with El Nino when heavy rainfall may have flushed out *Anopheline* mosquitoes from their breeding sites. According to Githeko, Lindsay, Confalonieri & Patz, (2000), modelling and mapping the distribution of malaria vectors may facilitate species - specific vector control activities. It has also been shown in Western Kenya that the risk of malaria transmission in the highland areas can be predicted with simple rainfall and temperature dependent predictive model. The study of relationships between climate and health in West Africa dated back to pre-independent days. For example the effect of climate on Influenza epidemics in West Africa including Nigeria was investigated for May 1950 - April 1951 by Freyche and Klimt (1951). In that study, they found that type A influenza epidemics were greatly influenced by seasons. In another study, Cvjetanovic (1976) investigated the causes of severe seasonal epidemics of Cerebrospinal Meningitis (CSM) belt in the Sahelian part of West Africa. Among the possible causes which he noted were changes in temperature and extension of drought areas due to climate change.

Based on the analysis of one longitudinal study in Burkina Faso and another in Nigeria, Greenwood, Blackbrough, Bradley & Wali, (1984) postulated that dry air and overcrowding in winter may predispose individuals to systemic Meningococcal infection. Similarly in the Nigeria's study (covering 1977 - 1979), peak clinical meningitis incidence was strongly correlated with the highest mean maximum temperature of the dry (winter) season and inversely correlated with absolute humidity to a lesser, although still significant, extent. Also, Nwankwo *et al* (1988) noted seasonal variation in respiratory syncytial virus (RSV) infection in children that was examined in Benin City. They concluded that RSV infections occur all year round with a peak during the rainy season.

Having review the contributions of several authors and their views on the state of health and climate, the importance of climate information in health programme cannot be over emphasised. The limited number of studies and understanding of these relationship in Nigeria posed a serious constraint. Most earlier researchers emphasised the use of GIS/RS and other longitudinal study, but few studies were done on the impacts of climate variations and diseases in Nigeria. Therefore, this study will go a long way to close the gap in the literature and in understanding the relationship in Nigeria.

2.3 SOME CHARACTERISTICS OF DISEASES USED IN THIS STUDY

2.3.1 Malaria

Malaria is one of the vector borne diseases that are influenced by climate. It is a serious and sometimes a fatal disease caused by a parasite called Plasmodium (*Plasmodium falciparum; P. vivax; P. ovale and P. malariae).* It occurs in over 100 countries and territories of the world and more than 40% of the people in the world are at risk (WHO, 1996). The World Health Organization estimates that yearly, about 300 – 500 million cases of malaria occur and more than 1 million people die of malaria (WMO, 1996).

In Nigeria malaria has consistently been the commonest reported disease and also among the top three causes of reported deaths. The actual incidence and mortality rates of malaria are unknown due to incomplete and irregular reporting. However estimates indicate that children under the age of 5 years have 2 – 4 attacks of malaria a year and approximately 50% of the adult population experience at least one episode of malaria per year. Also, mortality estimates shows that about 200 to 300 thousand deaths mostly in children occur in each year (WHO, 2003). Malaria is one of the greatest impediments to child survival and development as well as to socio-economic improvement in Nigeria.

Humans get malaria from the bite of malaria – infected mosquito. When a mosquito bites an infected person, it ingests microscopic malaria parasites found in the person's blood. The malaria parasite must grow in the mosquito for about a week or more before infection can be passed on to a person. After a week of the mosquito bite the parasites go from the mosquito's mouth into the person's blood. The parasite then travel to the person's liver, enter the liver's cells, grow and multiply. During this time when the parasites are in the liver, the person will not yet feel sick. But when the parasites leave the liver and enter the red blood cells; (this may take as little as 8 days or as many as several months), the parasites grow and multiply, the red blood cells burst, forcing the parasites to attack other red blood cells. Toxins from the parasite are also released into the blood, making the person feel sick (Alakija, 2000)

The influence of climatic conditions on the malaria and its parasites has been addressed in numerous studies, in most of which attention is restricted to the effect of temperature, rainfall and relative humidity (WHO, 1996). For example, precipitation is an important factor with respect to insects such as mosquitoes. These insects have aquatic larvae and pupae stages, and it is precipitation that determines the presence or absence of breeding sites. The impact of precipitation on breeding sites however depends on local evaporation rates, soil percolation rates, slope of the terrain, and proximity of large water bodies and rivers. Many species breed in the residual water that remains after flooding in the rainy season. However, extremely heavy precipitation will wash vector larvae away, or kill them directly, (WHO, 1996).

High relative humidity favours most metabolic processes in vector organism. At high temperatures, relatively high humidity prolongs the survival of most arthropods. Low humidity levels cause some vectors to feed more frequently to compensate for dehydration.

Table 2.3: Temperature profile of mosquitos development (WHO, 1996).

minimum temperature for mosquito development

optimum temperature for moquitos

8, 9,10, . . ….. 14, 15, 16, 17, 18, 19, . . …. . . 25, 26, 27,. . . . . 40 °C

minimum temperature for parasite development

maximum temperature

An increase in temperature accelerates the vectors metabolic processes consequently affecting their nutritional requirements. Blood-feeding vectors then need to feed more frequently. Their biting rate therefore increases, which can in turn, lead to increase in egg production. Temperature changes can also affect the distribution of many arthropod vectors since this is limited geographically by minimum and maximum temperatures (and humidity). Moreover, since most of the physiological functions of arthropod vectors are subject to optimal temperatures, any changes in minimum temperatures, could greatly affect arthropod survival (WHO, 1996).

2.3.2 Measles

Measles is a highly contagious viral disease, which affects mostly children. It is caused by a virus in the paramyxovirus family and it is normally passed through direct contact and through the air. The first sign of measles is usually a high fever, which begins about 10 to 12 days after exposure to the virus, and lasts 4 to 7 days. A runny nose, a cough, red and watery eyes, and small white spots inside the cheeks can develop in the initial stage. After several days, a rash erupts, usually on the face and upper neck. Over about 3 days, the rash spreads, eventually reaching the hands and feet. The rash lasts for 5 to 6 days, and then fades. On average, the rash occurs 14 days after exposure to the virus (within a range of 7 to 18 days).

Most measles-related deaths are caused by complications associated with the disease. Complications are more common in children under the age of 5, or adults over the age of 20. The most serious complications include blindness, encephalitis (an infection that causes brain swelling), severe diarrhoea and related dehydration, ear infections, or severe respiratory infections such as pneumonia. Severe measles is more likely among poorly nourished young children, especially those with insufficient vitamin A, or whose immune systems have been weakened by HIV/AIDS or other diseases.

It is transmitted via droplets from the nose, mouth or throat of infected persons. Initial symptoms, which usually appear 10–12 days after infection, include high fever, runny nose, bloodshot eyes, and tiny white spots on the inside of the mouth. Several days later, a rash develops, starting on the face and upper neck and gradually spreading downwards. The virus infects the mucous membranes, then spreads throughout the body. Measles is a human disease and is not known to occur in animals (WHO, 2012). A survey of measles in an urban area of Nigeria revealed an annual incidence rate of 11.8% among under-fives and associated with an acute case fatality rate of 3.3 % (Byass *et al,* 1995). In 2013, about 84% of the world's children received one dose of measles vaccine by their first birthday through routine health services – up from 73% in 2000. During 2000-2013, measles vaccination prevented an estimated 15.6 million deaths making measles vaccine one of the best buys in public health (WHO, 2015)

2.3.3 Meningitis

Meningococcal disease is a contagious disease caused by the meningococcus (Neisseria meningitidis), a Gram-negative bacterium (WHO, 1997). There are two clinical forms of meningococcal disease. Meningococcal meningitis is the more common entity, especially during epidemics; outcome is good if appropriately treated. In contrast, meningococcal septicaemia, in which bacteria are found in the blood stream, is less common but highly fatal, even when actively treated. Cases in which both meningitis and septicaemia occur simultaneously are usually regarded as cases of meningitis. Meningococcal meningitis, commonly designated as cerebrospinal meningitis, is the only form of bacterial meningitis which causes epidemics. Epidemics can occur in any part of the world. However, the largest epidemics occur mainly in the semi-arid areas of sub-Saharan Africa, designated the African meningitis belt. Apart from epidemics, meningococcal meningitis occurs sporadically throughout the world, with seasonal variations, and accounts for a variable proportion of endemic bacterial meningitis. In non-epidemic conditions, only laboratory investigation of cerebrospinal fluid (CSF), obtained by lumbar puncture, can reliably differentiate meningococcal meningitis from other types of bacterial meningitis. Meningitis occurs endemic and epidemic worldwide. Common in both temperate and tropical climates, with sporadic cases throughout the year in both urban and rural areas. Its greatest prevalence is during the dry season with an irregular interval of 5-10 years. (WHO, 2003). Menicogoccal infection occurs more commonly in children and young adults, in male more than in females, and more commonly in adults under crowded living conditions, such as in barracks and institutions. Large epidemics have occurred in hot dry regions. A broad area of high incidence has existed for many years in the sub-Sahara region of Africa. A typical epidemics starts in the middle of the dry season and end a few months later with the onset of rains (Greenwood et al, 1984). Between February and April 1996, the disease affected thousands of people in parts of northern Nigeria, many whom died (WHO, 2003).

The infection agent is Neisseria meningitides (*N. intracellularis*), *the meningcoccus* and the reservoir is man. The mode of transmission is by direct contact, including droplets and discharges from nose and throat of infected persons. The incubation period varies from 2-10 days, commonly 3-4 days. In a study carried out in Nigeria peak clinical meningitis incidence was strongly correlated with the highest maximum mean temperature of the (winter) season and inversely correlated with absolute humidity. This suggested that atmospheric conditions determine efficacy and dosage of airborne transmission (WHO, 1996).

2.3.4 Pneumonia

Pneumonia is a form of acute respiratory infection that affects the lungs. The lungs are made up of small sacs called alveoli, which fill with air when a healthy person breathes. When an individual has pneumonia, the alveoli are filled with pus and fluid, which makes breathing painful and limits oxygen intake. It is characterized by the sudden onset of a single shaking chill with fever, pain in the chest, usually dyspnoea and leucocytosis and cough productive of ‘rusty’ sputum. Pneumonia can be bronchial rather than lobar, especially in children.

Vomiting and convulsions have been observed as the first manifestations. Pneumococcal pneumonia is an important cause of death, especially in infants and the aged. It occurs most frequent in industrial cities and lower economic groups. It also occurs in all climates and seasons. Infectious agent is *streptococcus pneumoniae* (*pneumococci*). The reservoir is man. Pneumococci are commonly found in the upper respiratory tract of healthy person throughout the world. Mode of transmission is by droplet spread, by direct oral contact or indirectly through article freshly soiled with respiratory discharges. Person to person transmission is common, but illness among causal contacts and attendants is infrequent. Incubation period is not well determined but believed to be 1 to 3 days. Pneumonia is the single largest infectious cause of death in children worldwide. Pneumonia killed an estimated 935 000 children under the age of five in 2013, accounting for 15% of all deaths of children under five years old. Pneumonia affects children and families everywhere, but is most prevalent in South Asia and sub-Saharan Africa. Children can be protected from pneumonia, it can be prevented with simple interventions, and treated with low-cost, low-tech medication and care.

2.3.5 Tuberculosis

Tuberculosis is a chronic mycobacterial disease, which is important as a cause of disability and death in many parts of the world. Primary infection usually goes unnoticed clinically; tuberculin sensitivity appears within a few weeks; lesions commonly become inactive, leaving no residual changes except pulmonary or tracheobronchial lymph node calcifications may progress, however, to active pulmonary tuberculosis, pleurisy or lympho-haematogenous involvement. Serious outcome of primary infection is more frequent in infants than in older persons. Pulmonary tuberculosis generally arises from a latent primary focus and if untreated has a variable and often a symptomatic course with exacerbation and remissions but may be cured with chemotherapy. Clinical status is established by presence of tubercle bacilli in sputum, or by progression or retrogression as detected in serial X-rays following a definitive bacteriologic diagnosis. Abnormal X-ray densities indicative of pulmonary infiltration, cavitation, or fibrosis commonly occur before clinical manifestation. Cough, fatigue, fever, weight loss, hoarseness, chest pain and haemoptysis may occur but often are absent until advanced stages.

Extra pulmonary tuberculosis is much less common than pulmonary. It includes tuberculosis meningitis, acute haematogenous tuberculosis and involvement of bones and joints, eyes, lymph nodes, kidneys, intestines, larynx, skin or peritoneum. Diagnosis is by recovery of *tubercle bacilli* from lesions or exudates. Tuberculosis occurred in all parts of the world, numerous countries have showed downward trends of mortality and morbidity for many years. Mortality rate range from below 5 to 100 deaths per 100,000 populations per year. In a study carried out in the former Bendel State of Nigeria, between 37.1% and 43.7% of suspected cases of tuberculosis were confirmed yearly from 1975 to 1978 (Alakija, 2000). Also in annual report 6, Mile Four Hospital, Abakaliki, south-eastern Nigeria, 534 new cases of tuberculosis were recorded in 1989 in one general hospital alone.

The mortality and morbidity rates increase with age, higher in males than in females, much higher in non-whites than in whites. Epidemics have been reported among children in crowded classrooms or other groups congregated in enclosed spaces. The infectious agent is *Mycobacterium tuberculosis*, the human *tubercle bacillus*, and M. *bovis* in cattle, swine and other animals. A typical mycobacteria occasionally produce disease indistinguishable from pulmonary tuberculosis except by culture of the organisms. The mode of transmission is by exposure to bacilli in airborne droplet nuclei from sputum of infected persons. Indirect contact through contaminated articles or dust may occur, but is not important. Direct invasion mucous membrane or break in the skin is extremely rare. Bovine tuberculosis result from exposure to tuberculosis cows, usually by ingestion of unpasteurized milk or ordinary products and sometimes by airborne spread to farmers and animal handlers. Incubation period is from infection to demonstrate primary lesion, about 4 to 12 weeks, to progressive pulmonary or extra-pulmonary tuberculosis may be years.

CHAPTER THREE

3.0 METHODOLOGY

3.1 The data, Sources and characteristics

The data used for this study are of two types, namely (a) Climatic data, and (b) Data on incidence of diseases. Data on various climatic elements include those on rainfall, temperature (maximum and minimum), relative humidity, radiation and surface wind speed. Data on climatic elements were collected from the Nigerian Meteorological Agency, Lagos. The climatic data were collated on monthly basis, and tested for homogeneity.

Table 3.1, shows the data types, sources and duration with some comments.

Table 3.1: Shows the data types, sources and duration with some comments

DATA TYPES	SOURCE	DURATION	COMMENTS
Climate Data Temperature Rainfall Humidity Radiation Wind (speed & direction)	Nigerian Meteorological Agency, Oshodi, Lagos	(a)1958-2009 for computing averages/means of the climatic data (b) 1982 - 2009 for studying relationships	Mainly instrumental data
Health Data Reported cases of diseases Mortality data Morbidity data	(a) Office of Statistics, Broad Street, Lagos (b) Epidemiology Dept., Federal Ministry of Health, Abuja	1982 - 1997 1998 – 2009	Data obtained at National, State and LG levels (Hospitals, dispensaries, health clinics and through clinical reports)

The spatial distribution of the Meteorological stations of Nigeria is as located in figure 1.1. Table 3.2 shows the meteorological stations in each ecological zones. However, data on incidence of diseases, which comprises of reported cases of diseases including (morbidity and mortality data), were collected from Office of Statistics, Lagos and Epidemiology Department, Federal Ministry of Health, Abuja.

Table 3.2: Selected Meteorological Stations in each Ecological Zones

Ecological Zone	**Meteorological Station**
SAHEL SAVANNAH	Katsina; Nguru; Maiduguri; Potiskum; Sokoto
SUDAN SAVANNAH	Kano; Gusau; Bauchi; Yelwa; Yola; Ibi
GUINEA SAVANNAH	Kaduna; Lokoja; Makurdi; Minna; Jos; Bida; Ilorin; Oshogbo; Enugu
RAIN FOREST	Ikeja; Ondo; Benin
MANGROVE SWAMP FOREST	Warri; Portharcourt; Calabar

One of the most critical obstacles to this study is lack of high – quality epidemiological data on disease incidence for many locations. These data are needed to establish an empirical basis for assessing climate influences and to develop and validate predictive models. Data exchange is affected by governmental concerns related to state national security. In fact, student's accessibility to data are very limited to certain number of years and to a pattern of record. For example, it was not easy to collect annual morbidity data for more than 10 years and at the same time collect either monthly record for all the States or Local Government Areas in the Country. Most major public health institutions rely primarily on State/Local public health personnel to submit surveillance data voluntarily (mostly from the records of hospitals and clinics). In most cases these records are poorly kept and submissions are not regular. Even those data collected from secondary sources are full of errors where data quality control could be performed.

Similarly, meteorological data also are found to be inaccurate even when quality control test are done. In some cases data are not available which means interpolation or extrapolation of such data may put the results obtained unreliable. There are many missing values in some, while some are full of inconsistencies. Arithmetic mean method, isoyetal linear interpolation and isopleth method and weighed arithmetic mean methods are used to fill in the gap. If the missing data are more than three and continuous, such data are excluded from the study.

However, for the purposes, time-frame, and extent of this study, the data obtained, having passed through various quality checks are sufficient for a preliminary analysis of the relationship between some selected diseases and climatic variables.

3.2 Data Analysis

The methodology used in this study involves the use of statistical analyses especially with respect to:

(i) Mean Analysis

(ii) Time Series Analysis

(iii) Pearson Correlation Analysis

(iv) Canonical Correlation Analysis and

(v) Standardized Anomaly

All the statistical analyses were done using the statistical software package, System Statistics (SYSTAT) version 10.2. Mappings were done using GIS software package, ArcView version 3.3 and Surfer version 8. All other mathematical calculations were done using Microsoft Excel software package. In satisfying the objectives of the study, the techniques used as illustrated in Figure 3.1 are as follows:

3.2.1 Nature of Climate Variation

The nature of climate variation was determined using simple descriptive statistics and dispersion. The climatic parameters (rainfall, temperature, radiation, relative humidity) computed data were mapped for contour analysis using surfer software packages and graphical methods using MS Excel Spreadsheet. Mean monthly variation, yearly variation and trends were determined.

3.2.1.1 Mean Average Values

The mean values of climatic and diseases data used in this study were calculated from the equation which can be expressed in the form:

$$\overline{X} = \frac{\sum_{j=1}^{n} x_j}{N} \qquad (3.1)$$

where j = variables; 1+2+3…..n

N = total number of the variables

In order to study the geographical distribution with respect to annual and monthly variations and variability, mean values/long-term averages were used. Spatial and temporal mapping were done using Surfer version 8 software.

3.2.2 Spatio-Temporal Distribution of Selected Diseases

Time series analysis and contour analysis were mapped using density dot method. In order to identify varying conditions of wet, dry and near normal condition, rainfall anomaly indices were used (DMNC, 1999). Spatial analysis were also done using Surfer software packages to determined monthly and yearly trends in the distribution of selected diseases.

3.2.2.1 Time Series Analysis

A time series is a collection of observations made sequentially in time and most climatic data are collected as time series. The special feature of time analysis is that successive observations are usually not independent. By producing a time series graph the characteristics of the time series can be examined. One of the aims of using time series is to find patterns in the data, to separate out these patterns and examine the variation about these patterns (separating positive/negative variations from the series through different smoothing method - (degree of polynomial). Therefore, the aim of employing this analysis is to look at the trends (whether the series, disregarding fluctuations, increases, decreases or remains constant over the time interval) and seasonal effects (whether repetitive of patterns over months or years with a series).

3.2.2.2 Standardized Anomaly

The equation for the standardized anomaly can be expressed in the form

$$Y = \frac{x - \bar{x}}{\sigma} \qquad \text{…………………………………….. (3.4)}$$

Where x is the climatic parameter

$\bar{x}$ = long term average (mean)

σ = Standard Deviation

Y= Standardized anomaly

In order to determine the regional correlation coefficients (or analysis) of climatic parameters on the selected diseases, three stations were selected in the Northern region (Sokoto, Kano, Maiduguri), four from the Central region (Minna, Jos, Yola, Makurdi) and three from the Southern region (Lagos, Port Harcourt and Enugu). These selections were done based on availability of data and spatial geographical distribution. Because of non-availability of long-term diseases data, 1981-2009 periods were used for the correlations and the standardized anomalies.

3.2.3 Climate Variation and Diseases

Pearson correlation method was used to determine the strength of the linear association between climatic parameters and diseases as indicated by the correlation coefficient. This was done for the five ecological zones. The Sahel savannah, Sudan Savanna, Guinea Savanna, Tropical Forest and Mangrove/Coastal zones.

In order to further establish the statistical relationship between the climatic elements and occurrence of the selected diseases and to be able to determine how much variance in one set of variable is accounted for by the other set (Tabachnick & Fidell, 1996). Canonical correlation technique was used for selected cities across Nigeria.

The null hypotheses on the existence of relationships was tested using student‘t’ distribution and Wilks’s Lambda test of significance.

In order to establish the climatic condition favorable for malaria transmission in Nigeria, relative frequencies were used (Craig, Snow, Sveur, 1999). Rainfall greater than 80mm, temperature ranged between 18°C and 32°C and relative humidity greater than 60% were computed for the ecological zones across the country. Twenty-eight stations were selected across the country based on the availability of climatic data 1958 – 2009. Graphical representation was used to depict the possible modulation effects of climatic elements on annual and monthly trends for the selected diseases (Omonijo & Oguntoke, 2009).

3.2.3.1 Pearson Correlation Analysis (PCA)

Pearson Correlation Analysis (PCA) was used to determine the strength of the linear association between climatic parameters and disease variables as indicated by the ***correlation coefficient***. Given a set of observations (x_1, y_1), (x_2,y_2),...(x_n,y_n), the formula for computing the correlation coefficient is given by

$$r = \frac{1}{n-1} \Sigma \left(\frac{x - \overline{x}}{s_x}\right)\left(\frac{y - \overline{y}}{s_y}\right) \qquad \text{.....................} \ \textbf{(3.2)}$$

Where x = mean monthly malaria data

y = mean monthly data for rainfall …etc.

S_x = standard deviation of variable x

S_y = standard deviation of variable y

3.2.3.2 Canonical Correlation Analysis (CCA)

Cannonical Correlation Analysis (CCA) was carried out in order to study the statistical relationship between the climatic factors and the occurrence of the selected diseases. Canonical Correlation is one of the most useful general of the multivariate techniques. It is used to investigate the overall correlation between two sets of variables (***p’*** and ***q’***). Where ***p’*** = *Climatic parameters and* ***q’*** = *Diseases data.* The basic principle behind canonical correlation is determining how much variance in one set of variables is accounted for by the other set along one or more axes (Tabachnick *et al*, 1996).

The general equations for performing a canonical correlation are as follows:

$$\mathbf{R} = \mathbf{R}_{yy}^{-1}\mathbf{R}_{yx}\mathbf{R}_{xx}^{-1}\mathbf{R}_{xy} \qquad \text{.............................} \quad \mathbf{(3.3)}$$

Where **R** is the product of the inverse of the correlation matrix of ***q'*** (**R_{yy}**), a correlation matrix between ***q'*** and ***p'*** (**R_{yx}**), the inverse of correlation matrix of ***p'*** (**R_{xx}**), and the other correlation matrix between ***q'*** and ***p'*** (**R_{xy}**), (Afifi & Klark, 1996).

These analyses were done using System Statistics (SYSTAT Version 10.2). The output of (**R**) gives the following Variables:

(a) R^2 which gives the percentage ability of independent variables (Climatic parameters – Rainfall, Maximum Temperature, Minimum Temperature, Relative Humidity, Radiation and Wind Speed) in predicting dependent variable (selected diseases – Malaria, Measles, Pneumonia, Cerebro-Spinal-Meningitis (CSM) and Tuberculosis.

(b) F - Statistic is used to determine the relative importance of the variable. Least helpful for discriminating among the variables. (When F is small).

(c) Adjusted R^2 value deduces the amount to which the predicted power of the regression analysis is decreased by adding the extra climate variables.

(d) Probability value (P) which expresses the probability that the correlation is due to chance alone and as such P close to zero indicate high significance.

(e) Canonical Correlation Analysis (CCA) examines point specific, and indicates the percentage of possible occurrence of independent variable (Selected disease – Malaria, Measles, pneumonia Cerebro Spinal Meningitis (CSM), and Tuberculosis) in the locality.

3.3 Hypotheses Testing

Ho: Null Hypothesis

1. There is no significant trend in the variations of the climatic elements over the study region.

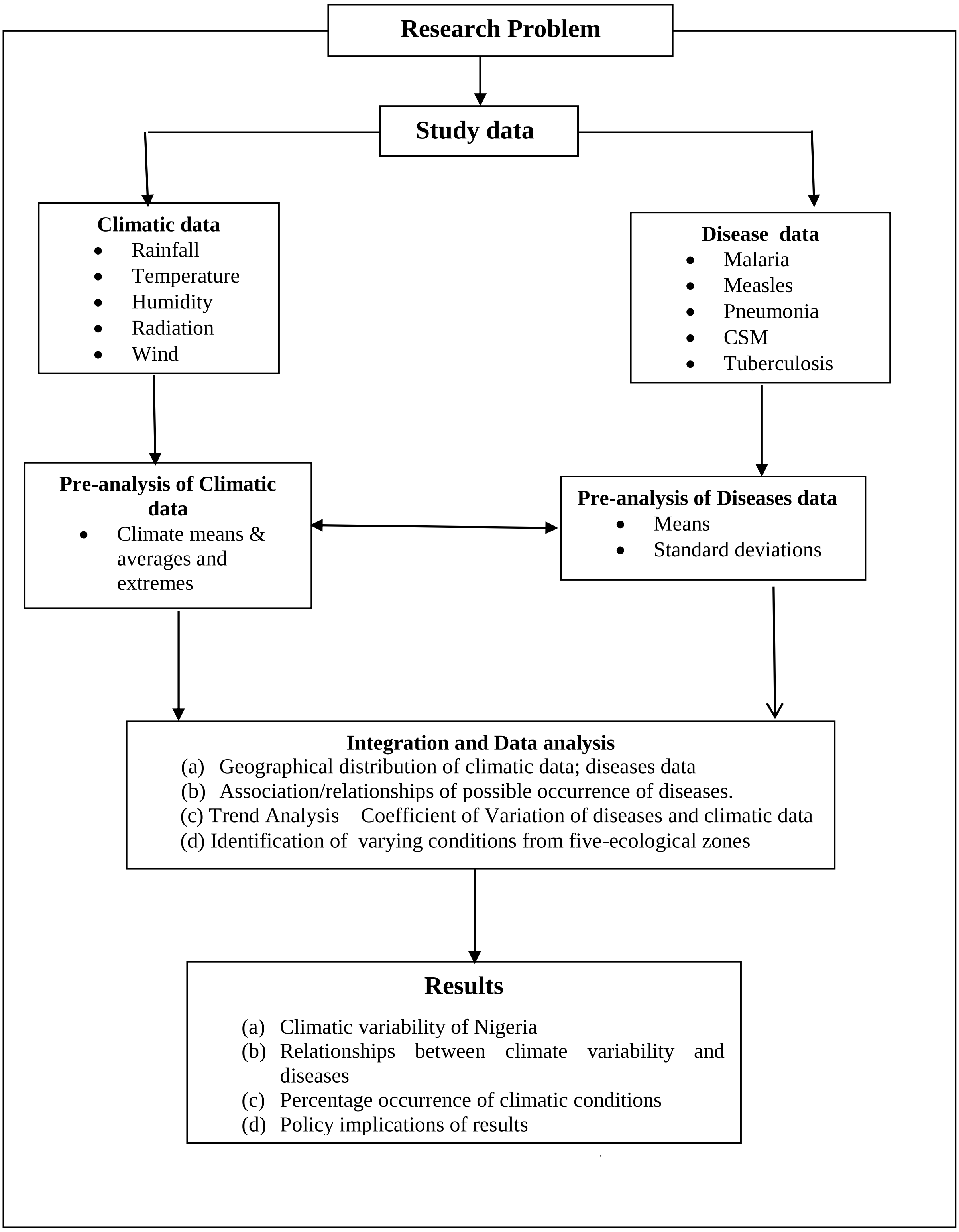

Fig. 3.1: The Research Design

1. There is no significant shift in the spatial occurrences of selected diseases over the period of study
2. There is no significant relationship between selected climatic elements and disease incidence

The null hypotheses were tested using Wilk's Lambda significant test in conjuction with Ballets's V to test the significance of the first canonical correlation. If $p<0.05$, the two sets of variables are significantly associated by canonical correlation (Tabachnick *et al*., 1989). Analysis of Variance (ANOVA); Linear regression and Multivariates analysis are among the techniques used to test for the Hypotheses using System Statistics software.

CHAPTER FOUR

4.0 RESULTS

4.1 Nature of Climatic Variation in Nigeria

4.1.1 Rainfall

4.1.1.1 Mean Annual Rainfall Distribution

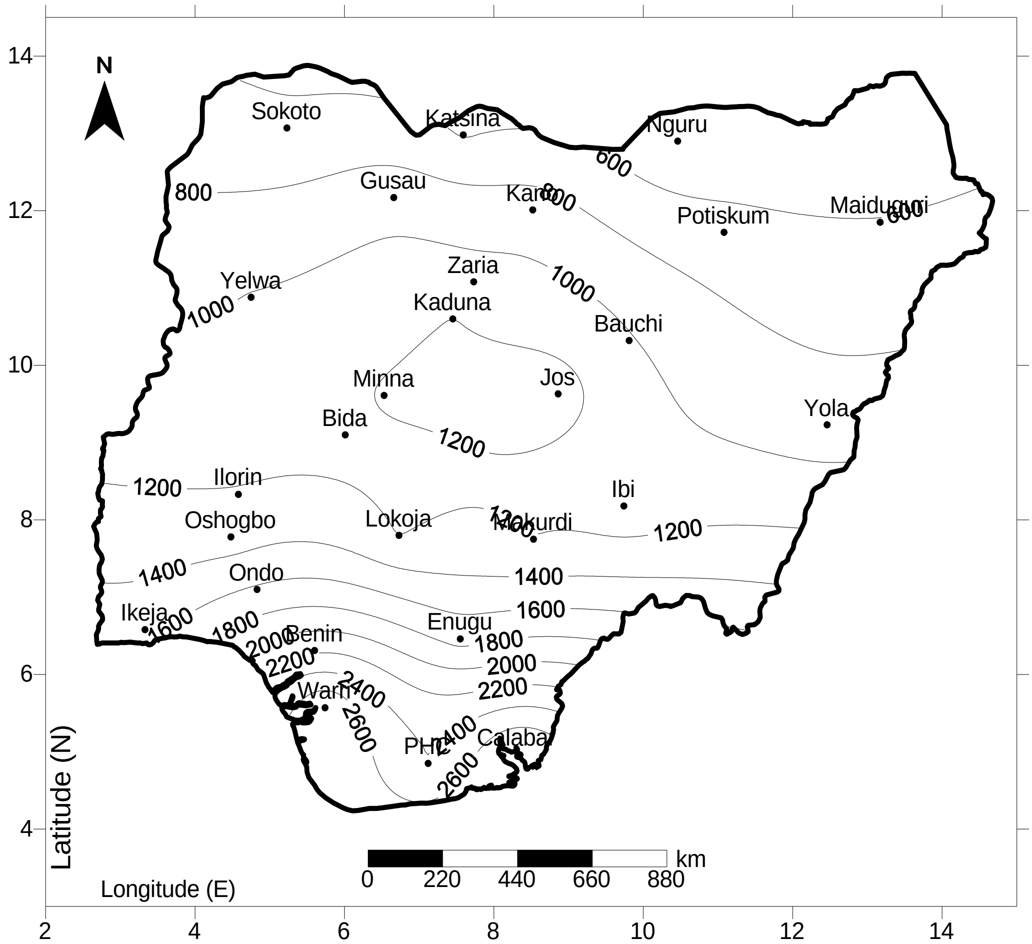

Fig. 4.1: Mean Annual Total Rainfall in Nigeria

The mean annual rainfall distribution is presented in Figure 4.1. This was achieved by computing the long-term rainfall averages of the selected stations from 1958 -2009. The results was then transfer into Surfer software's environment for necessary mapping.

4.1.1.2 Mean Monthly Rainfall in Nigeria

The mean monthly rainfall for some climatic stations in Nigeria is as shown in Figure 4.2. Monthly rainfall was computed for the study period 1958 – 2009, using excel software. This is to exhibits the monthly distribution of rainfall parameters using Histogram method of analysis. The figure depicts various modes of rainfall that existed across the country.

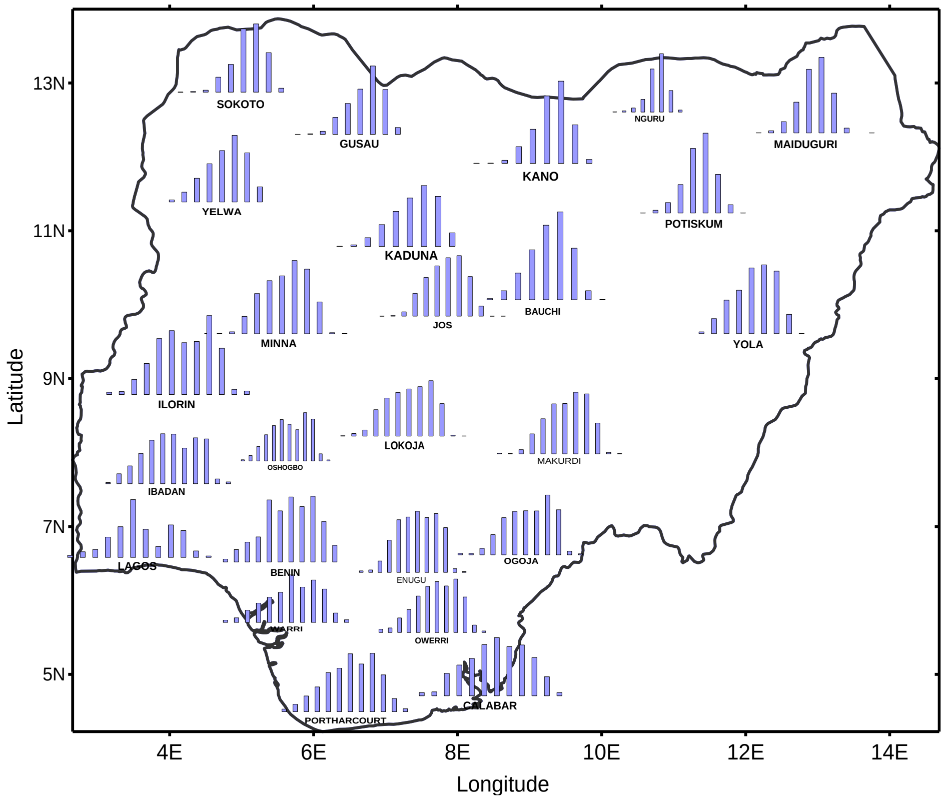

Fig. 4.2: Distribution of Mean annual-monthly rainfall (mm) for Nigeria for the period 1958-2009

4.1.1.3 Trends and Temporal Distribution of Rainfall

Figure 4.3 shows the rainfall trends over Nigeria from 1958 – 2009. The mean rainfall was computed using time series analysis. The same data was subjected to linear regression analysis in order to determine the significance of the trends.

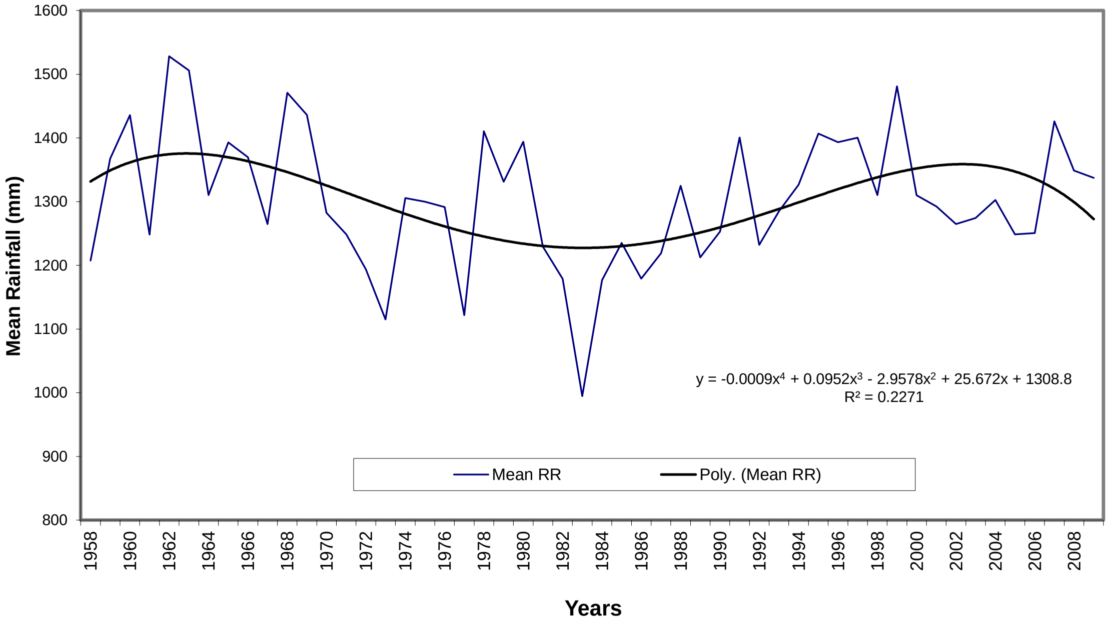

Fig. 4.3: Rainfall trends over Nigeria (1958-2009)

Figure 4.4 shows standardized rainfall anomaly over Nigeria between 1958 and 2009. This was achieved using equation 3.4. Figure 4.5 and 4.6 are the standardized rainfall anomaly over Southern and Northern Nigeria for the study period.

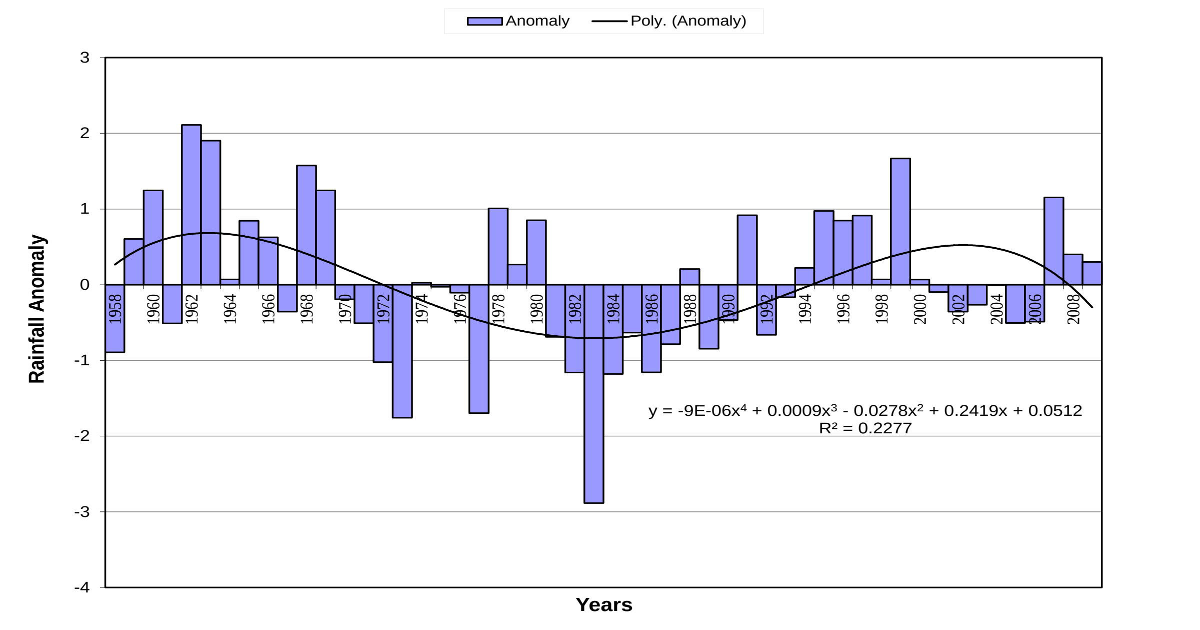

Fig. 4.4 Standardized Rainfall Anomaly over Nigeria(1958-2009)

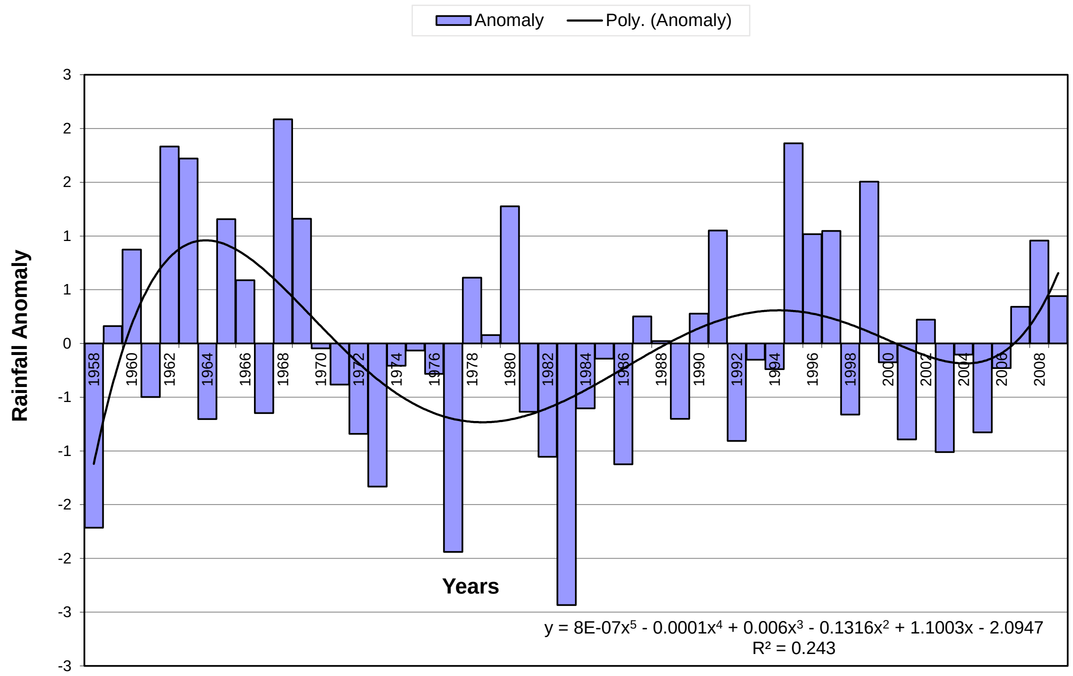

Fig. 4.5 Standardized Rainfall Anomaly over Southern Nigeria (1958-2009)

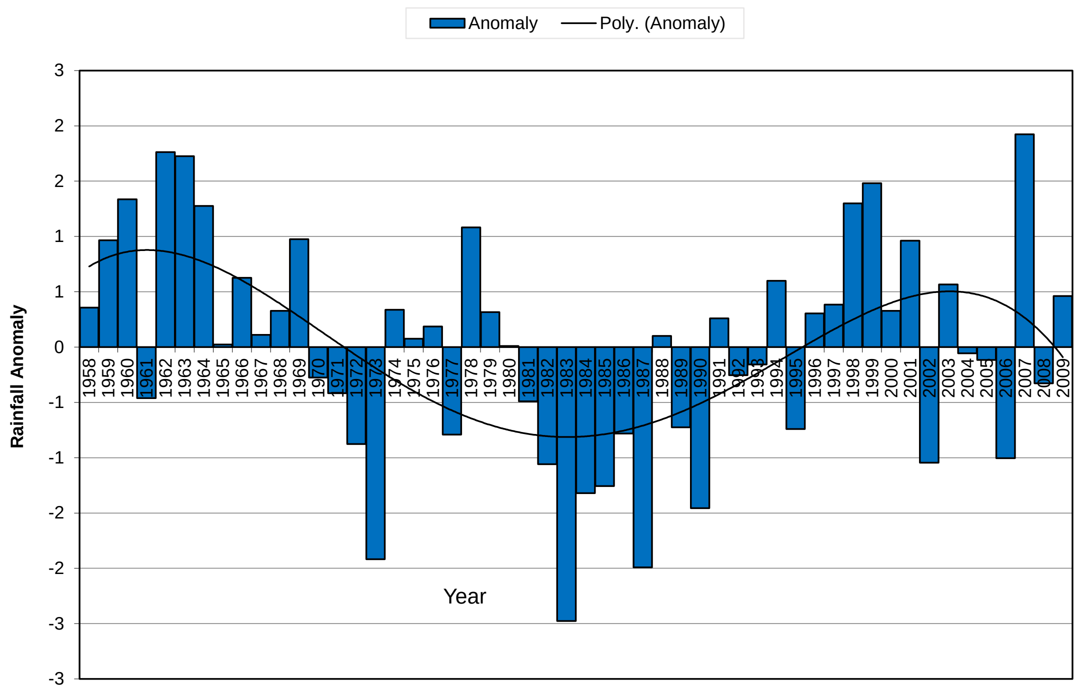

Fig. 4.6: Standardized Rainfall Anomaly over the Northern Nigeria (1958-2009)

4.1.2 Variability and Trends over Ecological Zones

Figure 4.7 is the map of Nigeria showing climatological stations and their classification as used in this study. This was achieved by computing the various stations within an ecological zones. Sahel zone (<600mm); Sudan savannah (600 – 1000mm); Guinea savannah (1000 – 1500mm); Tropical rainforest (1500 – <2000mm) and Swamp forest (>2000mm), (Ojo, 2008). The mean annual rainfall from 1958 – 2009 was used to generate the ecological zones. The map was wrap up with surfer software package.

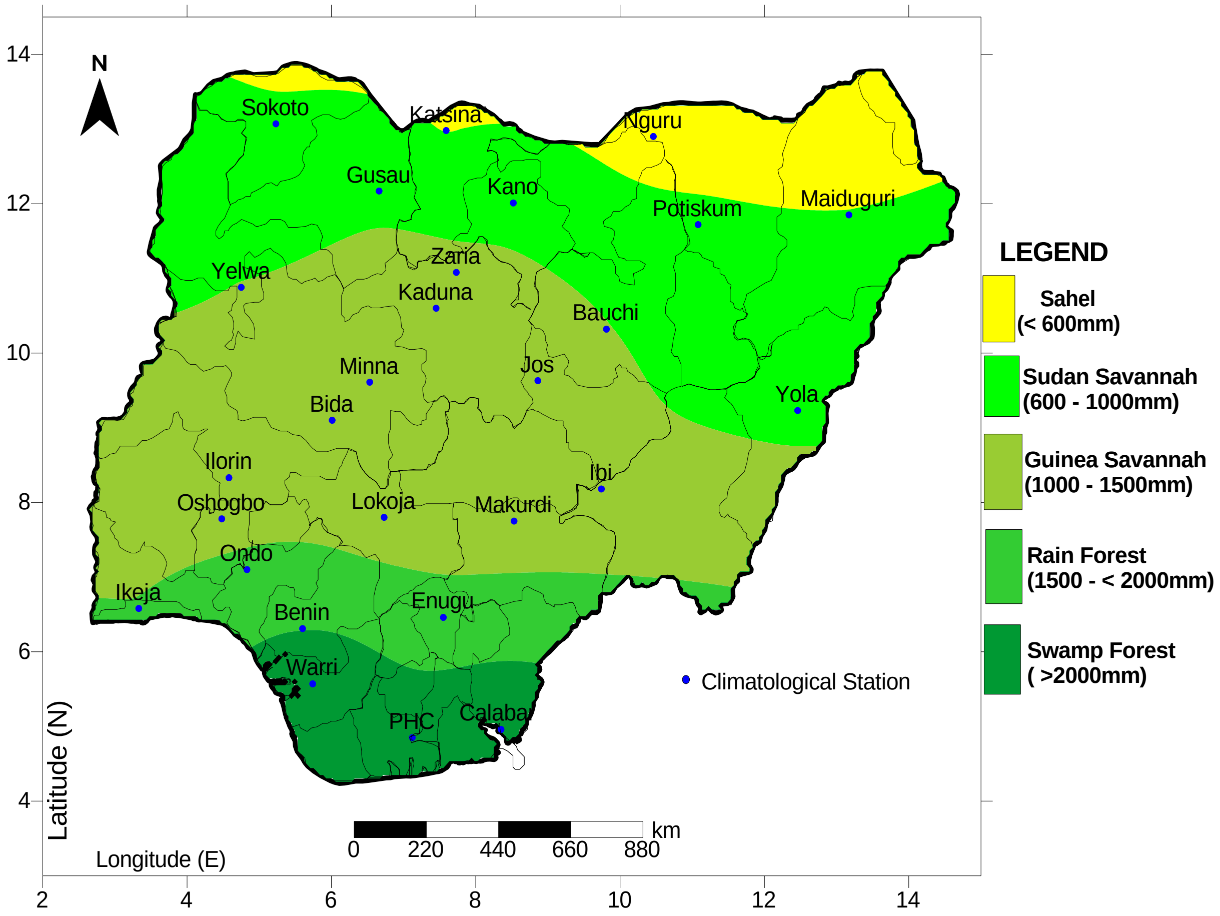

Fig. 4.7: Map of Nigeria showing Climatological Stations and their Classification into Ecological Zones, Adapted from Ojo, 2008)

4.1.2.1 Sahel Zone

Figures 4.8; 4.9; and 4.10 are the standardized rainfall anomaly over Katsina; Nguru; and Maiduguri respectively.

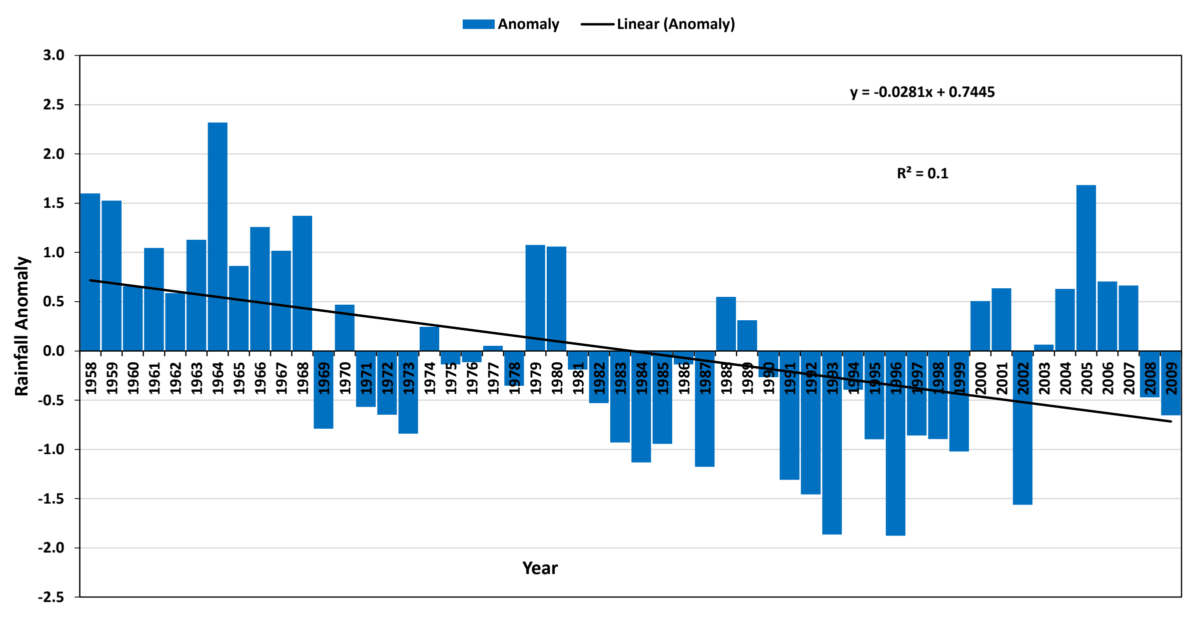

Fig. 4.8: Standardized Rainfall Anomaly over Katsina

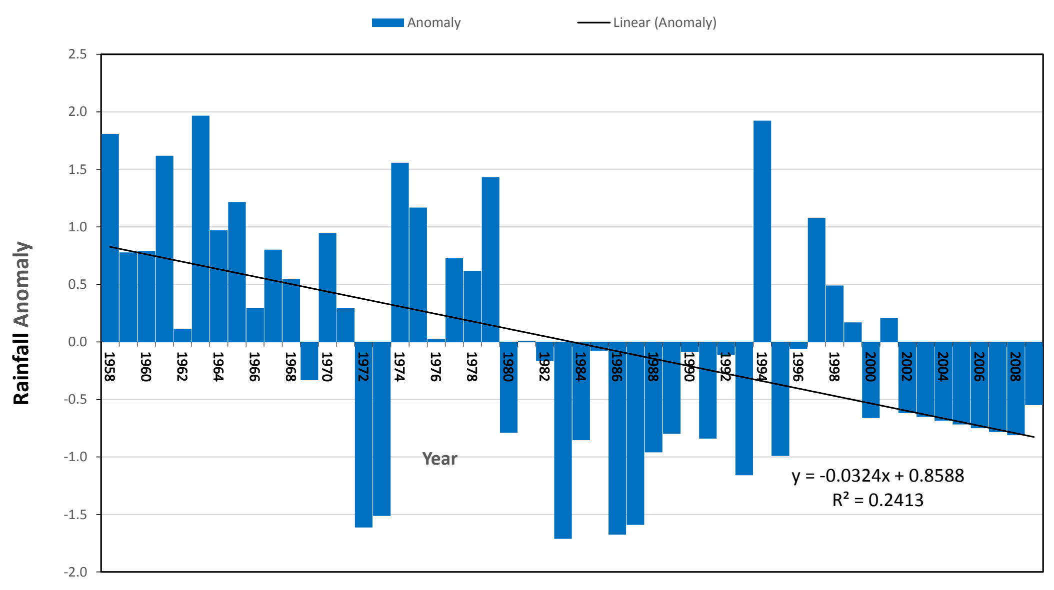

Fig. 4.9: Standardized Rainfall Anomaly over Nguru

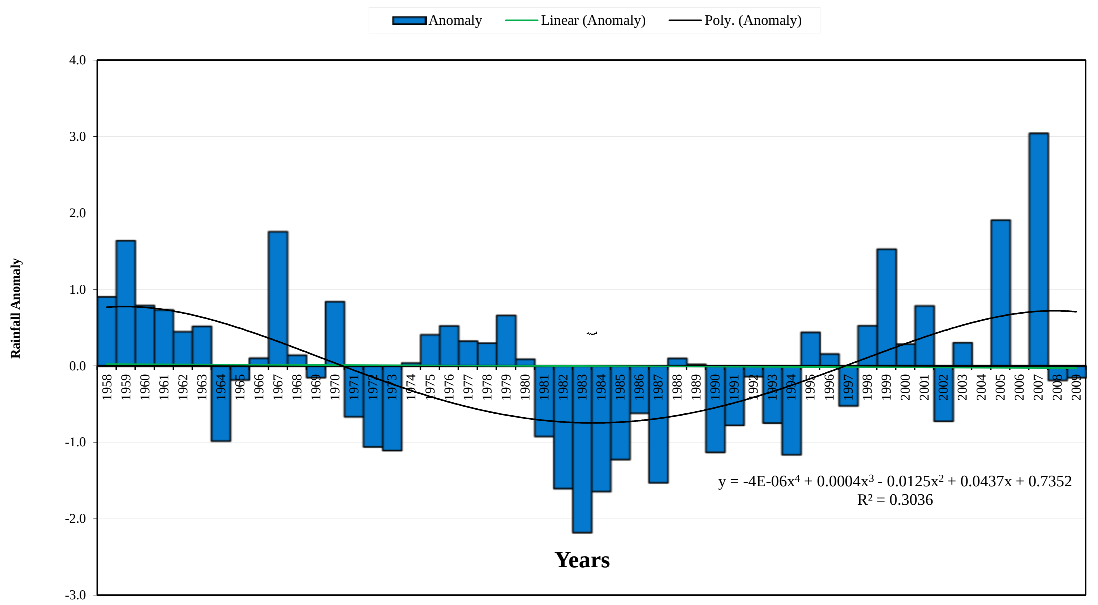

Fig. 4.10: Standardized Rainfall Anomaly over Maiduguri

4.1.2.2 Sudan Savannah Zone

Figures 4.11, 4.12, 4.13 and 4.14 are the standardized rainfall anomaly over Sokoto, Yelwa, Kano and Bauchi.

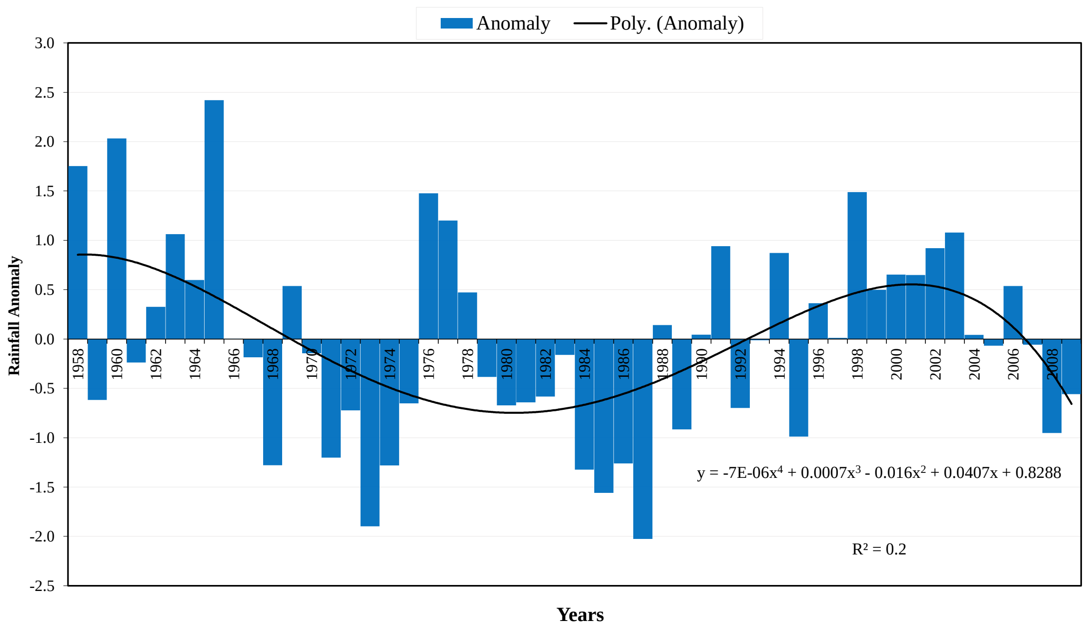

Fig.4.11: Standardized Rainfall Anomaly for Sokoto (1958-2009)

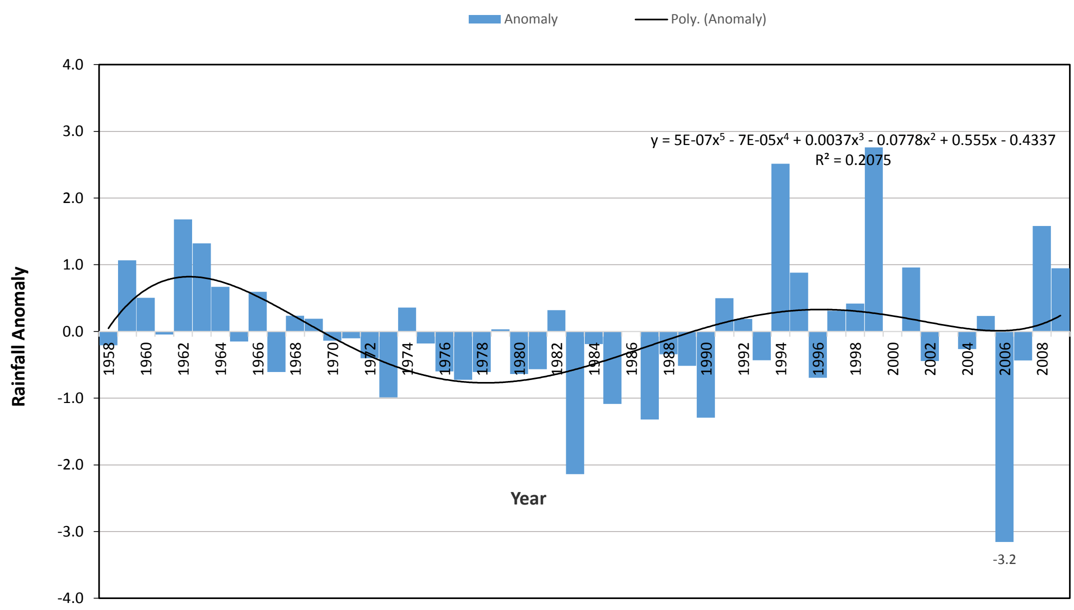

Fig.4.12: Standerdized Rainfall Anomaly over Yelwa

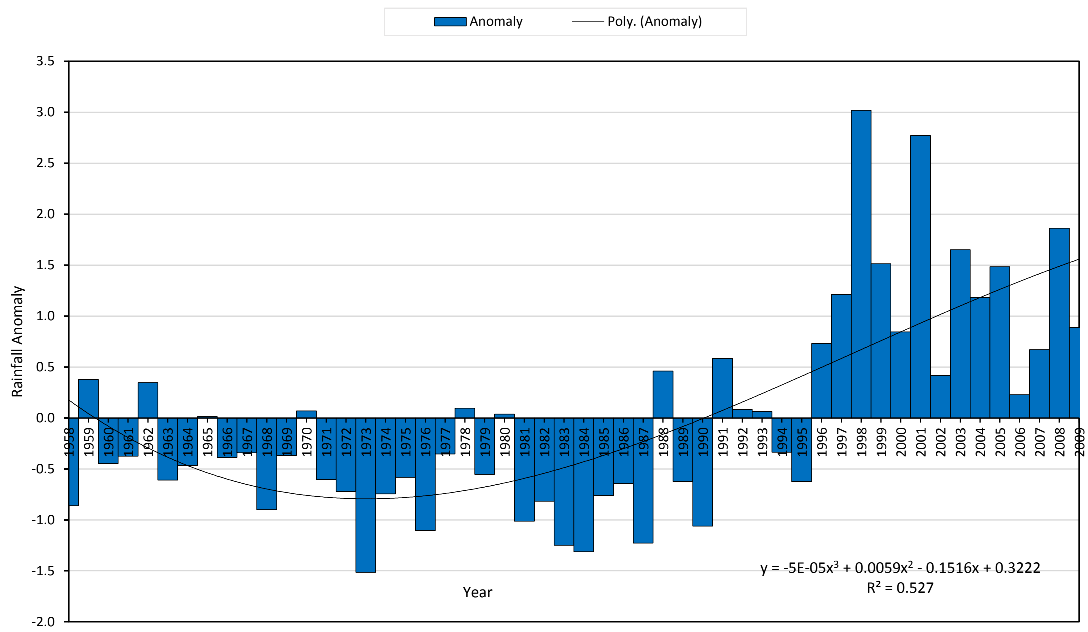

Fig. 4.13: Standardized Rainfall Anomaly over Kano

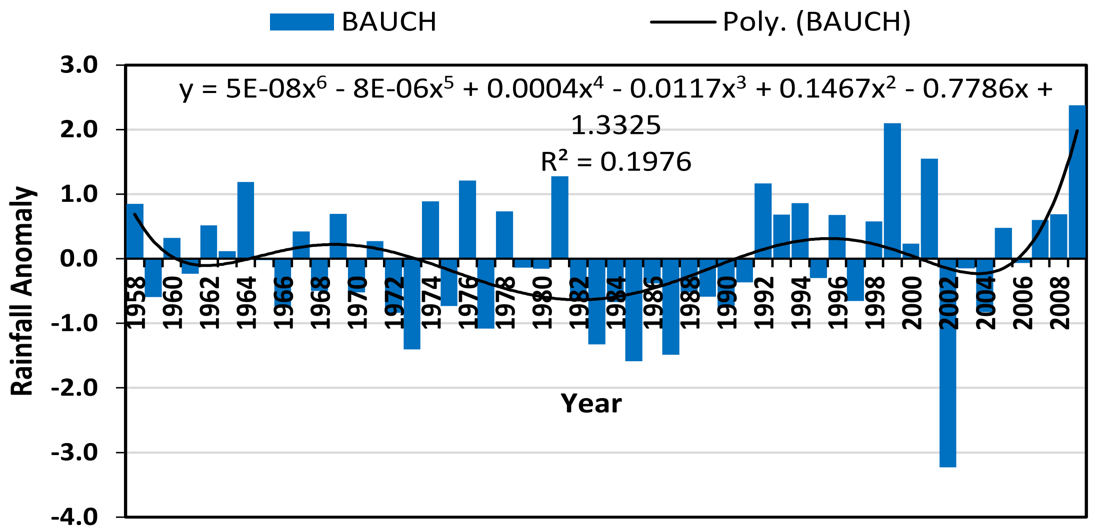

Fig. 4.14: Standardized Rainfall Anomaly over Bauchi

4.1.2.3 Guinea Savannah Zone

Figures 4.15; 4.16; 4.17; 4.18 show the standardized rainfall anomaly over Lokoja, Enugu, Minna and Ilorin between 1958 and 2009 respectively.

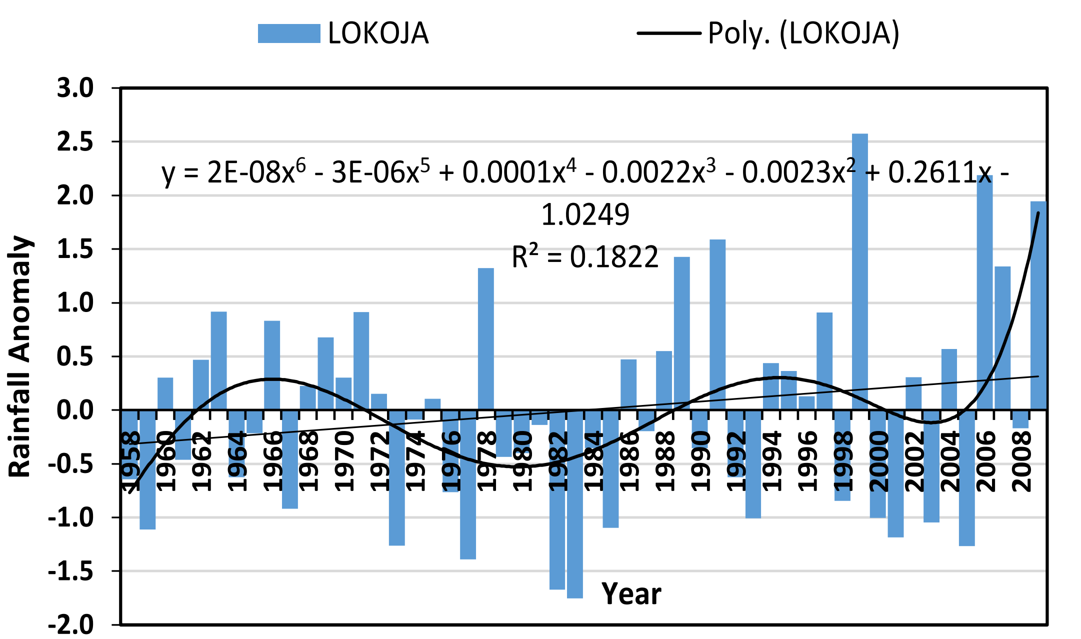

Fig. 4.15: Standardized Rainfall Anomaly over Lokoja

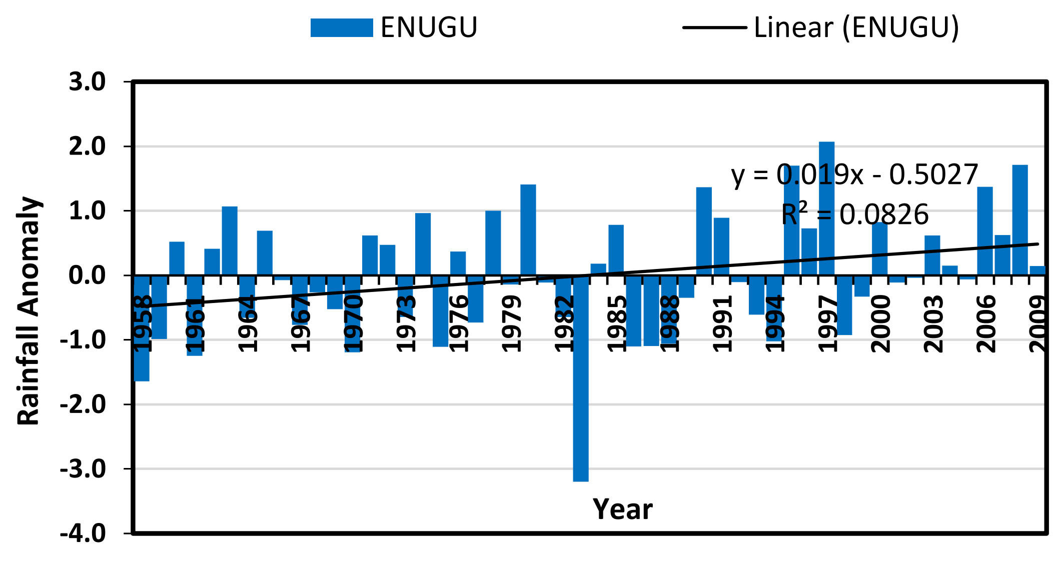

Fig. 4.16: Standardized Rainfall Anomaly over Enugu

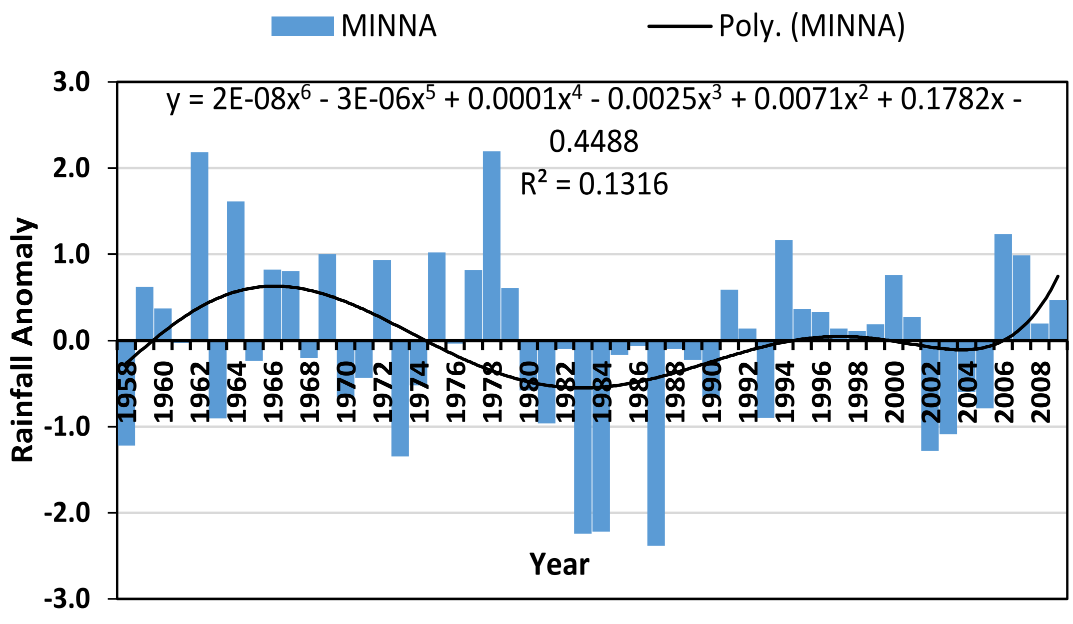

Fig. 4.17: Standardized Rainfall Anomaly over Minna

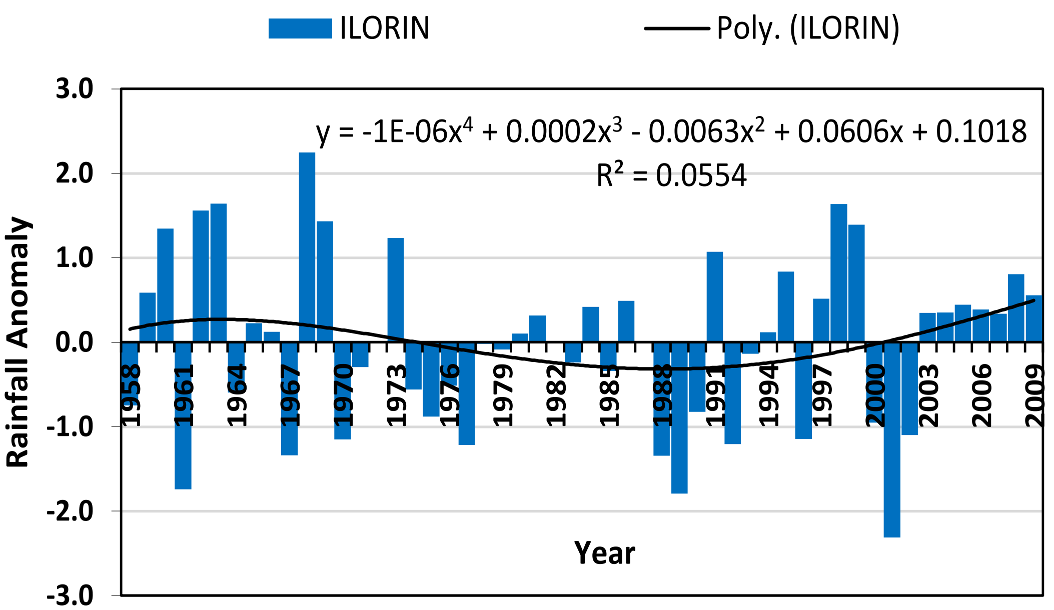

Fig. 4.18: Standardized Rainfall Anomaly over Ilorin

4.1.2.4 Rain Forest Zone

Figures 4.19; 4.20; 4.21; and 4.22 show standardized rainfall anomaly over Ondo, Oshogbo, and Ikeja respectively.

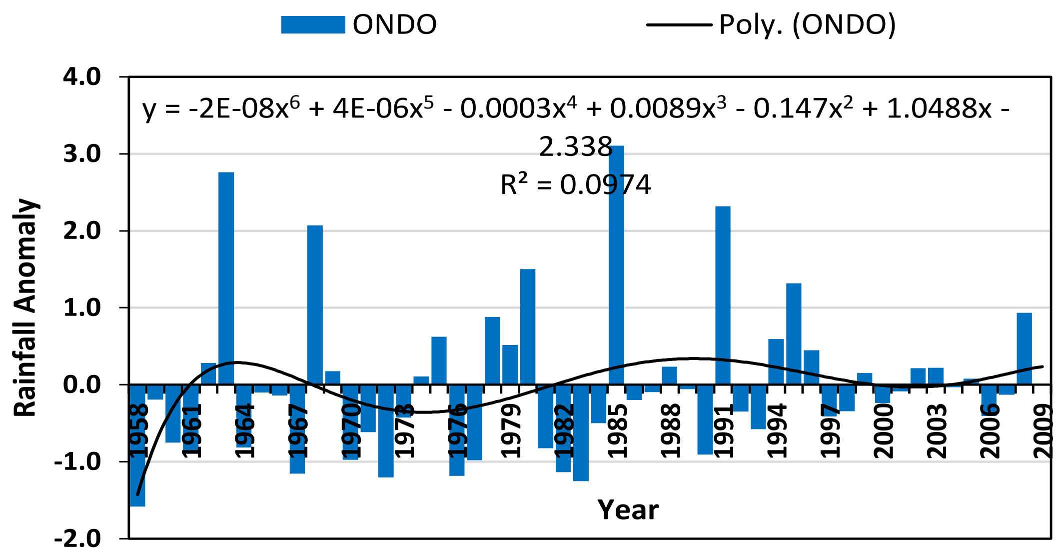

Fig. 4.19: Standardized Rainfall Anomaly over Ondo

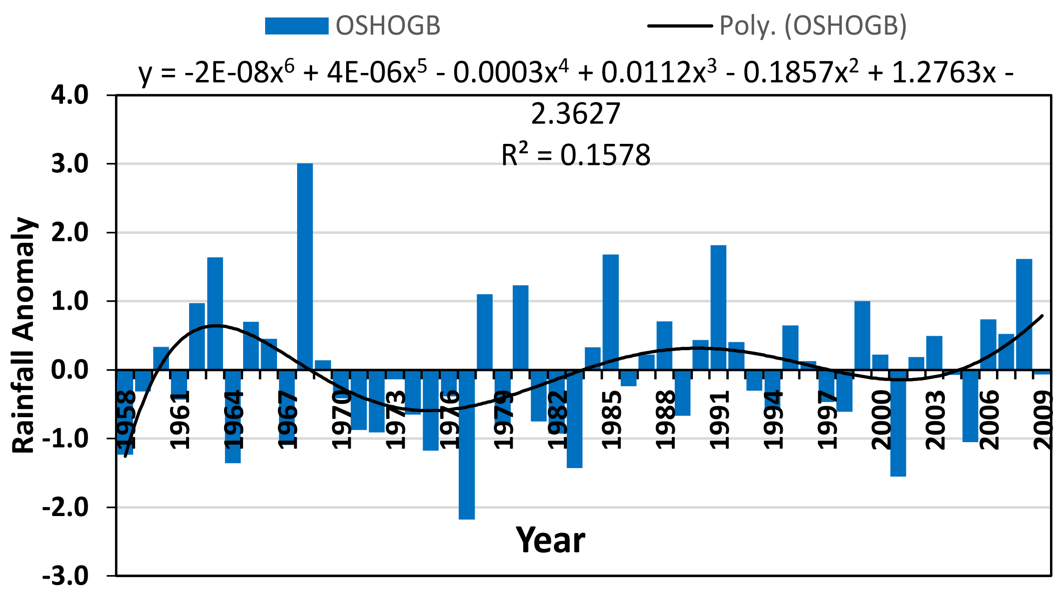

Fig. 4.20: Standardized Rainfall Anomaly over Oshogbo

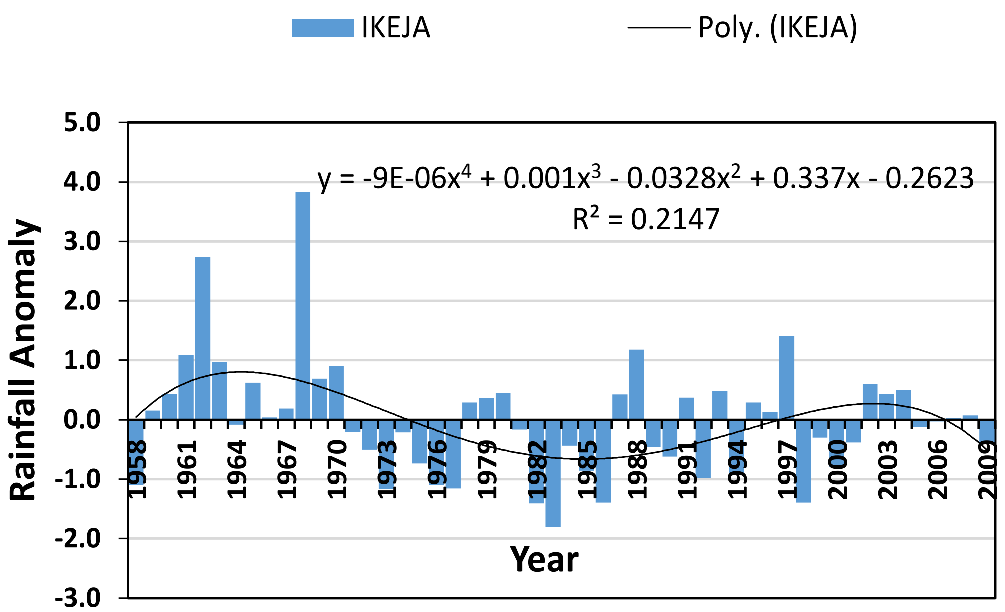

Fig. 4.21: Standardized Rainfall Anomaly over Ikeja

4.1.2.5 Mangrove Swamp Forest Zone

Figures 4.22; 4.23; 4.24 and 4.25 show the standardized rainfall anomaly for Benin, Warri, Portharcourt and Calabar over the Mangrove swamp forest zone under the study period.

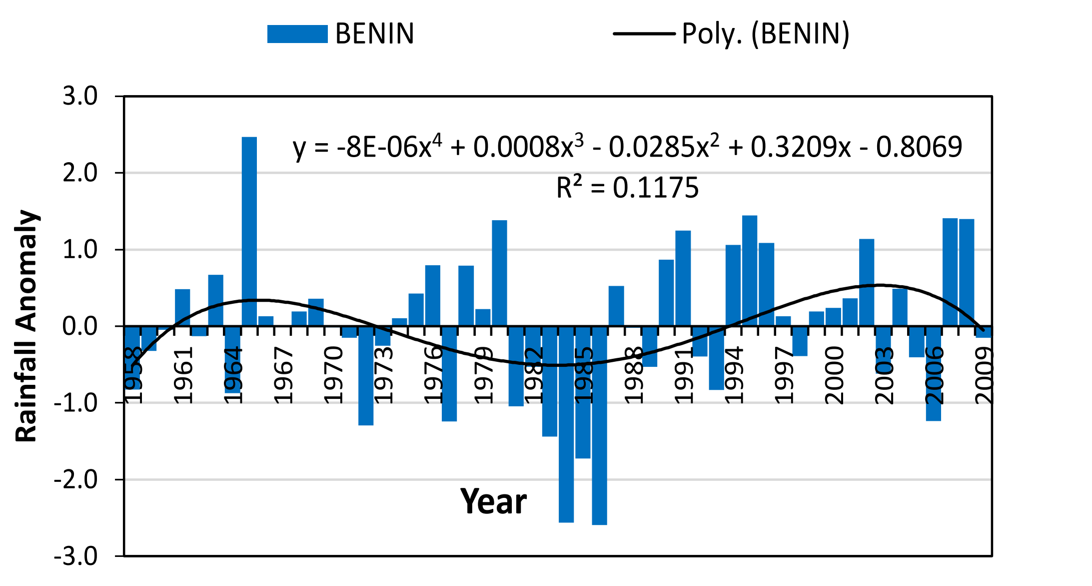

Fig. 4.22: Standardized Rainfall Anomaly over Benin

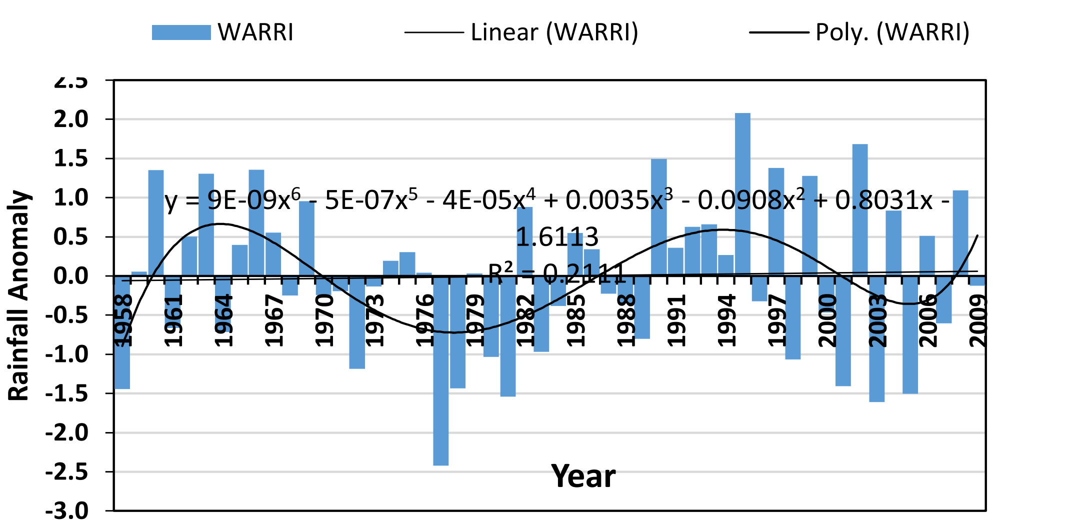

Fig. 4.23: Standardized Rainfall Anomaly over Warri

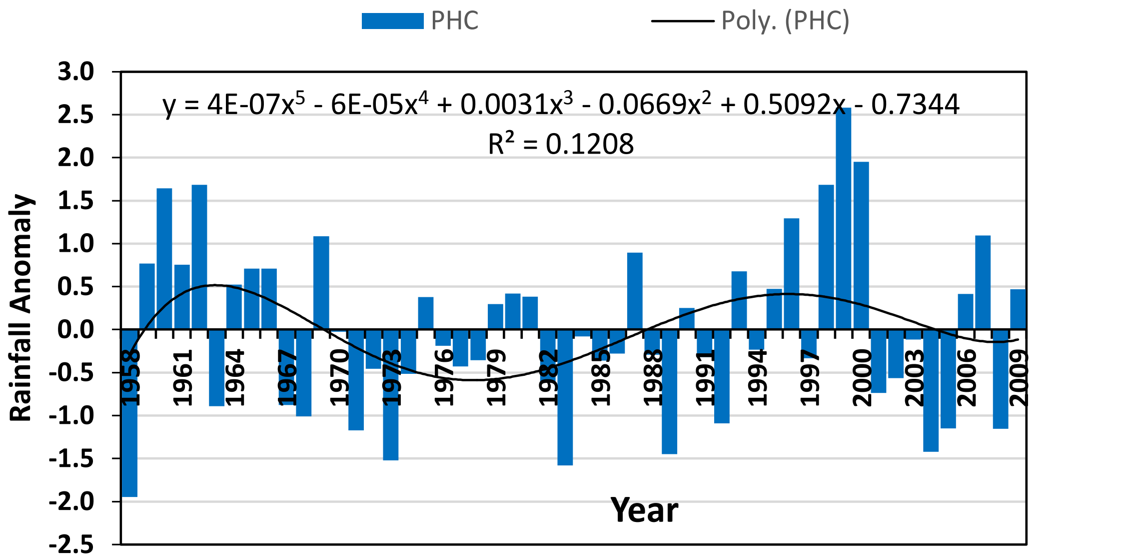

Fig. 4.24: Standardized Rainfall Anomaly over Portharcourt

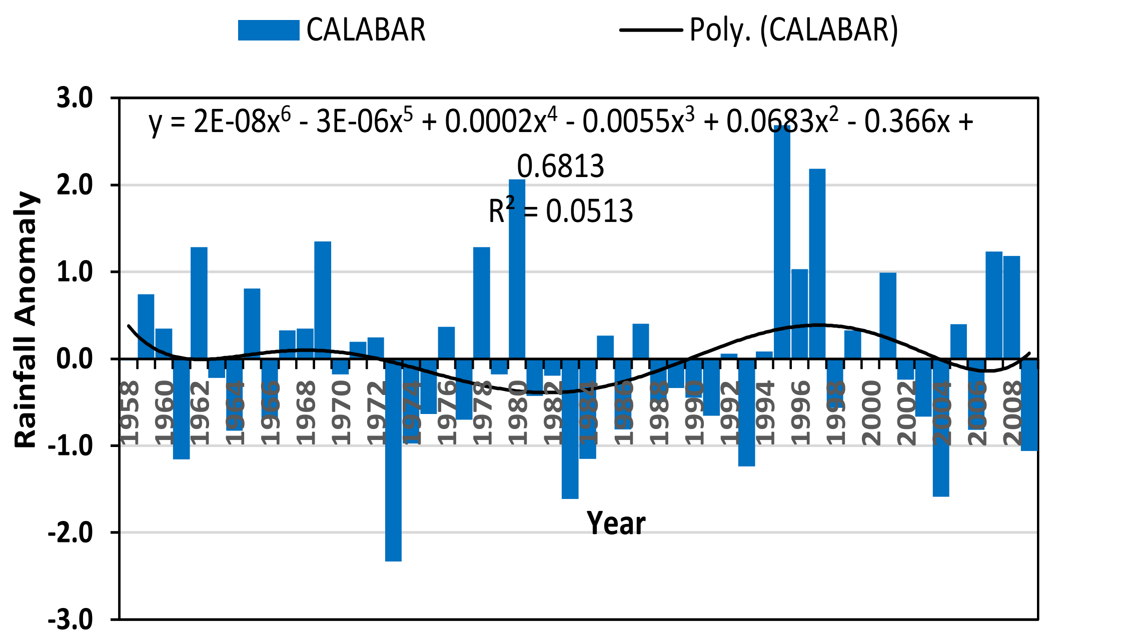

Fig. 4.25: Standardized Rainfall Anomaly ove Calabar

4.1.3 Nature of Temperature

Figure 4.26 is the mean maximum temperature for Nigeria. This was achieved by computing the mean temperature from 1958 – 2009. The result was transfer to surfer software environment for spatial mapping. Similarly Figure 4.27, the mean annual minimum temperature for Nigeria between 1958 and 2009 is presented.

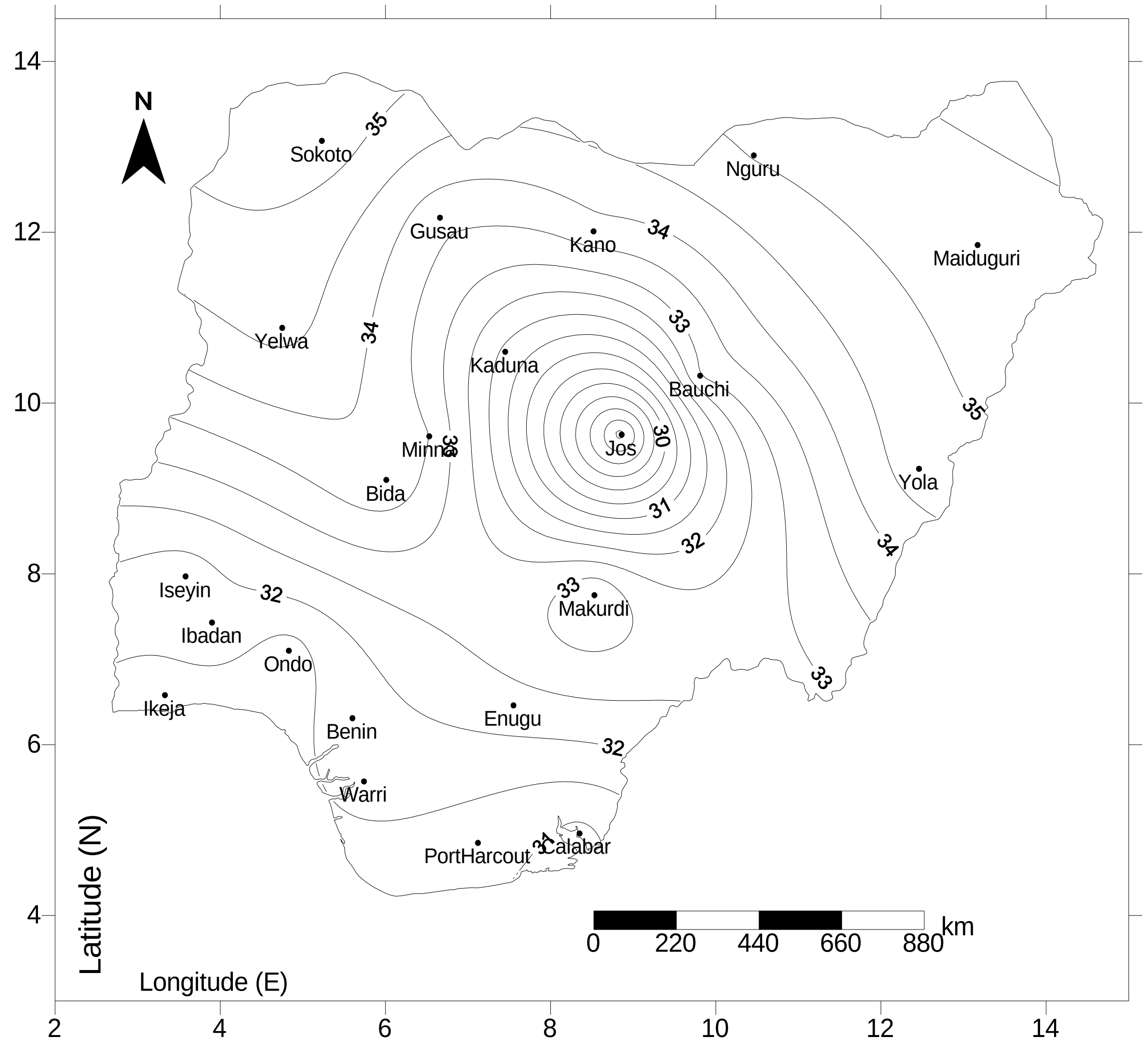

Fig. 4.26: Mean Annual Maximum Temperature for Nigeria

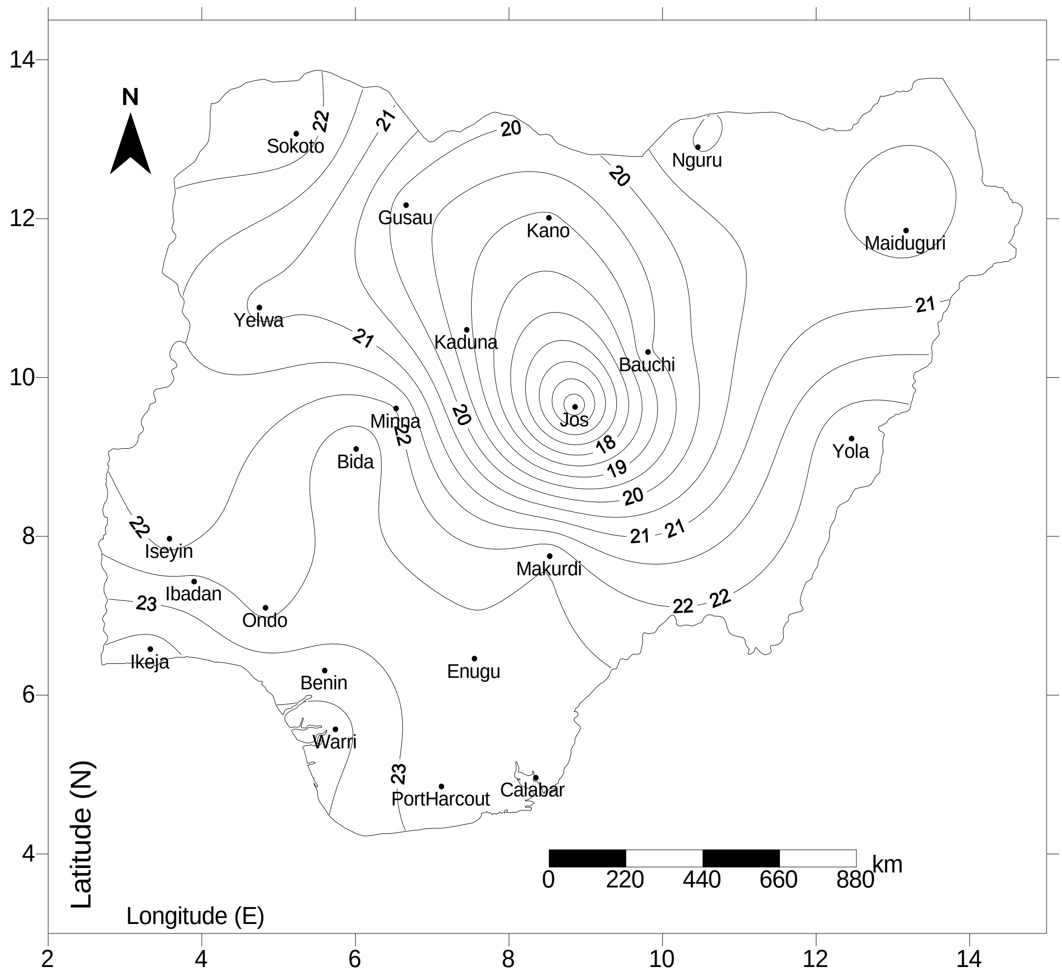

Fig. 4.27: Mean Annual Minimum Temperature (C) for Nigeria

4.1.3.1 Temperature Trends

Figures 4.28 and 4.29 are the trends in mean maximum temperatures for Kano in the north and Lagos in the southern part of the country. Time series analysis was done to infer variability using excel software and linear regression and Analysis of Variance (ANOVA) to determine the significant of the various trends that were manifested.

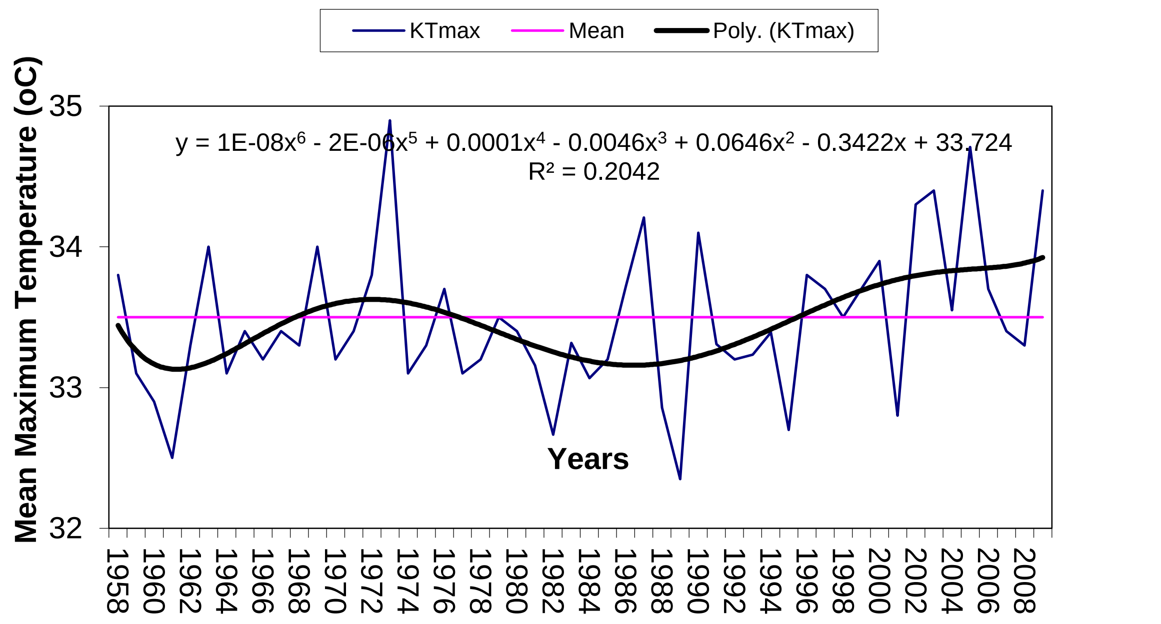

Fig. 4.28: Trends in Mean Maximum temperature over Kano

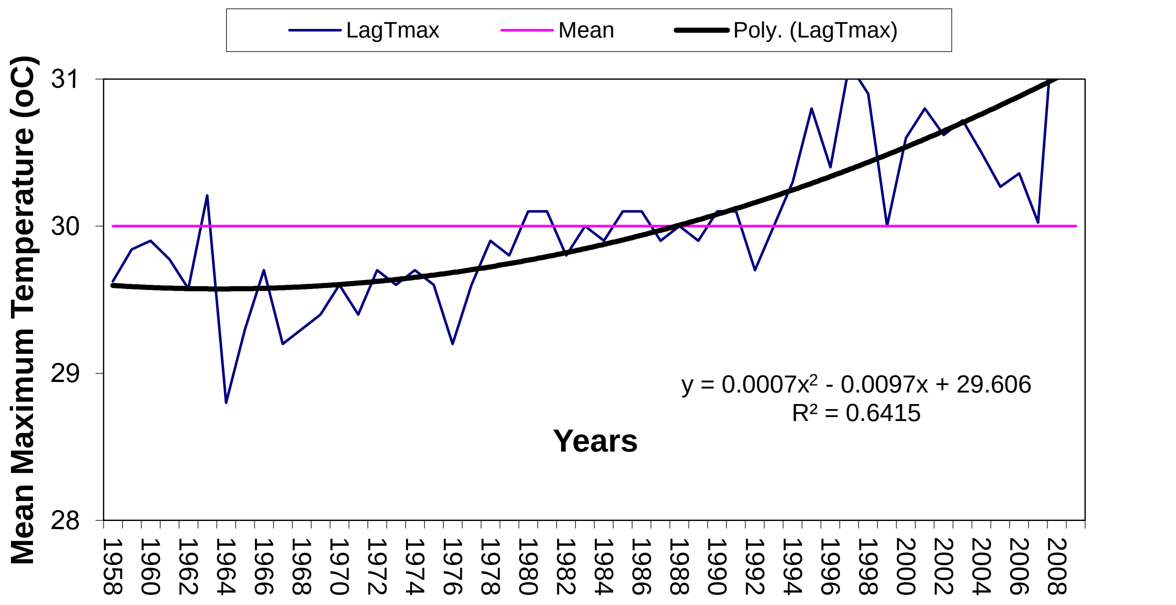

Fig. 4.29: Trends in Mean Maxmum Temperature over Lagos

4.1.4 Distribution of Temperature in Ecological Zones

4.1.4.1 Sahel savannah

Figure 4.30 is the mean maximum temperature over Nguru. The mean maximum temperature from 1958 – 2009 was analysed using excel software. Linear regression analysis was further used to established the significant status of the trends. Ditto for Figure 4.31 over Potiskum and 4.32 over Sokoto.

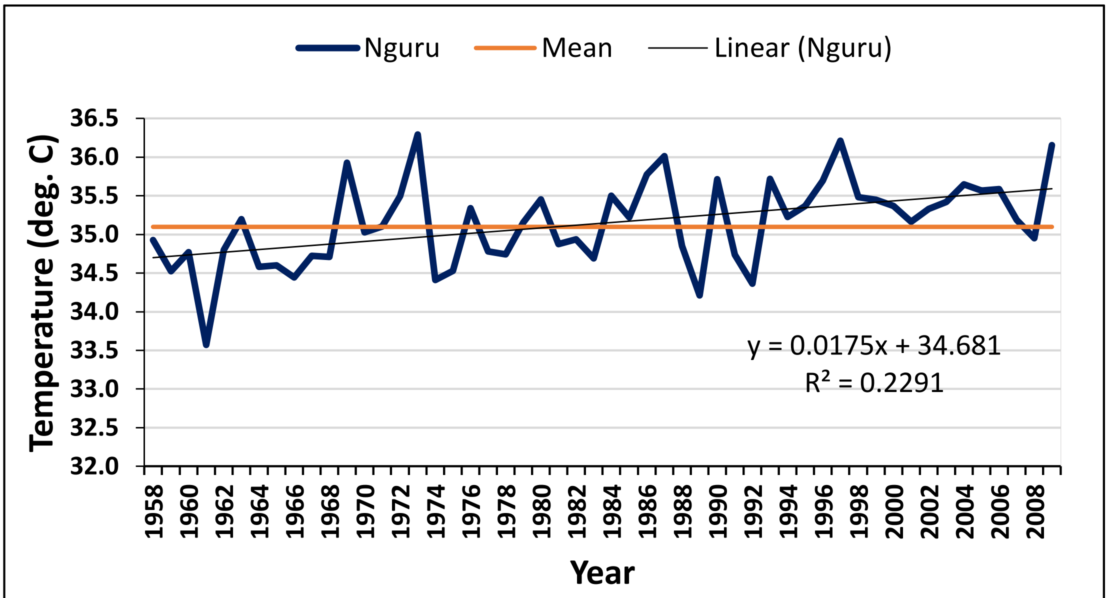

Fig. 4.30: Mean Maximum Temperature over Nguru

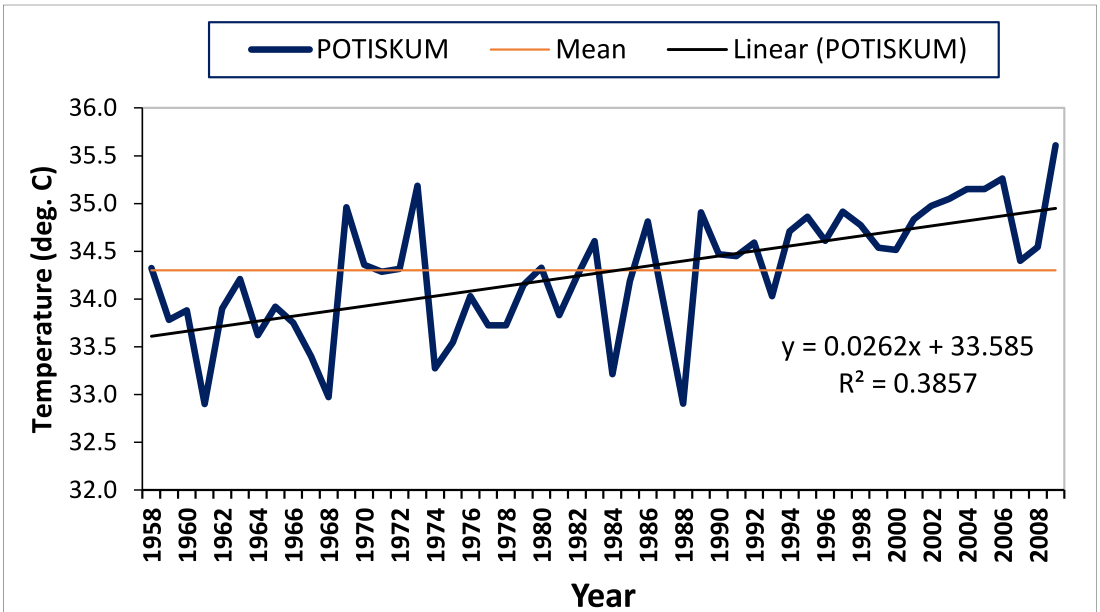

Fig. 4.31: Mean Maximum Temperature over Potiskum

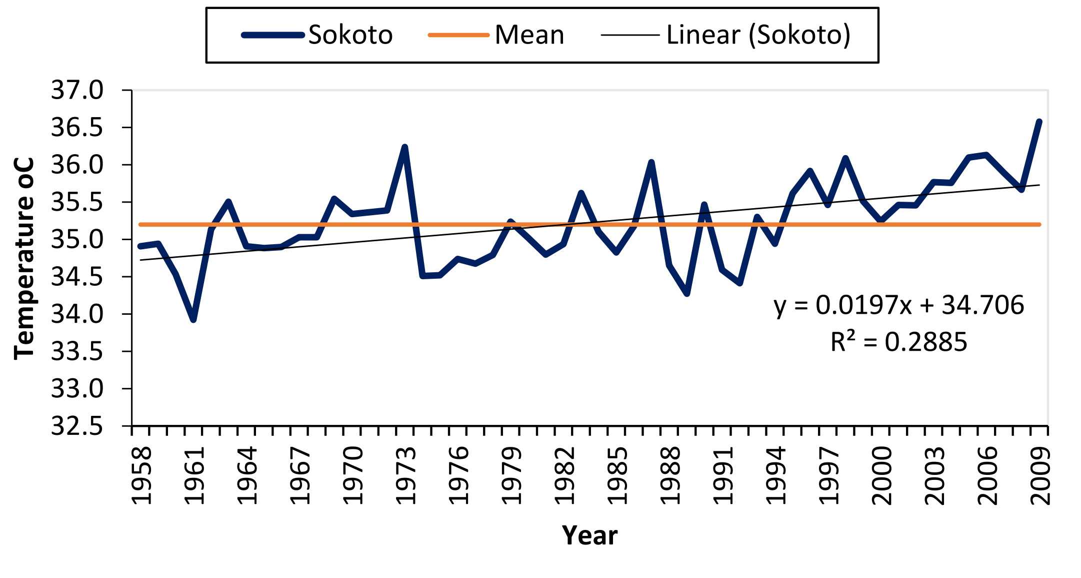

Fig.4.32: Mean Maximum Temperature over Sokoto

4.1.4.2 Sudan Savannah Zone

Figure 4.33 shows the mean maximum temperature over Kano, Figure 4.34 and 4.35 over Gusau and Yola in Sudan savannah zone.

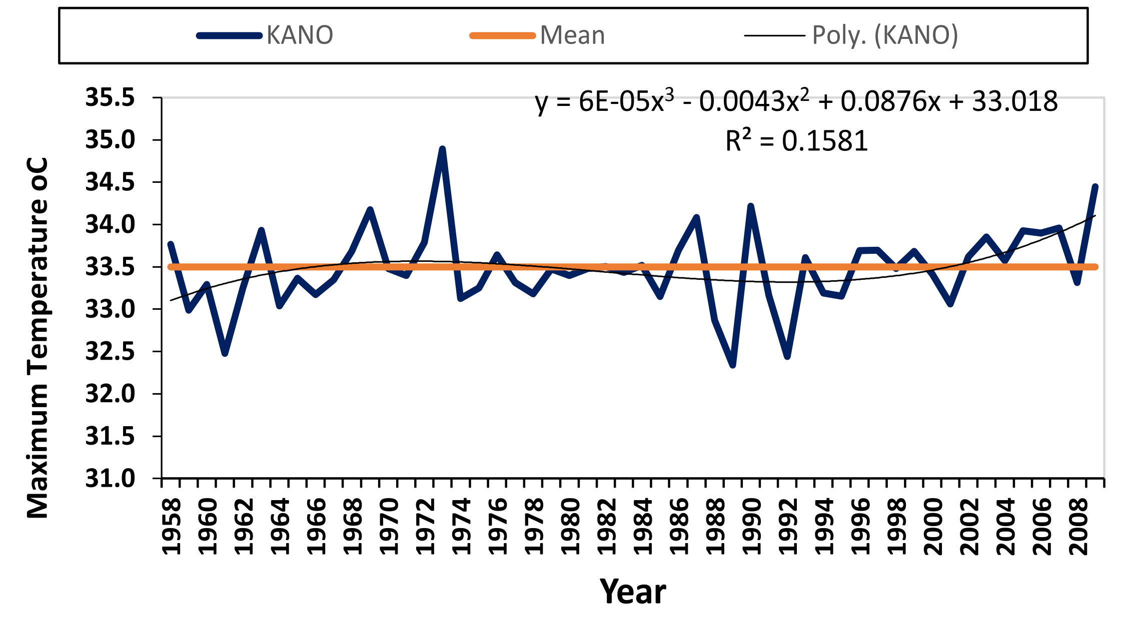

Fig. 4.33: Mean Maximum Temperaure over Kano

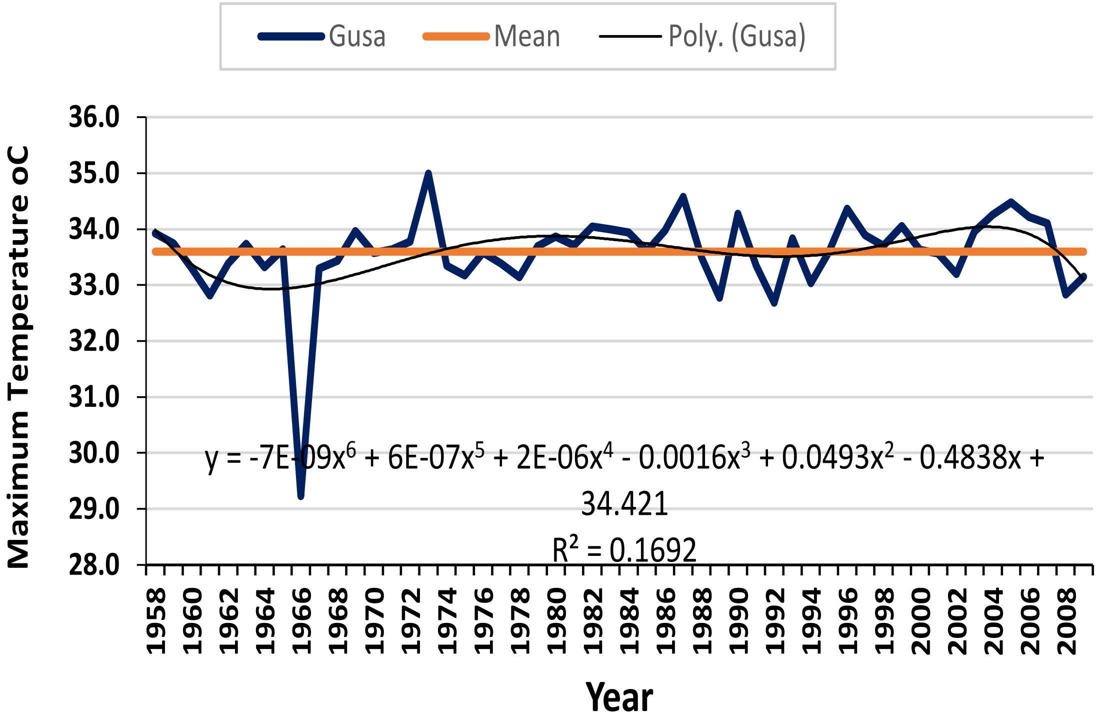

Fig.4.34: Mean maximum temperature over Gusau

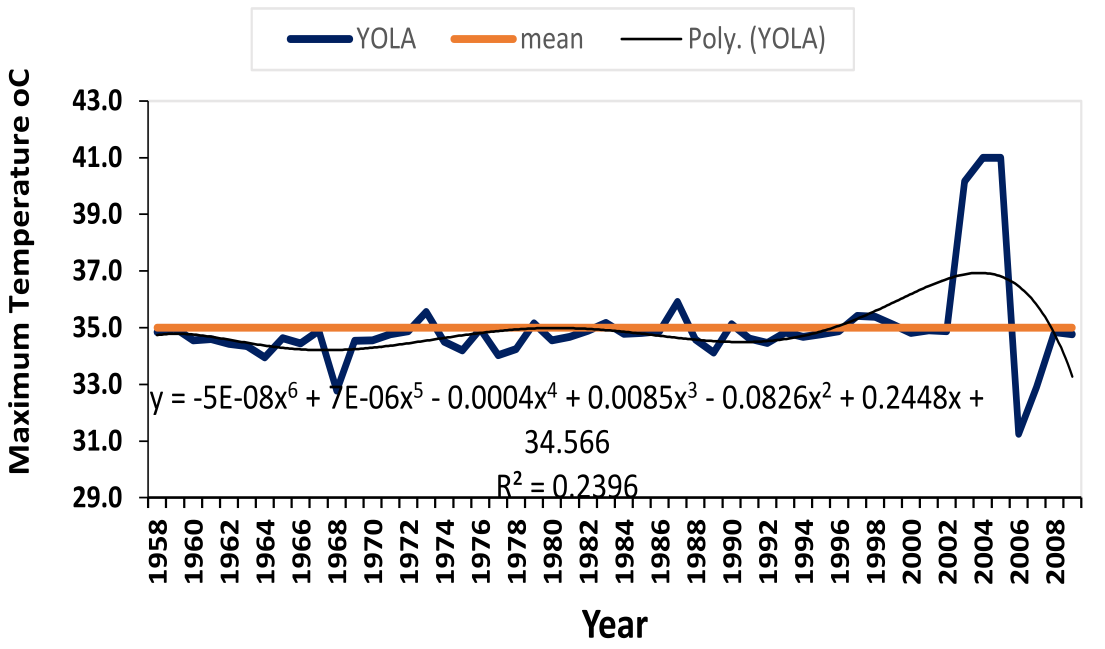

Fig. 4.35: Mean Maximum Temperaure over Yola

4.1.4.3 Guinea Savannah Zone

Figure 4.36 is the mean maximum temperature over Jos. Figures 4.37; and 4.38 were mean maximum temperature over Lokoja and Kaduna.

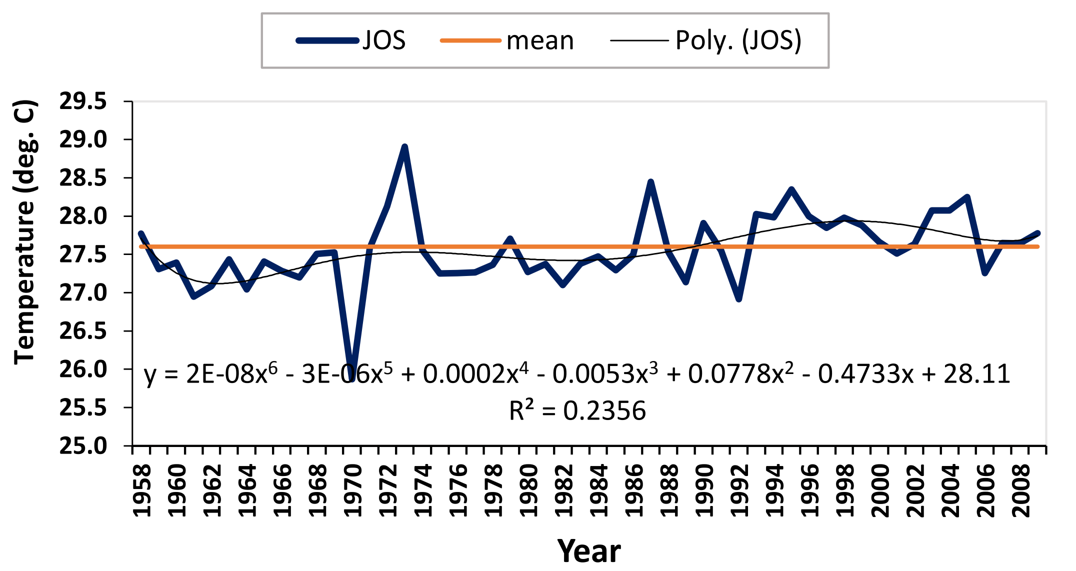

Fig. 4.36: Mean Maximum Temperature over Jos

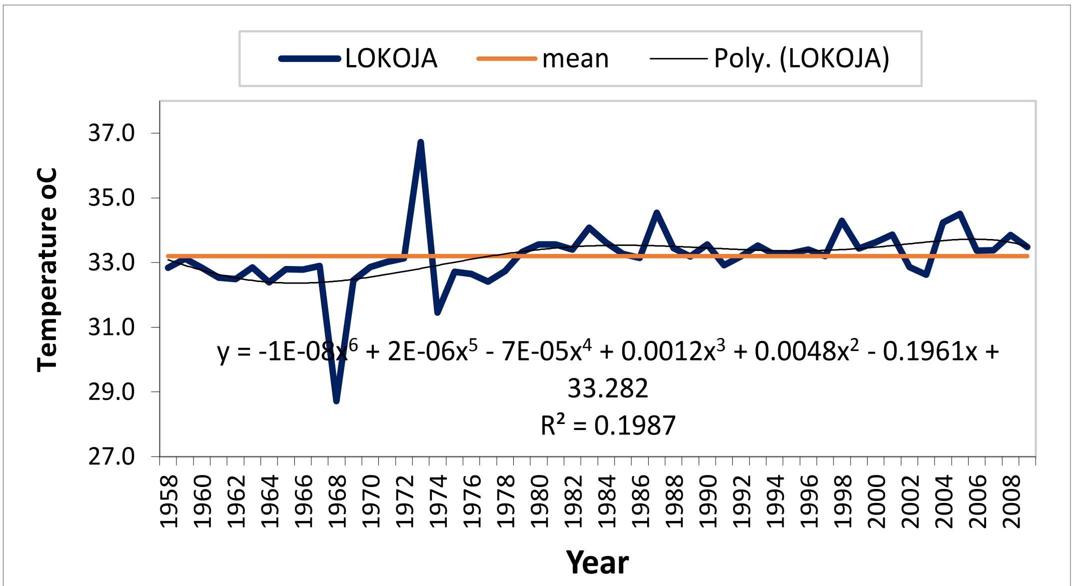

Fig. 4.37: Mean Maximum Temperature over Lokoja

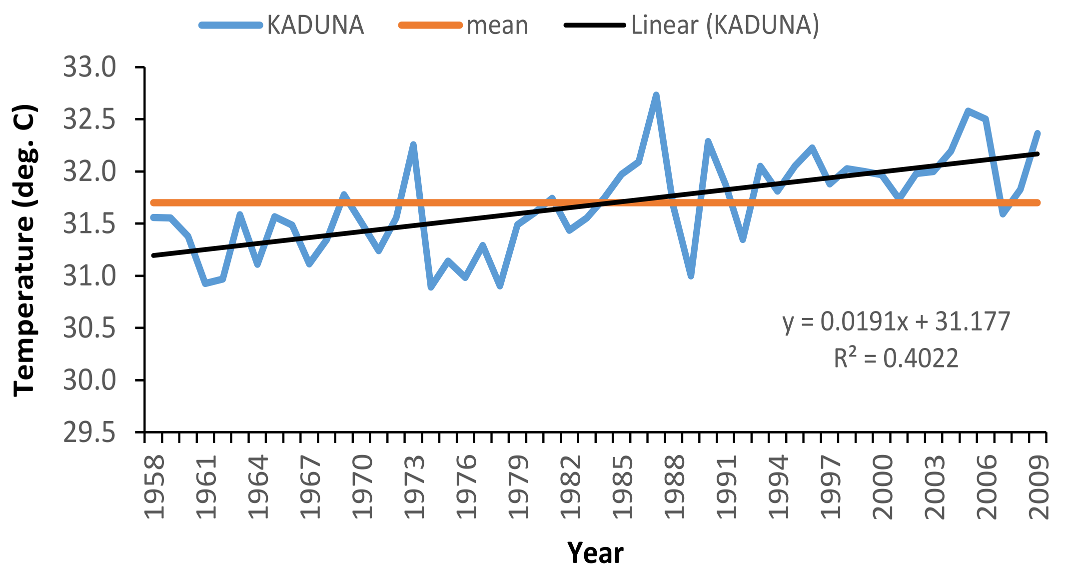

Fig. 4.38: Mean Maximum Temperature over Kaduna

4.1.4.4 Rain Forest Zone

Figures 4.39, 4.40 and 4.41 are the mean maximum temperature over Ikeja, Enugu and Ondo respectively for Tropical forest.

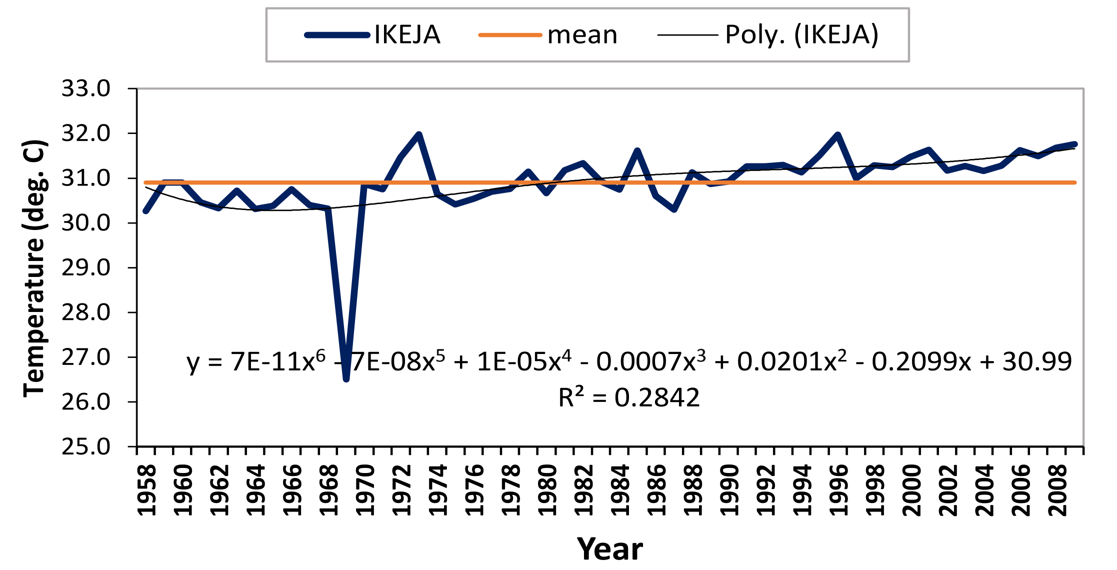

Fig. 4.39: Mean Maximum Temperature over Ikeja

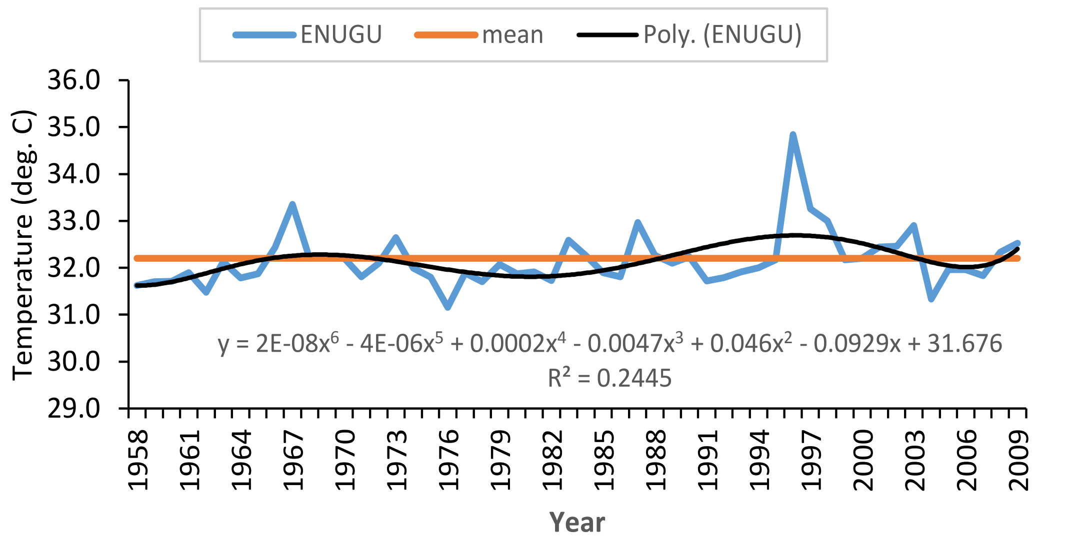

Fig. 4.40: Mean Maximum Temperature over Enugu

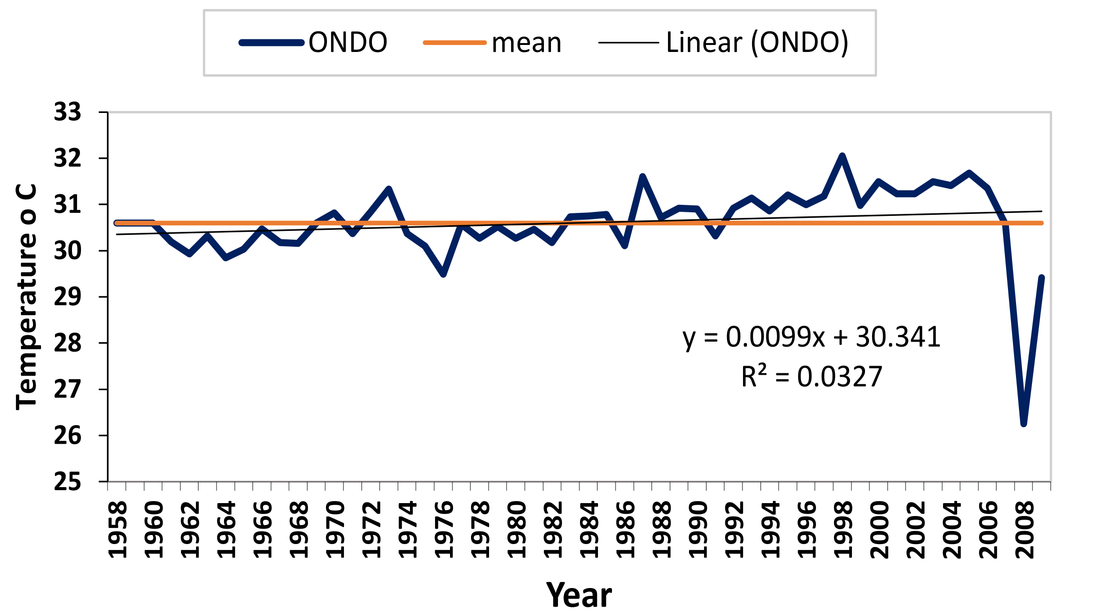

Fig. 4.41: Mean Maximum Temperature ove Ondo

4.1.4.5 Mangrove Zone

Figure 4.42 is the mean maximum temperature over Warri and Figure 4.43 is the mean maximum temperature over Calabar.

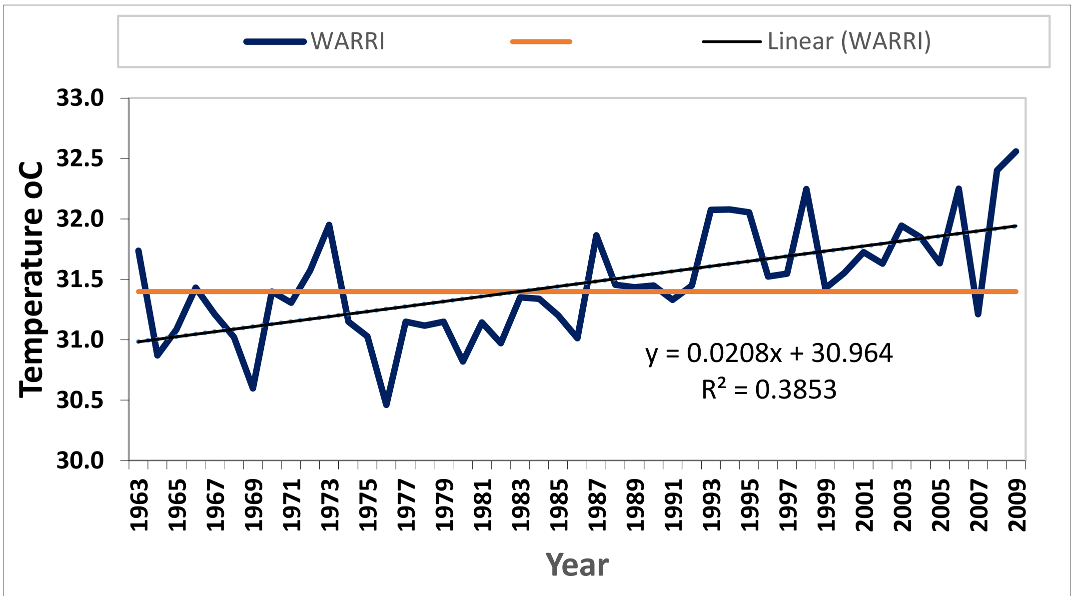

Fig. 4.42: Mean Maximum Temperature ove Warri

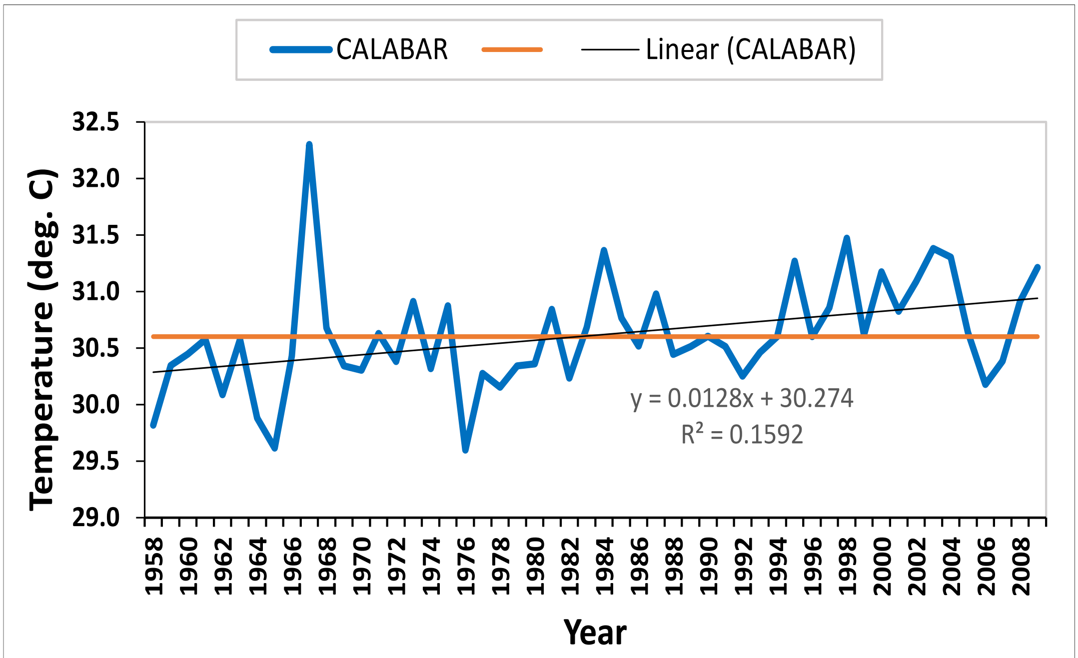

Fig. 4.43: Mean Maximum Temperature over Calabar

4.1.5 DISTRIBUTION OF OTHER SIGNIFICANT CLIMATIC PARAMETER

4.1.5.1 Relative Humidity

Figure 4.44 is the mean annual distribution of relative humidity in Nigeria. The climatic parameters were computed from the dry bulb and dew point temperature as a factor or expression of how humid or saturated the air could be in percentage. These figure are computed using ten years data.

4.1.5.2 Solar Radiation

Figure 4.45 and 4.46 are the maps of mean annual solar radiation and mean sunshine hour's distribution.

4.1.5.3 Surface Wind

Figure 4.47 and 4.48 are the maps of mean wind direction in degrees and wind speed in meter per second.

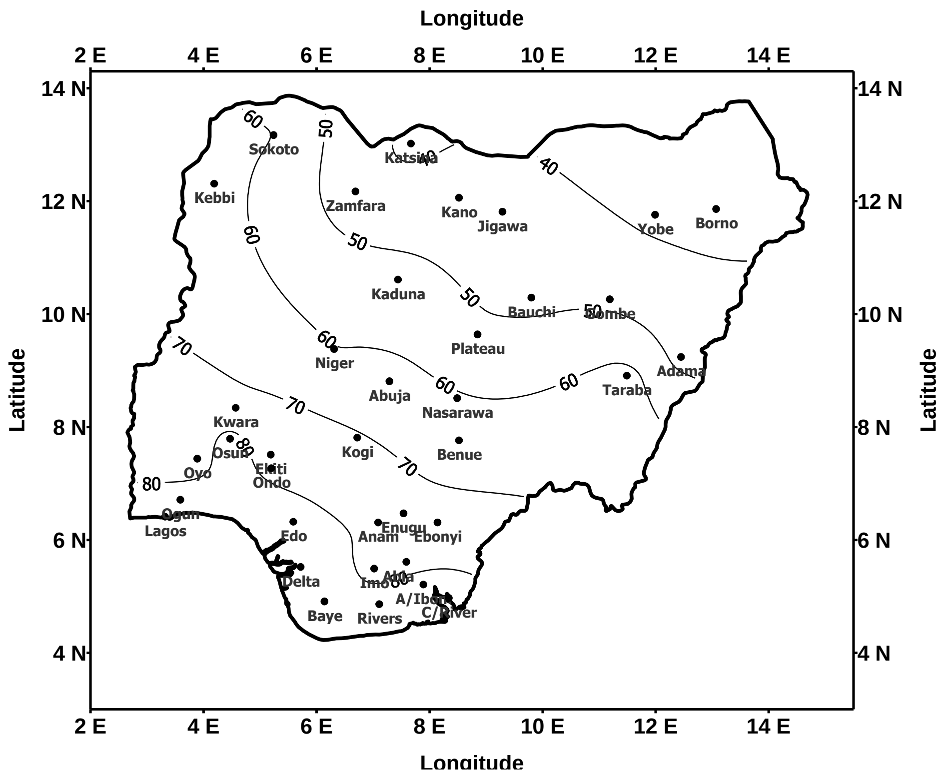

Fig. 4.44: Mean Annual Distribution of Relative Humidity (%) in Nigeria

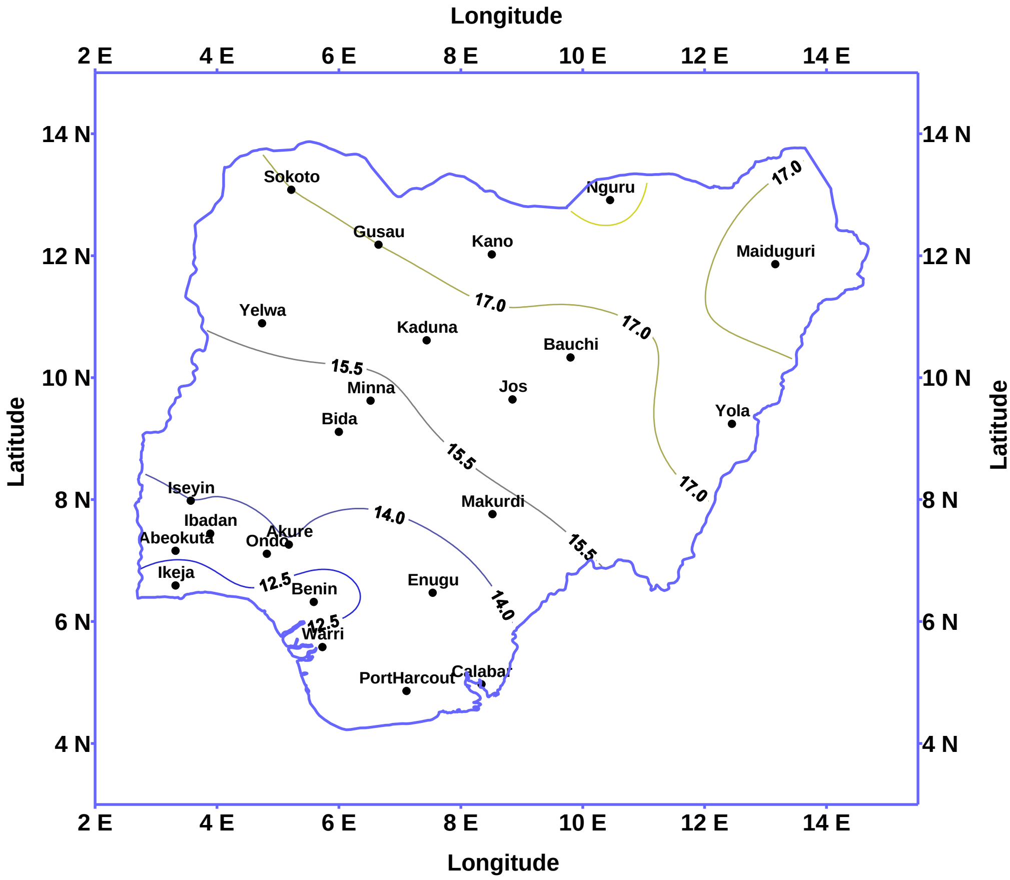

Fig. 4.45: Mean Distribution of Solar Radiation W/m2 (1992-2001)

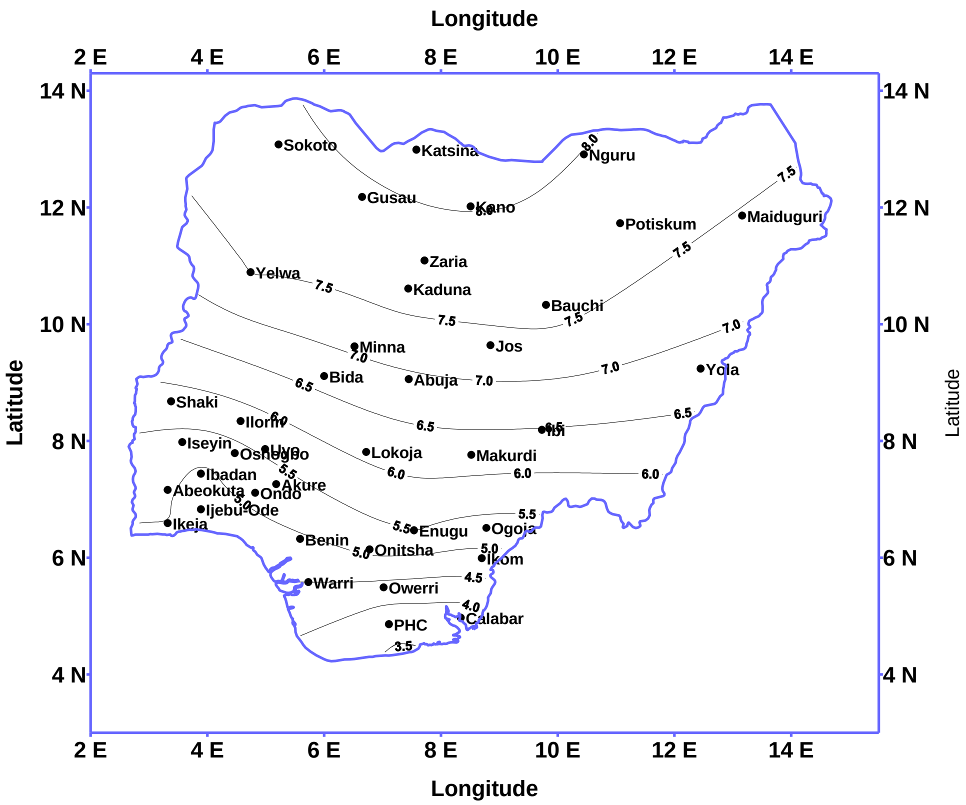

Fig. 4.46: Mean Sunshine Hours Distribution in Nigeria

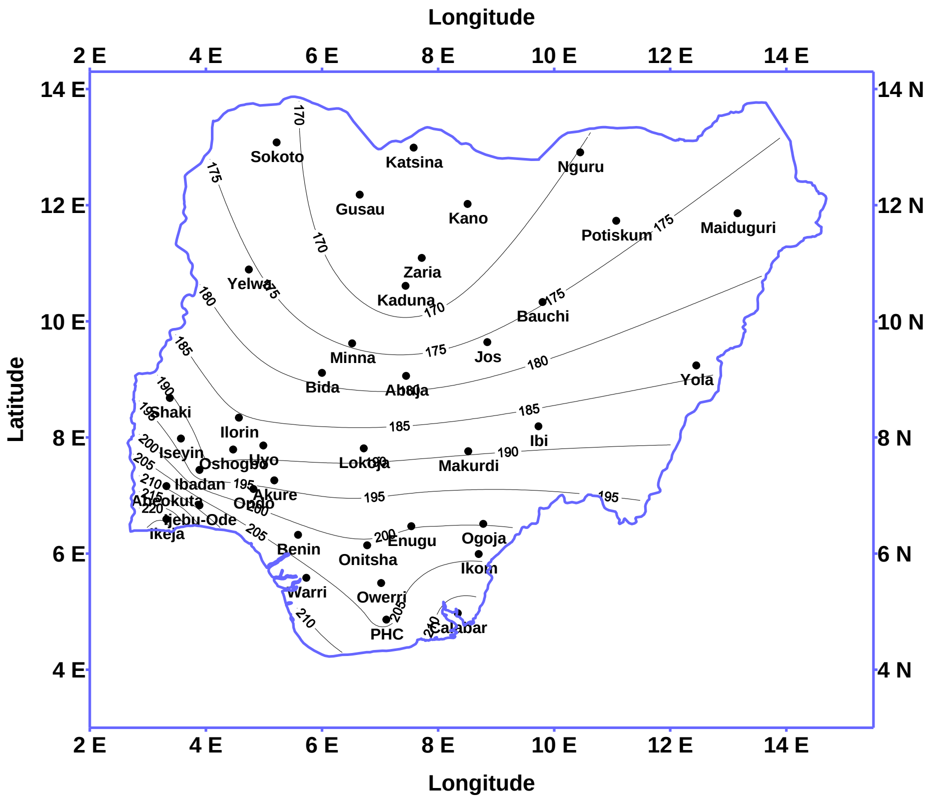

Fig. 4.47: Mean Wind Direction (deg.) in Nigeria

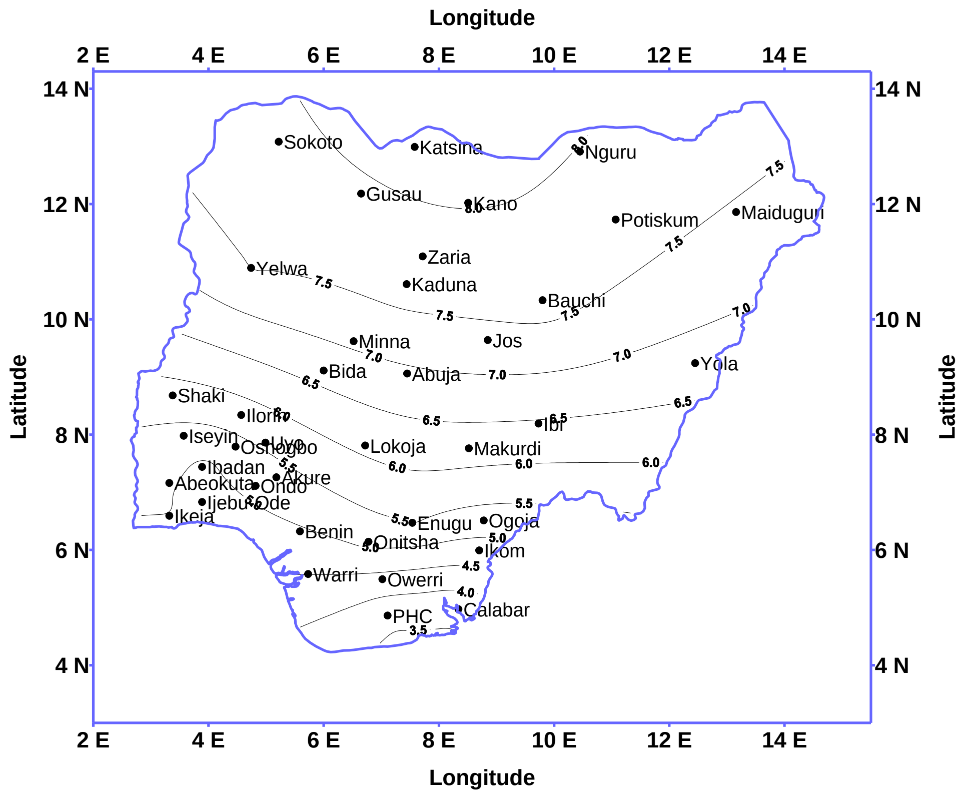

Fig. 4.48: Mean Wind Speed (m/s) Distribution in Nigeria

4.2 SPATIO-TEMPORAL DISTRIBUTION OF SELECTED DISEASES

4.2.1 Malaria

4.2.1.1 Mean Annual Distribution of Malaria in Nigeria

Figure 4.49 shows the mean annual distribution of malaria in Nigeria between 1982 and 2009. This is the reported cases of malaria incidence per population per thousand for the whole Nigeria between 1982 and 2009. Figure 4.50 is the Malaria prevalence in Nigeria in 1997. Figure 4.51 and 4.52 are the maps of malaria prevalence in 1982 and 2008 respectively.

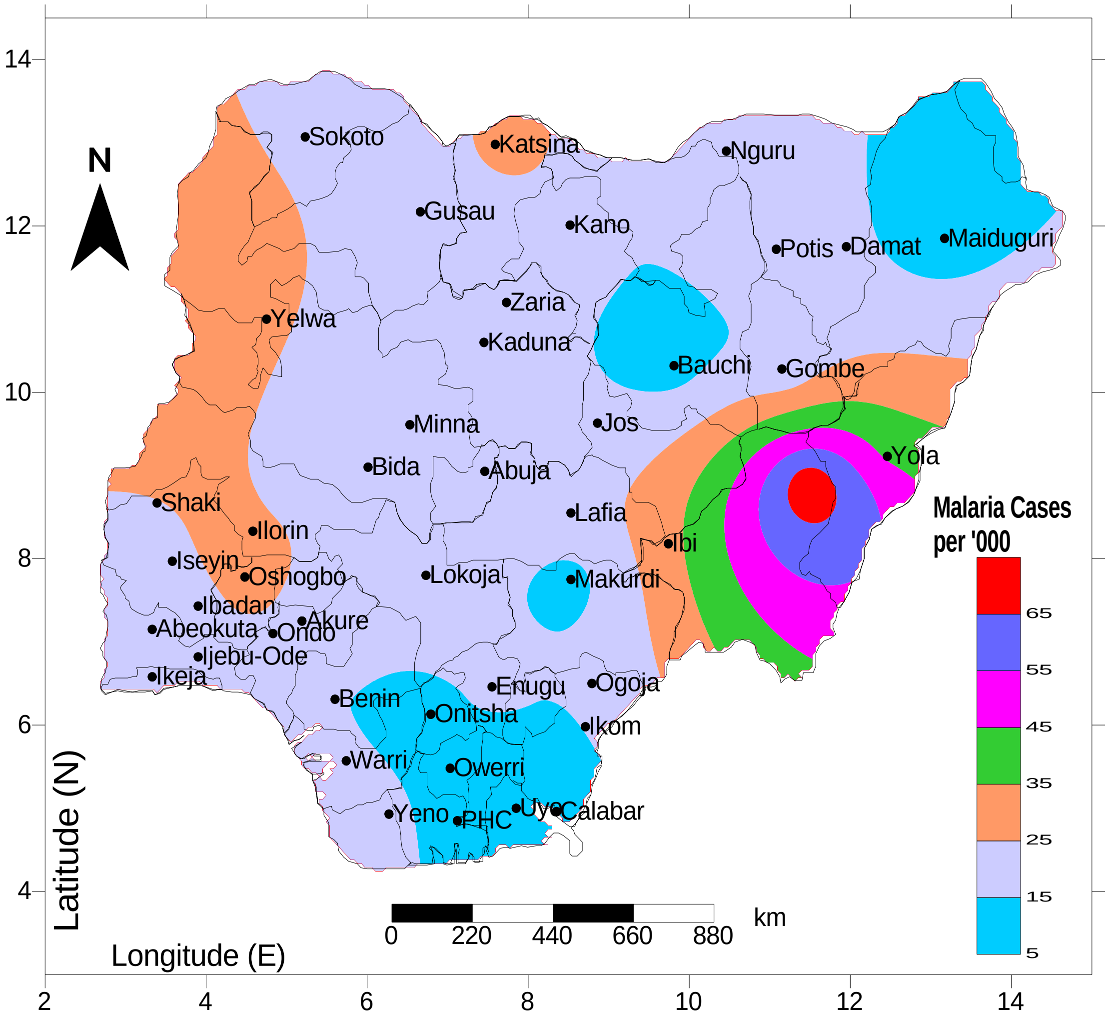

Fig. 4.49: Mean Annual Distribution of Malaria (1982-2009)

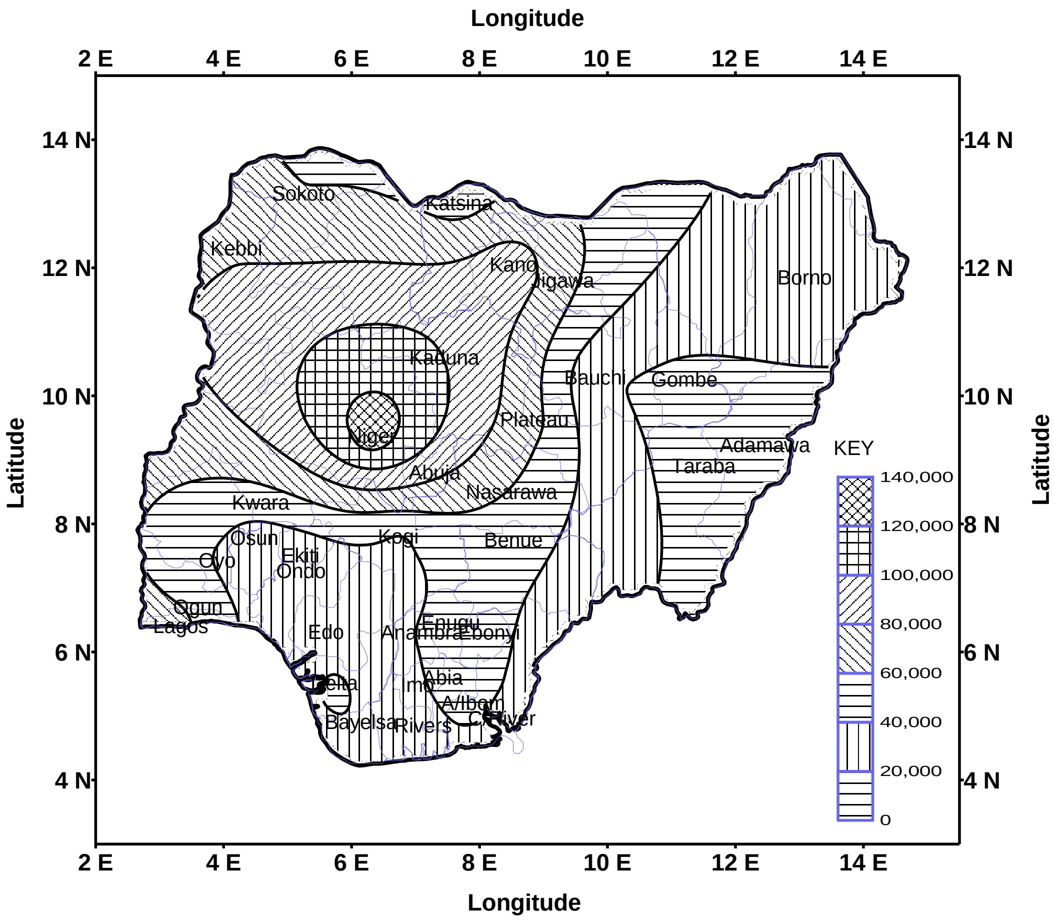

Fig.4.50: Malaria Prevalence in Nigeria in 1997

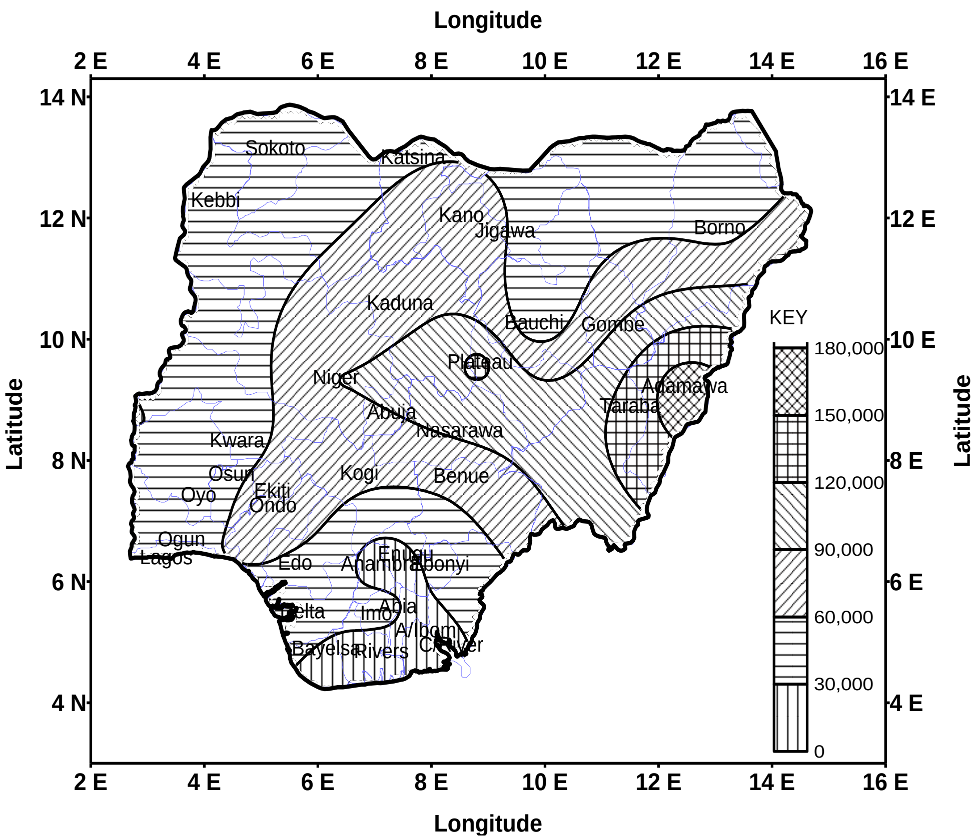

Fig. 4.51: Malaria Prevalence in Nigeria in 1982

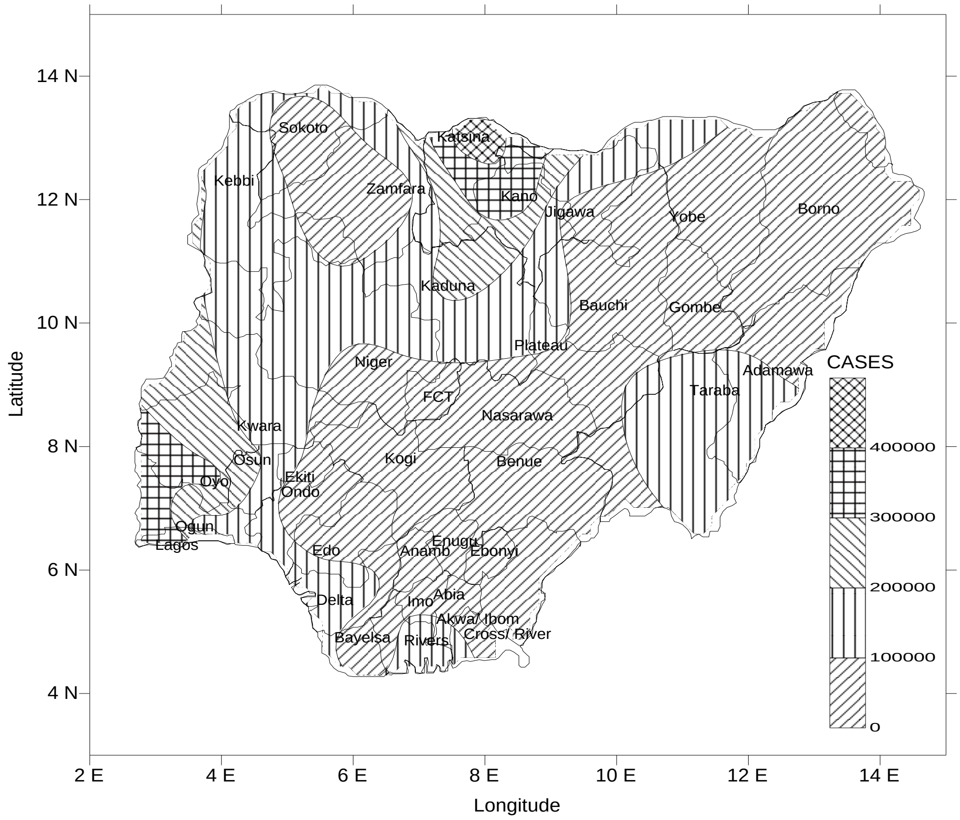

Fig. 4.52: Malaria prevalence in 2008

4.2.1.2 Mean Decadal Distribution of Malaria

Figures 4.53a is the mean decadal distribution of malaria between 1999 and 2008. Figure 4.53b is the mean decadal distribution of malaria between 1989 and 1998. Figure 4.53c is the mean decadal distribution of malaria between 1978 and 1988. Figure 4.54 is the mean monthly variation of malaria incidence between 1992 and 2009. Figure 4.55 is the yearly trends of reported cases of malaria incidence between 1981 and 2009.

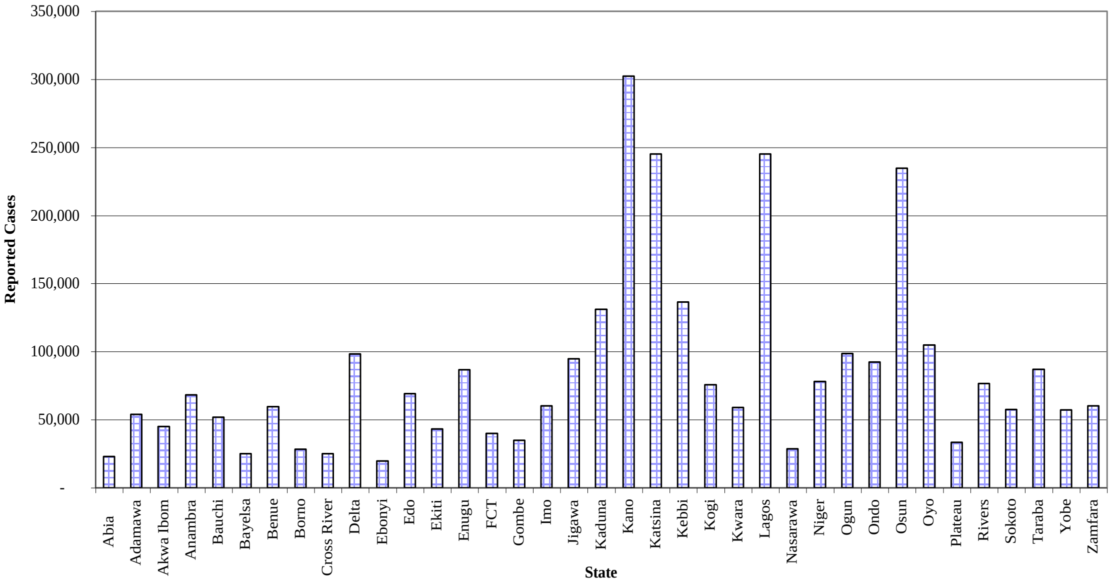

Fig. 4.53a: Mean Decadal Distribution of Malaria (1999 – 2008)

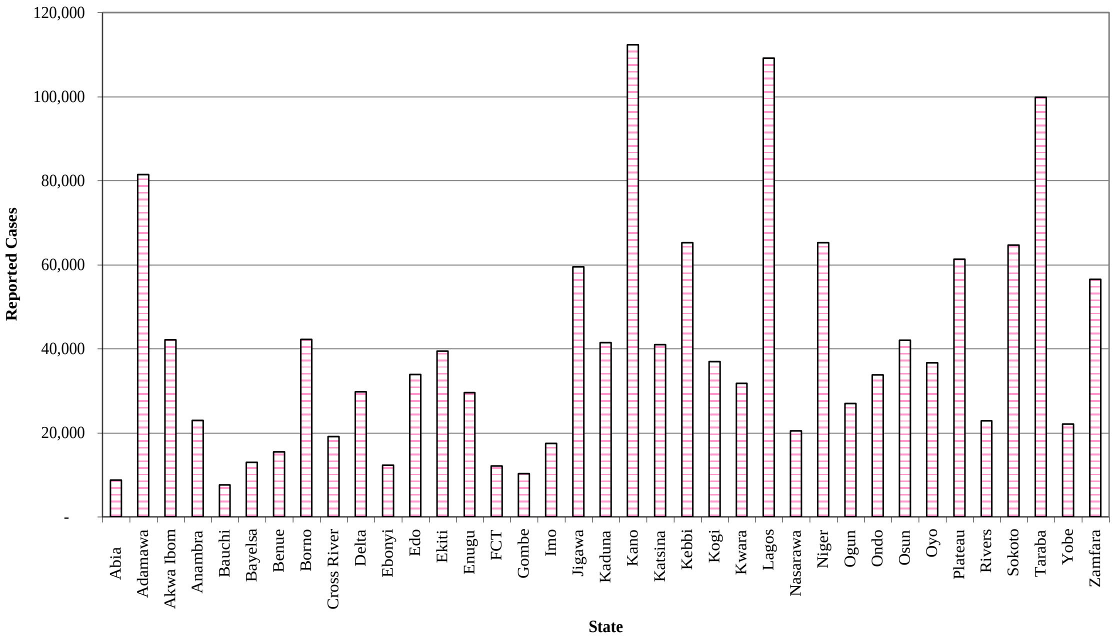

Fig. 4.53b: Mean Decadal Distribution of Malaria (1989 – 1998)

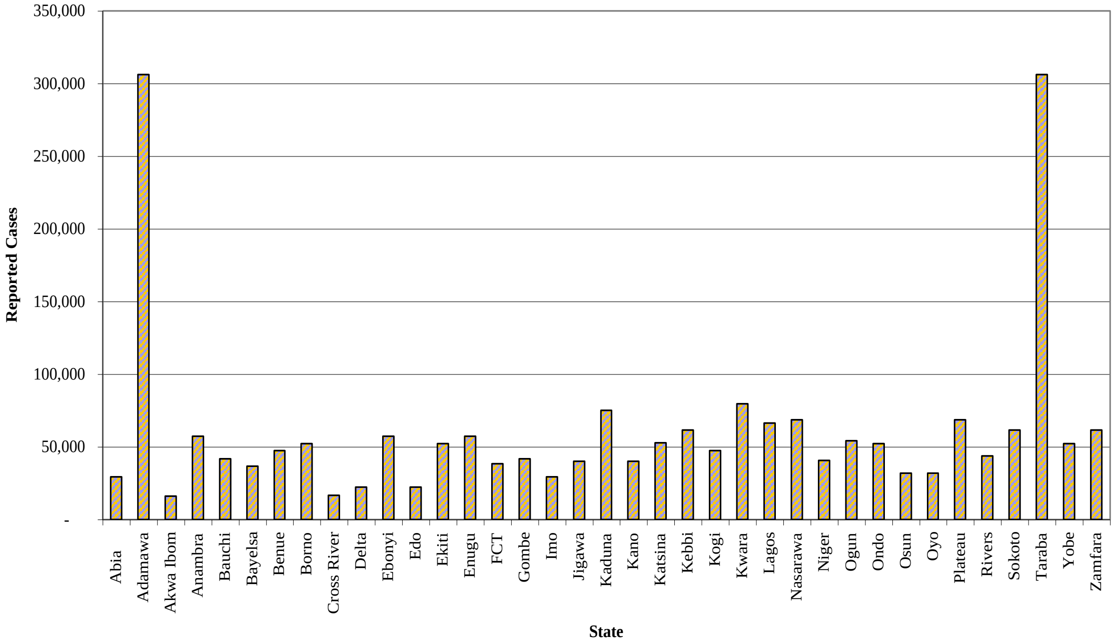

Fig. 4.53c: Mean Decadal Distribution of Malaria (1978 – 1988)

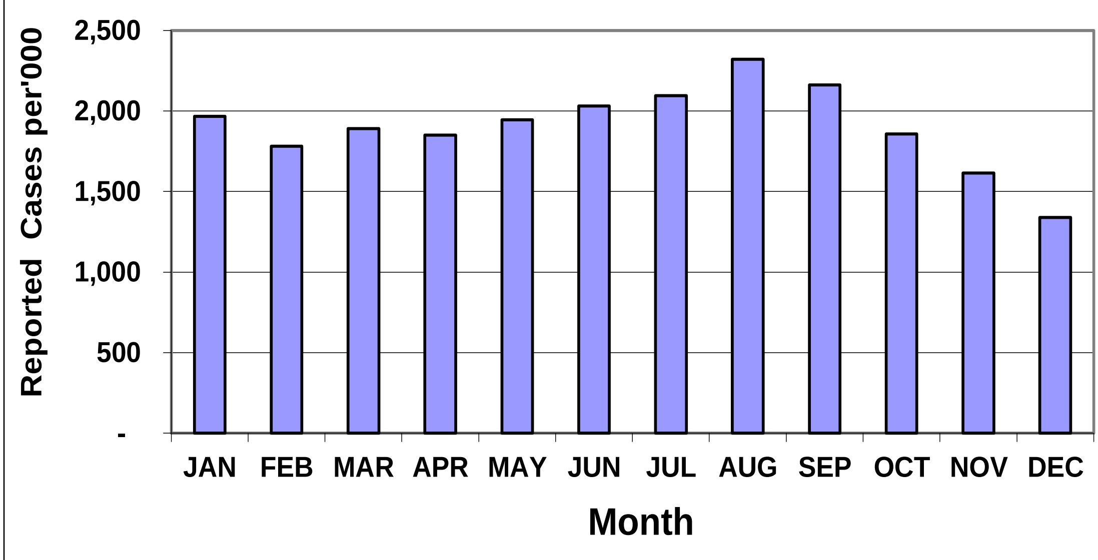

Fig. 4.54: Monthly Variation of Malaria incidence (1992-2009)

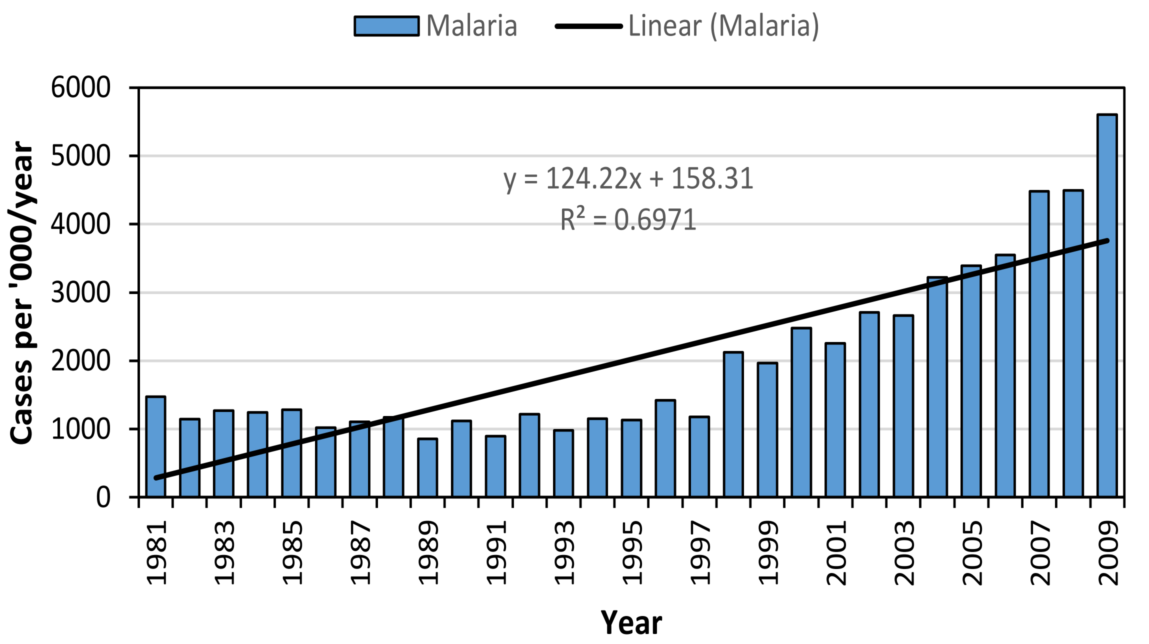

Fig. 4.55: Yearly trends of reported cases of malaria incidence (1981-2009)

4.2.1.3 Climatic Conditions Suitable for Malaria Transmission

4.2.1.3.1 Sahel Savannah Zone

Figure 4.56a is the monthly precipitation over Sahel savannah ecological zone. This was computed from the climatic stations over this zone using probability of monthly rainfall greater than 80mm, (Gilles *et al.*, 1993). Figure 4.56b is the monthly mean temperature over Sahel savannah ecological zone area. This was computed using a relation that the temperature suitable for climatic conditions suitable for malaria transmission ranged between 18°C and 32°C. Figure 4.56c is the monthly relative humidity over Sahel savannah ecological zone. When relative humidity over 60% is suitable for malaria transmission.

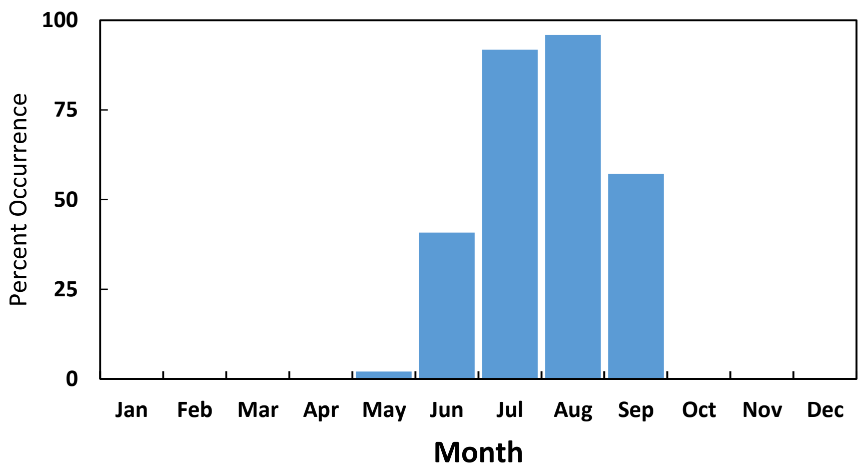

Fig. 4.56a : Monthly precipitation over Sahel Savanna ecological zone (P>80mm)

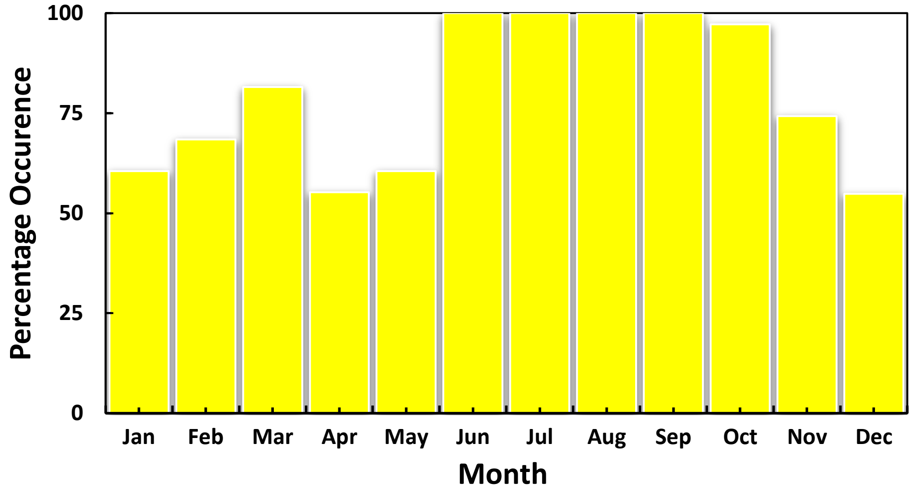

Fig. 4.56b: Monthly mean temperature over Sahel Savanna ecological zone areas (18C<T<32C)

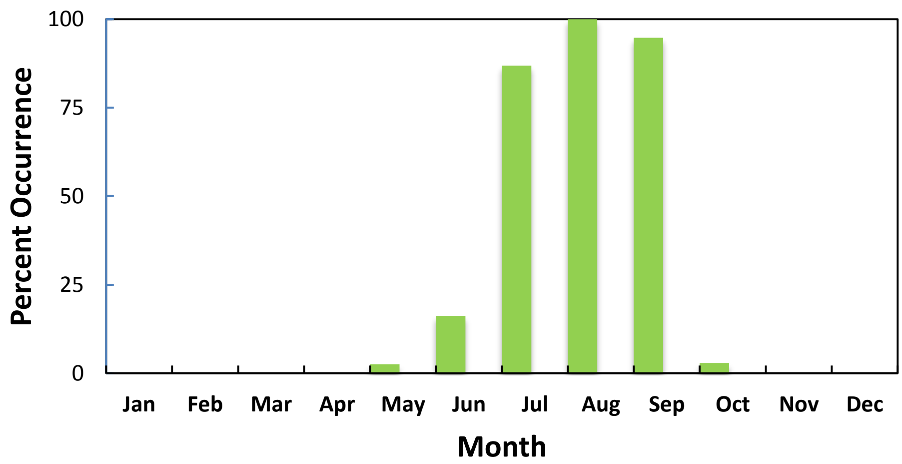

Fig. 4.56c: Monthly Relative Humidity over Sahel Savanna ecological zone (RH>60%)

4.2.1.3.2 Sudan Savannah Zone

Figure 4.57a, is the monthly precipitation over Sudan savannah ecological zone using rainfall greater than 80mm. Figure 4.57b is the monthly mean temperature over Sudan savannah ecological areas using temperature between 18°C and 32°C. Figure 4.57c is the monthly relative humidity over Sudan savannah ecological zone when relative humidity is greater than 60%.

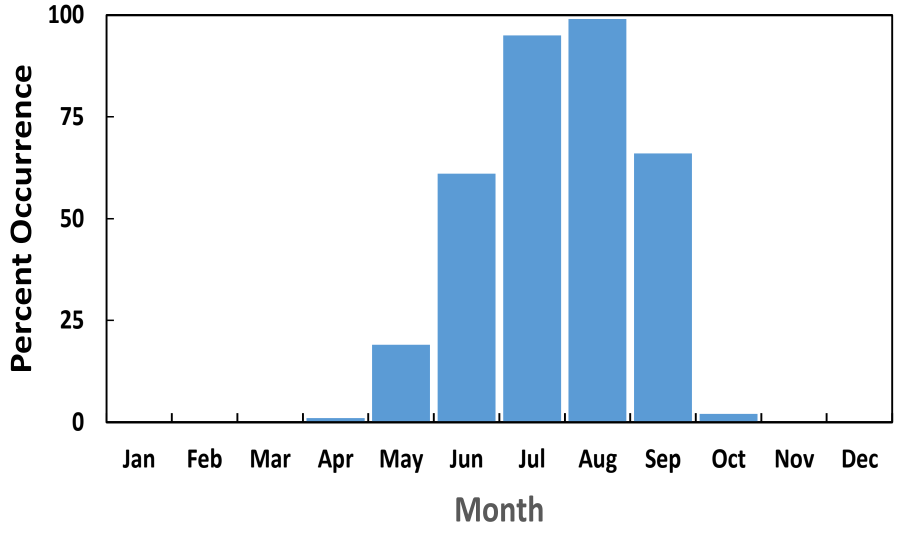

Fig. 4.57a: Monthly precipitation over Sudan Savannah ecological zone (P>80mm)

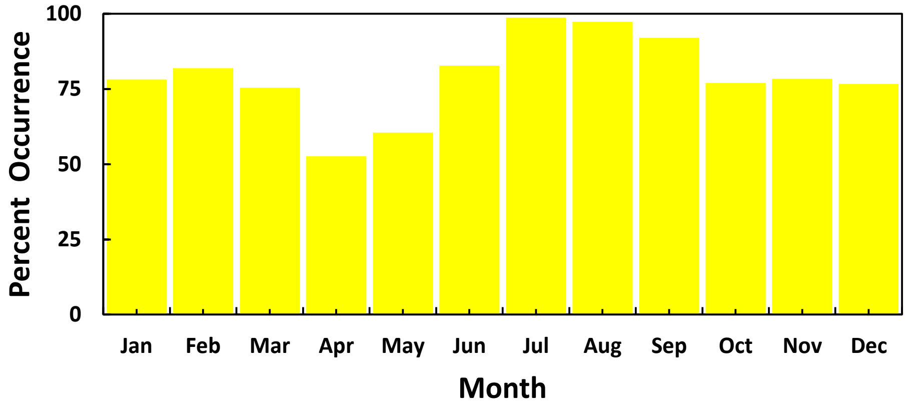

Fig. 4.57b: Monthly mean temperature over Sudan Savanna ecological zone areas (18C<T<32C)

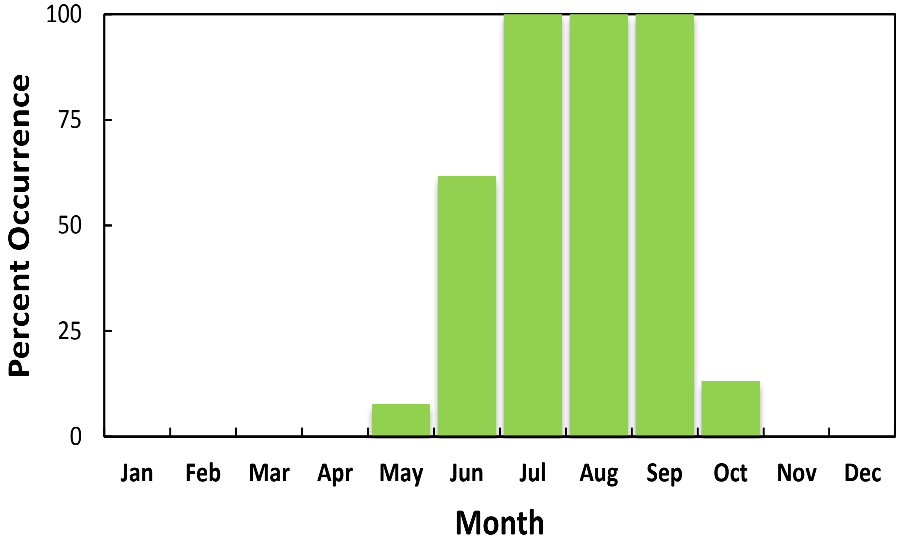

Fig. 4.57c: Monthly Relative Humidity over Sudan Savannah ecological zone (RH>60%)

4.2.1.3.3 Guinea Savannah Zone

Figure 4.58a, is the monthly precipitation over Guinea savannah ecological zone using rainfall greater 80mm. Figure 4.57b is the monthly mean temperature over Guinea savannah ecological zone areas using temperature between 18°C and 32°C. Figure 4.58c is the monthly relative humidity over Guinea savannah ecological zone when relative humidity is greater than 60%.

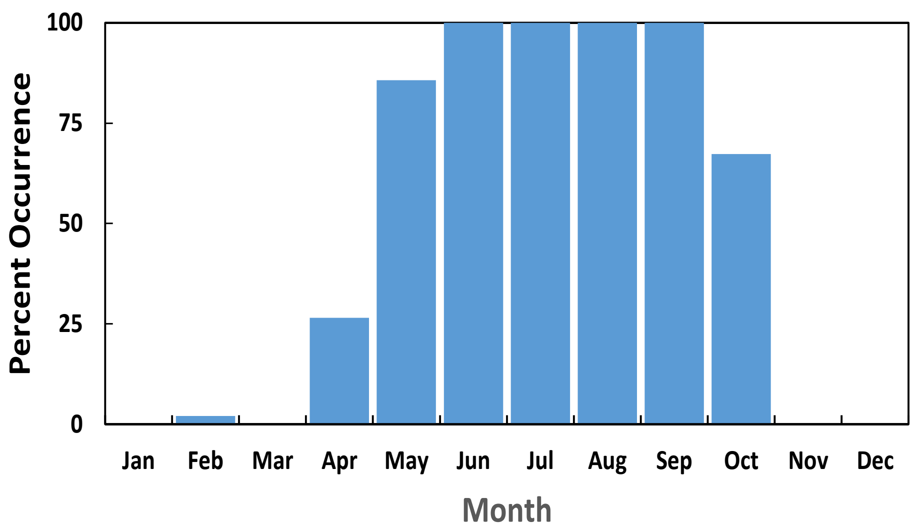

Fig. 4.58a: Monthly precipitation over Guinea Savannah ecological zone (P>80mm)

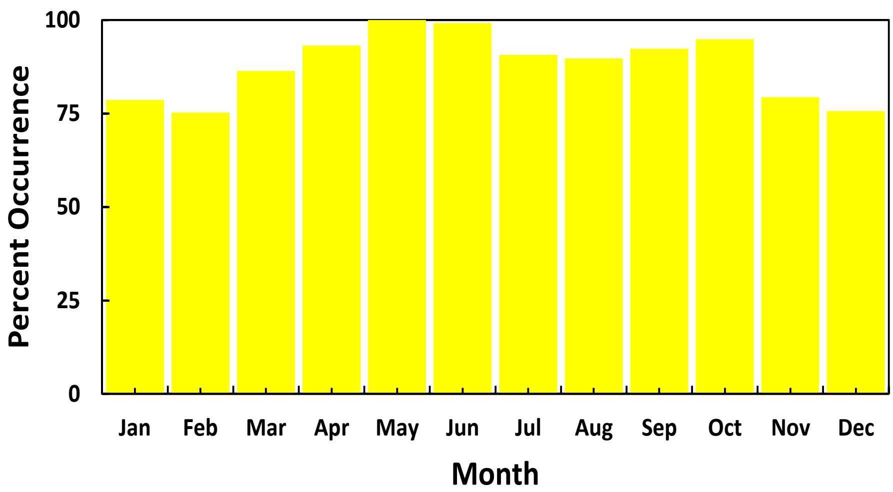

Fig. 4.58b:l Monthly mean temperature over Guinea Savannah ecological zone areas (18C<T<32C)

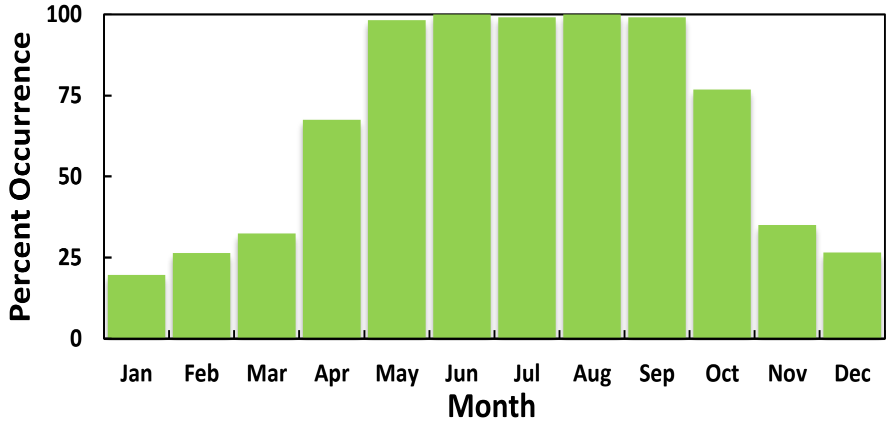

Fig. 4.58c: Monthly Relative Humidity over Guinea Savannah ecological zone (RH>60%)

4.2.1.3.4 Rain Forest Zone

Figure 4.59a is the monthly precipitation over tropical rain forest ecological zone using rainfall greater than 80mm. Figure 4.59b is the monthly mean temperature over tropical forest ecological areas using temperature between 18°C and 32°C. Figure 4.59c is the monthly relative humidity over tropical forest ecological zone with relative humidity greater than 60%.

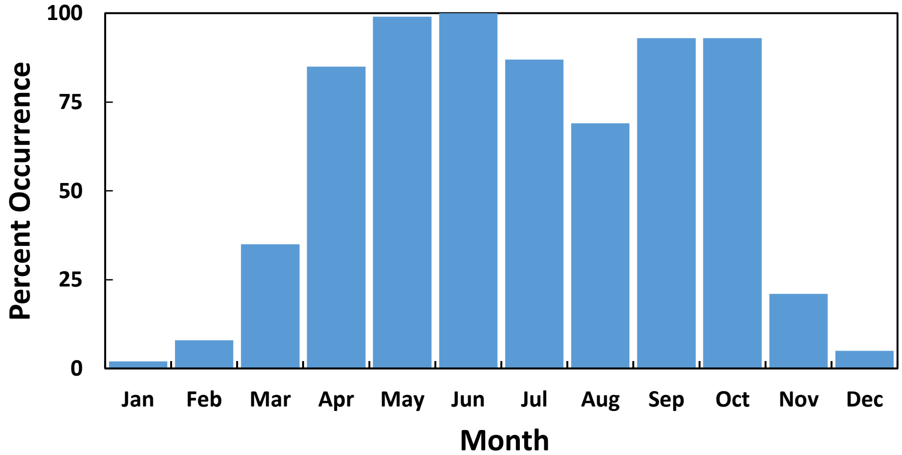

Fig. 4.59a: Monthly precipitation over Tropical Forest ecological zone (P>80mm)

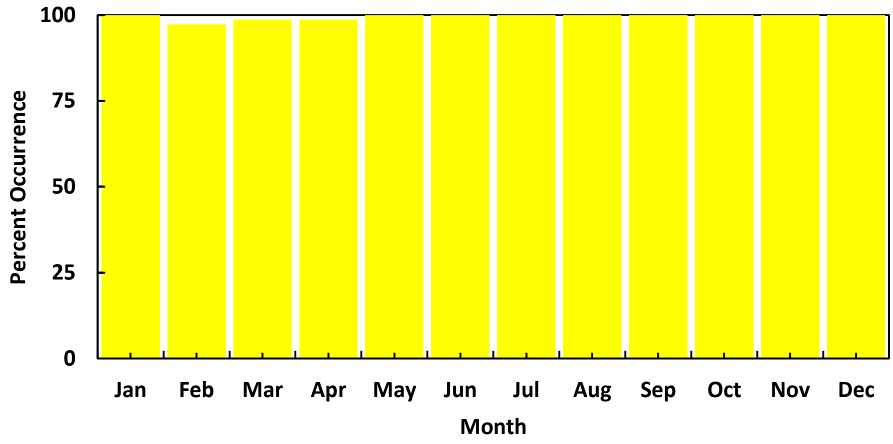

Fig. 4.59b: Monthly mean temperature over Tropical Forest ecological areas (18C<T<32C)

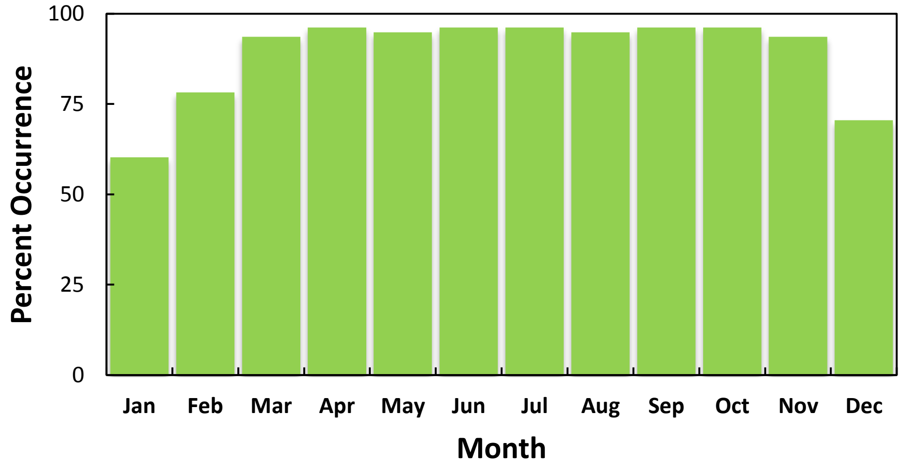

Fig. 4.59c: Monthly Relative Humidity over Tropical Forest ecological zone (RH>60%)

4.2.1.3.5 Mangrove Swamp Forest Zone

Figure 4.60a is the monthly precipitation over mangrove swamp forest ecological zone using rainfall greater than 80mm. Figure 4.60b is the monthly mean temperature over swamp forest ecological zone using temperature between 18°C and 32°C. Figure 4.60c is the monthly relative humidity over swamp ecological forest zone with relative humidity greater than 60%.

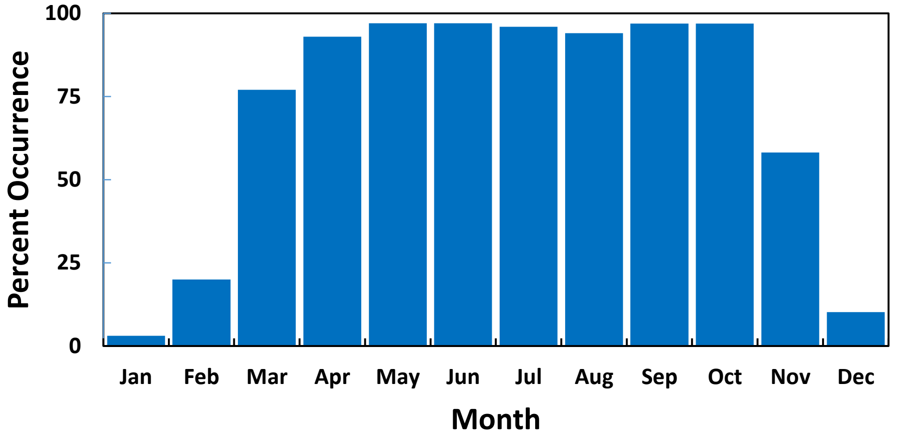

Fig. 4.60a: Monthly Precipitation over Mangrove Swamp ecological zone (P>80mm)

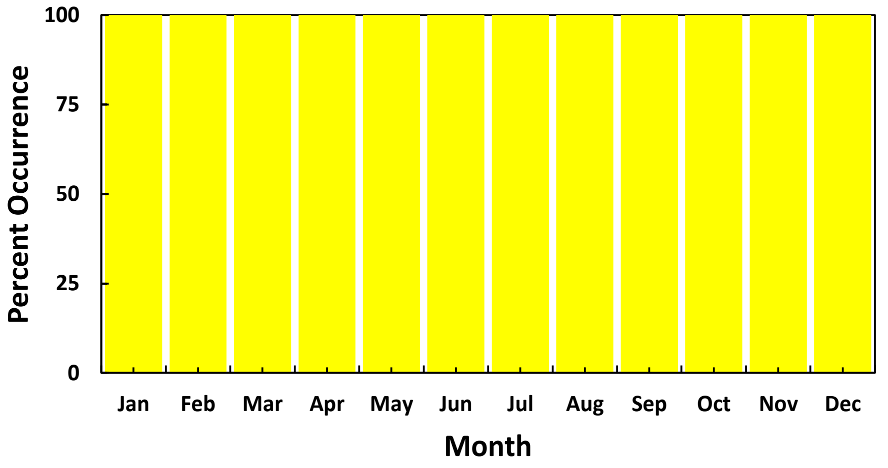

Fig. 4.60b: Monthly mean temperature over Mangrove Swamps ecological region (18C<T<32C)

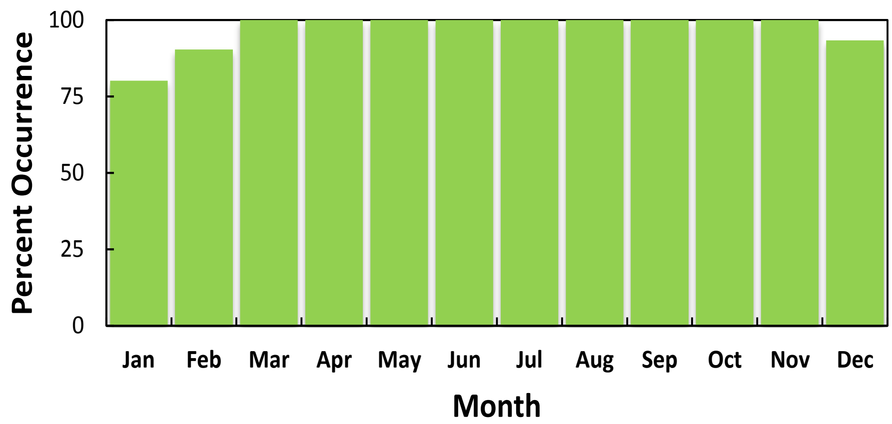

Fig.4.60c: Monthly Relative Humidity over Mangrove Swamps ecological zone (RH>60%)

4.2.1.4 Malaria Prevalence over Jos Plateau Area

Figure 4.61a is the trends of malaria and maximum temperature over Plateau state of Nigeria between 1982 and 2009. Linear regression and polynomial regression was used to determine the nature of trends over the mountainous region. Figure 4.61b is the trends of malaria and rainfall over Plateau state of Nigeria between 1982 and 2009. Linear regression and polynomial regression was used to determine the nature of trends.

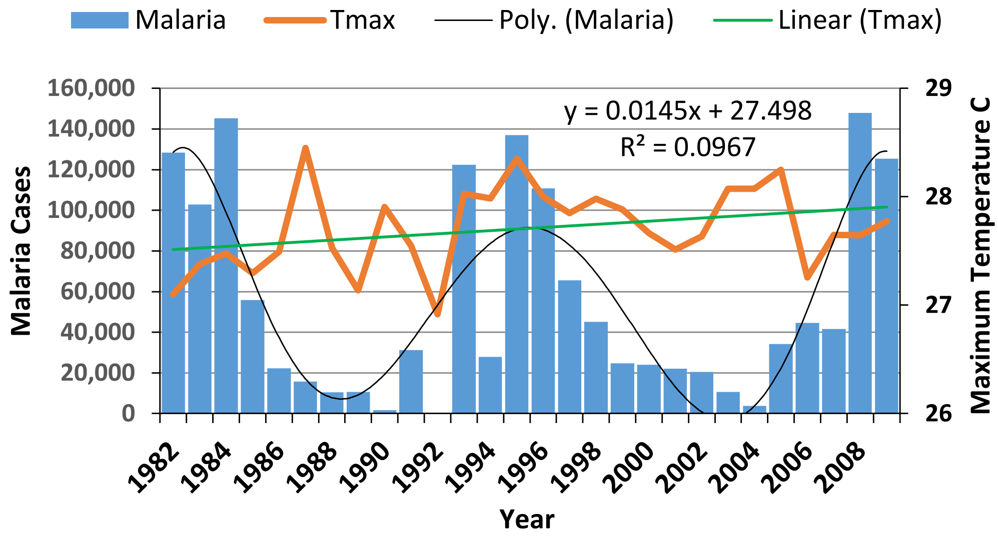

Fig. 4.61a: Trends of Malaria and Maximum Temperature over Plateau State of Nigeria (1982-2009)

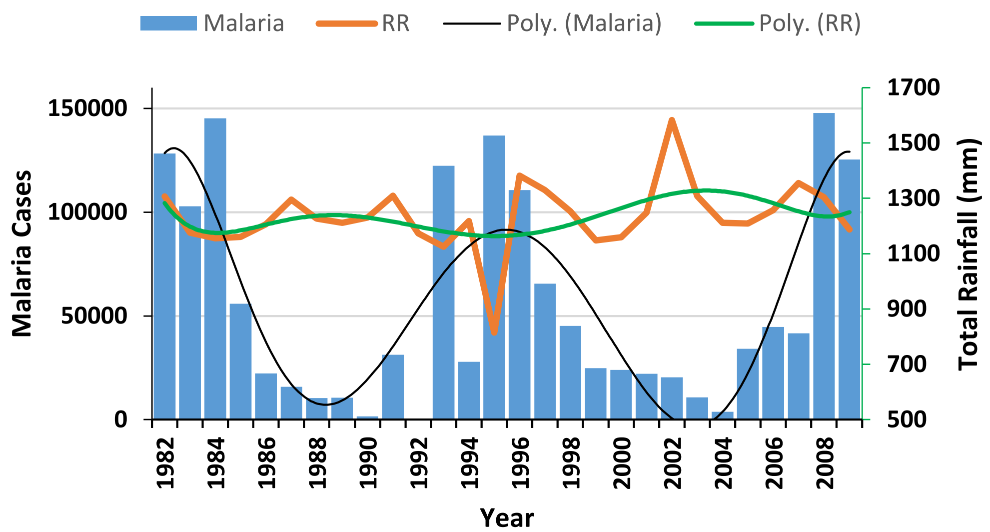

Fig. 4.61b: Trends of Malaria and Rainfall over Plateau State of Nigeria (1982-2009)

4.2.2 Measles

Figure 4.62 shows the mean annual distribution of measles in Nigeria between 1981-2009. The map was generated using Arc view version 3.2. Figure 4.63 is the yearly distribution of measles in Nigeria between 1982 and 2009. Figure 4.64 and 4.65 are the distribution of measles in Nigeria in 1997 and 2008. Figure 4.66 is the mean monthly variation of measles in Nigeria between 1981 and 2009.

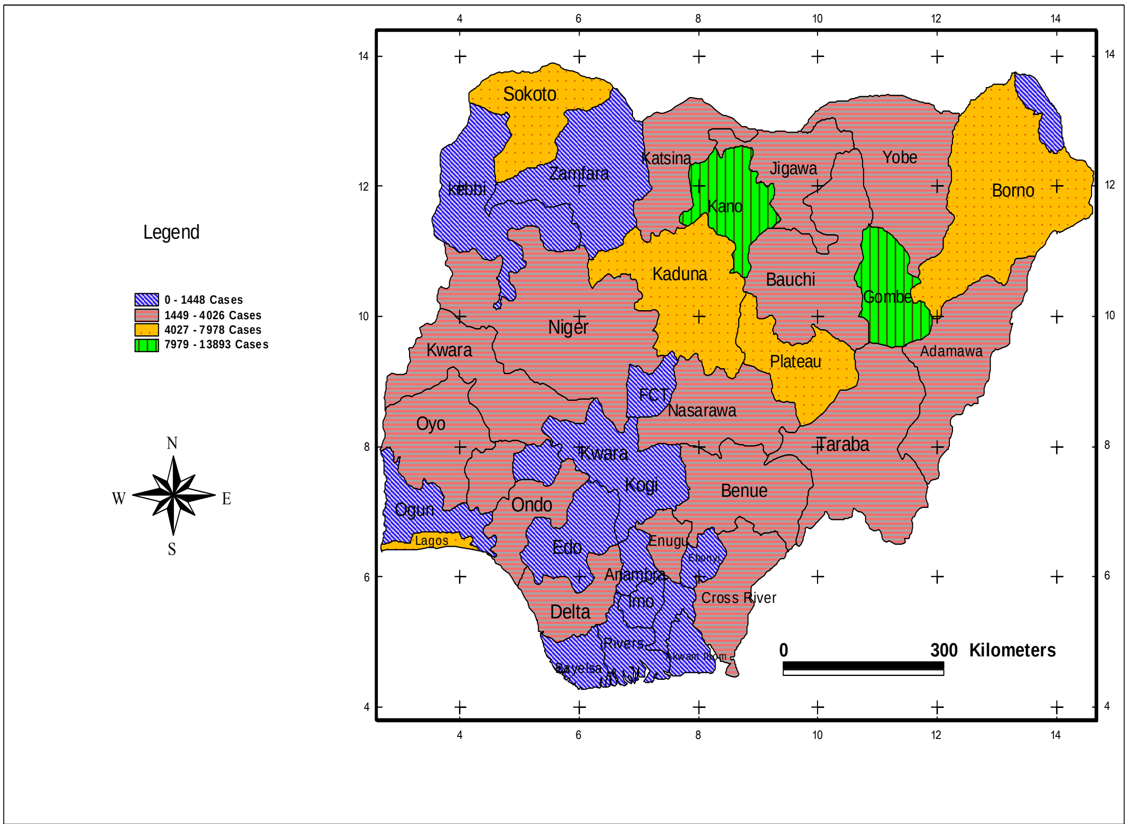

Fig. 4.62: Mean Annual Distribution of Measles in Nigeria (1981 – 2009)

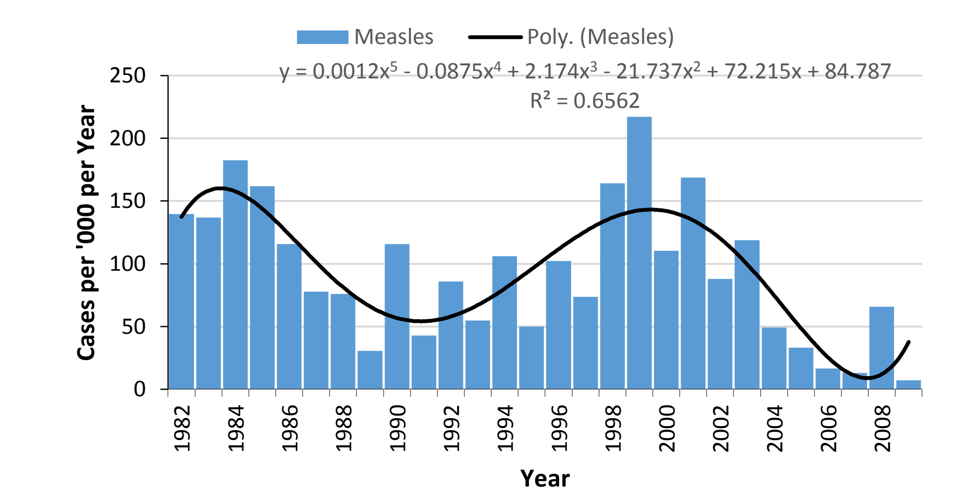

Fig. 4.63: Yearly Distiribution of Measles in Nigeria (1982-2009)

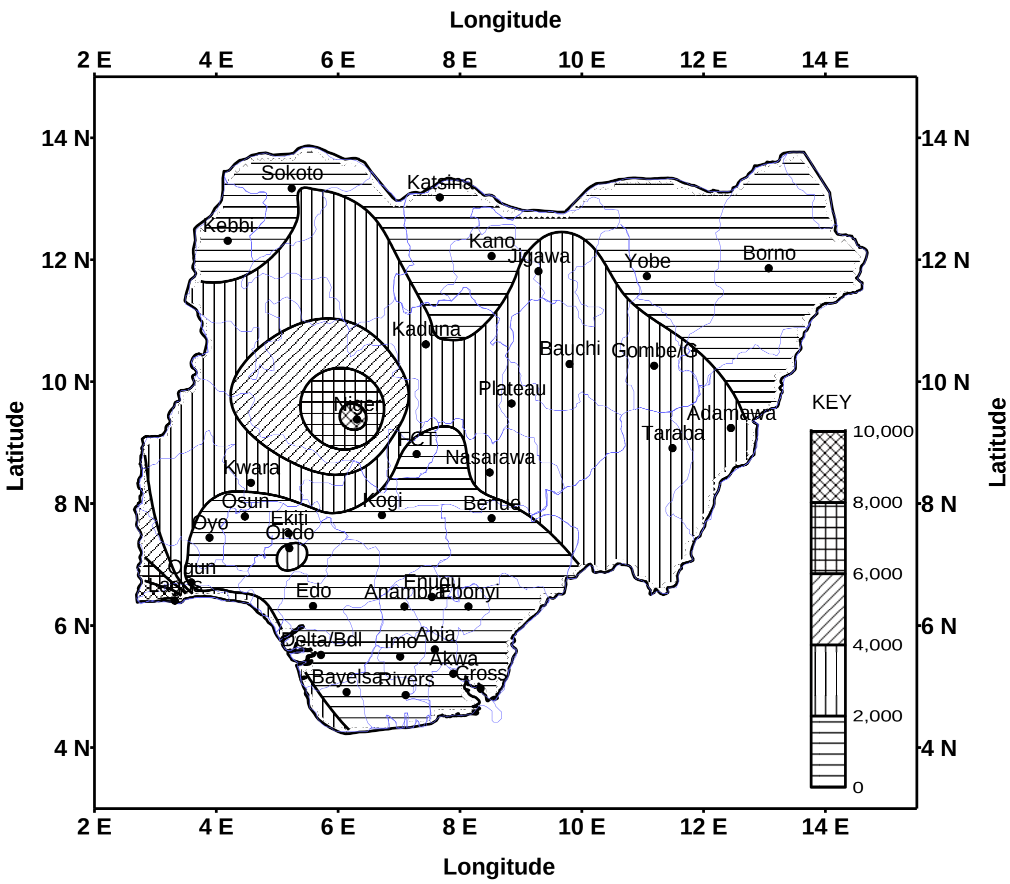

Fig. 4.64: Distribution of Measles in Nigeria 1997

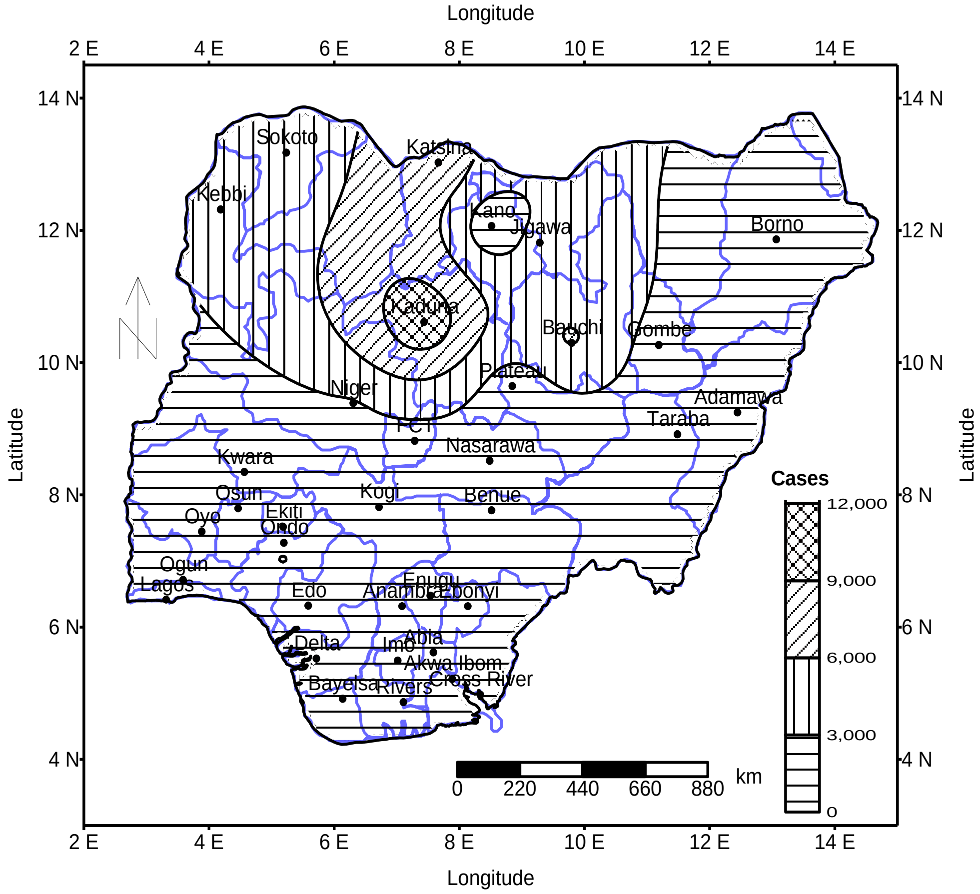

Fig. 4. 65: Distribution of Measles in Nigeria in 2008

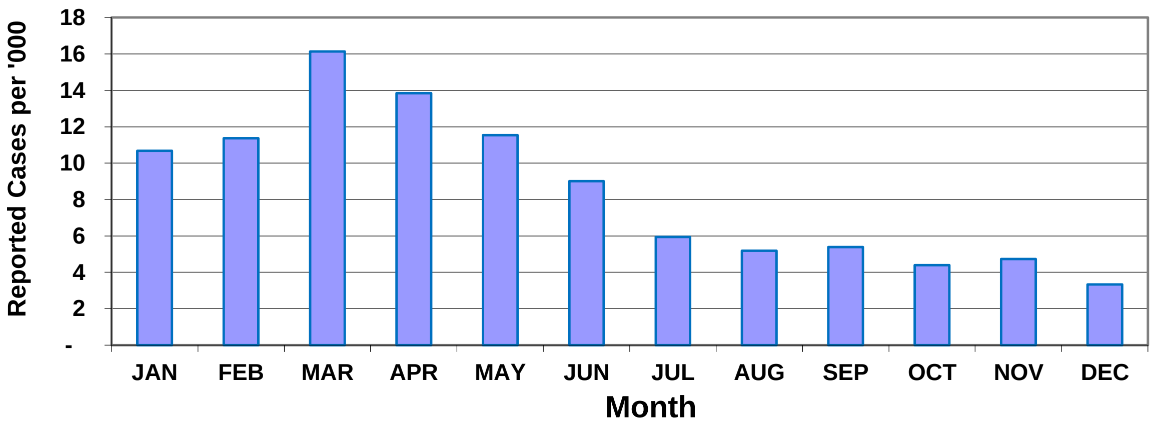

Fig. 4.66: Mean Monthly Variation of Measles in Nigeria (1992-2009)

4.2.3 Pneumonia

Figure 4.67 is the mean spatial distribution of pneumonia in Nigeria between 1982 and 2009. Figure 4.68 is the distribution of pneumonia in Nigeria in 2007. This was mapped using surfer software. Figure 4.69 is the yearly distribution of pneumonia in Nigeria between 1982 and 2009. Figure 4.70 is the monthly variation of pneumonia in Nigeria between 1992 and 2009.

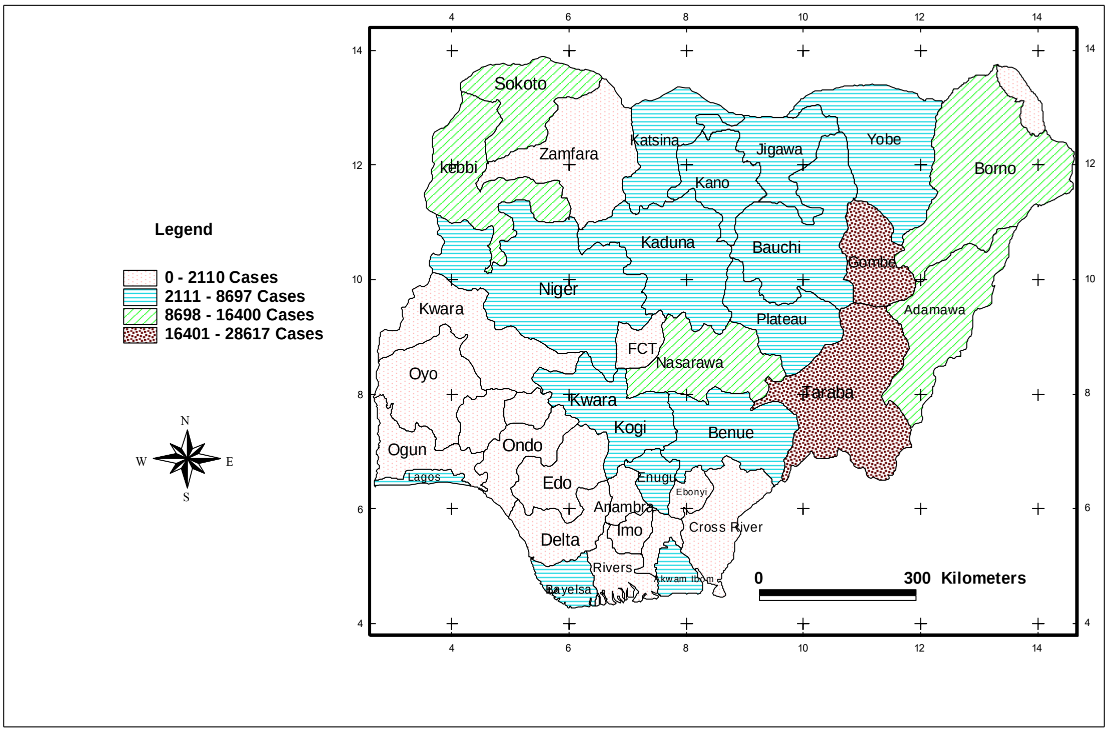

Fig. 4.67: Mean Spatial Distribution of Pneumonia in Nigeria (1982-2009)

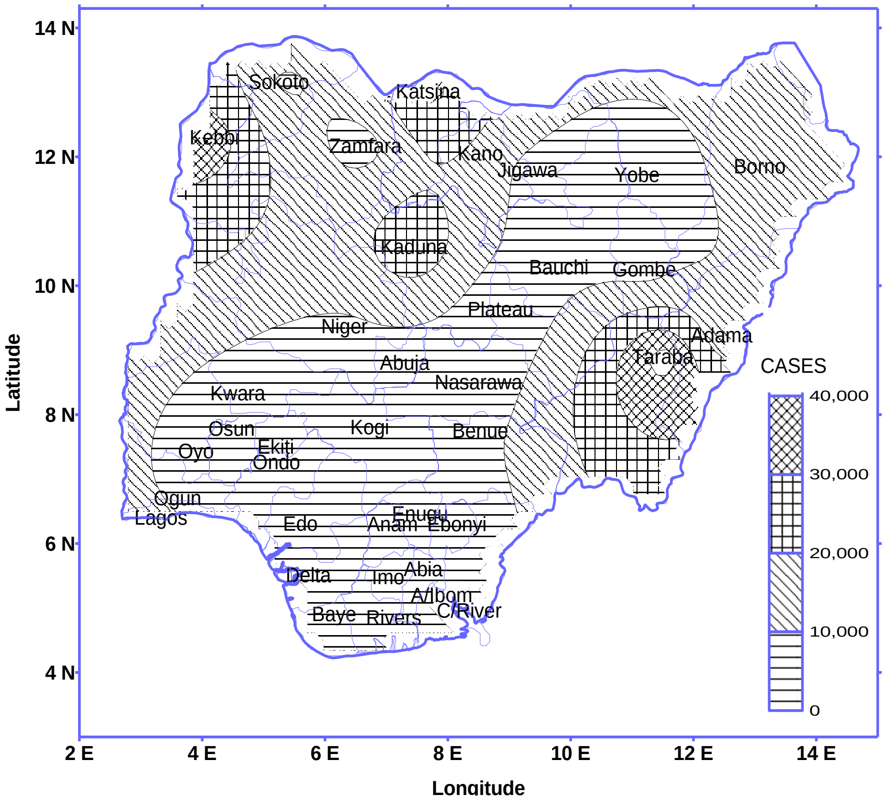

Fig. 4.68: Distribution of Pneumonia in Nigeria in 2007

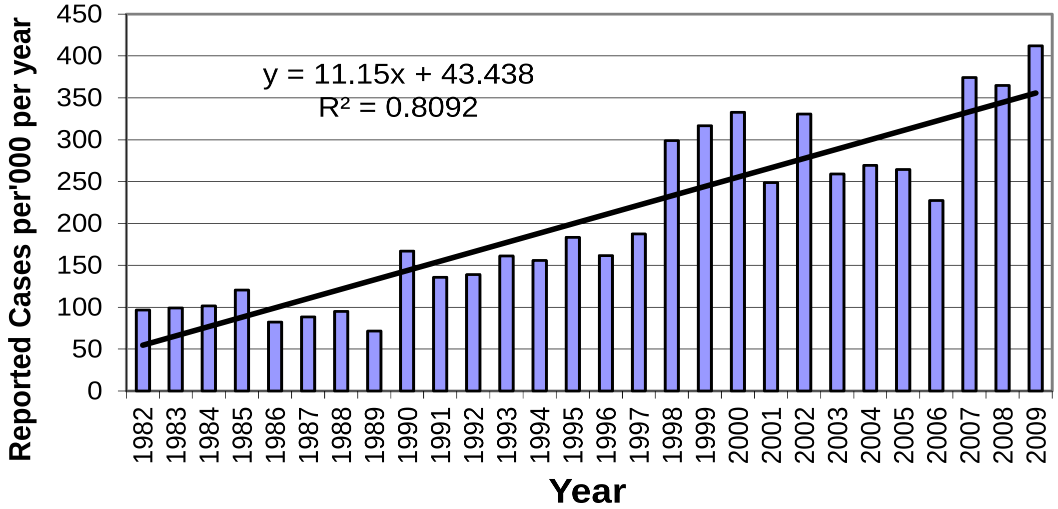

Fig. 4.69: Yearly Distribution of Pnemonia in Nigeria (1982-2009)

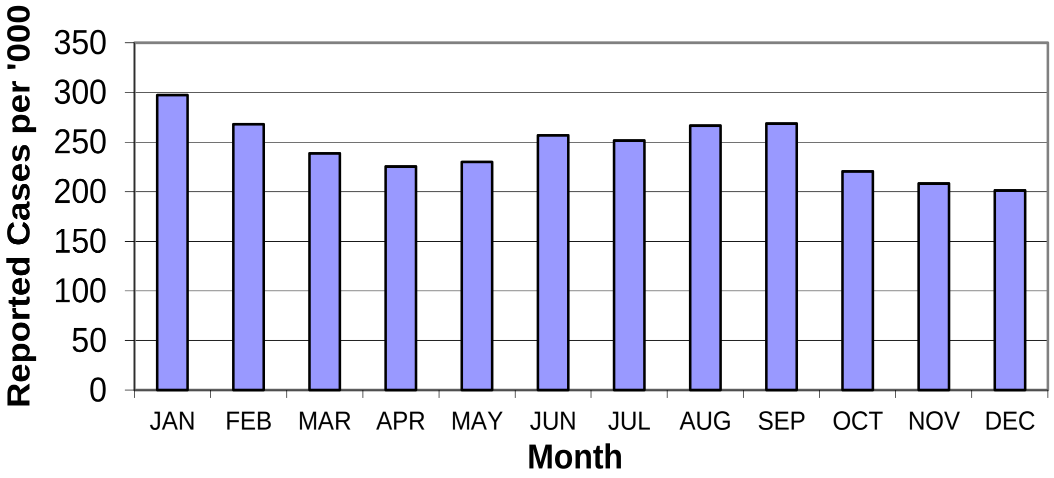

Fig. 4.70: Monthly Variation of Pneumonia in Nigeria (1992-2009)

4.2.4 Cerebro-Spinal-Meningitis

Mean Spatial distribution of Cerebro-Spinal –Meningitis (CSM) between 1982 and 2009 is as shown in figure 4.71. Similarly, figure 4.72 is the distribution of CSM in Nigeria in 2008 using surfer software. Figure 4.73 is the yearly distribution of CSM in Nigeria between 1982 and 2009. Figure 4.74 shows the monthly variation of cerebro-spinal-meningitis between 1982 and 2005.

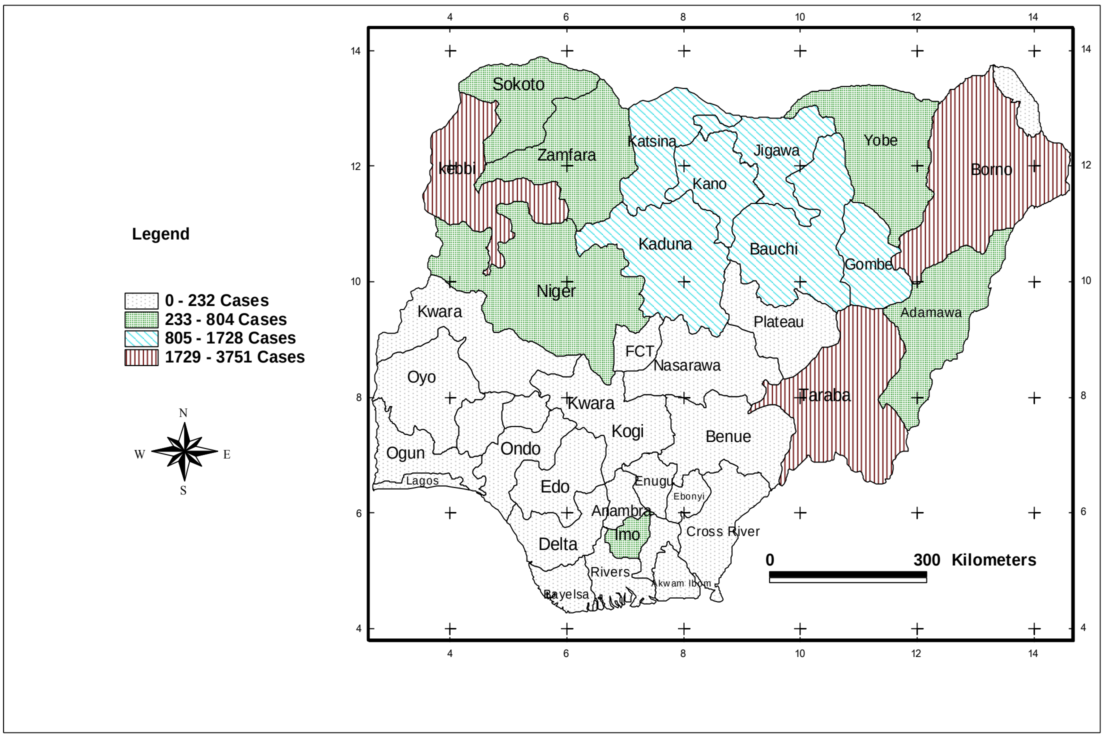

Fig. 4.71: Mean Spatial Distribution of Cerebro- Spinal- Meningitis (CSM) in Nigeria (1982-2009)

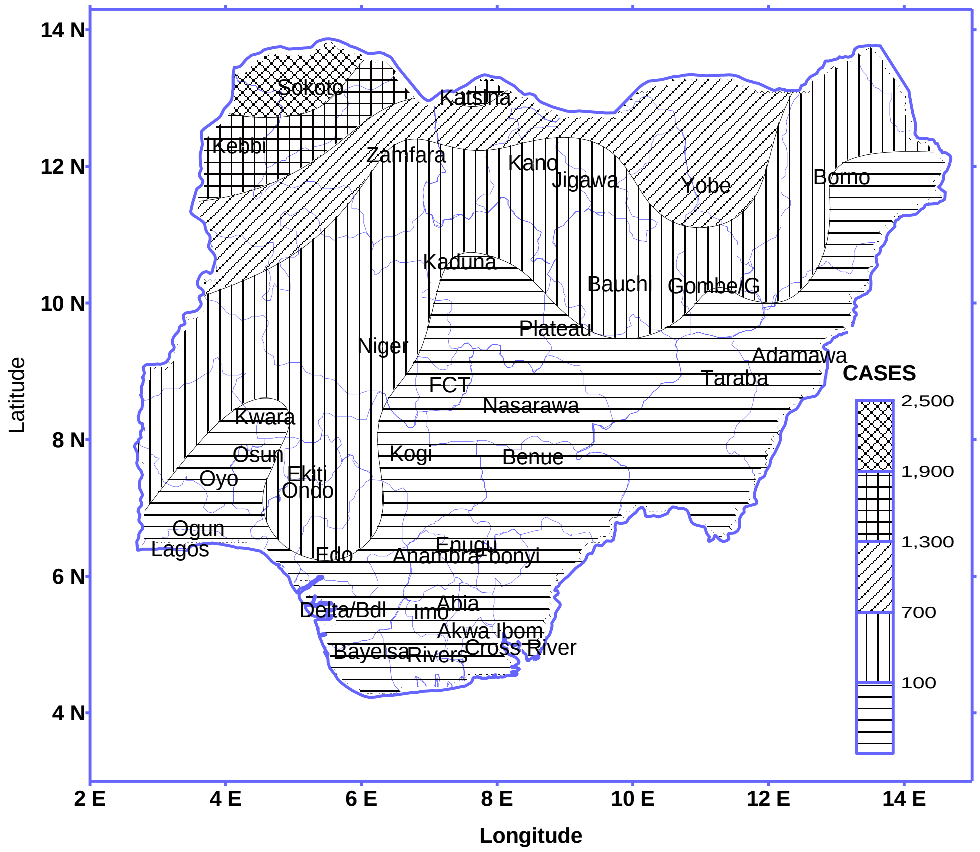

Fig. 4.72: Distribution of CSM in Nigeria in 2008

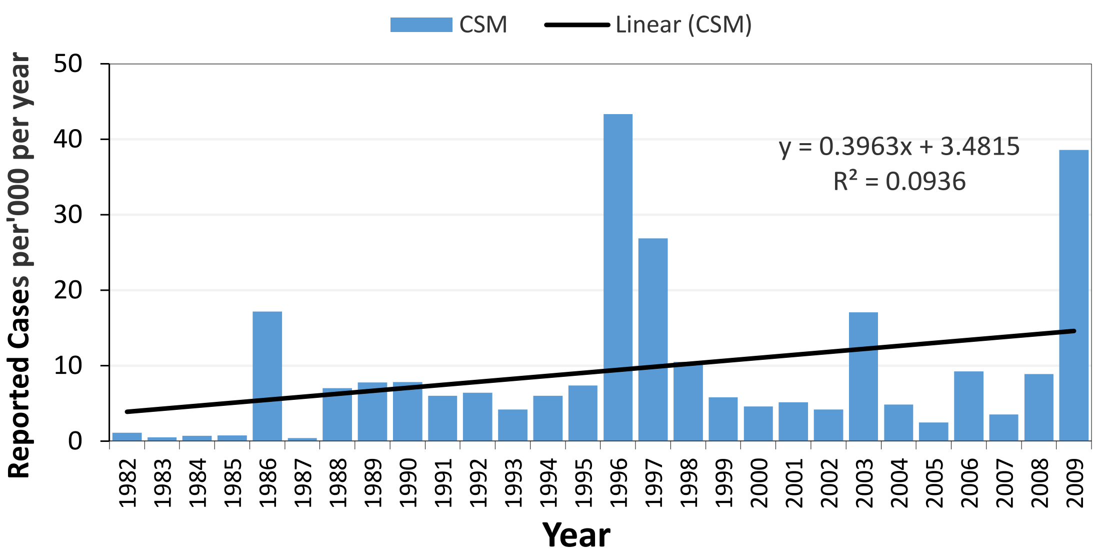

Fig. 4.73: Yearly Distribution of Cerebro-Spinal-Maningitis (CSM) in Nigeria (1982-2009)

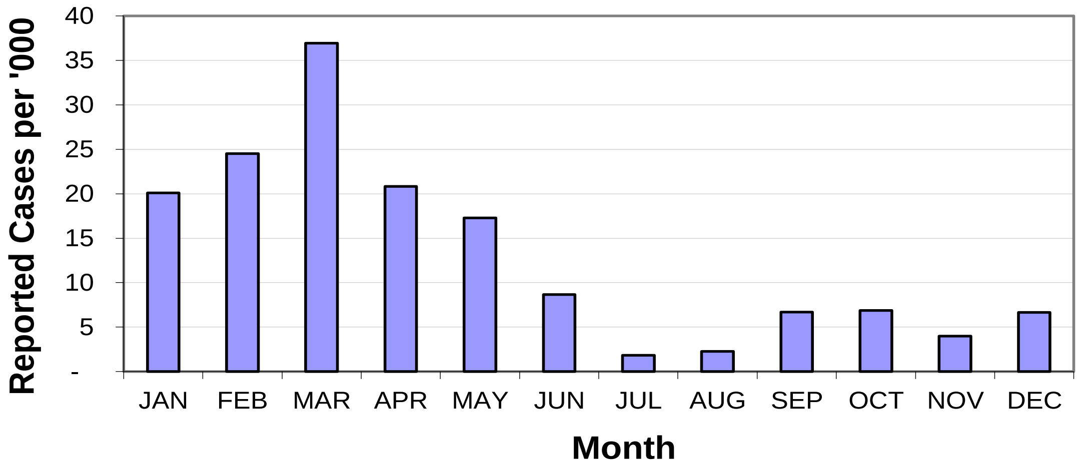

Fig. 4.74: Monthly Variation of Cerebro-Spinal-lMeningitis(CSM) 1992-2005

4.2.5 Tuberculosis

Figure 4.75 is the mean annual tuberculosis (TB) in Nigeria between 1982 and 2009. Figure 4.76 is the distribution of tuberculosis in Nigeria in 2008 using surfer software for its mapping. Figure 4.78 is the mean monthly variation of tuberculosis in Nigeria between 1992 and 2005.

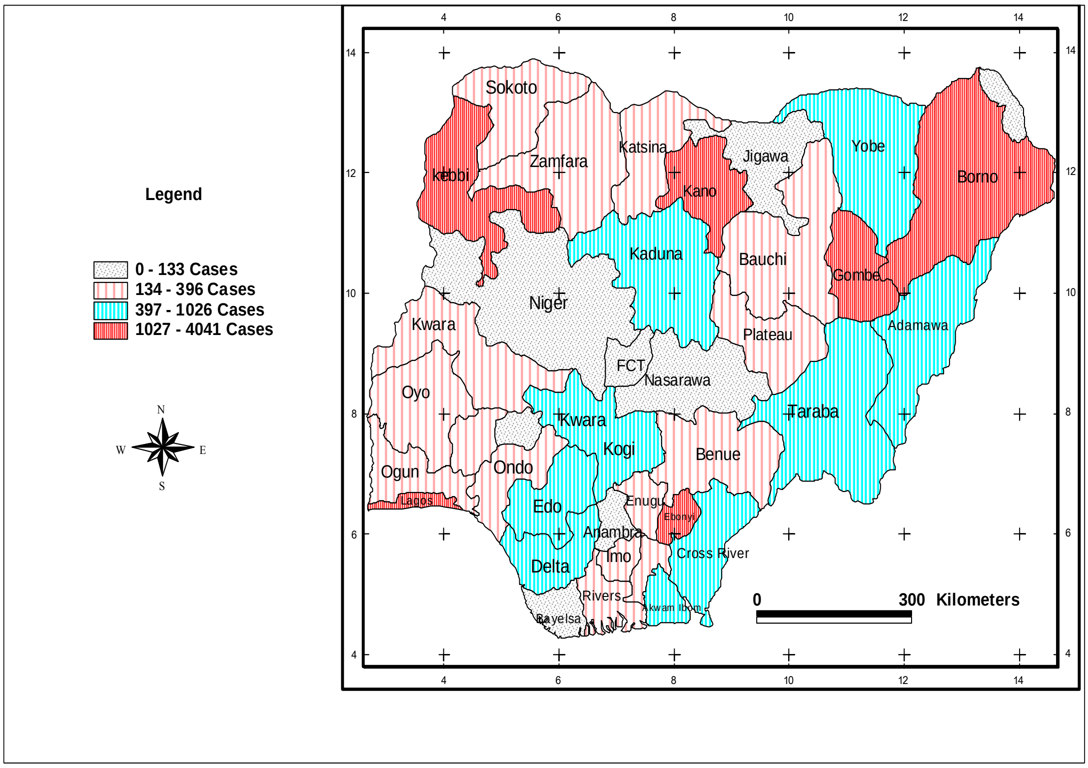

Fig. 4.75: Mean Annual Tuberculosis in Nigeria (1982-2009)

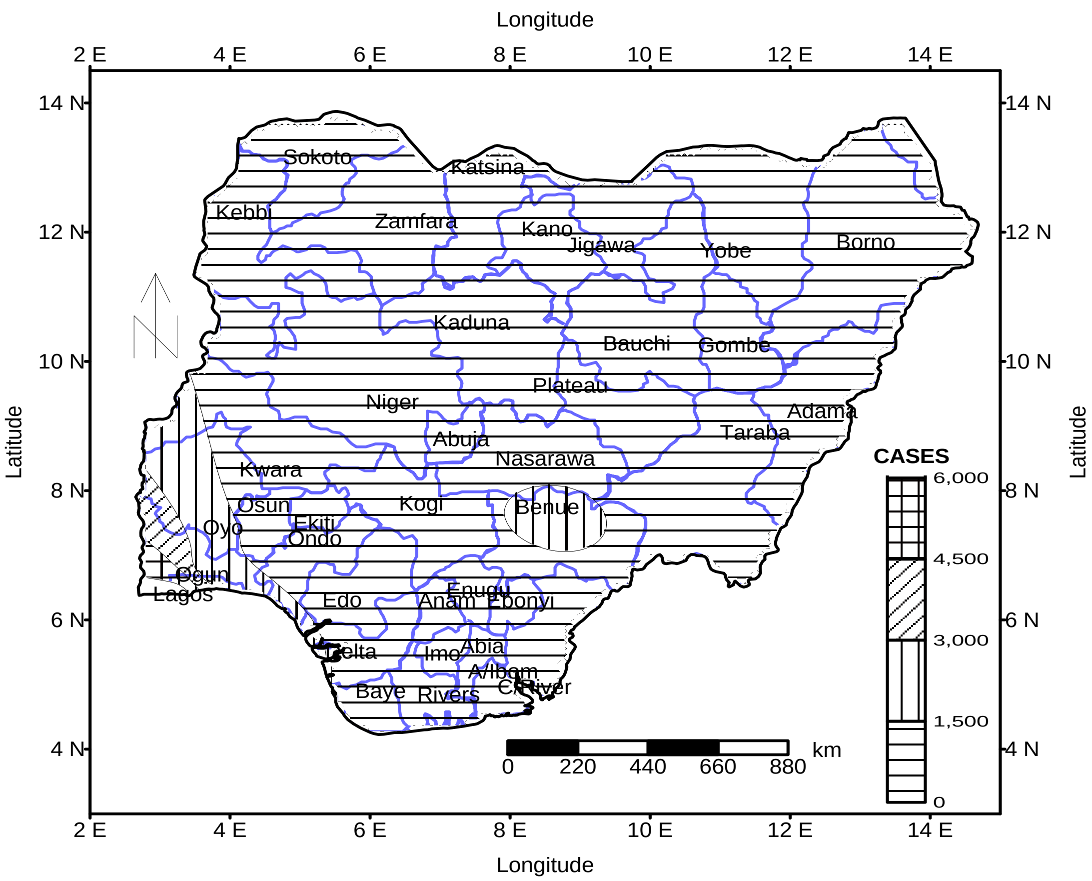

Fig. 4.76: Distribution of Tuberculosis in Nigeria in 2008

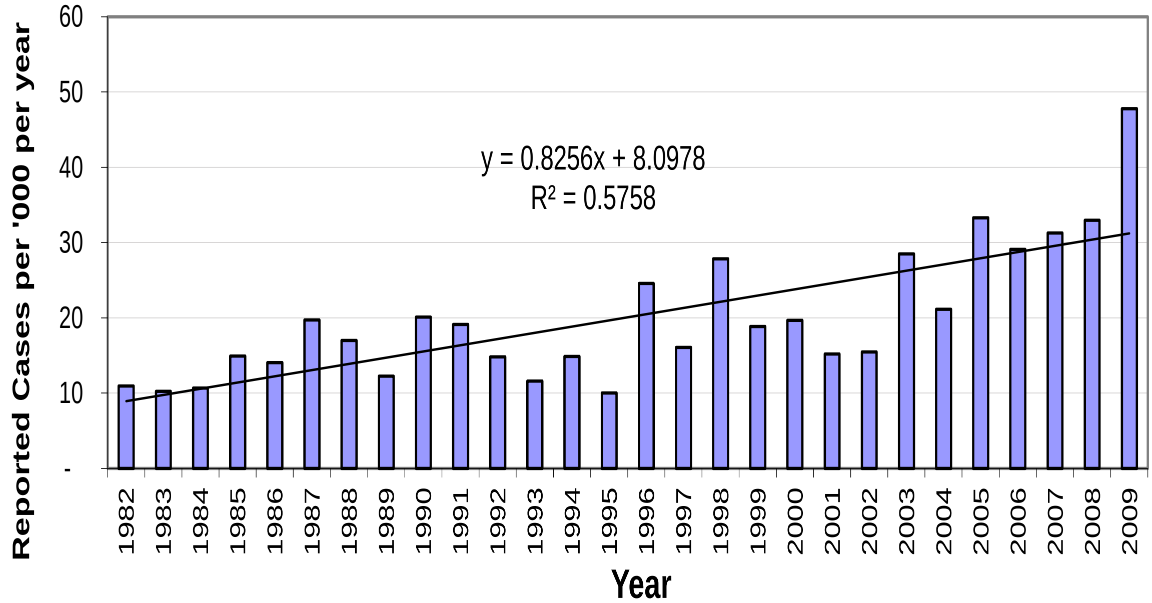

Fig. 4.77: Yearly Distribution of Tuberculosis(TB) in Nigeria (1982-2009)

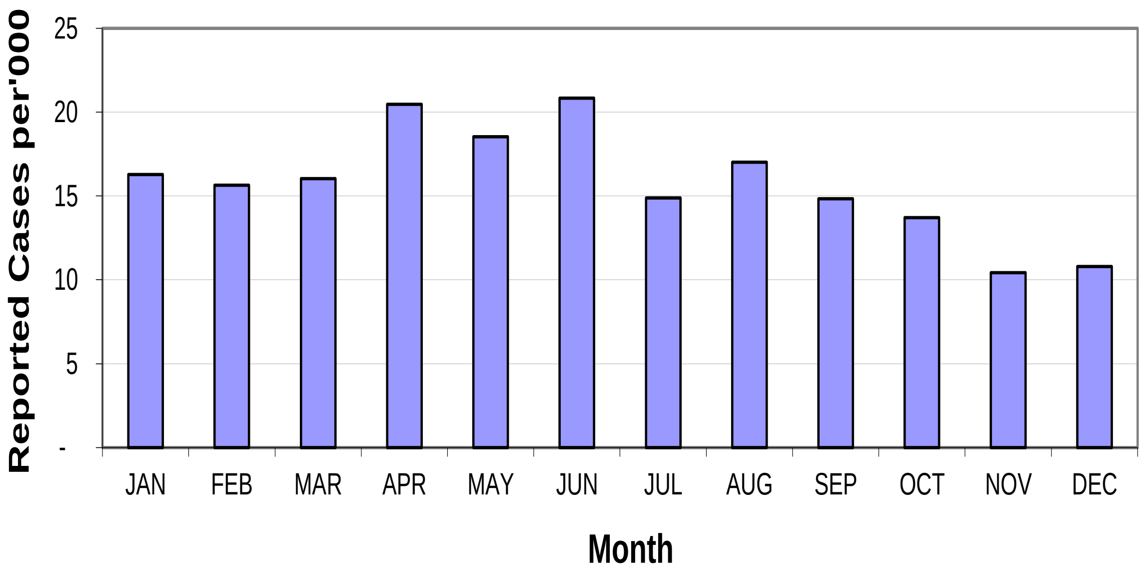

Fig. 4.78: Mean Monthly Variation of Tuberculosis(TB) in Nigeria (1992-2005)

4.3 RELATIONSHIPS BETWEEN CLIMATIC PARAMETERS AND DISEASES

4.3.1 Correlation between Climatic Parameters and selected Diseases

Table 4.1 is the correlation coefficient (r) between selected diseases and climatic parameters in Nigeria. The table was analysed using Karl Pearson coefficient method of correlation between different seven climatic parameters and the selected diseases using System Statistics (SYSTAT) version 10.2.

Table 4.1: Correlation Coefficient (r) between Selected Diseases and Climatic Parameters in Nigeria.

Climatic Parameter	Reported cases of MALARIA	Reported cases of MEASLES	Reported cases of PNEUMONIA	Reported cases of CSM	Reported cases of TUBERCULOSIS
Mean Air Temperature	-.032	-.185**	.077*	.004	.181**
Radiation	.358**	.720**	.728**	.776**	.466**
Rainfall	-.523**	-.662**	-.597**	-.712**	-.484**
Temperature (maximum)	.331**	.568**	.617**	.753**	.538**
Temperature (minimum)	-.315**	-.685**	-.435**	-.632**	-.254**
Relative Humidity	-.356**	-.730**	-.709**	-.851**	-.512**
Surface Wind Speed	-.077*	.387**	.621**	.643**	.392**

**. Correlation is significant at the 0.01 level

*. Correlation is significant at the 0.05 level

4.3.2 Correlation between Climatic Parameters and Selected Diseases in the Five Ecological Zones

Tables 4.2; 4.3; 4.4; and 4.5 are the correlation coefficient between selected diseases and climatic parameters over the five ecological zones.

Table 4.2: Correlation coefficient (r) between selected diseases and Climatic parameter (Radiation) over the Ecological Zones

Climatic Parameter (RADIATION)	Reported cases of MALARIA	Reported cases of MEASLES	Reported cases of PNEUMONIA	Reported cases of CSM	Reported cases of TUBERCULOSIS
SAHEL ZONE	.314**	.601**	.552**	.600**	.396**
SUDAN SAVANNAH	.449**	.662**	.657**	.726**	.411**
GUINEA SAVANNAH	.460**	.785**	.749**	.796**	.532**
TROPICAL FOREST	.391**	.726**	.750**	.805**	.503**
MANGROVE / COASTAL	.302**	.716**	.751**	.806**	.468**
**. Correlation is significant at the 0.01 level					
*. Correlation is significant at the 0.05 level					

Table 4.3: Correlation coefficient (r) between selected diseases and Climatic parameter (Maximum Temperature) over the Ecological Zones

Climatic Parameter (Maximum Temperature)	Reported cases of MALARIA	Reported cases of MEASLES	Reported cases of PNEUMONIA	Reported cases of CSM	Reported cases of TUBERCULOSIS
SAHEL ZONE	.228*	.375**	.490**	.674**	.520**
SUDAN SAVANNAH	.410**	.480**	.471**	.604**	.487**
GUINEA SAVANNAH	.388**	.583**	.597**	.754**	.567**
TROPICAL FOREST	.357**	.614**	.645**	.805**	.550**
MANGROVE / COASTAL	.303**	.633**	.692**	.790**	.533**
**. Correlation is significant at the 0.01 level					
*. Correlation is significant at the 0.05 level					

Table 4.4: Correlation coefficient (r) between selected diseases and Climatic parameter (Relative Humidity) over the Ecological Zones

Climatic Parameter (Relative Humidity)	Reported cases of MALARIA	Reported cases of MEASLES	Reported cases of PNEUMONIA	Reported cases of CSM	Reported cases of TUBERCULOSIS
SAHEL ZONE	-.340**	-.608**	-.634**	-.808**	-.528**
SUDAN SAVANNAH	-.474**	-.714**	-.609**	-.775**	-.456**
GUINEA SAVANNAH	-.454**	-.775**	-.740**	-.862**	-.570**
TROPICAL FOREST	-.411**	-.739**	-.719**	-.873**	-.538**
MANGROVE / COASTAL	-.291**	-.742**	-.699**	-.861**	-.480**
**. Correlation is significant at the 0.01 level					
*. Correlation is significant at the 0.05 level					

Table 4.5: Correlation coefficient (r) between selected diseases and Climatic parameter (Minimum Temperature) over the Ecological Zones

Climatic Parameter (Minimum Temperature)	Reported cases of MALARIA	Reported cases of MEASLES	Reported cases of PNEUMONIA	Reported cases of CSM	Reported cases of TUBERCULOSIS
SAHEL ZONE	-.421**	-.597**	-.249*	-.454**	-.171
SUDAN SAVANNAH	-.286**	-.592**	-.255**	-.493**	-.111
GUINEA SAVANNAH	-.418**	-.701**	-.502**	-.648**	-.321**
TROPICAL FOREST	-.418**	-.757**	-.519**	-.727**	-.358**
MANGROVE / COASTAL	-.258**	-.734**	-.410**	-.683**	-.237*
**. Correlation is significant at the 0.01 level					
*. Correlation is significant at the 0.05 level					

4.3.3 Implication of Multiple Relationships

Table 4.6 is the result of multivariate analysis for malaria and some selected states of Nigeria using canonical correlation technique.

Table 4.6: $R^{2,}$ F-statistics, Probability (P), Adjust R^2 and Canonical Correlation (CCA) for Malaria in some selected States of Nigeria.

Selected State	R^2	F-Statistics	Probability (P)	Adjusted R^2	CCA
Adamawa	0.614	1.593	0.293	0.229	0.784
Benue	0.558	1.768	0.238	0.243	0.747
Borno	0.332	0.661	0.618	0.070	0.576
Enugu	0.453	9.940	0.008	0.407	0.673
Kano	0.322	1.586	0.254	0.119	0.568
Lagos	0.366	0.924	0.512	0.000	0.605
Niger	0.651	2.180	0.166	0.353	0.807
Plateau	0.519	2.699	0.092	0.327	0.720
Rivers	0.498	1.788	0.211	0.220	0.706
Sokoto	0.048	0.299	0.747	0.000	0.218

4.3.4 Hypothesis Testing

Table 4.7: Linear Regression – Statistics for Climatic Element Rainfall and Temperature over Kano and Lagos

```
Dep Var: YEAR   N: 52   Multiple R: 0.766   Squared multiple R: 0.587

Adjusted squared multiple R: 0.570   Standard error of estimate: 9.934
```

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)

CONSTANT	1299.487	103.867	0.000	.	12.511	0.000
KTMAX	3.128	2.684	0.109	0.958	1.165	0.250
LAGTMAX	19.295	2.458	0.736	0.958	7.850	0.000

Analysis of Variance

Source	Sum-of-Squares	Df	Mean-Square	F-ratio	P
Regression	6877.853	2	3438.926	34.851	0.000
Residual	4835.147	49	98.676		

Durbin-Watson D Statistic 0.785

First Order Autocorrelation 0.561

Plot of Residuals against Predicted Values

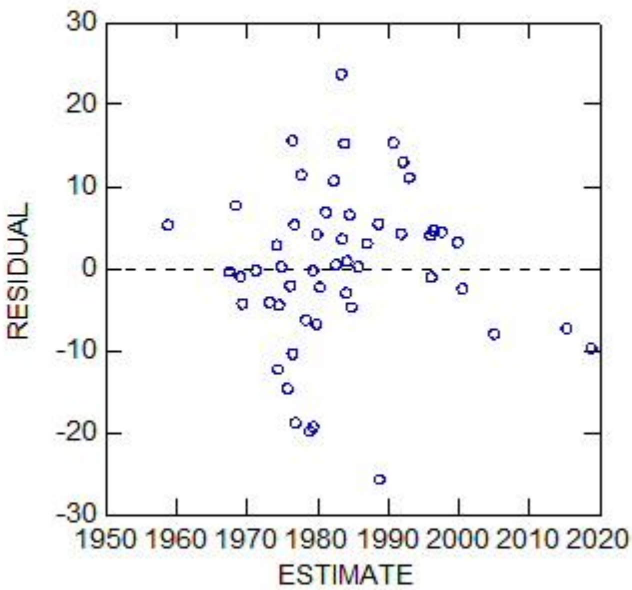

Table 4.8: Linear Regression – Statistics for selected diseases

Dep Var: YEAR N: 28 Multiple R: 0.941 Squared multiple R: 0.886

Adjusted squared multiple R: 0.860 Standard error of estimate: 3.080

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	1984.340	2.291	0.000	.	866.145	0.000
MALARIA	0.000	0.000	0.048	0.111	0.220	0.828
MEASLE	-0.000	0.000	-0.239	0.702	-2.783	0.011
PNEU	0.000	0.000	0.789	0.221	5.144	0.000
CSM	0.000	0.000	0.074	0.661	0.830	0.416
TB	0.000	0.000	0.015	0.183	0.092	0.928

Analysis of Variance

Source	Sum-of-Squares	Df	Mean-Square	F-ratio	P
Regression	1618.337	5	323.667	34.125	0.000
Residual	208.663	22	9.485		

28 is an outlier (Studentized Residual = -3.311)

Durbin-Watson D Statistic 1.703

First Order Autocorrelation 0.026

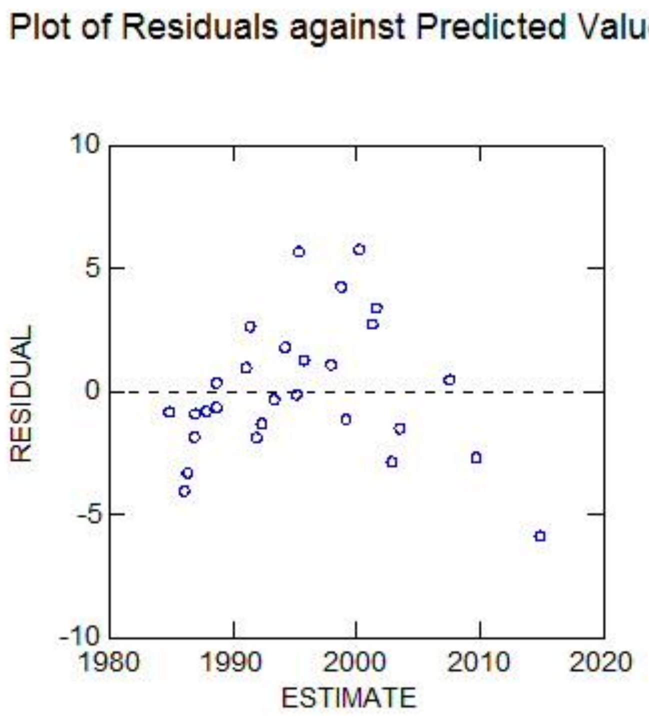

Table 4.9: Relationship between Climatic elements and the selected diseases

Climatic Parameters	**Malaria**	**Measles**	**Pneumonia**	**CSM**	**TB**	**Decision**
Mean Air Temp	No enough evidence	Sig. at 99% Cl	Sig. at 95% Cl	No enough evidence	Sig. at 99% Cl	Ho is rejected
Radiation	Sig. at 99% Cl	Sig. at 99% Cl	Sig. at 99% Cl	Sig. at 99% Cl	Sig. at 99% Cl	
Rainfall	Sig. at 99% Cl	Sig. at 99% Cl	Sig. at 99% Cl	Sig. at 99% Cl	Sig. at 99% Cl	
Temp(max)	Sig. at 99% Cl	Sig. at 99% Cl	Sig. at 95% Cl	Sig. at 99% Cl	Sig. at 99% Cl	
Temp(min)	Sig. at 99% Cl	Sig. at 99% Cl	Sig. at 99% Cl	Sig. at 99% Cl	Sig. at 99% Cl	
Relative Humidity	Sig. at 99% Cl	Sig. at 99% Cl	Sig. at 99% Cl	Sig. at 99% Cl	Sig. at 99% Cl	
Sfc Wind	Sig. at 95% Cl	Sig. at 99% Cl	Sig. at 99% Cl	Sig. at 99% Cl	Sig. at 99% Cl	

CHAPTER FIVE

5.0 DISCUSSIONS AND SUMMARY OF FINDINGS

5.1 Discussion of Results

5.1.1 Nature of Climatic Variation in Nigeria

The distribution of mean annual rainfall in Nigeria shows that rainfall is generally zonal with the amount of rainfall generally decreasing from the coast inland. The heaviest rainfall occurs in the south eastern parts with annual total of 2000mm or more. These decrease northward to less than 600mm in the northern fringe (Figure 4.1). The northward bends of the isoclines around Jos plateau illustrate the significance of relief in the pattern of rainfall distribution. The Jos Plateau stands out as having higher annual totals of rainfall than the average for its latitude (Ojo, 1977; 2008).

Figure 4.2 shows the mean monthly rainfall for the period 1958-2009. As expected and compared with the long-term mean, double maxima occur along the coastal and southwestern areas and single maximum in the central and northern parts of Nigeria.

JAN-MACH: Rainfall was either nil or minima during this period in most places across the country. Only stations located in the coastal areas enjoyed the influence of the maritime wind. Ikeja, Benin, Warri, Portharcourt, Calabar and Owerri are among the stations that recorded monthly averages between 16mm and 163mm. The rest of the country is under the influence of dry north easterly wind. Heat related diseases such as Measles, CSM, Tuberculosis are common in dry regions. This observation is in agreement with the work of Ayanlade, Adeoye & Babatimehin, (2010). The infiltration of south westerly begins to manifest towards the end of the quarter.

APR-JUN: Onset of rainfall is well established for the stations mentioned above. Monthly averages between 150mm and 414mm are common. Progressively, stations like Ibadan, Oshogbo, Ilorin, Lokoja and Makurdi are entering the rainy season proper with their first peak in the month of June. The moisture carrying wind (south-westerly) dominates the entire areas.

JUL-SEP: Most areas in the country receive enough rainfall, even from the coast to the northernmost part of the country during this period. The average monthly rainfall is between 171mm and 486mm for most stations. Stations like Minna, Jos, Bauchi, Yola, Yelwa, Kaduna, Potiskum, Sokoto, Gusau, Kano, Nguru and Maiduguri have their maximum during this period. The reason being that the whole country is under the influence of the rain bearing south-westerly (Ojo, 1977; Ojo *et al*., 2001). Consequently, rainfall related diseases are more pronounced during this period.

OCT- DEC: The average rainfall begin to decrease during this period, especially in stations like Nguru, Katsina, Maiduguri and Yelwa. This decrease in average rainfall becomes more pronounced as one progresses to the south. By November-December, the rainfall has been restricted to the southernmost part of the country. Diseases that are related to dryness or dust related diseases like Measles, Tuberculosis manifests.

5.1.1.2 Trends and Temporal Distribution of Rainfall

Figure 4.3 shows rainfall trends for Nigeria. It can be noted that the mean rainfall trends for the whole country shows three periods, in general. These include (a) a relatively rising period which occurred between 1958 and 1969 (b) a relatively falling period which occurred between 1970 and 1988 and (c) another relatively rising period between 1988 and 2007. However, there are a number of fluctuations in between the periods. This is also evident in standardized rainfall anomaly for Nigeria between 1958 and 2009 (Figure 4.4). In the regional characteristics of the rainfall trends, five periods may be noted for the southern Nigeria and three for the northern Nigeria patterns (Figures 4.5 & 4.6).

During the first wet period of 1958-1969, there were relatively less wet years than those observed for Nigeria as a whole for Southern Nigeria. For example, during the first wet period, there were about 8 years of rainfall above average for Nigeria as a whole, 8 years over Southern Nigeria and 9 years over Northern Nigeria. During the period of dry years between 1970-1994, there were about 20 dry years and only five (5) years 1978-1980, 1988 and 1991 of rainfall above average which were the recovery period. In contrast to this, there were 9 years of rainfall above average and 16 years of rainfall below average for Northern Nigeria. Also, during the relatively wet period between 1995-2009, there were 5 years of dry period for the whole Nigeria and 6 years for southern Nigeria and 2 years for northern Nigeria. All these indicate examples of the extent of rainfall variability from one part of Nigeria to the other.

5.1.1.3 Variability and Trends over Ecological Zones

Generally, there was a decreasing trends in the rainfall pattern on most stations in this zone. Figures 4.8, 4.9 and 4.10 show the standardized rainfall anomaly over Katsina, Nguru and Maiduguri, these are stations located in the Sahel ecological zone. Five periods was evident, relatively wet period which occurs between 1958 and 1965 (b) a relatively dry period which occurs between 1967 and 1975 (c) a short wet period between 1976 and 1978. (d) another relatively dry period which occurs between 1979 and 1987 (c) a period of recovery between 1996 and 2006.

The first decade (1958-2009) show period of wetter than normal rainfall for Katsina. The next three decades reveals a relatively dry period but the last decade show a recovery period.

Similar pattern was observed for Nguru, except that the dry period in the second decades recovered very fast. Generally, over the Sahel zone, there were more dry periods than the wet

(IPCC, 2007). For example, Maiduguri showed consistent dry period for almost four decades. Figure 4.10.

Fig. 4.11, 4.12 show the standardized rainfall anomaly over Sokoto and Yelwa. Three periods are evident, a relatively wet period which occurred between 1959 -1964 (b) a relatively dry period which occurred between 1965 and 1993 (c) another wet period which occurred between 1994 and 2009. The global drought of 1972/73, and 1979-1983 were evident (IPCC, 2007). Fig.4.13 shows the standardized anomaly over Kano. Two periods was evident, a relatively drier than normal since 1958 to 1995 and a consisted wetter than normal period from 1996 to 2009.

Similar to Yelwa was Bauchi with a relatively wet period between 1958 and 1981, (b) a relatively dry period between 1982 and 1991. (c) A period of recovery between 1992 and 2009 (Figure 4.14).

Figure 4.15, shows the variability of rainfall over Lokoja areas in Guinea Savannah ecological zone. An alternating period of wetter than normal and drier than normal periods with higher drier years, 27yrs of dry and 24yrs of wet periods were revealed. Also observed was a relatively pronounced consecutive dry period between 1973 and 1985. Similar pattern was also observed for Enugu (Figure 4.16). But in Figure 4.17, Minna had 25years of dryness and 26yrs of wetness with a decade of consecutive dryer than normal period (1980-1990). Similar pattern was also observed for Ilorin (Figure 4.18), with 26yrs of wetter than normal and 25yrs of drier than normal.

Generally, there was a slight rising trends in rainfall except Ikeja that shows a downward trends. Figures 4.19 is standardized rainfall anomaly over Ondo. Using 5years moving averages, about four wet, three dry periods can be identified. The most pronounced wetter years are 1963, 1968, 1983, and 1991. Generally, out of 51years under study, only 20years were wetter than long-term averages and 31years are drier than long-term averages. Similarly, Oshogbo had about 24years of wetter years and 27years of dry years. The pattern over Ikeja was quite different. Apart from showing downward trends, it reveals a significant wetter years from 1959 till 1970 (Figure 4.21). It shows the variability of rainfall over the southern parts. Apart from the early wet period, there have been a drier years from 1971-1977, 1981-1986 and 1989-2001. Generally, the trends pattern of rainfall over the swamp forest zone since 1958 was almost normal for all the stations compared. Figure 4.23 show the standardized rainfall anomaly for Warri. It reveals the most pronounced drier than long term averages from 1981-1986 and the most pronounced wet year was 1965. Two pronounced wet period can be seen over Portharcourt, 1959-1965 and 1983-2000. In all, 24years were wetter and 27years were drier. Figure 4.24. Similar pattern were revealed over Calabar with showing the most pronounced global drought of 1973-1975. (IPCC, 2013). However, 1995-1997 was the wetter years in the study period.

5.1.1.4 Nature of Temperature

The distribution of mean temperature in Nigeria shows that temperature was relatively higher in the northern Nigeria than the South during the study period. The mean maximum temperatures in the country vary from 28^{o}C to 36^{o}C, while the mean minimum temperatures vary from 15°C to 24°C. The highest maximum temperature occurs in places like Maiduguri, Nguru and Sokoto while the lowest maximum temperature occurs in highland area of Jos Plateau. Generally temperature increases northward. Figure 4.26 shows the mean maximum temperatures between 1971-2009. The highest values of higher than 35°C are located to the extreme north-western and north-eastern parts of the country (areas around Sokoto, Yelwa, Nguru and Maiduguri). The other parts of the country have temperatures in the range of 31°C-

34°C. Values are also relatively low around the Jos plateau where values are generally between 27^{o}C and 29^{o}C. The minimum temperatures generally vary between 14°C and 16°C over the Jos plateau. The highest values of the minimum temperatures are between about 19°C - 23°C. In the southern region, values of the minimum temperatures are generally between 22^{o}C and 23°C, while to the north they are approximately between 19°C – 21°C, with the exception of Sokoto State, where it was slightly higher than 21°C (Figure 4.27).

Temperatures generally show an increasing trend, for example Figures 4.28 and 4.29 show trends in mean maximum temperatures for Kano in the north and Lagos in the south respectively. There was an increase from the mean of 33.5^o to about 33.7^o C for maximum temperature over Kano and 29.4^{o}C to 30.5^{o}C for Lagos. In general, the temperatures show an increase of 0.058^{o}C per decade for Kano and 0.003^{o}C per decade for Lagos. In general, temperatures have generally been above normal since 1995 for Kano and 1982 for Lagos with relatively extreme years in 1973, 1987, 2000 and 2005 for Kano and 1980, and 1997/1998 period.

5.1.1.5 Distribution of Temperature in Ecological Zones

Generally, over Sahel ecological zone, temperature trends were rising since 1958 to 2009. The long-term average was 35.1^{o}C for Nguru (Figure 4.26). Similarly, Potiskum long-term average was 34.3 ^{o}C. Figure 4.27. Figure 4.32 shows Sokoto with long-term average of 35.2 ^{o}C. Since 1994, temperature has consistently on the increase annually. There was rising temperature trends over the Sudan savannah zone. Kano had slight rising trends with long-term averages of 33.5^{o}C, Figure 4.33. Gusau also exhibits similar pattern as observed in Figure 4.34, long-term averages was 33.6^{o}C. But Yola long-term averages was 35.0^{o}C, slightly higher temperature was recorded in 2003 and 2005 (40.2 -41^o C). There was rising temperature trends in most stations over Guinea savannah ecological zone. The long-term averages for Jos, Lokoja and Enugu was 27.6^{o}C, 33.2^{o}C and 32.2^{o}C respectively (Figures 4.36, 4.37 and 4.38).

Generally, there was rising trend of temperature from 1958 to 2009. Figures 4.39 and 4.40 show Ikeja and Benin with long-term averages of 30.9^{o}C and 31.3^{o}C respectively. Since 1978 temperature has been consistently on the increase above long-term averages. The situation over Ondo station was quite different. There was no significant changes in the temperature pattern, Figure 4.41. There was rising trends over most stations in the Swamp forest zone. For example Warri's long-term average was 31.4 ^{o}C and that of Calabar was 30.6 ^{o}C, as shown in Figures 4.42 and 4.43.

5.1.1.6 Distribution of other Significant Climatic Parameter

The distribution of relative humidity shows a general decrease from the coast inland. (Figure 4.44). Values ranging between 80% and above are common features during the dry season over the southern region. The mean value for northern region is between 40% - 60%, but in the dry season the relative humidity could be as low as 30% when the continental dry wind are dominant. The distribution of mean annual solar radiation is as shown in Figure 4.45. It generally decreases from the north to the south. Values such as 71.2 Wm^{-2} are common in the extreme north while in the south the radiation could be as low as 50.2 Wm^{-2}. This is due to the influence of cloud covers which distort, absorb, and reflect the incoming solar radiation from the sun. During the dry period, the dust particles also cause some attenuation and back scatter of incoming solar radiation. These causes drastical reduction of the amount of radiation getting to the surface.

Similar pattern is also revealed in the mean sunshine hour distribution in Nigeria (Fig. 4.46). The highest values of more than 8hrs of sunshine per day is located to the extreme north while the sunshine hours could be as low as 3hrs per day in the coastal regions of the south.

The mean wind direction and speed are as shown in Figure 4.47 and 4.48 respectively. There is a lot of variability in wind direction and speed throughout the year as can be seen on the maps. For example the wind pattern is south-easterly dominating from the northern region to become south-westerly in the south. Similarly, the wind speed decreases from the north to the south except over Jos area that has relatively high wind speeds throughout the year round because of its topographic location. Greater than 7.5m/s are very common in the north. The speed can be as low as 3.5m/s in the south.

5.1.2 Spatio-Temporal Distribution of selected Diseases

Figure 4.49 shows the mean annual distribution of malaria in Nigeria between 1982 and 2009. It is evident from the map that all States in the Country experienced the incidence of malaria during the period. This shows that the climate of Nigeria is very suitable for the production, propagation and transmission of malaria. In general, malaria is most prevalent in areas like Lagos, Adamawa, Taraba, Katsina and Kano States, but lowest in areas such as Rivers, Imo, Edo, FCT, Niger, Benue, Bauchi, Yobe and Borno States. According to Marten et al., The biological activity and geographic distribution of the malarial parasite and its vector are sensitive to climatic influences, especially temperature and precipitation.

Possible non-climatic factors for the distribution in Nigeria include level of education, (and is higher in the south than the north) poor knowledge of technology for preventing or curing malaria, and the level of poverty. There is also lack of awareness on the need to prevent or reduce the incidence of malaria especially in the north (CBN, 2009). In 1997, the highest prevalence was found over Niger State with more than 140,000 cases, Figure 4.50. The lowest was located over Taraba and Adamawa States. In 1982, the pattern changed, that Adamawa experienced more than 180,000 cases. This pattern continued as the prevalence continue to ravage the country. In 2008, Adamawa, Taraba reported more than 200,000 cases, Figure 4.51. The highest in that year was more than 400,000 cases over Katsina State, Figure 4.52.

The mean decadal distribution of Malaria is as shown in Figures 4.53a, 4.53b, 4.53c. A lot of variability is exhibited on the figures across the country. Relatively low cases were reported in 1987 with the exception of Adamawa and Taraba States which exhibited relatively high cases. In 1997, there was general increase in the cases reported but varies across the country. These increases were well pronounced in 2007 as almost all the states experienced a significant increase. States like Kano, Katsina, Kebbi, Lagos, Osun, Oyo and Taraba reported 565,232; 426,087; 272,135; 348,621; 268,683; 210,721 and 205,787 respectively. Many factors could be responsible for the high concentration of malaria in these areas. Among them are climatic conditions, for example, The frequent warnings that global climate change will allow falciparum malaria to spread into northern latitudes, including Europe and large parts of the United States, are based on biological transmission models driven principally by temperature (Rogers, D. J., and S. E. Randolph. 2000**)**. Poor sanitation, and favourable local environment such as orographic nature of highland areas and poverty levels. For example, poverty level for the high prevalent regions mentioned above ranges between 58% and 87% (CBN, 2009).

The mean monthly distribution of malaria for 1992-2009 in Nigeria is presented in Figure 4.54. The highest prevalence of malaria was in the month of August with about 2.32million cases while the minimum prevalence occurs during the month of December with over 1.33million cases. This was due to the fact that the climatic situation of some parts of the country was very much favourable among other things for the development, sustenance and transmission of malaria (Ojo *et al*, 2001). For example, the month of August appears to be a very conducive month climatic-wise, because all stations in the country are under wet conditions during this period. This means that the environment was greener; the plants are blossom with leaves. These will definitely allow mosquitoes to breed more. Many gutters are filled with water, and many leaves have accumulated water (and these are breeding places for mosquitoes). The availability of fresh leaves can even mean more food for the male mosquitoes and more energy to meet the female ones. Also people's attitude to their environment was generally poor. Dirty and weedy environment are good breeding grounds for mosquitoes. Related to this is the level of education of the people, majority of who are still not well informed on the various methods of preventing or discouraging the breeding of mosquito. The distributional pattern in the dry season is similar to that of the rainy season.

Figure 4.55 shows the yearly trend of reported cases of malaria incidence between 1981 and 2009 in Nigeria. This trend generally decreases between 1981 and 1997 and then increases until year 2009. In 1981 more than 1.4million cases of attack were reported. These rose to an alarming value of more than 2million in 1998. These values continued to increase till 2004 with over 3 million cases reported in the country. All this attests to the fact that malaria is still very much prevalence in Nigeria, (Millennium Development Report, 2005). According to the estimates, half of the Nigerian population have at least one episode of malaria annually and the majority of out patient's visits to hospitals are attributed to malaria (FMOH, 2009).

5.1.2.2 Climatic conditions suitable for Malaria Transmission

The climatic conditions considered suitable for its development and transmission through the mosquito stage of its life cycles are temperatures within the range 18°C to 32° C (Gilles *et al*

1993). This is based on the framework for the development of integrated malaria early warning systems (MEWS), based on vulnerability monitoring, seasonal climate variability data, and epidemiologic surveillance. Below 18°C parasite development decreases significantly. Above 32°C the survival of mosquito is compromised. Relative Humidity greater than 60% is also considered as a requirement for the mosquito to survive long enough for the parasite to develop sufficiently to be transmitted to its human host stage. Rainfall and surface water is required for the egg laying and laval stages of the mosquito life cycle and monthly rainfall above 80mm is considered as a requirement, (Craig *et al.,* 1999). These conditions were analysed for different ecological zones.

The Sahel zone received the minimum amount of rainfall in a year. The total annual rainfall ranges between 362.0mm and 1000.0mm during the study period (1958-2009). Stations that fell within this zone include Sokoto, Katsina, Gusau, Potiskum, Maiduguri and Nguru. Annual rainfall amount ranges between 371-978mm for Sokoto, 259.2mm-993.6mm for Katsina, 675.1mm – 1507.1mm for Gusau, 362.0mm – 1020.5mm for Potiskum, 263.5mm – 1076.3mm for Maiduguri and 236.7mm – 647.4mm for Nguru. Climatic conditions suitable for Malaria transmission for this zone varies from 41% in the month of June and 57% on monthly precipitation of 80mm and above (Figure 4.56a). Temperature of $18^oC<T<32^oC$ were also 100% in the month of June, July, August and September. Figure 4.56b, relative humidity greater that 60% also high only in the month of July through to September, (Figure 4.56c). Generally, stations within this zone experienced unimodal pattern of rainfall and have only $2^{1/2}$ months suitable for malaria transmission.

Selected stations that fell within the Sudan include Kano, Yola, Kaduna, Bauchi, Yelwa and Gombe. These stations receive annual precipitation amount in the range of 414.1mm – 1869.3mm for Kano, 681.8mm – 1326.2mm for Yola, 865.0mm – 1543.6mm for Kaduna, 381.8mm – 1556.2mm for Yelwa, 424.8mm-1400.6mm for Bauchi. Based on monthly precipitation of 80mm and more, 61%, 95%, 99% and 66% are observed in the month of June, July, August and September respectively, (Figure 4.57a). Mean temperature between 18^{o}C and 32^{o}C is more favourable in the month of July and August, (Figure 4.57b). Percent occurrence of relative humidity greater than 60% were also 62%, 100%, 100% for the month of June, July and September, (Figure 4.57c). Generally, climatic conditions suitable for malaria transmission was about 3$^{1/2}$ months.

Selected stations within Guinea Savannah zone include Enugu, Ilorin, Lokoja, Minna, Makurdi, and Jos. Annual precipitation ranges between 913.1mm and 2262.5mm for Enugu, 672.5mm and 1739.4mm for Ilorin, 834.6mm and1767.4mm for Lokoja, 823.4mm and 1583.1mm for Minna, 761.5mm and 1757.9mm for Makurdi, 814.7mm and 1812.0mm for Jos. Based on monthly precipitation of 80mm and above, percent occurrence was 86% for May, 100% for June, July, August, September and 67% for October respectively, (Figure 4.58a). Mean temperature between 18^{o}C and 32^{o}C are 70% or more for percent occurrence for all the months, (Figure 4.58b). Similarly, relative humidity greater than 60% are 68% for April, 98% for May, 100% for June, 99% for July, 100% for August, 99% for September and 77% for September, (Figure 4.58c).

Selected stations within the Tropical forest zone include: Benin, Ikeja, Owerri, Ondo, and Oshogbo. Annual precipitation varies from 1238.0mm and 3029.4mm for Benin, 1158.7mm and 2542.3mm for Ondo, 784.3mm and 1921.7mm for Oshogbo, 895.7mm and 2866.0mm for Ikeja. Rainfall greater than 80mm and more were 85% for April, 99% for May, 100% for June, 87% for July, 69% for August, 93% for September and October, (Figure 4.59a).

Percent Occurrence for mean temperature between 18^{o}C and 32^{o}C and relative humidity greater 60% were favoured throughout the year, Figures 4.59b and 4.59c. The climatic conditions for malaria transmission was suitable for about 7months (April-October).

Selected stations within the Mangrove swamp forest zone include Warri, Portharcourt, Calabar, Uyo and Lagos. This zone receives substantial amounts of rainfall in 9months (March-November). Annual precipitation varies between 1625.1mm and 3437.8mm for Warri, 1682.8mm and 3331.5mm for Portharcourt, 2112.1mm and 3757.1mm for Calabar, 958.2mm and 3264.1mm for Lagos Island. Based on climatic conditions greater than 80mm, mean temperature between 18^{o}C and 32^{o}C and relative humidity greater than 60%. The percent occurrence were more than 70% for 9months (Mar-Nov) for rainfall, relative humidity and 100% for mean temperature respectively (Figures 4.60a-c)

5.1.2.3 Malaria Prevalence over Jos Plateau

Figure 4.61a shows the relationship between temperature and Malaria over Jos Plateau. The trends of maximum temperature reveals slight rising trends as against wave form of malaria. The malaria trends shows 7-8 years cycle. Maximum temperature ranges between 27.1^{o}C and 28.4^{o}C during the study period (1982-2009). Similar findings was made in a study of malaria in the African highlands, Hay et al. found no significant change in long-term climate at four locations where malaria incidence has been increasing since 1976. Although, it was contended, however, that their conclusions are likely to be flawed by their inappropriate use of a global climate data set. Moreover, the absence of a historical climate signal allows no inference to be drawn about the impact of future climate change on malaria in the region. The existence of critical climate thresholds, the association between change in malaria incidence and change in climate can be biologically meaningful, even without "significant" climate change (Patz et al., 2002).

Figure 4.61b shows the relationship between Rainfall and Malaria over Jos plateau area. The minimum Malaria cycle coincides with the highest rainfall. This is in line with earlier observation that generally, rainfall correlates negatively with Malaria (Ayeni, 2011). Also according to Proestos *et al.*, (2015), that climate change can influence the transmission of vector-borne diseases (VBDs) through altering the habitat suitability of insect vectors.

5.1.2.4 Measles

Figure 4.62 shows the mean annual distribution of measles in Nigeria between 1981-2009. It is evident from the map that all states in Nigeria experienced the incidence of measles during the period. This could be due to the fact that all parts of Nigeria experience dry period at one time or the order, since measles is very much associated with dry season (WHO, 2003). The highest cases were found in the northern parts particularly in Kano and Gombe areas. This could be due to the fact that the length of the rainy season is very short compared to the southern part of Nigeria. Other reasons could be due to the level of education and cultural beliefs. For example there is a cultural believe that measles are not treated in the orthodox ways in Northern Nigeria. The relatively low prevalence observed to the south is as a result of the environmental conditions which do not highly favour the transmission of measles except in the dry season period. Figure 4.63 also shows the yearly distribution for example between 1982-2009. Critical examination revealed variability from year to year. High cases of Measles were reported in 1984, 1985, and 1999 with over 150 thousand, 150 thousand and 200 thousand cases respectively. The lowest case was in 2009. Linearity could not smooth the series except polynomial of fifth order. Figure 4.64 shows the measles prevalence in 1997. The highest of more than 10,000 cases was reported over Niger and Lagos states. The least cases were found in most parts of the southern states. Figure 4.64 shows the spatial distribution of measles in 2008. Kaduna state having the highest of more than 12,000 cases in the year. Cases ranges between 3,000 and 9,000 were most prevalent in other parts of the north with few cases of less than 3,000. The southern parts reported cases less than 3,000 throughout the year.

Figure 4.66 shows mean monthly variation of Measles in Nigeria. The highest reported cases were during the dry season period particularly in March and April when the atmospheric conditions are usually hot and dry in many parts of the country. Almost all parts of the country are under dry conditions except along the coastal areas. Invariably the condition favours the proliferation of measles disease.

5.1.2.5 Pneumonia

The spatial distribution of pneumonia in Nigeria between 1982 –2009 is shown in Figure 4.67. A relatively high prevalence of pneumonia occurs in the North-eastern area Gombe, Taraba and Adamawa states and Sokoto state with cases ranging between about 16,000 and 28,000 cases. Relatively, cases between 8,000 and 16,000 were also experienced over parts of central areas. Relatively low reported cases dominated other parts of the country during the period. Similar pattern still featured in figure 4.68, the distribution of pneumonia in Nigeria in 2007. Cases higher than 10,000 occurred in both the north eastern and north western part of the country. The importance of climatic factors (temperature, precipitation, relative humidity and winds) as drivers in epidemiology is increasing under conditions of climate change. Indeed, recent changes in climatic conditions, particularly increased ambient temperature and fluctuations in rainfall amounts has been noted to be of utmost importance (Paz, 2015; WHO, 2014).

Figure 4.69 shows the yearly variations of pneumonia from 1981-2009. The highest reported cases of over 300,000 occurred in 1998, 1999, 2000, 2002, 2007 and 2008 respectively. There was a missing data in 2006. The lowest cases were in 1989 with less than 100,000 cases.

Pneumonia has shown a tremendous increase since 1990. Since 1981, an average of 195,000 cases has been reported on annual basis for the whole country.

The mean monthly variation of pneumonia in Nigeria for 1992-2009 is shown in Figure 4.70. The highest prevalence is in the month of January over 20,000 cases. The lowest cases are in November and December. All the year round there cannot be less than 15,000 cases of pneumonia. January being the peak of dry season must have contributed to the highest prevalence of pneumonia. Although pneumonia is a respiratory disease the climatic condition for the transmission is favoured almost every time of the year. That is why its cases used to be high throughout.

5.1.2.6 Cerebro-Spinal Meningitis

Mean Spatial distribution of Cerebro-Spinal –Meningitis (CSM) between 1981 – 2009 is shown in Figure 4.71. The north eastern parts of the country experienced relatively high cases of relatively more than 1,700 cases. The highest values occur to the extreme north eastern part of the country in Borno and Kebbi States. This is followed by Gombe, Bauchi, Kaduna, Kano, Jigawa and Katsina states in the same region. High temperatures have been found to exacerbate the outbreak of CSM. (WHO, 2003). In the southern part of the country, CSM cases are very low. This may not be unconnected to the relatively low temperature being experienced in the region. Average cases of less than 700 were reported during the study period. Similarly in 2008 spatial distribution map, higher cases were reported to the extreme north which decreases southward (Figure 4.72).

Examining yearly distribution of Cerebro-Spinal Meningitis from 1981 – 2009 reveals that relatively low cases were reported in 1982 until 1986 when 10,000 cases or less were reported. By 1987, the number of cases was reduced to about 392, while the values increased in 1988. In 1996, about 43,000 cases were reported. There have been gradual reductions in the values of CSM since 1996 (Figure 4.72).

Figure 4.74 shows the monthly variation of Cerebro-Spinal-Meningitis (CSM) between 1992 – 2009. CSM prevalence reaches its peak in the month of March and gradually decreases to reach the minimum in the month of July and August. It has been revealed that CSM is a dry season phenomenon (WHO, 2003) and in Nigeria, more than 2,500 cases occurred during these periods.

5.1.2.7 Tuberculosis

The spatial distribution of Tuberculosis in Nigeria between 1981 – 2009 is shown in Figure 4.75. Generally less than 1,000 cases were reported over parts of the south. In contrast to the southern parts of the country, between 1000 and 4000 cases were reported over parts of northern Nigeria especially around kebbi, Kano, Borno, and Gombe states,. But the distribution in 2008 shows different pattern (Figure 4.76) with higher cases located to the south western area. The rest parts of the country reported cases less than 1,500 with the exception of Benue states having cases up to 3,000. According to Oloyede and Akinbogun, 2013, Nigeria ranked fourth among the countries of the world with the highest burden of tuberculosis (TB) and new perspectives and ways of addressing TB treatment and control are needed as the disease continues unabated.

The yearly distribution of Tuberculosis (TB) from 1981 – 2009 is presented in Figure 4.77. The graph reveals a gradual increase in TB from 1981 to 2009. Over 10,000 cases were reported with the highest of 47,802 in 2009. There was a rise and fall pattern almost every year. Since 1981 the lowest value was in 2004 with 9,657 cases.

Monthly variability of Tuberculosis (TB) in Nigeria between 1992 – 2005 reveals the highest in July. Well over 1,500 cases were reported throughout the months except in November when 1,480 cases were reported (Figure 4.78).

5.1.8 Relationships between Climatic Parameters and Diseases

In order to examine the relationships between the climatic parameters and each selected diseases, Karl Pearson coefficient method of correlation was used. Table 4.1 shows the result of the Pearson correlation coefficient (r) between the selected diseases and the climatic parameters in Nigeria.

Mean air temperature had a significantly positive correlation with only pneumonia ($p<0.001$). But negatively with measles (malaria and CSM, not significant). Rainfall, minimum temperature and relative humidity correlated negatively with all the selected diseases at 99% significant level. While maximum temperature correlated positively with CSM, pneumonia, measles, TB, and Malaria ($p<0.001$). Surface wind speed significantly correlated positively with CSM, pneumonia, TB and measles but negatively with malaria. These implies that some climatic elements influences the life cycles of diseases (WMO, 2011).

5.1.3 Correlation between Climatic Parameters and selected Diseases in the Five Ecological Region

Table 4.3 shows the correlation coefficient (r) between selected diseases and climatic parameter over the ecological zones. Generally in all the ecological zones there was a negative correlation with rainfall for all the selected diseases. The correlation coefficient of -0.286 for malaria in the Sahel zone and -0.714 for CSM in the Tropical forest zone. This shows the level of relationship between rainfall and the selected diseases.

Table 4.4 shows the correlation coefficient (r) between the selected diseases and Radiation. It shows a general positive correlation with the selected diseases in all the ecological zones. It is 0.302 and 0.806 for malaria and CSM over the Mangrove /Coastal zone respectively. High radiation favour high cases of CSM.

Table 4.5 shows the correlation coefficient (r) between the selected diseases and maximum temperature. It also shows general positive correlation with all the selected diseases in all the ecological zones. It varies between 0.228 for malaria over the Sahel zone and 0.805 for CSM over the Tropical forest. It shows that high temperature favour high cases of CSM, Pneumonia and Measles in all the zones. Table 4.6 shows the correlation coefficient (r) between the selected diseases and Relative Humidity. It reveals general negative correlation in all the region. The mean value for northern region is between 40% - 60%, but in the dry season the relative humidity could be as low as 30% when the continental dry wind are dominant. It varies between -0.291 for malaria over the Mangrove / Coastal zone and 0.873 for CSM over the Tropical forest. Table 9 shows the correlation coefficient (r) between the selected diseases and Relative Humidity. It reveals general negative correlation in all the zones. It varies between -0.291 for malaria over the Mangrove / Coastal zone and 0.873 for CSM over the Tropical forest. Table 10 also shows negative correlation for all the selected diseases in the ecological zones. It varies between -0.111 for Tuberculosis over the Sudan savannah zone and -0.757 for Measles over the Tropical forest.

5.1.4 Hypothesis Testing

1. **The Null Hypothesis Ho**: state that there is no significant trend in the variations of the climatic elements over the study region. Based on ANOVA result of table 4.7.

Decision: The Null Hypothesis is rejected.

H1 is accepted: There is significant linear trend in the variations of the climatic elements over the study region.

2. The Null Hypothesis Ho: state that there is no significant shift in the spatial occurrences of selected diseases over the period of study. Based on ANOVA result of table 4.8. **Decision**: The Null Hypothesis is rejected.

H1 is accepted: There is significant shift in the spatial occurrences of selected diseases over the period of study.

3. The Null Hypothesis Ho: state that there is no significant relationship between selected climatic elements and diseases incidence. Based on ANOVA result of table 4.9.

Decision: The Null Hypothesis is rejected.

H1 is accepted: There is significant relationship between selected climatic elements and diseases incidence.

5.1.5 Implication of Multiple Relationship

To determine the implication of multiple relationship between the climatic and diseases variables. Multivariate analyses were carried out for the diseases selected for this study and for some selected States using canonical correlation. This is to examine point specific indicating the percentage of possible occurrence of dependent variables (selected diseases – Malaria, Measles, Pneumonia, CSM and Tuberculosis) in the locality. The results obtained from the analysis for Malaria is as shown in Table 11. The results in general indicate that there is a lot of variability in the values of coefficient of determination (R^2) for different parts of the country, indicating the percentage ability of climatic parameters (Rainfall, Temperatures- maximum and minimum; Relative Humidity and Wind Speed) in predicting

Malaria ranged between 4% and 65%, 6% and74% for Measles, 10% and 77% for Pneumonia; 18% and 79% for CSM; 1% and 56% for Tuberculosis. It also shows the percentage of possible occurrence of dependent variable (selected diseases). Table 4.8 – 4.11 for Measles, Pneumonia, CSM and Tuberculosis are found in Appendix I.

Weather fluctuations and seasonal to interannual climate variability influence many infectious diseases. The characteristic geographic distributions and seasonal variations of many infectious diseases are prima facie evidence of linkages with weather and climate.

In this study, it has been noted that there is a lot of variations and variability in the spatial and temporal characteristics of climatic parameters and selected diseases used in this study. It has also been found that a lot of variations and variability occur in the spatial and temporal distribution of the diseases selected for this study. For example, it has been found that out of the five diseases used in this study, malaria is fairly well correlated with rainfall, relative humidity and maximum temperature with values of 0.8, 0.7 and 0.6 respectively. The diseases is fairly well, but negatively correlated with radiation with r = -0.7. In contrast, malaria is poorly and negatively correlated with wind speed and mean air temperature. Also, measles disease is fairly well correlated with radiation, maximum temperature, wind speed and mean air temperature (r = 0.6, 0.8, 0.8, 0.8 respectively) while the disease is poorly correlated with minimum temperature (r = 0.4). The disease is also poorly and negatively correlated with relative humidity with r = -0.4. In contrast to both malaria and measles, CSM is poor correlated with all the selected climatic parameters used in the study. As for both malaria and measles, pneumonia is fairly well correlated with climatic parameters which include rainfall and radiation with r = 0.7 for both parameters. Pneumonia is also fairly well but negatively correlated with radiation (r = -0.6) and maximum temperature (also r = -0.6). It is however poorly correlated with the other climatic parameters used in the study. There is however no good relationship between the TB and any of the climatic parameters, as r is only 0.1 for the relationship between TB and rainfall, 0.0 for the relationship TB and relative humidity and minimum temperature and negative low correlation between TB and maximum temperature (r = -0.1), mean air temperature (r = -0.1) and solar radiation (r = -0.2).

The results of the spatial and temporal characteristics as well as the relationships between the climatic parameters and the diseases selected for this study show that

(a) There is a lot of variability in the distributional characteristics in space and time

(b) The relationships between the climatic parameters and the disease are generally low. It is only in few cases that the relationships are only fair with r => 0.6.

(c) From (a) and (b) above, there is no doubt that it is difficult to have any accurate prediction

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(a) There is a lot of variability in the distributional characteristics in space and time

(b) The relationships between the climatic parameters and the disease are generally low. It is only in few cases that the relationships are only fair with r => 0.6.

(c) From (a) and (b) above, there is no doubt that it is difficult to have any accurate prediction using the simple or multivariate correlations.

Climate change may affect the evolution and emergence of infectious diseases. Ecosystem instabilities brought about by climate change and concurrent stresses such as land use changes, species dislocation, and increasing global travel could potentially influence the genetics of pathogenic microbes through mutation and horizontal gene transfer, and could give rise to new interactions among hosts and disease agents. Such changes may foster the emergence of new infectious disease threats.

5.1.6 Policy framework based on the findings of this study

The National Health Policy and Strategy to achieve Health for all Nigeria was promulgated in 1988 as the first comprehensive national health policy (FMH, 2004).

The overall policy objective is to strengthen the national health system such that it would be able to provide effective, efficient, quality, accessible and affordable health services that will improve the health status of Nigerians through the achievement of the health-related Millennium Development Goals (MDGs). Among the main health policy targets is to have halted, by 2015, and begun to reverse the incidence of malaria and other major diseases.

Most infectious diseases have seasonal cycles that include spatial and temporal changes in prevalence and the seasonality of the diseases is driven by changes in rainfall, temperature and humidity. The protection of public health from an increasingly variable and changing climate is a priority for the health sector. Partnering with the meteorological community to ensure that weather and climate information is available and appropriate for health decisions is a key step in the process to managing climate risks. (AMCOMET, 2012).

Based on the findings of this study, it was evident that climatic elements varies in time and space and there has been a progressive increase in temperature throughout the study periods.

A framework to improve communication and planning between health ministries and climatological services can be develop in Nigeria.

The goal is to create a climate informed health sector and beneficiary communities that routinely request and use appropriate climate information to improve the effectiveness of health interventions.

Objectives

- Create institutional data sharing systems among the sectors and other relevant institutions

- Facilitate collaboration between ministries of Health and other government departments, empowering health professionals and ensuring that health and climate consideration are thoroughly integrated in government wide strategies.
- Increase the collection and accuracy of health data, particularly for vulnerable and underserved populations
- Fosters research on climate and health
- Organizes workshops and seminars
- Identifies gaps and bottlenecks which constrains the routine use of climatic information by health sectors
- Identifies and pursues the means to overcome these problems
- To reduce the burden of climate – sensitive diseases
- Linked health forecasting and early detection to specific actions to reduce risk that are firmly specific and take into account the social and cultural factors that make people more or less receptive to information

5.2 Summary of Findings

Objectives	Findings	Illustration
Nature of Climate Variations	• The climate characteristics in Nigeria vary in time and space. • The results of time series and standardized anomaly reveals three periods in rainfall trends since the middle of the last century. A relatively wet period which occurred between 1958 and	Fig. 4.1 & 4.2 Fig. 4.4, 4.5 & 4.6

	1969; a relatively dry period between 1970 and 1994; a relatively wet period between 1995 and 2009 which shows a period of some recovery generally for Nigeria as a whole.	
	• Regionally, five periods were noted for the southern Nigeria and four periods for the Northern Nigeria.	
	• It is also inferred from temperature analysis evidence of warming in Nigeria. Increase of 0.058°C per decade for Kano and 0.003°C per decade for Lagos.	Fig. 4.24 & 4.25
	• The selected diseases incidence a significant strong negative correlations between rainfall, minimum temperature, relative humidity in all the ecological zones while strong positive correlation existed between radiation, maximum temperature and all the selected diseases in all the ecological zones.	Fig. 4.8 to Fig. 4.25
	• Dryer conditions prevailed over Sahel, Sudan, Guinea and slightly over Mangrove swamp forest zones and wetter conditions prevailed only over the Tropical forest zone.	Fig. 4.28 to Fig. 4.43

Spatio-Temporal distribution of selected diseases in Nigeria.	• The result of contour analysis shows spatio-temporal variability in the distribution of the selected diseases. Highest values occurred in the month of January for Pneumonia; March for Measles, CSM; July for Tuberculosis and August for Malaria. • Climatic conditions suitable for malaria transmission over the ecological zones decreases from Mangrove swamp forest (9 months), through the Tropical forest (8 months), Guinea savannah (6 months), Sudan savannah (4 months) and Sahel savannah (3 months). • Malaria prevalence over Jos plateau region shows that minimum cycle coincides with the highest rainfall and temperature values.	Fig.4.49 to Fig. 4.77 Fig. 4.56a to Fig. 4.60c Fig.4.61a Fig. 4.61b
Climate Variation	• The result of the relationship shows high negative	

and diseases in Nigeria	correlation between rainfall, minimum temperature and relative humidity with all the selected diseases. • High positive correlation between radiation and maximum temperature with all the selected diseases. • The results of multivariate analysis shows the percentage ability of climatic parameters in predicting Malaria ranged between 4% and 65%; 6% and 74% for Measles; 10% and 77% for Pneumonia; 18% and 79% for CSM; 1% and 56% for Tuberculosis of the 10 selected cities.	Table 4.2 Table 4.7 Fig. 4.57 to Fig. 4.60

CHAPTER SIX

6.0 Conclusion & Recommendations/Contribution to Knowledge

6.1 Conclusion

Many Scientists shared the view that climate affect disease patterns because disease agents (viruses, bacteria, and other parasites) and their vectors (such as insects or rodents) are sensitive to climatic elements such as temperature, moisture, humidity, wind. But details of the extent of the impacts are not much researched into.

Results from this study have shown that there is a lot of variability in the spatial and temporal distribution of both the climatic parameters and the selected diseases used. The characteristics of climatic variation over the ecological zone of Nigeria is such that rainfall varies in time and space. Dryer conditions prevailed over the Sahel, Sudan, and Guinea and slightly over the Mangrove swamp forest zones and wetter conditions prevailed only over the Rain forest zone. Generally, temperature exhibited rising trend, but strongly over the Sahel region and Mangrove swamp forest zone and weakly over the Sudan and Guinea savannah zones. The relationships between climate and the selected diseases also vary and highly localized. Long-term temperature analyses reveals and confirm evidence of warming in Nigeria, which could have impacts on other climatic parameters and affect the incidence of diseases. The climatic conditions suitable for malaria transmission over various ecological zones reveals decreases from Mangrove swamp forest (9 months) through the tropical forest (8 months), Guinea savannah (6 months), Sudan savannah (4 months) and Sahel savannah (3 months).

Statistical analysis on the relationships between the climatic factors and the occurrence of the selected diseases is significant but highly dependent upon local scale parameters. Malaria occurrence that could be accounted for by climatic variables is highest in Niger State and lowest in Sokoto State. While for Measles, it is highest in Lagos State and lowest in Sokoto State. For Pneumonia it is highest in Lagos State and lowest in Sokoto State. But for Cerebro-

Spinal-Meningitis (CSM), it is highest in Kano State and lowest in Borno State. For Tuberculosis it is highest in Benue State and lowest in Sokoto State. Consequently, climate information can be of help in health early warning systems and understanding the relationships will foster a good working group between meteorological services and health ministries. Therefore, a prudent strategy is to set a high priority on reducing people's overall vulnerability to infectious disease through strong public health measures such as vector control efforts, water treatment systems, and vaccination programs.

6.2 Recommendations

The results from this study, however, can be used to influence policy on climate change and health control practices to stimulate action towards limiting the furthering of anthropogenic ally-caused climate change.

This point is made in view of the recognition that the major constraint to adequate forecasting and formulation of adaptation policies is the paucity of climate data in Nigeria. Long term studies on national and regional climate change in Nigeria should be embarked upon and vigorously pursued. The findings of such studies will be crucial for the formulation of adequate response and adaptation policies such as adequate resettlement programmes for those that may be displaced by climate change.

Research on the linkages between climate and infectious diseases must be strengthened. In most cases, these linkages are poorly understood and research to understand the causal relationships is in its infancy in Nigeria. Methodologically rigorous studies and analyses will likely improve our nascent understanding of these linkages and provide a stronger scientific foundation for predicting future changes. This can best be accomplished with investigations that utilize a variety of analytical methods (including analysis of observational data, experimental manipulation studies, and computational modelling), and that examine the consistency of climate/disease relationships in different societal contexts and across a variety of temporal and spatial scales. Progress in defining climate and infectious disease linkages can be greatly aided by focused efforts to apply recent technological advances such as remote sensing of ecological changes, high speed computational modelling, and molecular techniques to track the geographic distribution and transport of specific pathogens.

Strengthening the epidemiological surveillance programs. The lack of high-quality epidemiological data for most diseases is a serious obstacle to improving our understanding of climate and disease linkages. These data are necessary to establish an empirical basis for assessing climate influences, for establishing a baseline against which one can detect anomalous changes, and for developing and validating models. A concerted effort, in Nigeria and internationally, should be made to collect long-term, spatially resolved disease surveillance data, along with the appropriate suite of meteorological and ecological observations. Centralized, electronic databases should be developed to facilitate rapid, standardized reporting and sharing of epidemiological data among researchers.

Interdisciplinary research collaboration on climate and infectious disease linkages must be strengthened. Studies that consider the disease host, the disease agent, the environment, and society as an interactive system will require more interdisciplinary collaboration among climate modelers, meteorologists, ecologists, social scientists, and a wide array of medical and public health professionals. Encouraging such efforts requires strengthening the infrastructure within universities and funding agencies for supporting interdisciplinary research and scientific training.

6.3 Contributions to Knowledge

1. Categorically, the study drew out vivid description of Nigeria contemporary spatial climate variability in different ecological settings which provided baseline data for policy and decision making.

2. The relationship between some selected diseases incidence and contemporary spatial climatic variability in Nigeria was equally established. This will greatly assist in provided a parametric framework for matching climate variation with common disease occurrences which will enable health providers to either prevent, control or check the distributional patterns of diseases.

3. The study raised a model for understanding the complex interaction between average weather conditions, climatic and ecological systems for predicting the epidemiology of diseases.

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Appendix I: Multiple relationship between selected diseases in some selected states

Table 4.8: $R^{2,}$ F-statistics, Probability, Adjust R^2 and Canonical Correlation (CCA) for Measles in some selected States of Nigeria.

Selected State	R^2	F-Statistics	Probability (P)	Adjusted R^2	CCA
Benue	0.576	2.176	0.157	0.312	0.759
Borno	0.454	2.491	0.126	0.271	0.674
Kano	0.145	0.621	0.616	0.000	0.381
Lagos	0.742	4.022	0.049	0.557	0.861
Niger	0.611	1.572	0.293	0.223	0.782
Plateau	0.501	2.763	0.082	0.320	0.708
Rivers	0.246	0.587	0.711	0.000	0.496
Sokoto	0.064	0.447	0.649	0.000	0.254

Table 4.9: $R^{2,}$ F-statistics, Probability, Adjust R^2 and Canonical Correlation (CCA) for Pneumonia in each selected States of Nigeria.					
Selected State	R^2	F-Statistics	Probability (P)	Adjusted R^2	CCA
Benue	0.738	1.687	0.354	0.300	0.859
Borno	0.215	0.640	0.613	0.000	0.464
Kano	0.418	2.155	0.163	0.224	0.647
Lagos	0.777	4.877	0.031	0.618	0.881
Niger	0.767	2.747	0.144	0.488	0.876
Plateau	0.408	1.376	0.324	0.111	0.638
Rivers	0.430	0.904	0.534	0.000	0.655
Sokoto	0.101	0.559	0.588	0.000	0.317

Table 4.10: $R^{2,}$ F-statistics, Probability, Adjust R^2 and Canonical Correlation (CCA) for CSM in each selected States of Nigeria.					
Selected State	R^2	F-Statistics	Probability (P)	Adjusted R^2	CCA
Benue	0.202	0.152	0.965	0.000	0.450
Borno	0.186	0.611	0.627	0.000	0.432
Kano	0.797	11.783	0.002	0.729	0.893
Lagos	0.468	1.055	0.465	0.025	0.684
Niger	0.487	0.948	0.525	0.000	0.698
Plateau	0.511	2.352	0.132	0.294	0.715
Sokoto	0.332	2.729	0.109	0.210	0.576

Table 4.11: R^2, F-statistics, Probability, Adjust R^2 and Canonical Correlation (CCA) for Tuberculosis in each selected States of Nigeria.					
Selected State	R^2	F-Statistics	Probability (P)	Adjusted R^2	CCA
Benue	0.561	2.048	0.175	0.287	0.749
Borno	0.173	0.695	0.576	0.000	0.415
Kano	0.251	1.231	0.345	0.047	0.501
Lagos	0.398	1.191	0.385	0.064	0.631
Niger	0.324	0.639	0.699	0.000	0.569
Plateau	0.234	0.838	0.529	0.000	0.483
Rivers	0.149	0.314	0.892	0.000	0.386
Sokoto	0.010	0.067	0.935	0.000	0.101

Appendix II: Standardized Rainfall Anomaly over Ecological zones

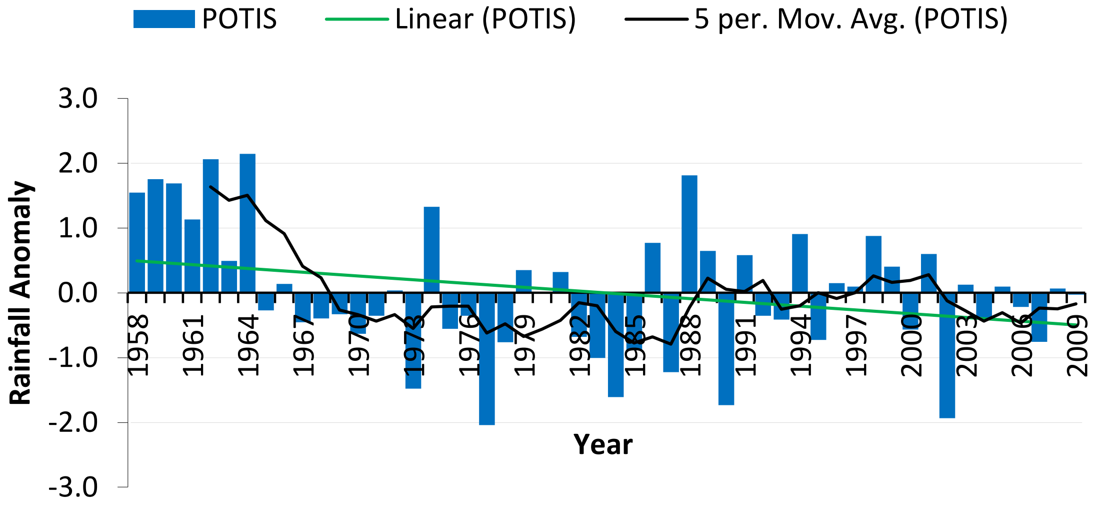

Fig. 4.79: Standardized Rainfall Anomaly over Potiskum

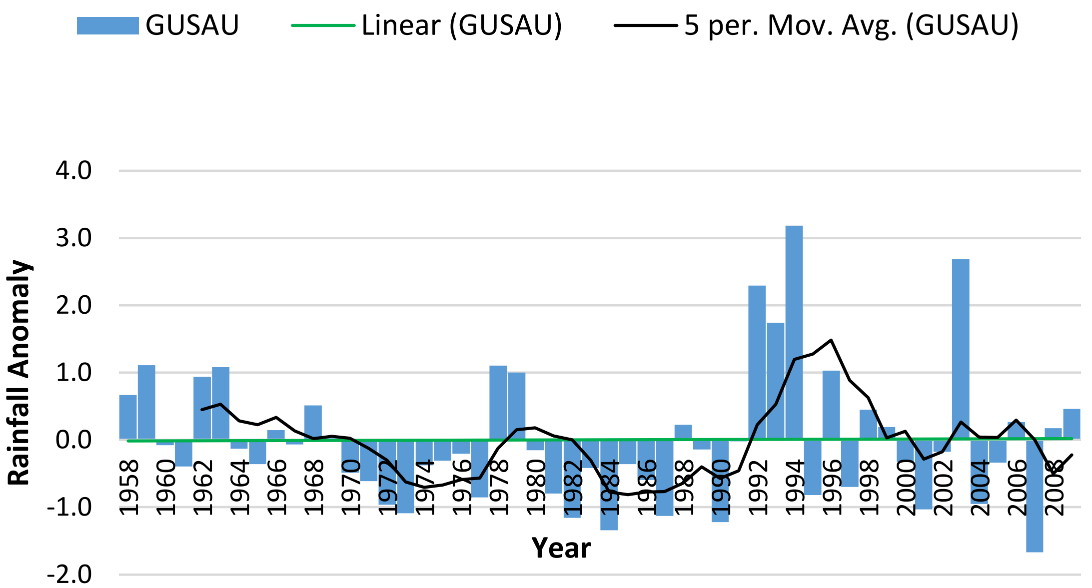

Fig. 4.80: Standardized Rainfall Anomaly ove Gusau

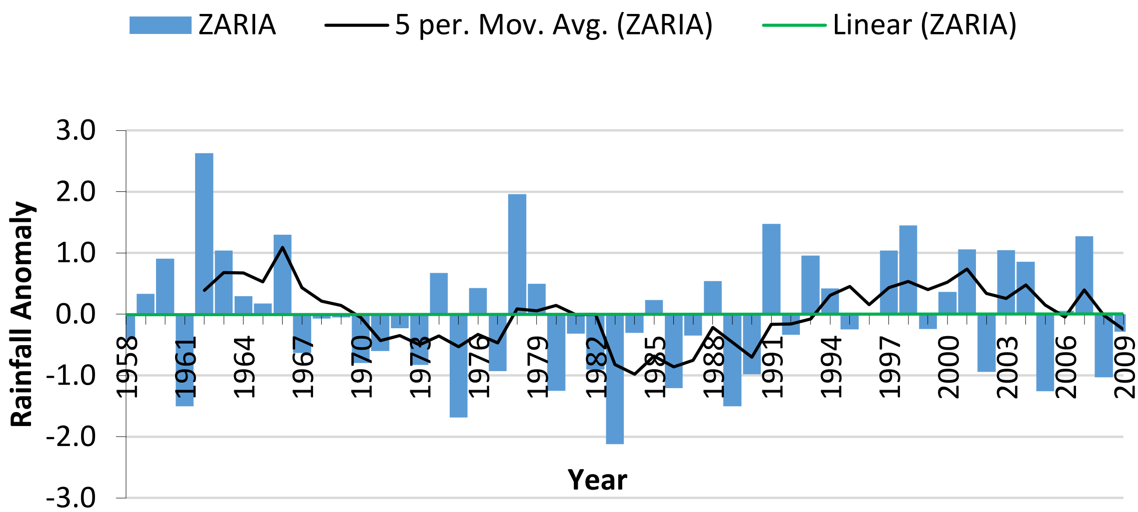

Fig. 4.81: Standardized Rainfall Anomaly over Zaria

Appendix III: Mean Maximum Temperature over Ecological zones

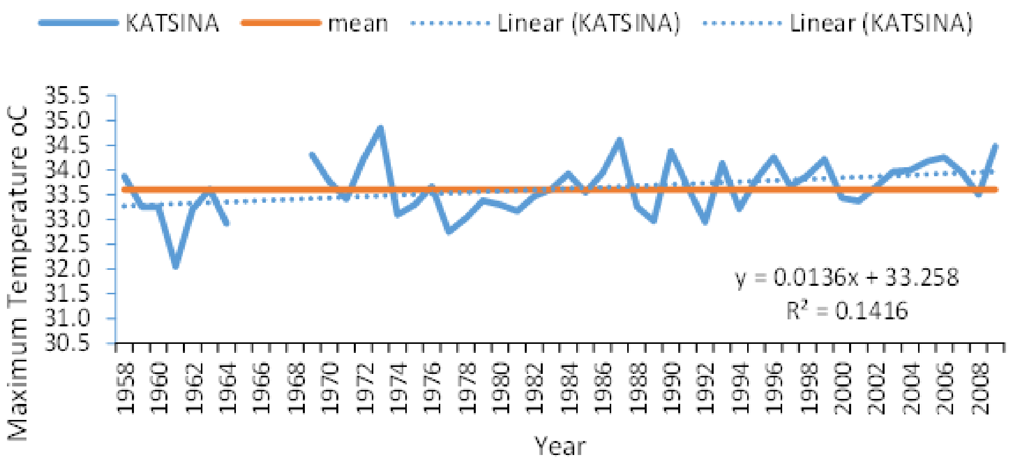

Fig. 4. 82: Mean Maximum Temperature over Katsina