ANALYSIS OF CLIMATE CHANGE IMPACT ON AGRICULTURE IN ZARIA LOCAL GOVERNMENT AREA OF KADUNA STATE

By

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DECLARATION

I declare that the work in this thesis entitled "**Analysis of Climate Change Impact on Agriculture in Zaria Local Government Area of Kaduna State**" has been done by me in the Department of Water Resources and Environmental Engineering under the supervision of Dr. D. B. Adie and Prof. C. A. Okuofu. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another Degree or Diploma at any University.

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CERTIFICATION

This thesis entitled "**ANALYSIS OF CLIMATE CHANGE IMPACT ON AGRICULTURE IN ZARIA LOCAL GOVERNMENT AREA OF KADUNA STATE**" by Aliyu Adamu meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to my late father Alhaji Adamu Dandajeh and my beloved mother Malama Sahura Adamu Dandajeh for given me moral as well as financial support.

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All praise be to Allah , the lord of the Universe, the most beneficent and merciful, master of the day of judgment and the controller of all creations on the earth both living and non-living. Peace and blessings be upon his messenger who was sent as a mercy to the world, prophet Muhammad (S.A.W), his family and companions and those who believe in his guidance and follow his footsteps until day of judgments.

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ABSTRACT

Climate change and variability is a global issue that needs to be given proper attention because of its impacts on the agriculture and other aspects of socio-economies. Annual rainfall and temperature data of four decades (1971-2010) for Zaria Local Government Area of Kaduna State located within Latitude $11^{o}08^{1}$N and Longitude $07^{o}41^{1}$E were obtained from Nigerian Meteorological Agency (NIMET), Zaria, and analysed in order to establish climate variability in the area. Three methods were used to study the climate variability namely: statistical differences between the two equal-length time scales of 1971-2000 and 1981-2010, respectively, coefficient of variability (CV); and the Anomaly approach. However, trend analysis using t test, Sen's estimator slope and Mann Kendall were also carried out in order to determine the trend in the climatic variables. On other hand, multiple non linear regression analysis was performed for the annual maize, millet and sorghum yields on the climatic variables using Sigma plot 11.0. The three models of the crops developed were evaluated using statistical error measurement. The result revealed that the differences between the two means of the equal-length time scales revealed variability of: 7mm, 0.50^{o}C, 0.30^{o}C and 0.40^{o}C for rainfall, maximum, minimum and mean temperatures, respectively. Similarly, the CVs of rainfall, maximum, minimum and mean temperatures were: 0.145, 0.026, 0.036 and 0.025, respectively indicating low variability. However, the anomaly results revealed that 21 years (52.5%) recorded dry; while 19 years (47.5%) recorded wet; 1983 having the highest dry of 323mm; and 1972 has the lowest dry of 15mm. On the other hand, the highest wet of 340mm occurred in 1978; while the lowest wet of 9mm was recorded in 1971. Moreover, 24 years (60.0%) were warmer than normal; 13 years (32.5%) less warm than normal; while 3 years (7.5%) had normal mean temperature. The Sen's estimator slope revealed downward trend of 94mm/yr in 1971-1980 decades; while it recorded upward trends of :90mm/yr, 30mm/yr and 118mm/yr, respectively during 1981-1990, 1991-2000 and 2001-2010 decades, but they are not statistically significant. However, the mean temperature recorded upward trends of 0.2^{o}C/yr, 0.2^{o}C/yr,0.1^{o}C/yr and 0.2^{o}C/yr, respectively in 1971-1980, 1981-1990, 1991-2000 and 2001-2010 decades. The regression analysis revealed that only 28.9%, 45.2% and 24.2%, respectively for maize, millet and sorghum yields variation can be accounted for by the rainfall and mean temperature. However, out of the three developed models, the millet model was the most fitted and valid as it recorded the lowest total and mean square errors of: 0.335 and 0.030, respectively. It was followed by the sorghum model with total and mean square errors of: 0.349 and 0.032, respectively; while the maize model was the least as it recorded highest total and mean square errors of: 1.457 and 0.132, respectively. Additionally, 1000 questionnaires were self- administered in order to study the perceptions of residents of the area on climate change. It was coupled with some Focus Group Discussions with farmers and Key Informant Interviews. The results revealed that climate change affect agricultural activities because the planting dates as well as harvesting dates are affected. Finally, it was concluded that climatic variables affect agriculture and some mitigation measures and adaptation options were proposed in order to control the climate change impacts.

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LIST OF ABBREVIATIONS AND SYMBOLS

mg/l: Milligram per litre

°C: Degree celsius

mm: Millimetre

ha: Hectre

ton: Tonne

ton/ha: Tonne per hectre

mm/yr: Millimetre per year

mg/day: Milligramme per day

ppm: Parts per million

GHGs: Greenhouse gases

Temp: temperature

Max: Maximum

Min: Minimum

Std. Error: Standard error

Rsqr: R squared

Adj Rsqr: Adjusted R squared

CHAPTER ONE

INTRODUCTION

1.1 General

According to the Intergovernmental Panel on Climate Change (IPCC, 2007a), climate change is defined as a statistically significant variation in either the mean state of the climate or in the variability of the mean state of climate, occurring for a long period (decades or longer). On the other hand, United Nations Framework Convention on Climate Change (UNFCCC, 1992), defined climate change as a change of climate that is caused either directly or indirectly by the human activities, which changes the constituent of the atmosphere, coupled with the natural climate variability observed over longer period.

Climate change is caused by greenhouse gasses (GHGs) such as carbon (iv) oxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). These gasses allow solar radiation from the sun to pass through the atmosphere but do not allow the reflected heat from going back into space which leads to the rise of earth's temperature (UNFCCC, 2007). With respect to the current trends, the International Energy Agency (IEA) in its global energy forecast, estimate a 53% rise in global basic energy need by the year 2030, with 70% of the energy coming from developing countries. However, as emerging countries, such as China and India grow, their role for energy need will account for an upward proportion of the total. Fossil fuels will certainly to take highest percentage of this increase, and the resultant GHGs released will in turn cause rising temperatures. However, since 1900 our globe has become warmer by 0.7^oC and will keep on rising at a predicted rate of 0.2^oC per decade. However, if it is not brought under control, it leads to a global warming of at least 1.4^oC (IPCC, 2001a; Nkemdirim 2003).

The National Oceanic and Atmospheric Administration (NOAA) in 2007 reported that the last decade of the 20th Century and the beginning of the 21st have been the warmest period in the whole world measurement of temperature records, which commenced in the mid-19th century. Global warming resulted to variation in temperature and precipitation that are already noticed in many parts of the world including Nigeria (Odjugo, 2010).

The main features of climate change are: rising in average global temperature; variations in cloud cover as well as rainfall on land; melting of ice caps and glaciers and decreased in snow cover; upward in ocean temperatures and their acidity, because of the absorbing heat of seawater and CO_2 from the atmosphere (UNFCCC, 2007). Similarly, global release of CO_2, CH_4 and N_2O have risen extensively due to human activities since 1750, and now are more than the pre-industrial values obtained from ice cores covering several hundreds of thousands of years (IPCC, 2007b).

Ngaira (2003) also reported that human activities are currently known as the main factors leading to climate change particularly in Africa. Land use changes such as, deforestation, overgrazing and vegetation burning add carbon load and also cause change in energy and moisture fluxes, with devastating result on weather and climate patterns at local and national levels.

Similarly, for the next coming decades, it is estimated that billions of people, especially those in developing countries will encounter deficit of water and food with negative effect to health and life due to climate change. Consequently, entire global action is required to make developing countries to withstand the effects of climate change that are occurring now and will continue in the future. However, because of global warming, the type, rate and magnitude of extreme events, such as tropical cyclones (including hurricanes and typhoons), floods, droughts and intense

rainfall events, heat waves are expected to rise even with little rise in temperature (UNFCCC,2007; Meehl et al, 2007).

IPCC (2007a) highlighted many uncertainties about climate change. The report stated that: warming of the climate system is now unequivocal and it is obvious that global warming is highly because of the man-made emissions of GHGs (especially CO_2). Moreover, during the last century, atmospheric quantity of CO_2 has risen from a pre-industrial value of 278mg/l to 379mg/l in 2005, and the average global temperature increased by 0.74°C (IPCC, 2007b). This is the greatest and quickest warming trend that scientists have been able to observe in the history of the Earth. Similarly, an increasing rate of warming has occurred during the last 25 years, and 11 of the 12 warmest years were recorded in the past 12 years (IPCC, 2007b). The IPCC report gives enough forecast for the 21st century which show that global warming will keep on progressing \and the best estimates revealed that the Earth could warm by 3°C by 2100

1.2 Statement of Research Problem

Human activity has already altered atmospheric characteristics such as temperature, rainfall, levels of CO_2 and ground level ozone. However, increase in fossil fuel burning and changes in land use have continued to emit, increasing concentrations of greenhouse gases into the atmosphere; and a rise in the amount of these gases has caused a rise in the amount of heat from the sun withheld in the Earth's atmosphere, which ideally suppose to be radiated back into space. This increase in heat has resulted to the greenhouse effect, which consequently led to climate change. The current population pressure and poverty has led to certain human activities such as deforestation and bush burning to increase the level of CO_2 in the atmosphere, which in turn increase global warming.

Climate change and variability has already set development efforts back, and made the achievement of the Millennium Development Goals (MDGs) significantly more tedious in Nigeria. Zaria Local Government Area and Nigeria as whole are vulnerable to climate change because of the dependence on rain-fed agriculture which relies directly or indirectly on climate change and variability. Moreover, agricultural activities from planting to harvesting are dependant either directly or indirectly to climate change and variability.

On the other hand, UNDP (2008) predicted that the impacts of climate change such as sea-level rise, droughts, heat waves, floods and changes in precipitation, could, by 2080, push 600 million people into food shortages and the number of people facing water scarcities would reached 1.8 billion.

1.3 Aim and Objectives of Study

The aim of the study is to analyse the rainfall and temperature data of four decades (1971-2010) with a view to establishing climate variability in the area.

The following are the objectives of the study:

(a) To study the climate change impact on agriculture;

(b) To come up with some mitigation measures required to control climate change;

(c) To propose some adaptation options that would be used to withstand the climate change impact on agriculture.

1.4 Justification of Study

The study of climate change and variability is crucial considering the fact that its impacts are numerous which include: its effects on water availability, quality and quantity, food security,

agriculture, health, air quality, species migration and sea level rise. These pose great environmental challenges as well as economic losses to the area, country and world at large. The study will sensitize individuals about the existence of climate variability, its impact on agriculture, mitigation measures to be taken as well as adaptation options to the impacts of climate change on the agriculture. Until recently, climate was generally taken for granted and with little thought that the climate change could be a problem with severe impacts (Ojo, 1987).

1.5 Scope and Limitations

The study involved the analysis of rainfall and temperature data of four decades (1971-2010), with a view to establishing climate variability in Zaria Local Government Area of Kaduna State and also to study the impact of climate change and variability on agriculture. However, mitigation measures needed and adaptation options to the impacts of climate change on agriculture were incorporated in the work. The areas not covered by the work involve the measurement of the atmospheric greenhouse gas emissions and using climate models to project future climatic state.

CHAPTER TWO

LITERATURE REVIEW

2.1 Climate

A simple definition of climate is the average weather condition of a place. A description of climate over a period (which could be from few years to few centuries) encompasses the averages of appropriate compositions of the weather during that period, together with the statistical variations of those components (IPCC, 1990). Climate is basically defined in terms of 30 year means, and higher-order moments about those means. Climate can also be defined as the statistical description in terms of the mean and variability of meteorological variables such as temperature, rainfall and wind over a period of time spanning from months to thousands or millions of years, but the classical period is 30 years, as defined by the World Meteorological Organization (WMO, 1988).

2.2 The Climate System

It is a system consisting of the atmosphere, the hydrosphere (comprising the water distributed on and below the earth's surface, and the cryosphere (the snow and ice on and below the earth's surface), the surface lithosphere (consisting the rock, soil and sediment of the earth's surface), and the biosphere (consisting earth's plant and animal life, and humanity), which, under the influence of the solar radiation accepted by the earth, determines the climate of the earth. Although climate basically relates to the different states of the atmosphere, only the other portion of the climate system also have important roles in forming climate, through their associations with the atmosphere (WMO, 1992).

2.3 Climate Change and Climate Variability

Climate change is referred to "all forms of climatic instability, irrespective of their statistical nature or physical causes Mitchell et al (1966). The IPCC (2001a) defines climate change broadly as "any change in climate over time whether due to natural variability or as a result of human activity". Conversely, UNFCCC (1992) defined climate change as a change of climate that is caused either directly or indirectly by the human activities, which changes the constituent of the atmosphere coupled with the natural climate variability occurred over longer period.

Climate changes are normally classified as long-term, short-term and fluctuations based on the time scale. Climate changes happening over time scales higher than or within those found with the orbital forcing frequencies of between 41,000 and 9,508,000 years are known as long-term. Climate changes happening for time scales shorter than those found with the orbital forcing frequencies are classified as short-term; while climate abnormalities on time scales less than 100 years are basically referred to as climate variability (Matondo et al, 2004).

The climate of a place or region is said to be changed if during a long period (basically decades or longer), a statistically significant change in either the mean state or variability of the climate for that area occurred (IPCC, 2007a). The United State Agency for International Development (USAID, 2007), reported that while climate change affect the whole world, the resultant changes would not to be the same globally ; there may be noticeable variations at country levels. Climate change causes a big challenge to Africa's economic growth, long-term prosperity, and the living of the already susceptible people.

On the other hand, climate variability is defined as the fluctuations in the mean state and other statistics of the climate on all temporal and spatial scales that exceeds that of individual weather events. The variability could be as a results of the natural internal processes inside the climate system (internal variability), or to changes in natural or anthropogenic external forcing (external variability). Climate variability can cause sudden changes, such as floods, droughts, or tropical storms. These changes can make great impacts on a country's economy particularly when the larger portion of economic growth is dependent on the weather and climate. The impacts of climate variability and change have higher effect for the less privileged in developing countries than those living in more developed nations (USAID, 2007).

2.4 Global Climate Change

It was reported that the global mean surface temperature has already risen by about 0.07°C per decade in the past 100 years (IPCC, 2007b). The increase has been more significant (about 0.18°C per decade) in last 25 years, in which decade (2001–2010) was reported as the warmest decade on record. The average temperature in that decade was higher than 1961–1990 mean by 0.46°C, and it was higher than (1991–2000) decade by 0.21°C. However, 1991–2000 was also warmer than the decades before it, consistent with a long-term warming trend (WMO, 2011).

However, due to prevailing global warming, mountain glaciers and snow cover have declined in both hemispheres. The global average sea level has been rising since 1961 at a mean rate of 1.8 mm/yr and since 1993 at 3.1mm/yr, in which expansion due heat, melting glaciers, ice caps, Greenland and Antarctic ice sheets play great role, causing the sea level rise (IPCC, 2007a). Moreover, noticeable upward in rainfall has occurred in the eastern parts of North and South America, northern Europe and northern and central Asia. The occurrence of intense rainfall

events has risen over most areas, which is accompanied with warming and increase in atmospheric water vapour. However, there has been some rainfall deficit in the Sahel, the Mediterranean, southern Africa and parts of southern Asia (IPCC, 2007a).

The African Ministerial Council on the Environment (AMCEN) in 2011 reported that the widespread changes in extreme events occur. It stated that, cold days, cold nights and frost occur less frequently, while hot days, hot nights, and heat waves occur more frequently. More severe and persistent droughts have been observed over wider areas since the 1970s, particularly in the tropics and sub-tropics.

2.5 Climate Variability and Change in Nigeria

Hengeveld et al (2005) provided criteria that can be applied to study evidence of climate change in a region. These includes: upward in temperature, rising evaporation, reduction in the quantity of rainfall in the continental interiors, rising rainfall in the coastal region, increasing changes in climate patterns and increasing rate and severity of extreme weather related events such as thunderstorms, lightning, floods, landslides, drought, unpredictable rainfall pattern, sea level rise, increase desertification and land degradation, evaporation, loss of forest cover and biological species which have been confirmed to exist in Nigeria. Moreover, the additional proof of climate change in Nigeria is the rise in rainfall quantity in the coastal areas since the 1970s, and a continuous decrease in precipitation amount and length in the continental interiors of the semi-arid region of Nigeria. The rise in precipitation in the coastal areas could be the major cause of floods affecting the coastal cities of Warri, Lagos, Port Harcourt and Calabar as observed by Ogundebi, 2004; Ikhile, 2007; Nwafor, 2007; Umoh, 2007; Odjugo, 2010. Moreover, Odjugo (2005; 2007) also found that the number of rainy days has reduced by 53% in northeastern

Nigeria and 14% in the Niger Delta coastal areas. These two changes in climate pattern are proof for the existence of changing climate in Nigeria.

FME (2011) reported that the Nigerian Meteorological Agency in 2008 studied the Nigerian climate from 1941 to 2000 periods and observed the following changes:

(a) Rainfall: In relation to past periods, during period of 1971 to 2000 periods, there was late onset and quick cessation of rainfall, which shortened the length of the rainy season in various parts of the country. From 1941 to 2000, annual rainfall dropped by 2 - 8 mm across most parts of the country, but increased by 2 - 4 mm in a few places (e.g. Port Harcourt).

(b) Temperature: From 1941 to 2000, long-term temperature increase was observed in most parts of the country. The main exception was in the Jos area, where a slight cooling was recorded. The most noticeable increases were recorded in the extreme northeast, extreme northwest and extreme southwest, where average temperatures rose by 1.4 - 1.9^{o}C.

Furthermore, Odjugo (2010) reported that the air temperature in Nigeria has risen between 1901 and 1970 and at a faster rate since 1970. The mean air temperature between 1901 and 2005 was 26.6^{o}C, while the rise in temperature for 105 years was 1.1^{o}C and rainfall has also declined. The rising temperature and falling rainfall in semi-arid region of Sokoto, Katsina, Nguru, and Maiduguri may have led to the rising evaporation, drought and desertification in Nigeria as reported by Odjugo and Ikhuoria (2003); Adefolalu (2007). Moreover, Constant loss of forest cover and biological species in Nigeria is related to global warming and climate change (Ayuba et al., 2007).

However, the study carried out by Fasona and Omojola (2005) on the climate change, human security and communal clashes in Nigeria revealed that all the stations in the Sahel region recorded less than average rainfall during 6 decades (1941 - 2000) periods. The decade 1950s recorded the greatest rainfall; while the decade 1980s was associated with the least rainfall from the total decadal mean. The resultant change in land cover between 1976 and 1995 basically revealed loss of prime arable lands due to climate change.

2.6 Causes of Climate Variability and Change

Factors that can shape the climate are called forcings or "forcing mechanisms". Forcing mechanisms can be either "internal" or "external". Internal forcing mechanisms are natural processes inside the climate system itself (for example, thermohaline circulation). External forcing mechanisms can either be natural (for example, changes in solar output) or anthropogenic (for example, increased emissions of greenhouse gases) (wikipedia, 2013a). IPCC (2007a) reported that the anthropogenic climate forcing is generally accepted as the main cause of the climate change, which includes greenhouse gases, aerosols, and land surface changes.

Moreover, studies have revealed that while a rise in the amount of greenhouse gasses would increase the global temperature, an increase in atmospheric aerosol would reduced it (global dimming and global cooling), but changes in the land cover could either increase or decrease the local temperature (AMCEN, 2011). Table 2.1 shows the major sources of carbon dioxide emissions in Nigeria.

Table 2.1: Major sources of carbon dioxide emissions in Nigeria

S/N	Source	% Contribution
1	Land use, land use change and forestry (LULUCF)	40
2	Gas flaring	30
3	Transport	20
4	Electricity	3
6	Industrial Processes	1
7	Other Energy	6

(FME, 2003)

Nkemdirim (2003) also reported that climate change can occur due to some natural causes such as solar output, sunspot activity, Milankovitch episodes and Vulcanicity or from human activities such as deforestation, overgrazing and rise in atmospheric CO_2 through burning of fossil fuels, or due to both the natural and human activities. Deforestation and vegetation burning can lead to a more rate of droughts, and this has been reported as one of the causes of frequent droughts in the Sahel region. The increasing aridity around the Moshi region in Tanzania and the rapid disappearance of ice caps on mountains in equatorial East Africa (Kilimanjaro, Kenya and Elgon) has been attributed to land use changes particularly deforestation and charcoal burning (Ngaira, 2007).

2.7 Impacts of Climate Change

The impacts of climate change could be on natural as well as human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts (IPCC, 2001b). Potential impacts refer to the impacts that may occur as a result of forecasted change in climate, without considering adaptation; while residual impacts refer to the impacts of climate change that would occur after adaptation (Levina and Tirpak, 2006). The various impacts

of climate change are droughts in some areas, while flooding in others affecting agriculture and food security, changing both surface and underground water supply and devastating ecosystems amongst others (Sawa and Adebayo, 2011). USAID (2007) also reported that the impacts of climate change include: sea level rise, changes in the intensity, timing and spatial spread of rainfall, changes in temperature (variation and mean values), and the frequency, intensity, and duration of extreme climate events such as droughts, floods, and tropical storms.

Flood is an overflow of water that submerges or "drowns" land (Wikipedia, 2013b). Floods are initiated by numerous factors such as: intense precipitation, highly accelerated snowmelt, higher winds over water, abnormal great tides, tsunamis, or malfunction of dams, or other structures that keep the water. Flooding can be tremendous by a rise in number of impervious surface or by other natural hazards such as wildfires, which decrease the amount of vegetation that can intercept precipitation. The water then flows through the land with magnitude that cannot be contained in a stream channels or be kept in natural ponds, other reservoirs. Climate change leads flooding due the fact when the climate is warmer, it lead to intense precipitation; sea level will go on rising close to most shoreline and excessive sea levels will be encountered more frequently (Bariweni et al, 2012).

The effects of climate change are particularly more harmful to Africa as it keeps on rising up through the coming centuries, usually increasing the original pressure and forming new ones. The resultant effects of climate change in Africa are severe and various changes are hoping to happen earlier and will certainly be higher in Africa than other continents. Additionally, Africa is liable to climate change because its large rural area people heavily relying on rain-fed agriculture that is susceptible to climate change (AMCEN, 2011). With regards to rural-urban migration of

the Nigerian work populace and climate change effect on food supply in Kaduna city, Abdullahi et al (2009) reported that as the 21st century proceeds, climate change will have an increasing impact on human society.

Moreover, Building Nigeria's Response to Climate Change (BNRCC, 2011) reported that climate change will temper with the effort to decrease hardship by most people, to do justice in development benefit among the gender group. It will also impair biological species, food and water quantity. Extreme weather event such disastrous flood had occurred in Nigeria and other parts of the globe. Recent analysis revealed that without proper adaptation, Nigeria could lose between 2% and 11% of the country's gross development product (GDP) by 2020, which could reach 6% and 30% by 2050, equivalent to 15 and 69 trillion. However all sectors of the Nigeria's economy such as: agriculture, water resources, biodiversity, health and sanitation, energy, transportation, communication, commerce and industry, education would be affected by climate change (FME, 2011).

Additionally, Ojwang et al (2010) added that the impacts of climate change are compounded also by non-climatic factors, including:

(a) Population displacement which lead to people to become squatters;
(b) Migration to neighboring areas looking for relief and/or better chances;
(c) Spoilage of crop fields and reduction in livestock, with severe effects;
(d) Continuous reduction in water quantity as the rivers are exhausted due to long term water deficit, and floods which affects quality;
(e) Disease outbreaks harming both human, animals and crops due to increase in temperatures or waterborne diseases as a result of floods;

Alayande et al (2010) defined the favourable climate for malaria occurrence as the rainfall accumulation above 80mm, mean temperature between 18°C and 32°C, and relative humidity above 60%. The study revealed that the seasonality of climate play role in malaria transmission in Nigeria and in the distribution of breeding areas for the mosquito vector thereby leading to malaria occurrence.

Climate change will affect the basic requirement for good health, clean air and water, enough food, required shelter and free from disease outbreak. The effects of climate change on health will be acutely felt and the most vulnerable are developing countries, with poor results for the attainment of the health-related Millennium Development Goals and for health equity (WHO, 2008).

Agriculture is the most susceptible of all human and economic activities to the consequences of climatic change particularly in developing countries, where technology development, creativity and adoption have been low to checkmate the negative results of changing environmental conditions. For instance, unsound management of agro-ecosystems coupled with high climatic events such as recurrent droughts, led to dry land becoming highly susceptible and expose to quick degradation and desertification. As a result, there is a decrease in output by farmers and increasing food insecurity (Munonye et al, 2008). Similarly, Acheampond (1998) reported that all elements of Agriculture from planting to harvesting are relying directly or indirectly on climate. Moreover, Nnaji (2001) found using some data from Northern Nigeria that crops have a climatological success range for reasonable yield.

2.8 Vulnerability to Climate Change

It is defined as the degree, to which a system is susceptible to, or incapable of coping with negative result of climate change, including climate variability and extremes (IPCC, 2007c). The term 'vulnerability' is one of the key concepts in the adaptation research. It is highly utilized and assessed in regards to its applicability, use and meaning. O'Brien et al. (2004) highlighted two common meanings of vulnerability in terms of climate change. The definitions revealed that vulnerability can be defined as a residual of climate change impacts when adaptation has been removed, and that the second definitions revealed vulnerability as a general feature or condition created by multiple factors and processes, but increased by climate change. There are three main issues which are mutually exclusive involved in any evaluation of vulnerability: the exposure of a system to climate variations, its sensitivity and adaptive capacity (Luers et al, 2003; Turner et al, 2003; Fussel and Klein, 2006; IPCC, 2007c).

Following the definition provided above, vulnerability can be expressed scientifically according to (Adesina and Adekunle, 2011) as follows:

$$V = (I - A_d) \quad (2.1)$$

Where V is vulnerability, I is potential impact, and A_d is adaptive capacity

Exposure is the amount of climate disturbance in which a certain system encountered. The disturbance could be variations in climate states or changes in climatic behaviour including the level and rate of extreme events (Adesina and Adekunle, 2011). Sensitivity is the stage to which a system is impaired, negatively or positively, by climate-related forces. It is also the stage to which a system is change or affected by internal or external forces. This measure is dependent upon the socioeconomic and ecological states and revealed the level to which a system will be

changed by environmental force (Adesina and Adekunle, 2011). Adaptability is the amount of modifications possible in practices, processes, or structures of systems to the expected or genuine variations of climate. It is also a measure of the resistance to negative climatic forces and the coping capacity of a region. The coping capacity is normally regarded as a subset of adaptation. It is defined as the level to which systems can be adjusted to tackle the changing conditions (Adesina and Adekunle, 2011).

Additionally, vulnerability study determines the objects or individuals that are exposed and sensitive to change. It involves the consideration of the conditions that make individuals or the environment vulnerable, availability of natural and financial resources; self-protection capability; and so on (Tompkins, 2005). Adesina and Adekunle (2011) study the vulnerability to climate change of the six geopolitical zones of Nigeria and found that vulnerabilities vary broadly across the country. The highest vulnerable is the northeast zone, followed by the northwest, while southwest is the least followed by the south east. This implies that adaptation requirements are not the equal in all the zones of the county.

2.9 Resilience to Climate Change

Resilience is the degree of change a system can pass through without changing state IPCC (2001b). However, UKCIP (2003), also defined resilience as the likelihood of a system to keep its state when pass through some forces or the capability of a system to regain its state from the excessive load that may have been detrimental to its state. This is also associated with the ability of a community or society prone to hazards to withstand changes, so as to maintain an allowable stage of work. It is influence by the level to which the social system is able to organize itself so as to improve its ability through past disasters experience for adequate subsequent protection

(UN/ISDR, 2004). In the first definition resilience means the capability not to be damaged, while in the second definition, resilience implies that the damage can happened, but the system will be able to recover from it. The essential of these differences is in the usage of 'resilience' and attempts to measure it or measure methods that rise resilience (Levina and Tirpak, 2006).

Klein et al (2004) analysed the usage of resilience on practice and suggested to use "adaptive capacity as the general concept that encompasses the ability to prepare and plan for hazards and to utilize technical measures throughout a hard event. The resilience can thus be considered as one aspect that improves adaptive capacity".

2.10 Mitigation of Climate Change

In climate change research, mitigation is "an anthropogenic intervention to decrease the origins of greenhouse gases or improve their reservoirs." It is aimed on reducing net emissions in order to retard and consequently reverse the amount of greenhouse gases in atmosphere (IPCC, 2001a). ***The relevant*** actions involved in mitigation are placed into two areas: the decrease of GHG emissions and the capture, fixing and sequestration of carbon. However, other mitigation actions include: geo-engineering to neutralize the impact of global warming by forming cooling effects which prevent greenhouse heating; and embarking on technology development for wiping out the greenhouse gases from the atmosphere (Atilola, 2012). Moreover, it has been revealed that currently, the cost and benefit of controlling climate change are roughly the same. Mitigation actions are generally taken in developed country because they have high economic growth, while adaptation actions are taken in less privileged countries.

Mitigation of climate change is of great concern because, if global warming is not minimized, it could lead to large-scale impairment in food supply in the future that the globe would be incapable of controlling it. Similarly, agricultural sector play role in releasing emissions and also a good contributor to emission reductions and carbon sequestration (FAO, 2008). Setting the international mitigation targets has been carried out by signing the Kyoto Protocol in 1997. The protocol compelled that by the period from 2008 to 2012, developed countries and economics in transition are engaged to decrease their GHG emissions by about 5% compared to their 1990 levels (Bruin, 2011).

2.11 Adaptation to Climate Change

Adaptation is defined the adjustment in natural or human systems in response to real or anticipated climatic forces or their effects, which reduces harm or opens up beneficial opportunities (IPCC, 2007c). It is also a phenomenon by which strategies to reduce, withstand and take advantages of the effects of climatic events are improved and utilized (Levina and Tirpak, 2006). UKCIP (2003) also describe adaptation to climate change as the process or result of a process that leads to a minimal effect, or obtaining benefits involved in climate variability and change. (IPCC, 2001b) reported various types of adaptation as: anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation. Moreover, originally adaptation was perceived as a secondary and long-term issue if mitigation actions prove abortive, but it is now obvious that some amount of adaptation is necessary, particularly in developing countries (UNDP and GGCA, 2009).

2.11.1 Types of Adaptation

IPCC (2001b) had distinguished different types of adaptation as follows:

(a) Anticipatory Adaptation: It is an adaptation that occurs prior to the observation of climate change impacts. It is also called a proactive adaptation;

(b) Reactive Adaptation: It is an adaptation that occurs after the observation of climate change impacts;

(c) Autonomous Adaptation: It is an adaptation that does not require a conscious response to the climatic forces but is exacerbated by ecological changes in natural systems and by market or welfare changes in human systems. It is also called spontaneous adaptation;

(d) Planned Adaptation: It is an adaptation that occurs as a result of purposeful policy decision, due to a knowledge that situations have changed or will change and the required action to come back to, maintain, or achieved a required state;

(e) Private Adaptation: It is an adaptation that is originated and use by individuals, households or private companies. Private adaptation depends actor's interest;

(f) Public Adaptation: It is an adaptation that is originated and use by governments at all levels. Public adaptation is normally channeled at collective demand.

2.11.2 Adaptive Capacity

It is the capability of a system to withstand climate change (including climate variability and extremes), to reduce likely damages, to utilized opportunities, or manage the effects of climate change (IPCC, 2007c). It is also the tendency of a system to modify its features or behaviour, so as to increase its withstanding abilities due to current climate variability, or subsequent climate conditions. The adaptive capacity as a measure that lead to adaptation can be used to improve system's withstanding ability and upgrades its coping scope thereby decreasing its susceptibility to climate impact. The adaptive capacity present in a system implies the set of resources to be used for adaptation and the capability of that system to utilize the resources efficiently for

adaptation. It is feasible to distinguish between adaptive potential, a theoretical higher level of responses based on global expertise and expected results within the planning horizon of the evaluation, and adaptive capacity that is limited by available information, technology and resources of the system under observation (UNDP, 2005).

Yohe and Tol (2001) outlined the following determinants for adaptive capacity:

(a) The limit of available technological options for adaptation;

(b) The availability of resources and their spread within the individuals ;

(c) The standard of institutions, level of decision-making authority, and the decision criteria that would be applied;

(d) The level of human capital, coupled with education and personal security;

(e) The available of social capital coupled with the definition of property rights;

(f) The ability of the system access to risk-spreading processes;

(g) The ability of decision makers to manage information, utilization of sound information and the quality of the decision-makers and

(h) The public's determination of the origin of stress and the degree of exposure

2.11.3 Adaptation Assessment

Adaptation assessment is the practice of assessing options to adapt to climate change and measuring them based on criteria such as abundance, advantages, costs, efficiency, and feasibility (IPCC, 2001b). The term 'Adaptation Assessment' is difficult in some cases to be used in practice. Currently, there is no set of rules that help in the assessment of adaptation options strongly across areas and conditions. When analysing adaptation, one can consider a number of lives that can be saved, or a value of financial losses that could be avoided, or the cost

efficiency of the adaptation project itself. It is due to the fact each particular case and every particular condition is different. Adaptation assessment within countries and regions is associated with constrains (Levina and Tirpak, 2006).

CHAPTER THREE

MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 Study Area

Zaria Local Government Area of Kaduna State is located within Latitude 11^0 10^1N and Longitude 7^0 39^1E (Fig.3.2). The climate in the area is divided into two: dry and rainy seasons. The dry season is usually from November to March and the temperatures recorded are within an average of 28^0C towards the end of the dry season. The rainy season is usually from April to October. The daily mean maximum temperature reaches a peak in April and a minimum occurs between December and January. The area enjoys a tropical savannah climate with the annual total rainfall of about 1099mm (Adamu, 2008) and a population of 408,198 based on the 2006 census.

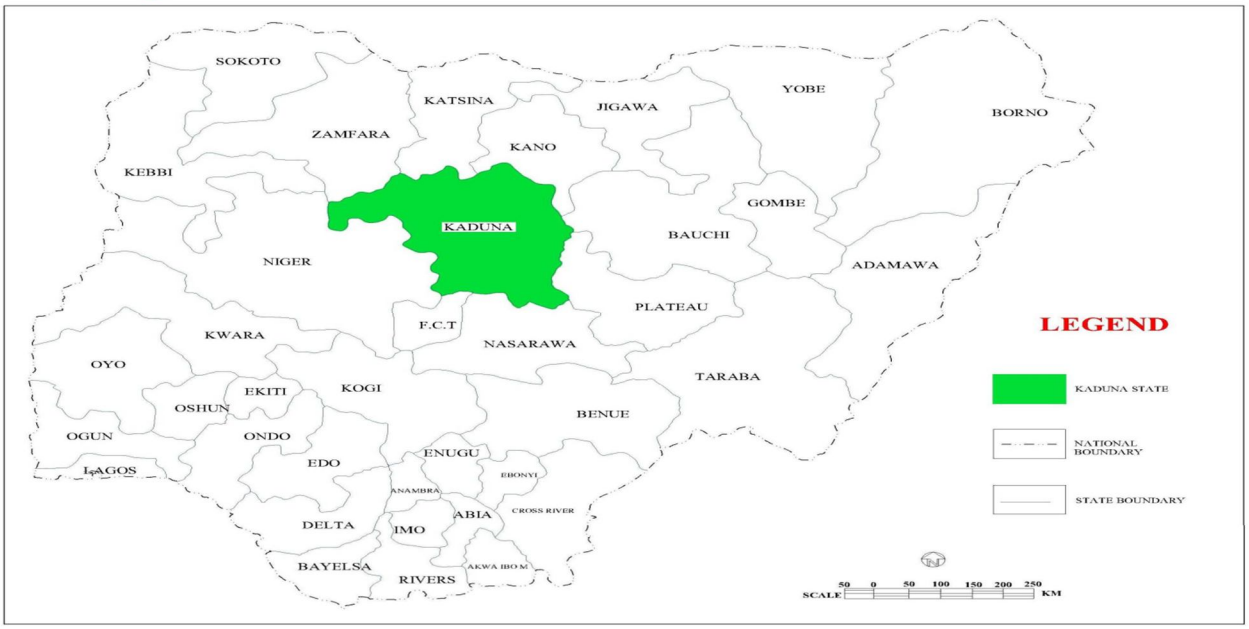


Fig.3.1: Map of Nigeria showing Kaduna State, Source:
Yusuf and Shuaib (2012)

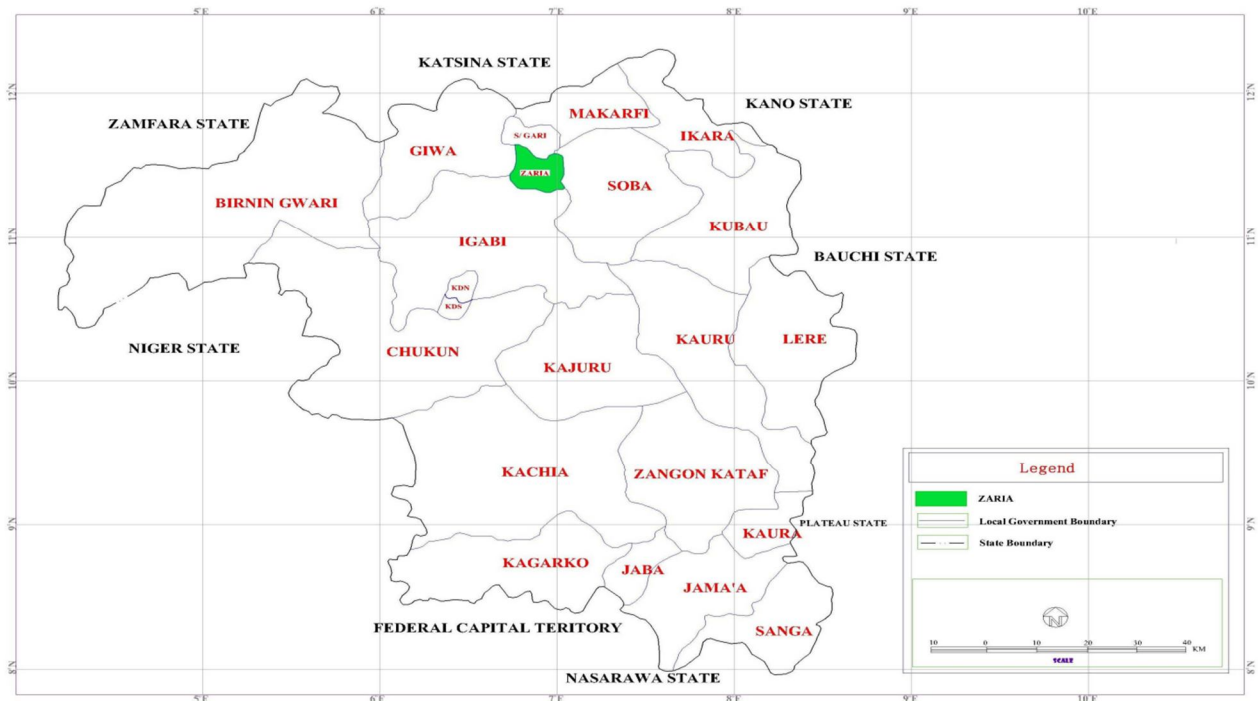


Fig. 3.2: Kaduna State map showing Zaria Local Government Area,
Source: Yusuf and Shuaib (2012)

In order to achieve the objectives of this study, the following materials were also used:

(a) Monthly rainfall data of four decades (1971-2010)

(b) Monthly maximum and minimum temperatures of four decades (1971-2010)

(c) Monthly mean temperatures of four decades (1971-2010)

(d) Annual yields of Sorghum, Maize and Millet (2001-2011)

(e) Sigma plot 11.0 software

(f) Statistical package for social sciences (SPSS) version 17.0

3.2 METHODS

The method adopted in this study involved data collection and analysis. The data collected include: minimum and maximum temperatures, and annual yields of three cereal crops namely: maize, millet and sorghum. The three methods used in the establishment of climate

variability are: simple approach, coefficient of variability (CV) and anomaly method. However, trend analysis using parametric and non parametric methods was carried out in order to establish variation in the climatic variables. Time series homogeneity test was also performed in order to know the quality and reliability of the climatic data. Similarly, multiple non linear regression analysis was carried out with a view of studying the contribution of the climatic variable to the variation in the annual yields of the three crops. The models developed from the multiple non linear regression analysis were evaluated using statistical error measurements. Additionally, structured Questionnaires were administered; Focus Group Discussions (FGD) and Key Informant Interviews (KII) were also carried out.

3.2.1 Data Collection: The monthly rainfall, monthly maximum and minimum temperatures of four decades (1971-2010) were obtained from the Nigerian Meteorological Agency (NIMET), Zaria, located within the Nigerian College of Aviation Technology. The annual yields for three popular cereal crops (sorghum, maize and millet) for the area from 2001 to 2011 were obtained from National Agricultural Extension and Research Liaison Services (N.A.E.R.L.S), Ahmadu Bello University, Zaria.

3.2.2 Determination of Mean Temperature: The mean temperatures are obtained by using Eq. 3.1 stated as:

$$T_m = \left(\frac{Tx+Tn}{2}\right) \tag{3.1}$$

In which T_m is the mean temperature, Tx is the maximum temperature and Tn is the minimum temperature

3.2.3 Time Series Homogeneity Tests

Homogeneity of a given time series data can be determines various methods, but the non parametric Thom's homogeneity test was employed in this study (Karabulut et al, 2008). Homogeneity in a climate series is said to occur when its variations are caused by changes in weather and climate (Attah, 2013). For N greater than or equal to 25, if the climate series is homogenous, the distribution of the number of runs (R) approximates a normal distribution with the mean (E) and variance, $S(R)$as:

$$E(R) = \frac{N+2}{2} \tag{3.2}$$

$$S(R) = \frac{N(N-2)}{4(N-1)} \tag{3.3}$$

$$Z = \frac{R-E(R)}{\sqrt{S(R)}} \tag{3.4}$$

For $\alpha = 0.01$ level of significance, the null hypothesis (H_0), that the data is homogenous is accepted if $|Z| \leq 2.58$, otherwise an alternative hypothesis (Ha) is accepted. For $\alpha = 0.05$ level of significance, the null hypothesis (H_0), that the data is homogenous is accepted if $|Z| \leq 1.96$, otherwise an alternative hypothesis (Ha) is accepted.

3.2.4 Determination of Climate Variability: The following three methods were used to determine the climate variability in the area:

3.2.4.1 Simple Approach: This method measures the climate variability by dividing the climatic time series into two periods of equal length as recommended by WMO (1988). The two equal-length time scales used are: 1971-2000 and 1981-2010. The differences between their means (μ) and standard deviations (δ) are computed and climate variability is obtained by Eqs. 3.5 and 3.6 as:

$$C_v = \mu_1 - \mu_2 \tag{3.5}$$

$$C_v = \delta_1 - \delta_2 \tag{3.6}$$

In which C_v is the climate variability, μ_1 is the mean of the first time scale, μ_2 is the mean of the second time scale, δ_1 is the standard deviation of the first time scale and δ_2 is the standard deviation of the second time scale.

The mean (μ) and the standard deviation (δ) were obtained using the following statistical formulae:

$$\mu = \frac{\sum_{i=1}^{n} x_i}{n} \tag{3.7}$$

$$\delta = \sqrt{\frac{\sum_{i=1}^{n}(x_i-\mu)^2}{n-1}} \tag{3.8}$$

In which x_i is the climatic variable, n is the sample size and other terms as previously stated.

The statistics for the Skewness and Kurtosis were obtained using Eqs. 3.9 and 3.10, respectively.

$$g_1 = \frac{\frac{1}{n-1}\sum_{i=1}^{n}(x-\mu)^3}{\delta^3} \tag{3.9}$$

$$g_2 = \frac{\frac{1}{n-1}\sum_{i=1}^{n}(x-\mu)^4}{\delta^4} \tag{3.10}$$

In which g_1 and g_2 are the skewness and kurtosis, respectively, other terms as previously stated.

3.2.4.2 Coefficient of Variability (CV): This is the second method I used in determining the climate variability. It compares the size of standard deviation relative to the mean of the data. It was obtained using Eq. 3.11:

$$cv = \frac{\delta}{\mu} \quad (3.11)$$

CV value of below 0.1 (10%) indicates low variability, above 0.9 (90%) reveals high variability (Durdu, 2009; Attah, 2013). The climate is stable if CV is less than or equals 0.4 (40%), after which it becomes unstable (Zuming, 1987; Lane et al, 1999; Attah, 2013).

3.2.4.3 Anomaly Method: In this method, the average value of the climatic variables over a period of 30 years (climate normal) was computed. The climate normal used was the mean of 1971-2000 climatic periods as recommended by NIMET (2010). The anomaly was obtained by subtracting the climate normal from yearly mean of each climatic variable as shown in Eq. 3.12.

$$A = \bar{x}_i - \mu_{30} \quad (3.12)$$

Where A is the anomaly, μ_{30}= climate normal and $\bar{x}_i$ = average value of the climatic variable.

The anomaly approach enables the determination of rainfalls higher than normal (wet) which are designated by positive values and rainfalls lower than normal (dry), designated by negative values. With respect to mean temperature, it enables the determination of mean temperature higher than normal (hot), designated by positive values and mean temperature lower than normal (cooling) designated by negative values for the years over the period of study.

The decadal variability of rainfall, maximum, minimum and mean temperatures were obtained by using the deviation of the decadal mean (10 years mean) of each climatic variable from the climate normal of the climatic variable as presented in equation (3.13) as:

$$\mathrm{D_a} = \mu_{10} - \mu_{30} \quad (3.13)$$

$$\mathrm{D_a} = \frac{\mu_{10} - \mu_{30}}{\mu_{30}} \times 100 \quad (3.14)$$

Where D_a is the decadal anomaly, μ_{10} is the decadal mean, and other term as previously defined

3.2.5 Trend Analysis

Trend analysis was used to determine the increase or decrease of the values of the random variable during the period (1971-2010) in statistical terms. The estimate of the magnitudes of the trends in the annual rainfall, annual maximum, minimum and mean temperatures of the four decades and their statistical significances were obtained. The methods employed in detecting the trend of the climatic variables were both parametric and non-parametric tests (Longobardi, 2009; Jain, 2012; Attah, 2013). The parametric test used is the Student's t-test, while the non-parametric tests used were the Mann Kendall and Sen's estimator slope methods (Longobardi, 2009; Karbulut, 2008). The non parametric test is more reliable and better when the distribution data are skewed, and it is a function of ranks of the observations. However, unlike the parametric test, non parametric test it is not affected by the outliers (Onoz and Bayazit, 2003; Oke and Ismai'l, 2012).

3.2.5.1 Student's t-test

This method was performed by regressing climatic variable (y) on the time (x). The method assumed a linear trend in the time series. The regression analysis was carried out by considering time as the independent variable, while the annual rainfall, annual maximum, minimum and mean temperatures as the dependant variables (Jain, 2012).

The general statistical model use to represent linear regression is shown as Eq. 3.15:

$$yi = \beta_0 + \beta x_i + \varepsilon_i \quad (3.15)$$

Where yi is the ith observation of the dependant variable (response), x_i is the ith value of the independent variable (years), β_0 is the intercept (constant), β is the slope of the regression line (trend of the climatic variables), ε_i is random error. The regression analysis was carried out SPSS version 17.0 software. It is expected that the statistics in Eq. (3.16) follows student's t-distribution that has $n-2$ degrees of freedom (Longobardi, 2009):

$$t = \frac{\beta}{\frac{\sum_{i=1}^{n}(y_i-\hat{y}_i)^2}{(n-2)\sum_{i=1}^{n}(x-\bar{x})^2}} \tag{3.16}$$

Where t is the student's t value, β is the slope (trend), n is the sample size, $y_i - \hat{y}_i$ is the error, $\bar{x}$ is the mean of the independent variable x, $n-2$ is the degrees of freedom. The term $\hat{y}_i$ is defined by the Eq. 3.17

$$\hat{y}_i = \beta_0 + x_1 \beta \tag{3.17}$$

The null hypothesis (H_o) that the trend in the climatic variables is not statistically significance is obtained when the computed value of t is less than the critical value. The alternative hypothesis (H_a) is obtained if the calculated value of t is greater than the critical value.

3.2.5.2 Sen's Estimator Slope

The Sen's estimator slope is highly applicable in detecting the extent of the trend in the time series climatic variable (Jain, 2012). In this method, the slopes (T_i) of all the data pairs were computed using Eq. 3.18 according to Jain (2012):

$$T_i = \frac{x_j - x_k}{j-k} \tag{3.18}$$

Where $i = 1, 2 \ldots \ldots \ldots \ldots N$, in which N is the number of observations, x_j and x_k are values of the climatic data at times $j$and k, respectively, for which ($j > k$). The median of these values of T_i is regarded as the Sen's estimator slope, which is calculated in Eq. 3.19 (Jain, 2012) as:

$$\beta = \begin{cases} T_{\frac{(N+1)}{2}} & if\ N\ is\ odd \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) & if\ N\ is\ even \end{cases} \quad (3.19)$$

If β has positive value, it signifies an inclining trend, while a negative value of β implies a declining trend in the climatic time series. The statistical significance of the trend is ascertained using the Mann Kendall test.

3.2.5.3 Mann Kendall test

This test was employed in order to determine the presence of trend or otherwise in the climatic variables and the statistical significance of the trend (Jain, 2012). The Mann Kendall indentified the null hypothesis (H_0) of the presence of trend versus the alternative hypothesis (H_a) that there is no trend. The Mann Kendall test can be applied to non normal distribution that has seasonality, missing values and unusual data (Attah, 2013). The climatic data were divided into: 1971-1980, 1981-1990, 1991-2000 and 2001-2010. The trends for the climatic data were then obtained.

The Mann Kendall (S) statistics is defined by (Jain, 2012; Longbardi, 2009; Karabulut, 2008) as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(x_j - x_i) \quad (3.20)$$

Where n is the number of data points, x is the observed climatic variable, $x_j > x_i$, taking $(x_j - x_i) = \theta$, the value of $sign\ (\theta)$ was obtained as follows :

$$sign\ (\theta) = \begin{cases} +1 \ldots\ldots & \theta > 0 \\ 0 \ldots\ldots & \theta = 0 \\ -1 \ldots\ldots & \theta < 0 \end{cases} \quad (3.21)$$

The Z statistics (standard normal deviate statistics) was estimated using (Jain, 2012; Longbardi, 2009; Karabulut, 2008) as:

$$Z = \begin{cases} \frac{S-1}{\sqrt{var(s)}} & if\ s > 0 \\ 0 & if\ s = 0 \\ \frac{S+1}{\sqrt{var}(s)} & if\ s < 0 \end{cases} \quad (3.22)$$

Where the variance, $var(s)$ is obtained using the Eq. 3.23

$$var(s) = \frac{n(n-1)(2n+5) - \sum_{q=1}^{p} t_q\,(t_q-1)(2t_q+5)}{18} \quad (3.23)$$

Where p is the number of tied groups (zero differences between the compared values of the climatic data), t_q is the number of the data points in the qth tied group.

The null hypothesis (H_0) is rejected and alternative hypothesis is accepted if the calculated value of $|Z| > Z_{\propto/2}$ at $\propto$ level of significance, otherwise the null hypothesis (H_a) is accepted (Jain, 2012). At $\propto = 0.05$, $Z_{\propto/2} = 1.96$ and at $\propto = 0.01$, $Z_{\propto/2} = 1.65$ (Attah, 2013).

3.2.6 Multiple Regression Analysis

Multiple regression analysis was carried out in order to determine the relationship between the climatic variables and crop yields. The analysis described the effects of the two independent variables jointly on the yields of the crops. The dependant variables (response) are the yields of maize, millet and sorghum, while the independent variables (predictors or explanatory) are the annual rainfall and annual mean temperature. The scatter plots (Appendix E) of the dependant variable against the independent variable for each of the three crops were plotted in order to determine the nature of the relationship. The scatter plots revealed non linear relationships between the crop yields and the climatic variables, hence the selection of multiple non linear regression analysis. The scatter plots were obtained using Excel, while the multiple non linear

regression analysis was performed using Sigma plot 11.0 software. The general multiple linear regression model equation is shown in Eq. 3.24:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_n X_n + \varepsilon_i \quad (3.24)$$

Where Y is the dependant variable (response), β_0 is the intercept, X_1, X_2 and X_n are the independent variables (predictors), β_1, β_2 and β_n are the coefficients of X_1, X_2 and X_n, respectively and ε_i is the error that has normal distribution with mean of zero.

For multiple linear regressions with only two independent variables, Eq. 3.24 is reduced to Eq. 3.25 as shown:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon_i \quad (3.25)$$

All terms as previously defined

The multiple regression equation was transformed to, multiple non linear regression equation by taking the logarithm base 10 of the dependant variable and the independent variables as shown in Eq. 3.26.

$$\log Y = \beta_0 + \beta_1 \log X_1 + \beta_2 \log X_2 \quad (3.26)$$

For the three cereal crops, the following multiple non linear regression equations were applied:

$$\log M_{zy} = \beta_0 + \beta_1 \log R + \beta_2 \log T \quad (3.27)$$

$$\log M_{ly} = \beta_0 + \beta_1 \log R + \beta_2 \log T \quad (3.28)$$

$$\log S_{gy} = \beta_0 + \beta_1 \log R + \beta_2 \log T \quad (2.29)$$

In which M_{zy}, M_{ly} and S_{gy} are the annual maize, millet and sorghum yields, respectively, R is the annual rainfall and T is the annual mean temperature, β_0, β_1 and β_2 as previously defined.

The coefficient of determination (R^2) explained the proportion or fraction of the variation in the response variable that can be accounted for by the two predictors in the multiple regression models (Attah, 2013).

3.2.7 Model Validation and Statistical Evaluation

The following statistical error measurements were used to for the evaluation and validation of the developed statistical regression models for the three crops:

3.2.7.1 Total Error

The total error was obtained using Eq. 3.30. The lower the total error, the better the accuracy, validity and relevant fitness of the developed statistical model (Oke and Aderounmu, 2013).

$$E^2 = \sum_{i=1}^{n}\left(y_{ob} - y_{pr}\right)^2 \quad (3.30)$$

Where E^2 is the total error, y_{ob} is the observed yield, y_{pr} is the predicted yield and n is number of observations

3.2.7.2 Absolute Error

The absolute error was determined using Eq. 3.31. The smaller the absolute error, the better the correctness, validity as well as the relative fitness of the developed statistical model (Oke and Aderounmu, 2013)

$$AE = \sum_{i=1}^{n}\left|\left(y_{ob} - y_{pr}\right)\right| \quad (3.31)$$

Where AE is the absolute error, other terms as previously define

3.2.7.3 Mean Absolute Error

It was computed using Eq. 3.32. The less the mean absolute error, the better the correctness, validity and fitness of the developed statistical model (Oke and Aderounmu, 2013).

$$MAE = \frac{\sum_{i=1}^{n}|(y_{ob}-y_{pr})|}{n} \quad (3.32)$$

Where MAE is the mean absolute error, other terms as previously define

3.2.7.4 Mean Squared Error

The mean squared error was computed using Eq. 3.33. The lower the mean squared error, the better the correctness, fitness and validity of the developed model (Oke and Aderounmu, 2013).

$$MSE = \sqrt{\sum_{i=1}^{n}\left(y_{ob} - y_{pr}\right)^2} \quad (3.33)$$

Where MSE is the mean absolute error, other terms as previously define

3.2.8 Administration of Questionnaires

One thousand (1000) Structured-Questionnaires were self-administered in the area in order to determine the level of awareness of the residents of the area on climate change, their perceptions on climate change and variability. In order to obtain proper coverage, the area was divided into 9 sections. The names of each section as well as the number of Questionnaires administered in it are stated in Table 3.1:

Table 3.1: No of questionnaires administered in the area

Sections	No of questionnaires	% of the questionnaires
Zaria city	440	44.0
Tudun-Wada	210	21.0
Dakace	50	5.0
Tukur-Tukur	75	7.5
Wusasa	35	3.5
Gwargaje	50	5.0
Tudun-Jukun	49	4.9
Gyellesu	60	6.0
Offices	31	3.1
Total	1000	100

The numbers of the Questionnaires administered in the 9 sections of the area were varied due to the population size of each part and as such the differences in the number of Questionnaires administered in the 9 sections of the area are due the population sizes. The part with higher population received higher numbers of Questionnaires. The Questionnaires were analysed using the SPSS version 17.0.

3.2.9 Focus Group Discussions (FGD)

Focus Group Discussions was conducted with twenty farmers to obtain some information on the impacts of climate variability and change on their agricultural activities. The formats or questions of the Focus Group Discussions are as follows:

i. What kind of change in climate do you notice in the recent years?
ii. Has there been change in rainfall pattern?
iii. How does climate variability affect your agricultural activities?

iv. What effects do climate variability has on your agricultural yield?

v. What are other factors that affect your agricultural yield other than climate variability?

vi. Do you have climate forecasting tools to guide you?

3.2.10 Key Informant Interviews (KII)

Key Informant Interviews were conducted with a view to getting some information on climate variability and change and its possible impacts on agriculture and health. The interviews were conducted with: Assistant Director Extension and Training, National Agricultural Extension and Research Liaison Services (N.A.E.R.L.S), Ahmadu Bello University, Zaria; Head of Department (Science), Division of Agricultural Colleges (D.A.C), Ahmadu Bello University, Zaria; Officer-in-Charge of Meteorological Section, Institute for Agricultural Research (I.A.R), Ahmadu Bello University Zaria; Associate Professor/Consultant, Department of Medicine, Ahmadu Bello University Teaching Hospital Zaria; The formats for the interviews were as follows:

Interviews with Assistant Director Extension and Training, N.A.E.R.L.S, Ahmadu Bello University Zaria:

i. What are the types of variables that affect agricultural yield?

ii. What are the climatic variables that affect agricultural yield?

iii. What are the non-climatic variables that affect agricultural yield?

iv. How do climate change impacts affect agricultural activities?

v. How does drought, in particular affect agricultural yield?

Interviews with Head of Department (Science), D.A.C, Ahmadu Bello University, Zaria:

i. What are some basic indicators of climate change?

ii. How does climate change affect agricultural activities?

iii. How does flood in particular affects crops?

Interviews with Officer-in-Charge of Meteorological Section, I.A.R, Ahmadu Bello University Zaria:

i. Is climate changing?

ii. What do you observe about the rainfall and temperature based on the measurements you do in I.A.R?

iii. Do you record drought in some years?

Interviews with Associate Professor/Consultant, Department of Medicine, Ahmadu Bello University, Teaching Hospital, Zaria:

i. Are there types of climate change impacts on the health of people?

ii. What are the direct impacts of climate change on health of people?

iii. What are the indirect impacts of climate change on health of people?

iv. How do droughts and floods affect the health of people?

v. What can you add about the impact of climate change on the health of the people?

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Homogeneity Test

Table 4.1 showed the homogeneity test performed on the climatic variables. The result revealed that the annual rainfall, maximum, minimum and mean temperatures during the four decades (1971-2010) were homogenous. The Z statistics is also shown in the Table, in which the result signified that, the homogeneity of all the climatic elements were statistically significant at 95% confidence level as the computed Z value was less than 1.96 for all the climatic elements considered. The data homogeneity is important in identifying the reliability as well as the suitability of the time series data for climate change and variability studies (Toumenvirta, 2002). This implied that the climatic data were good and reliable for the climate variability and change analysis.

Table 4.1: Homogeneity test for the climatic variables

	Climatic variables			
	Rainfall	Maximum Temperature	Minimum Temperature	Mean Temperature
Z value	1.6*	1.32*	0.69*	1.32*

* Z value is significant at α=0.05

4.2 Variations in the Annual Climatic Variables

Figures 4.1 - 4.4 present the annual variations in the rainfall, maximum, minimum and mean temperatures, respectively during the four decades (1971-2010). The Figs. revealed that some years recorded higher values of the climatic variables than other years.

Figure 4.1 depicts the annual variations in the rainfall during the four decades. It was discovered that 1978 year recorded the highest rainfall value of 1349 mm followed by 1998, 1991 and 2007 having 1266 mm, 1239 mm and 1220 mm respectively; but 1997 and 2003 have approximate annual rainfall values of 1200 mm each. On the other hand, 1983 recorded the lowest rainfall value of 686 mm. The Figure however showed that the rainfall fluctuates during the four decades because some years recorded higher rainfall than others, while some years recorded lower rainfall than others.

The implication of heavy rainfall events is the destruction of crops, soil erosion, difficulty in cultivating land due to water logging of soils (IPCC, 2007c). Similarly, seasonal and spatial rainfall variation to a higher extent affect farming activities as most farmers rely on favourable climatic condition to commence their farming activities (Bhandari, 2013). However, precipitation characteristics play a vital role in determining agricultural yield of crops (Audu, 2012). When the rainfall is optimum, it would be accompanied with high crop yield and when the rainfall is higher than normal, it can result to the destruction of crops (Audu, 2012).

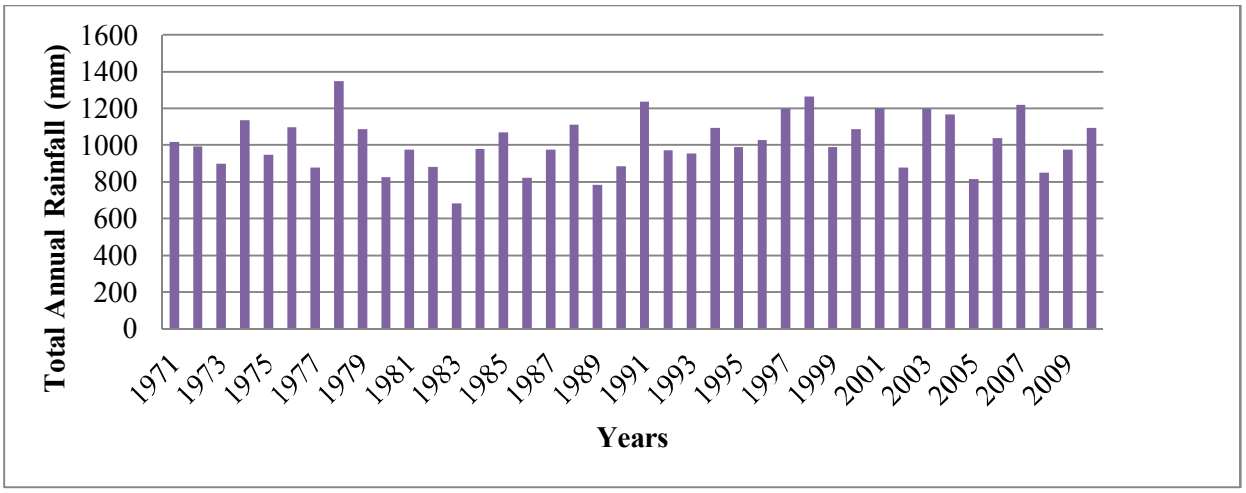


Figure 4.1: Variations in the annual rainfall (1971-2010)

Figure 4.2 presents the annual variations in the maximum temperatures during the four decades (1971-2010). It was discovered that 2006 year had the highest maximum temperature of 34.6^{o}C; it was followed by 2007, 2005 and 1973 having values of: 34.1^{o}C, 33.7^{o}C and 33.1^{o}C, respectively. However, 1975, 1977 and 1992 recorded maximum temperature values of: 31.1^{o}C each; while 1978 and 1980 had 31.0^{o}C and 31.2^{o}C, respectively. On the other hand, 1989 has the lowest maximum temperature value of 30.8^{o}C. The Figure revealed that there were changes in the maximum temperatures recorded, as some years recorded higher maximum temperatures than others, while some recording lower maximum temperatures than others.

Most agricultural crops are negatively affected by increase in the maximum temperature (Bhandari, 2013). However, extremely warmer condition can lead to decrease in the yield of crops because the soil-water availability is impaired (IPCC, 2007c). Additionally, higher maximum temperature is capable of resulting to respiration to overruled photosynthesis thereby leading to reduction in the net crop yield (Rasul et al, 2014).

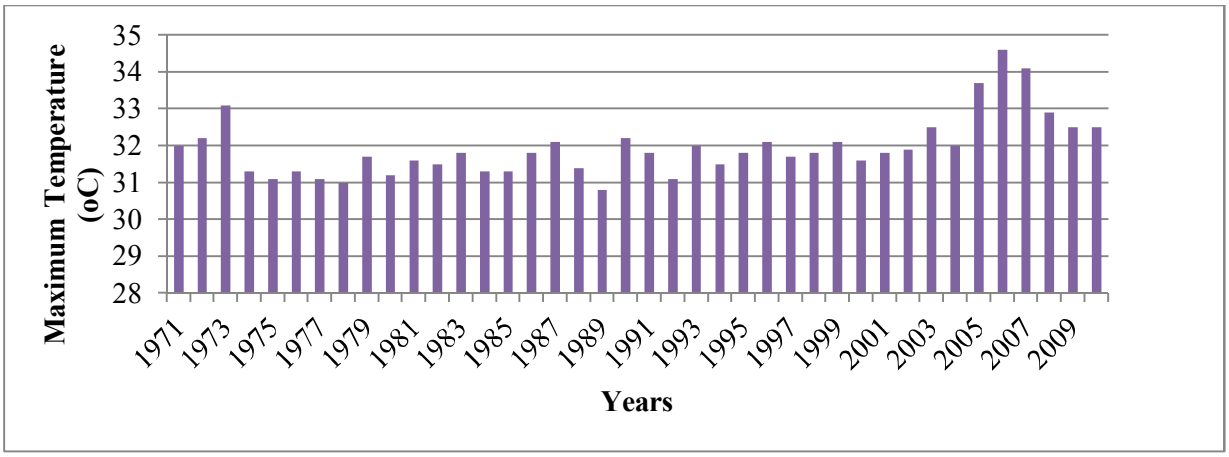


Figure 4.2: Variations in the annual maximum temperature (1971-2010)

Figure 4.3 contains the yearly variations in the minimum temperatures during the four decades (1971-2010). It was discovered that 2010 year recorded the highest minimum temperature value of 20.1^{o}C; it was followed by 2009, 2006 and 1998 having minimum temperature values of 20.0^{o}C each; 1993 and 1999 recorded minimum temperatures of 19.9^{o}C each; while 1997, 2002, 2003 and 2004 recorded minimum temperatures of 19.6^{o}C each during the four decades. On the other hand, 1980 and 1981 recorded the lowest minimum temperature values of 17.7^{o}C each. However, the Figure revealed some fluctuations in the minimum temperatures over the four decades with some years recording higher minimum temperature than the others, while some years recorded lower minimum temperature than others.

It is important to note that higher temperatures are harmful to crops. The increase in temperature affects the physiological processes needed for crop growth and development (Rasul et al, 2014).

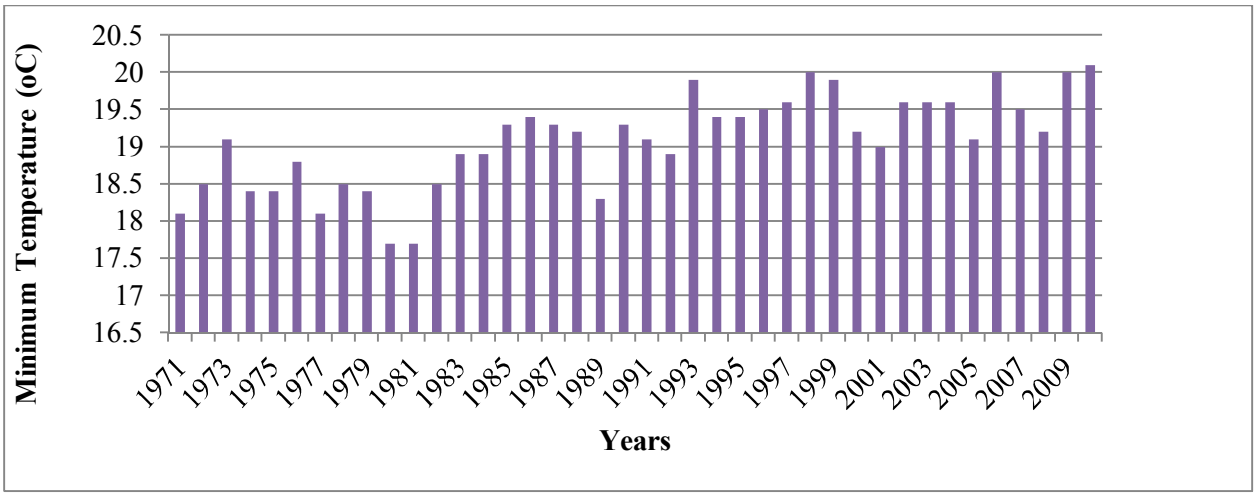


Figure 4.3: Variations in the annual minimum Temperature (1971-2010)

Figure 4.4 depicts the yearly variations in the annual mean temperature recorded during the four decades (1971-2010). From the Figure, the highest mean temperature value of 27.3^{o}C occurred in year 2006; this is to say that year 2006 was the warmest year amongst the forty years considered in this study. Meanwhile, the second warmest year was the 2007 having value of 26.8^{o}C; it was followed by 2005, 2010, 2009, 1973, 2003 and 1993 having values of: 26.4^{o}C, 26.3^{o}C, 26.3^{o}C, 26.2^{o}C, 26.1^{o}C and 26.0^{o}C, respectively. On the other hand, the least warm years were 1980 and 1989 which recorded mean temperatures of 24.5^{o}C each. However, the Figure revealed some changes in the mean temperatures recorded during the four decades with some years recording higher mean temperature than others.

The yearly variation in the climatic elements has notable implication on the sustainable agriculture (Bhandari, 2013). The development and growth of a crop depends upon the exposure of the crop to mean temperature during its growing stage (Ramirez et al, 2003).

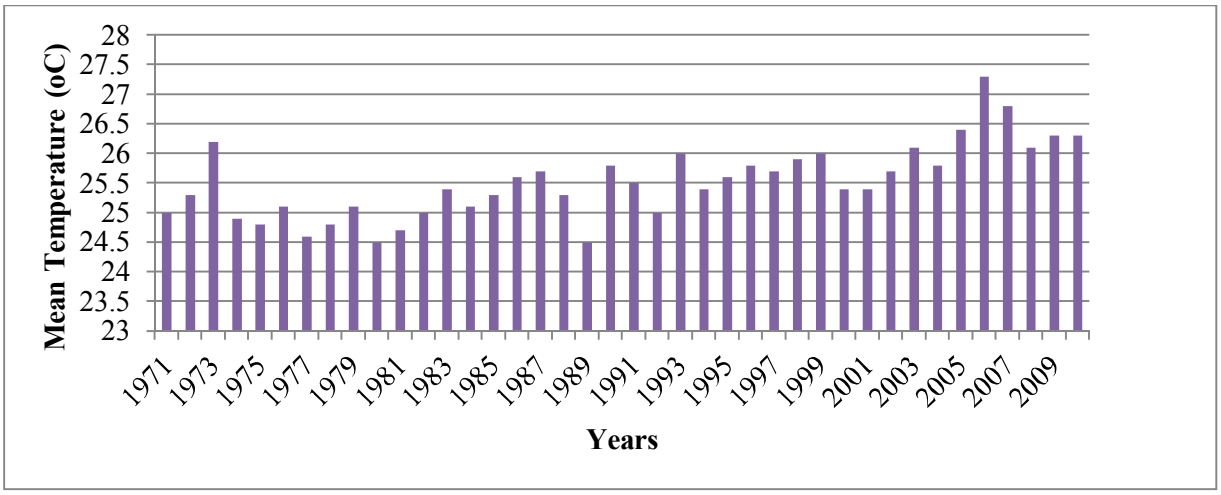


Figure 4.4: Variations in the annual mean Temperature (1971-2010)

4.3 Descriptive Statistics of the Climatic Variables

The descriptive statistics of the climatic variables during the four decades (1971-2010) is presented in the Table 4.2. The statistical parameters in the table are: maximum, minimum, mean, median and standard deviation

Table 4.2: Descriptive statistics of the climatic variables (1971-2010)

Statistical parameters	Climatic variables			
	Maximum temperature (^{o}C)	Minimum temperature (^{o}C)	Mean temperature (^{o}C)	Rainfall (mm)
Maximum	34.6	20.1	27.3	1349
Minimum	30.8	17.7	24.5	686
Mean	31.9	19.1	25.5	1018
Median	31.8	19.2	25.5	992
Standard deviation	0.815	0.636	0.629	148

The highest maximum temperature during the four decades was 34.6^{o}C; while the lowest value was 30.8^{o}C with the corresponding mean, median and standard deviation of: 31.9^{o}C, 31.8^{o}C and

0.815^{o}C, respectively on annual basis. On the other hand, the minimum temperature had the highest value of 20.1^{o}C and lowest value of 17.7^{o}C, with the corresponding mean, median and standard deviation of: 19.0^{o}C, 20.0^{o}C and 0.684^{o}C, respectively. However, the mean temperature recorded the highest value of 27.3^{o}C and lowest value of 24.5^{o}C with the corresponding mean, median and standard deviation of: 25.5^{o}C, 25.5^{o}C and 0.629^{o}C, respectively. The annual rainfall recorded the highest value of 1349 mm and lowest value of 686 mm, with the corresponding mean, median and standard deviation of: 1018 mm, 992 mm and 148 mm, respectively. The result implied that the rainfall recorded highest variability during the four decades as it had the highest standard deviation (148mm) amongst the climatic variables. It was followed by the maximum temperature (0.815), minimum temperature (0.636), while the mean temperature was the least (0.629). The variation of these climatic elements has great consequences on reliable agriculture as reported by Bhandari (2013). The crop growth however, relies on the degree of hotness or coldness to which the crop is subjected to when it is growing (Ramirez et al, 2003).

4.4 Variability of the Climatic Elements

The variability of the maximum temperature, minimum temperature, mean temperature and annual rainfalls during the four decades (1971-2010) are shown in Table 4.3. The variability was in terms of the differences between the means, standard deviations, coefficient of variability, skewness and kurtosis of two the equal-length time scales of 1971-2000 and 1981-2010, respectively. The overall (1971-2010) mean, standard deviation, coefficient of variability, skewness and kurtosis are also shown in the Table.

Table 4.3: Variability of the climatic elements within Zaria (1971-2010)

Statistical parameters	Periods	Maximum temperature	Minimum temperature	Mean temperature	Annual rainfall
Mean ($\bar{x}$)	1971-2010	31.9	19.0	25.5	1018
	1971-2000	31.6	18.9	25.3	1009
	1981-2010	32.1	19.2	25.7	1016
	Variability	-0.5	-0.3	-0.4	-7
Standard deviation (δ)	1971-2010	0.816	0.684	0.630	148
	1971-2000	0.542	0.688	0.512	147
	1981-2010	0.853	0.455	0.622	149
	Variability	-0.311	0.233	-0.110	-2
Coefficient of variability (CV)	1971-2010	0.026	0.036	0.025	0.145
	1971-2000	0.017	0.036	0.020	0.145
	1981-2010	0.027	0.024	0.024	0.146
	Variability	-0.010	0.012	-0.004	-0.001
Skewness (g_1)	1971-2010	1.545	-0.293	0.525	0.072
	1971-2000	0.765	-0.172	0.026	0.196
	1981-2010	1.591	-0.850	0.473	-0.164
	Variability	-0.826	0.678	-0.447	0.360
Kurtosis (g_2)	1971-2010	2.784	-0.662	0.338	-0.363
	1971-2000	1.591	-0.643	-0.874	0.248
	1981-2010	2.820	0.708	1.022	-0.593
	Variability	-1.229	-1.351	-1.896	0.841

In Table 4.3, all the climatic elements recorded some level of variability. The variability of maximum, minimum, mean temperatures and annual rainfall are: -0.5^{o}C, -0.3^{o}C, -0.4^{o}C and -7 mm, respectively using the differences between the means of the equal-length time scales of 1971-2000 and 1981-2010, respectively. The negative sign signified that the mean of base line time scale (1971-2000) is lower than the mean of the second time scale (1981-2010) which in turn implies variability of the climatic elements. However, in terms of the variability using the differences between the standard deviations of the equal-length time scales of the climatic

variables, the recorded variabilities are: -0.311^{o}C, 0.233^{o}C, -0.110^{o}C and -2 mm for maximum temperature, minimum temperature, mean temperature and annual rainfall, respectively.

The coefficient of variability (CV) of the maximum temperature, minimum temperature, mean temperature and annual rainfall from (1971-2010) are: 0.026 (2.6%), 0.036 (3.6%), 0.025 (2.5%) and 0.145 (14.5%), respectively indicating low variability. The rainfall had the highest CV value as compared to maximum, minimum and mean temperatures. This implied that amongst the climatic elements, rainfall recorded the greatest climate variability. On the other hand, the CVs of the climatic variables using the time scales of 1971-2000 also recorded some changes. The values are: 0.017 (1.7%), 0.036 (3.6%), 0.020 (2.0%) and 0.145 (14.5%), respectively for maximum temperature, minimum temperature, mean temperature and annual rainfall; while for the 1981-2010 time scale, the CVs are: 0.027 (2.7%), 0.024 (2.4%), 0.024 (2.4%) and 0.146 (14.6%), respectively. This implied that for the two equal- length time scale considered, all the climatic elements were associated with low variability.

Similarly, the differences in the skewness of the two equal-length time scales for maximum temperature, minimum temperature, mean temperature and annual rainfall are: -0.826, 0.678, -0.447 and 0.360, respectively; while the differences in the kurtosis of the two equal-length time scales for maximum temperature, minimum temperature, mean temperature and annual rainfall are: -1.229, -1.351, -1.896 and 0.841, respectively, implying that the climatic data were skewed.

Additionally, the analysis of the distribution of the historic data (skewness) for the 1971-2010 showed that the maximum temperature, mean temperature and rainfall had the positive values of 1.545, 0.525 and 0.072, respectively; implying that they were right skewed. Attah (2013) also found the distribution of the historic data for the period of 1960 - 2006 to be right skewed and

which was in accordance with the Nigerian Meteorological Agency (NIMET) observation of the late onset of and early cessation of rainfall since 1911, leading to shortening of rainy season and in the occurrence of August break.

The onset of rainfall marks the planting time, its distribution and duration lead to reasonable crop yield; while the cessation time marks the harvesting period of the crops (Audu, 2012). The decrease in the onset and cessation dates of rainfall, result to decrease in the length of the rainy season as well as the associated reduction in the yield of the crops as reported by Sawa and Adebayo (2010). It can also affect the hydrologic characteristics of an area as the water availability can be impaired.

4.5 Anomalies of the Climatic Variables

The anomalies of the climatic variables during the four decades (1971-2010) were computed in order to know the deviation of each climatic variable from the established normal climate. The established normal rainfall, maximum, minimum and mean temperatures are: 1009 mm, 31.6^{o}C, 18.9^{o}C and 25.3^{o}C, respectively. The deviation from this climate normal signifies climate variability.

Figure 4.5 depicts the rainfall anomaly during the four decades (1971-2010). The base line as can be observed in the Figure is the line that correspond to zero and it is the average rainfall record of thirty years which also implies the normal rainfall (1009 mm). The positive values (above zero) signify rainfalls that were higher than normal (wet); while the negative values (below zero) imply rainfalls that were lower than normal (dry). From the rainfall anomaly, 19 years (47.5%) recorded wet due to the fact that the rainfalls that occurred in those years were greater than the normal rainfall; while 21 years (52.5%) recorded dry because the rainfalls that occurred in those years were below normal rainfall.

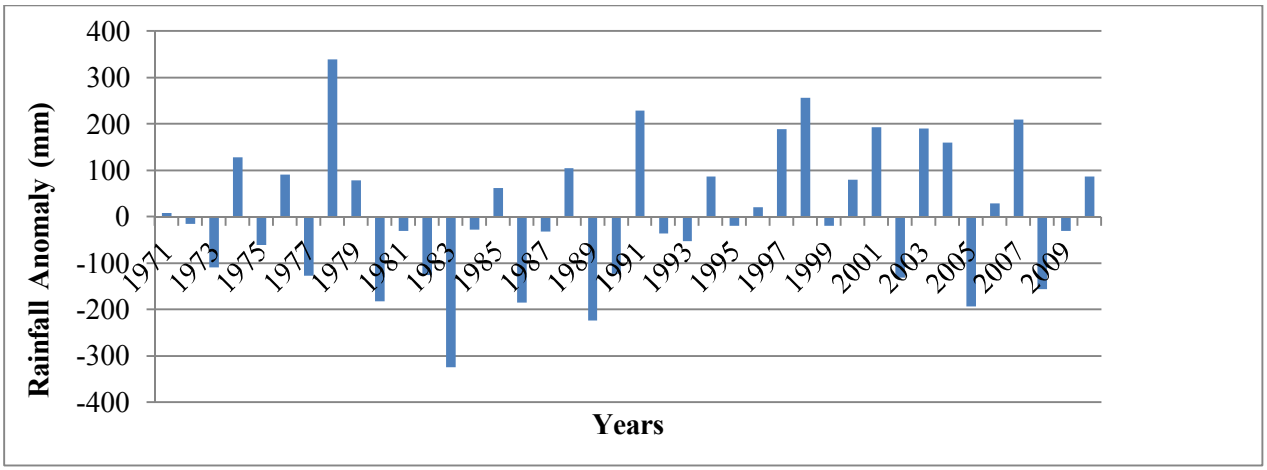


Figure 4.5: Rainfall anomaly (1971-2010)

The greatest wet of 340 mm occurred in 1978, followed by 1998 and 1991 having 257 mm and 230 mm, respectively; while the least wet of 9 mm happened in 1971. In addition, other years that recorded annual rainfalls higher than normal recorded wet that ranged between those of 1971 and 1978. Meanwhile, Attah (2013) obtained an increase in rainfall of 100 mm (26%) per decade relative to the average value for the period in lower Kaduna catchment. However, the greatest dry of 323 mm happened in 1983; while the least dry of 15 mm occurred in 1972. Other years that recorded deficit of rainfall had values between those of 1972 and 1983. It can be said that the wet that occurred from 1971-2010 in the area ranged from 9 mm – 340 mm; while the dry ranged from 15 mm – 323 mm.

The occurrences of wet or dry during the forty years had no definite pattern. It was observed that the period 1971 recorded wet of 9 mm; periods 1972 - 1973 recorded dry of 15 mm and 108 mm, respectively; while period 1974 recorded wet of 129 mm. Then 1975 had dry of 60 mm, the next two years 1976 and 1977 recorded a wet and a dry of 91 mm and 127 mm, respectively. The next two consecutive years 1978 and 1979 were associated with wet of 340 mm and 80 mm, respectively; while the next five consecutive years (1980, 1981, 1982, 1983 and 1984) recorded

dry of: 182 mm, 30 mm, 125 mm, 323 mm and 28 mm, respectively. In addition, the year following the five years of dry (1985) recorded another wet of 63 mm and then the next two consecutive years 1986 and 1987 encountered dry of: 184 mm and 31 mm, respectively. Nevertheless, after the dry of 1987, a wet of 106 mm was recorded in 1988 and then the next two consecutive years 1989 and 1990 encountered dry of: 223 mm and 123 mm, respectively. Following the dry of 1989 and 1990, 1991 recorded a wet of 230 mm; while the next two consecutive years (1992 and 1993) recorded dry of: 36 mm and 52 mm, respectively. The dry of 1992 and 1993 were followed by a wet of 88 mm in 1994 and then a dry of 18 mm in 1995.

Additionally, the next three consecutive years (1996, 1997 and 1998) were associated with wets of: 21 mm, 190 mm and 257 mm, respectively and then 1999 recorded a dry of 18 mm. Following the dry of 1999, the two periods (2000 and 2001) were associated with wet of: 81 mm and 193 mm, respectively and then followed by a dry of 131 mm in 2002. The next two consecutive years, 2003 and 2004 had wet of: 191 mm and 160 mm, respectively and then followed by a dry of 193 mm in 2005. Then the next two consecutive years 2006 and 2007, were associated with wet of: 30 mm and 211 mm, respectively; implying that 2007 recorded wet of 181 mm more than 2006. The next two consecutive years 2008 and 2009 recorded dry of: 156 mm and 30 mm, respectively and then followed by a wet of 88 mm in 2010. It can now be said that the occurrences of wet and dry have no definite pattern but one or more years of wet could be followed by one or more years of dry and vice versa but the commonest pattern obtained in this study is that one year of dry could be accompanied by two years of wet.

Climate variability poses a great challenge and it is a limiting factor in agriculture because of the practices of rain-fed agriculture (Audu, 2012). Agricultural drought results to the reduction in

moisture availability in the soil below the optimum amount needed by the crop during various stages of its growth cycle, leading to impaired growth and decreased in yield (Bhandari, 2013).

Figure 4.6 depicts the anomalies of Maximum temperature, during the four decades (1971-2010). The reference line in each Figure represents the mean value of the climatic variable over thirty (30) years and which in turn implies the climate normal. However, any yearly mean value that is above the reference line (positive) signifies that the year is warmer than normal; while any yearly average value of the climatic variable that is below the reference line (negative) signifies that the year is less warm than normal.

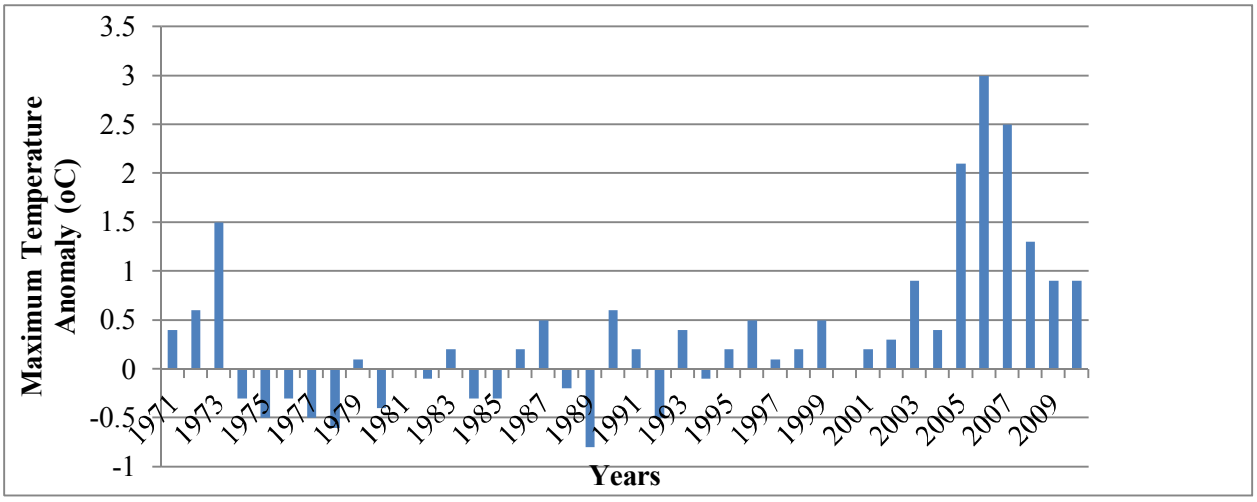


Figure 4.6: Maximum temperature anomaly (1971-2010)

In Fig. 4.6, year 2006 recorded the highest hot which was higher than normal by 3.00^{o}C. It was followed by 2007, 2005 and 1973 which were higher than normal by: 2.50^{o}C, 2.10^{o}C and 1.50^{o}C, respectively; while 1979 had the least hot which was higher than normal by 0.10^{o}C but 1981 and 2000 were associated with normal maximum temperatures as they recorded maximum temperature of 31.60^{o}C each, which tallied with the established normal maximum temperature. The 3.00^{o}C obtained in this study is lower than the value of 15.30^{o}C obtained by Attah (2013) in

the lower Kaduna Catchment. Other years that recorded higher maximum temperature than normal had values between 0.10^{o}C - 3.00^{o}C. However, 1989 had the highest deficit, which was lower than normal maximum temperature by 0.80^{o}C. It was followed by 1978 which was lower than normal by 0.60^{o}C; but 1975, 1977 and 1992 were below normal by 0.50^{o}C each. However, 1982 and 1994 recorded the least deficit of maximum temperature of 0.10^{o}C each. Other years that recorded lower maximum temperature than normal had values between 0.10^{o}C - 0.80^{o}C.

In addition, 25 years (62.5%) recorded higher maximum temperature than normal; 13 years (32.5%) recorded lower maximum temperature than normal; while only 2 years (5%) recorded normal maximum temperature.

Figure 4.7 contains the minimum temperature anomaly during the four decades (1971-2010) in which year 2010 had the highest surplus of the minimum temperature. The 2010 was 1.20^{o}C higher than the established normal minimum temperature (18.90^{o}C). This value is lower than the value of 8.20^{o}C obtained by Attah (2013) in the lower Kaduna Catchment. It was followed by 2006, 2009, 1998 and 1999 which were higher than the normal by 1.10^{o}C, 1.10^{o}C, 1.10^{o}C and 1.00^{o}C, respectively; but 2001 had the least surplus of minimum temperature as it was higher than normal by 0.10^{o}C. This implied that other years that recorded higher minimum temperature than normal had values between 0.10^{o}C - 1.20^{o}C.

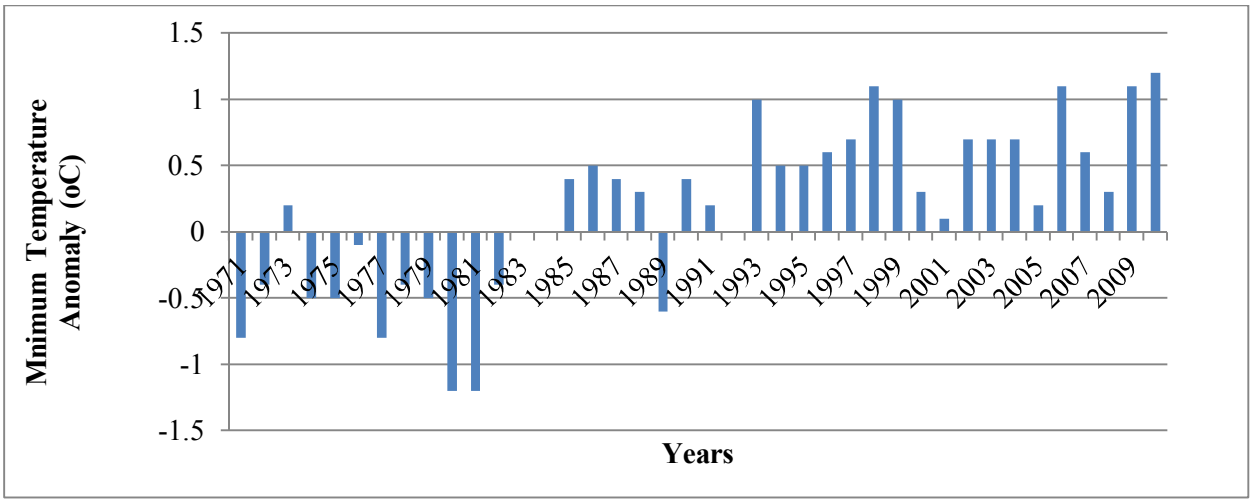


Figure 4.7: Minimum temperature anomaly (1971-2010)

On the other hand, 1983, 1984 and 1992 recorded normal minimum temperature as they had the same value with the established normal minimum temperature. However, 1980 and 1981 had the highest deficits of minimum temperature which were below normal by 1.20^{o}C each. They were followed by 1971 having deficit of 0.80^{o}C, but 1976 has the least deficit because it was lower than normal by 0.10^{o}C. This implied that other years that recorded lower minimum temperatures than normal, recorded values between 0.10^{o}C - 1.20^{o}C. However, 25 years (62.5%) recorded higher minimum temperature than normal; 12 years (30%) recorded lower minimum temperature than normal; while 3 years (7.5%) had normal minimum temperature.

Figure 4.8 contains the mean temperature anomaly during the four decades (1971-2010) in which year 2006 had the highest surplus of the mean temperature which was higher than the normal mean temperature by 2.00^{o}C. It was followed by 2007, 2005, 2009, 2010 and 1973 which were higher than normal by: 1.50^{o}C, 1.10^{o}C, 1.00^{o}C, 1.00^{o}C and 0.90^{o}C, respectively. On the other hand, 1983, 1994, 2000 and 2001 were associated with the least surplus of the mean temperatures which were higher than normal by 0.10^{o}C each. This implied that other years that

recorded higher mean temperatures than normal recorded values between 0.10°C - 2.00°C. Nevertheless, 1980 and 1989 had the highest deficit of mean temperatures which were lower than normal by 0.80°C each. They were followed by 1977, 1981, 1975, 1978, and 1974 which were lower than normal by: 0.70°C, 0.60°C, 0.50°C, 0.50°C and 0.40°C, respectively. On the other hand, 1976, 1979 and 1984 recorded the least deficit of mean temperatures which were lower than normal by 0.20°C each. Other years that recorded lower mean temperatures than normal recorded values between 0.20°C - 0.80°C. However, 1972, 1985 and 1988 recorded normal mean temperatures due to the fact that their values tallied with the established normal mean temperature (25.30°C).

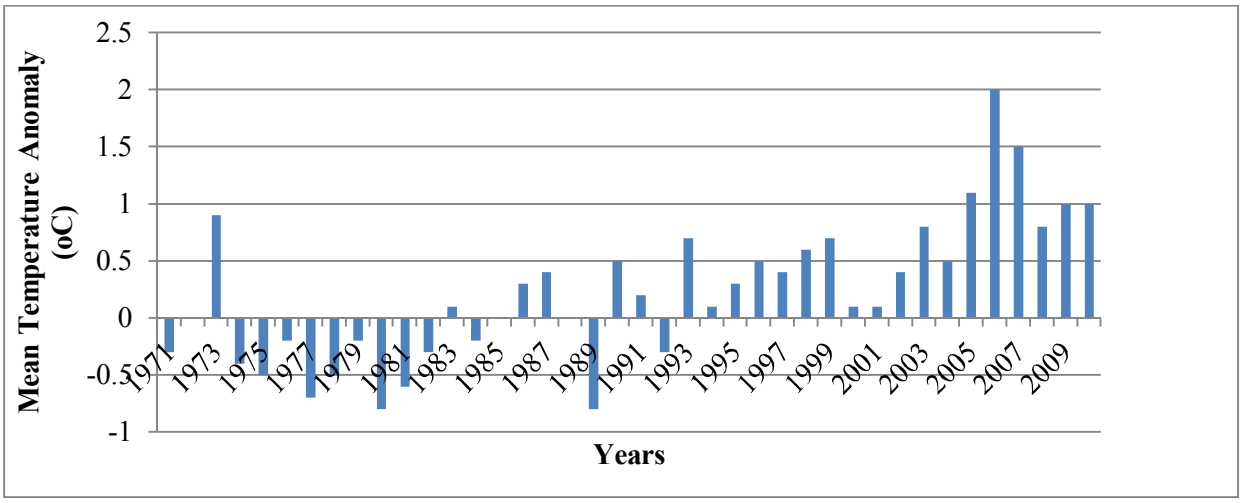


Figure 4.8: Mean temperature anomaly (1971-2010)

Additionally, 24 years (60.0%) recorded higher mean temperatures than normal; 13 years (32.5%) recorded lower mean temperatures than normal; while 3 years (7.5%) recorded normal mean temperatures. It was also discovered that 9 years in the 1991-2000 decade recorded higher mean temperatures than normal; while all the 10 years in the last decade (2001-2010) recorded

higher mean temperatures than normal, which indicated that the climate is changing and the area as well the country are becoming warmer than before and that also tallied with the global trend.

Odjugo (2010) found that the air temperature in Nigeria was steadily increasing especially from the 1970s. However, between 1901-1935 and 1936-1970 climatic periods, temperature anomalies were below the 1971-2005 normal, but 22 years (63%) out of the 35 years were above the normal between 1971 and 2005. The temperature anomalies showed that climate change signal is stronger as from the 1970s and concluded that Nigeria like most part of the world is experiencing the basic features of climate change. On the other hand, the mean temperature anomaly in this study revealed that 19 years out of 35 years (54%) between 1971 and 2005 were above normal mean temperature. This implied that between 1971 and 2005, Nigeria had more years that recorded higher mean temperatures than normal than the area.

Table 4.4 extracts the years in which the rainfalls were higher than normal (wet) or lower than normal (dry) in relation to increase in the mean temperature (higher than normal), decrease in mean temperature (lower than normal) or normal mean temperature. It was discovered that out of the 19 years that recorded wet, 12 years were associated with increase in mean temperatures; 5 years were associated with decrease in mean temperatures; while the remaining 2 years were associated with normal mean temperature.

Similarly, out of the 21 years that recorded dry, 12 years were associated with increase in the mean temperatures; 8 years were associated with decrease in the mean temperatures; while the remaining 1 year was associated with normal mean temperature. With this, it can be said that the occurrence of wet or dry could be associated with increase in mean temperature, decrease in mean temperature or normal mean temperature as it is seen in Table 4.4. The commonest recent

pattern based on the results obtained in the area is that a year of wet or dry is commonly accompanied by increase in mean temperature

Table 4.4: Comparisons of the years of occurrence of wet/dry in relation to increase, decrease or normal mean temperature

Years	Wet/dry	Increase/decrease/normal mean temperature
1971	wet	decrease
1972	dry	normal
1973	dry	increase
1974	wet	decrease
1975	dry	decrease
1976	wet	decrease
1977	dry	decrease
1978	wet	decrease
1979	wet	decrease
1980	dry	decrease
1981	dry	decrease
1982	dry	decrease
1983	dry	increase
1984	dry	decrease
1985	wet	normal
1986	dry	increase
1987	dry	increase
1988	wet	normal
1989	dry	decrease

Table 4.4 Contd.

1990	dry	increase
1991	wet	increase
1992	dry	decrease
1993	dry	increase
1994	wet	increase
1995	dry	increase
1996	wet	increase
1997	wet	increase
1998	wet	increase
1999	dry	increase
2000	wet	increase
2001	wet	increase
2002	dry	increase
2003	wet	increase
2004	wet	increase
2005	dry	increase
2006	wet	increase
2007	wet	increase
2008	dry	increase
2009	dry	increase
2010	wet	increase

4.6 Decadal Variability of the Climatic Variables

The decadal variability of the rainfall during the four decades (1971-2010) is presented in Table 4.5 using the normal rainfall of 1009 mm. The Table also contains the decadal mean and

percentage changes in the rainfall. The positive sign implies surplus of rainfall (wet); while the negative sign entails deficit of rainfall (dry) in the particular decade under consideration.

Table 4.5: Decadal variability of rainfall, μ_{30}= 1009mm (climate normal)

Decades	μ_{10} (mm)	μ_{10} - μ_{30} (mm)	% change
1971-1980	1024	15	1.5
1981-1990	920	-89	-8.8
1991-2000	1083	74	7.3
2001-2010	1045	36	3.6

From Table 4.5, it was discovered that 3 decades (75%) out of 4 decades were associated with wets; while only one decade (25%) encountered dry. The decades that recorded wets are: 1971-1980, 1991-2000 and 2001-2010; while 1981-1990 was the only decade that was associated with dry when compared to the established normal rainfall. Nevertheless, 1991-2000 decade had the wet of 74 mm (7.3%). It was followed by 2001-2010 that was 36 mm (3.6%) higher than normal; while 1971-1980 had the least wet of 15 mm (1.5%). On the other hand, 1981-1990 was the only decade that encountered dry of 89 mm (8.8%). It can be said that on decadal basis, the rainfall increase in the area during the last two successive decades (1991-2000 and 2001-2010).

However, despite decade 1971-1980 recorded wets, 5 years in it were associated with dry, while 5 years were associated with wets. Similarly, decade 1981-1990 recorded dry, but 2 years recorded wets in it, while the remaining 8 years recorded dry. More so, decade 1991-2000 recorded wet, but 6 years recorded dry in it, while the remaining 4 years recorded wets. Finally,

decade 2001-2010 recorded wet, but 4 years recorded dry in it; while the remaining 6 years recorded wets.

It is important to note that, while the decadal rainfall for the last two decades (1991-2000 and 2001-2010) in the area increased by 74 mm and 36 mm, respectively, Odjugo (2011) found the temporal rainfall pattern of Nigeria to showed declining trend. He reported that between 1901 and 1938, rainfall decrease was insignificant, but from 1971-2008 the decline became higher. The mean rainfall value for the 1901-1938 was 1571 mm, while it dropped to 1480 mm in 1971-2008, which revealed reduction of 91 mm. This implied that, while the area recorded increase in rainfall, Nigeria had recorded decrease in rainfall based on the two studies.

Additionally, the decadal rainfall result for 2001-2010 obtained is similar to some of the results obtained in some parts of the world. WMO (2011) reported that large parts of the Northern Hemisphere were associated with wetter-than-normal conditions during the last decade (2001-2010), especially the eastern United States of America, northern and eastern Canada, and many areas of Europe and central Asia. South America including Colombia, parts of northern and southern Brazil, Uruguay and northeastern Argentina encountered higher than normal rainfall, as recorded in most areas of South Africa, Indonesia and northern Australia. Conversely, other regions were recorded normal rainfall. The western United States of America, southwestern Canada, Alaska, most parts of southern and Western Europe, most parts of southern Asia, central Africa, central South America, and eastern and southeastern Australia were the most affected. In Nigeria, some areas recorded higher than normal rainfall as Attah (2013) reported that the rainfall in lower Kaduna catchment increased by 100mm per decade from 1971-2006.

Table 4.6 shows the decadal variability of the maximum temperature with the corresponding percentage changes in the maximum temperature during the four decades using the established normal maximum temperature of 31.6°C. The positive sign reveals that the decade recorded higher maximum temperature than normal; while the negative sign entails that the mean maximum temperature of that decade is lower than normal. It was discovered that 1971-1980 and 1981-1990 had normal maximum temperatures; while 1991-2000 and 2001-2010 were higher than the normal maximum temperature by 0.2 (0.6%) and 1.3°C (4.1%), respectively. It can then be said that the maximum temperature over the last two decades (1991-2000 and 2001-2010) was on the increase. However, 2001-2010 recorded the highest maximum temperature which was above the normal by 1.3°C. This result is similar to the global trend as WMO, (2011) reported that 48 out of 102 countries (47%) reported that their highest national maximum temperatures occurred in 2001-2010.

Table 4.6: Decadal variability of Maximum temperature, μ_{30}= 31.6°C (climate normal)

Decades	μ_{10} (°C)	μ_{10} - μ_{30} (°C)	% change
1971-1980	31.6	0.0	0.0
1981-1990	31.6	0.0	0.0
1991-2000	31.8	0.2	0.6
2001-2010	32.9	1.3	4.1

Table 4.7 depicts the decadal variability of the minimum temperatures from 1971 to 2010 using the normal minimum temperature of 18.90°C. It was discovered that 1971-1980 decade was associated with deficit of the minimum temperature, while 1981-1990 was normal. The

remaining two decades (1991-2000 and 2001-2010) encountered surplus of the minimum temperature. The first decade (1971-1980) recorded deficit of 0.5^{o}C (2.7%); while the last two decades (1991-2000 and 2001-2010) recorded increment of 0.6 (3.2%) and 0.7^{o}C (3.7%), respectively. Nevertheless, it was learnt that the minimum temperature was on the increase over the last two decades, which can affect crop growth and development (Ramirez et al, 2003).

Table 4.7: Decadal variability of Minimum temperature, μ_{30}= 18.90^{o}C (climate normal)

Decades	μ_{10} (^{o}C)	μ_{10}- μ_{30} (^{o}C)	% change
1971-1980	18.4	-0.5	-2.7
1981-1990	18.9	0.0	0.0
1991-2000	19.5	0.6	3.2
2001-2010	19.6	0.7	3.7

Table 4.8 contains the decadal variability of the mean temperature during the four decades (1971-2010) using the normal mean temperature of 25.30^{o}C. It was discovered that the first two decades (1971-1980 and 1981-1990) were associated with deficit of the mean temperature; while the remaining two decades (1991-2000 and 2001-2010) encountered surplus of the mean temperature. In other words, 50% of the four decades encountered deficit of the mean temperature; while 50% had surplus of the mean temperature. The first decade (1971-1980) recorded deficit of 0.3^{o}C (1.1%); while the second decade (1981-1990) recorded deficit of 0.1^{o}C (0.4%) implying that it was 0.2^{o}C lower than the first decade. However, the third decade (1991-2000) recorded an increment of 0.3^{o}C (1.2%); while the last decade (2001-2010) recorded an increment of 0.9^{o}C (3.6%), signifying that the last decade was warmer than the third decade by

0.6°C. This implied that the mean temperature was on the successive increase during the last two decades with each decade having higher mean temperature than the previous decade. The last decade (2001-2010) was the warmest decade as evidenced from Table 4.8, which in turn tallied with the global trend (WMO, 2011).

Table 4.8: Decadal variability of Mean temperature, μ_{30}= 25.30°C (climate normal)

Decades	μ_{10} (°C)	μ_{10} - μ_{30} (°C)	% change
1971-1980	25.0	-0.3	-1.1
1981-1990	25.2	-0.1	-0.4
1991-2000	25.6	0.3	1.2
2001-2010	26.2	0.9	3.6

Additionally, despite 1971-1980 decade recording lower mean temperature than normal, 8 years recorded lower mean temperature than normal in it; 1 year recorded higher mean temperature than normal; while the remaining 1 year recorded normal mean temperature. Similarly, despite 1981-1990 decade recording lower mean temperature than normal; 4 years recorded higher mean temperature than normal in it; 4 years recorded lower mean temperature than normal; while the remaining 2 years recorded normal mean temperature. However, despite 1991-2000 decade recording higher mean temperature than normal, 9 years recorded higher mean temperature than normal in it; while only 1 year recorded lower mean temperature than normal. Similarly, 2001-2010 decade recorded higher mean temperature than normal and all the years in it recorded warmer mean temperature than normal; no year in the decade recorded lower mean temperature than normal. The increase in mean temperature has great effect on the sustainable agriculture

(Bhandari, 2013). However, the development and growth of a crop depends on the exposure of the crop to mean temperature during its growing stage (Ramirez et al, 2003).

This result is similar to the findings of the IPCC (2007a) which stated that the last decade was the warmest decade ever occurred since the beginning of the instrumental recording of temperature in 1850 and it is an evidence of climate change. This implies that the area and the country at large as other countries in the world are experiencing some basic elements of climate change as reported by Odjugo (2010). Nevertheless, WMO (2011) stated that: 'climate change is accelerated in 2001-2010, which was the warmest decade ever recorded in all continents of the globe and the magnitude of increase since 1971 has been significant.

However, while global temperature for the past 100 years has increased by 0.74^{o}C, Odjugo (2011) found that of Nigeria between 1901-1938 and 1971-2008 climatic periods to increase by 1.78^{o}C. Attah (2013) also reported mean temperature rise of 0.454^{o}C per decade (2%) relative to the average value for the period. The increase in the mean temperature also increased the annual rainfall by 100mm per decade (26%).

4.7 Trend Analysis

4.7.1 Parametric Test

The result of the regression of rainfall on years carried out is depicted in Table 4.9. The slope of the regression of rainfall on years during 1971-2010 periods represents the trend in the rainfall. The result revealed an upward trend of the rainfall of 0.168mm/yr during the climatic periods. This also implied that the area recorded increase in rainfall of 1.68mm/decade for the four decades studied. In order to established the statistical significance of the trend, t test was performed and the result is presented in Table 4.10

Table 4.9: Regression analysis of rainfall on years

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	974.452	47.550	0.168	20.493	0.000
Years	2.125	2.021		1.051	0.300

a. Dependent Variable: Rainfall

The t test result shown in Table 4.10 determined the statistical significance of the upward trend in the rainfall. The absolute computed t value obtained is 43.139, which is greater than the critical value of t (1.685) at 95% confidence level. This implied that the upward rainfall trend of 1.68mm/decade in Table 4.9 was statistically significant at 95% confidence level.

Table 4.10: t test for rainfall

	Paired differences					T	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Years and Rainfall	-997.52	146.24	23.12	-1044.29	-950.74	-43.139	39	.000

Table 4.11 showed the result of the regression of maximum temperature on years during 1971-2010 periods. The result revealed an upward trend of the maximum temperature of 0.534^{o}C/yr during the climatic periods. This also signified that the area recorded increase in maximum temperature of 5.34^{o}C/decade in the four decades. In order to establish the statistical significance of the upward trend in the maximum temperature, t test was carried out and the result is presented in Table 4.12.

4.11: Regression analysis of maximum temperature on years

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	31.182	.225		138.602	.000
Years	.037	.010	.534	3.891	.000

Dependent Variable: MaxT

The t test result shown in Table 4.12 determined the statistical significance of the upward trend in maximum temperature obtained in Table 4.11. The absolute computed t value obtained in Table 4.12 is 6.419, which is greater than the critical value of t (1.685) at 95% confidence level. This implied that the computed upward trend of 5.34^{o}C/decade in maximum temperature is statistically significant at 95% confidence level.

Table 4.12: t test for maximum temperature (1971-2010)

	Paired differences					T	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Years - MaxT	-11.44500	11.27659	1.78299	-15.05143	-7.83857	-6.419	39	.000

Table 4.13 showed the regression of the minimum temperature on years during 1971-2010 periods. The result revealed an upward trend of the minimum temperature of 0.759^{o}C/yr during the climatic periods. This also signified that the area recorded increase in minimum temperature of 7.59^{o}C/decade during the four decades. In order to established the statistical significance of the upward trend in the minimum temperature, t test was carried out and the result is shown in Table 4.14

Table 4.13: Regression analysis of minimum temperature on years

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	18.238	.135		135.048	.000
Years	.041	.006	.759	7.197	.000

The t test shown in Table 4.14 revealed the statistical significance of the upward trend in the minimum temperature obtained in Table 4.13. The absolute computed t value obtained in the Table 4.14 is 0.798, which is less than the critical value of t (1.685) at 95% confidence level. This implied that the computed upward trend of 7.59^{o}C/decade in minimum temperature obtained in Table 4.13 is not statistically significant at 95% confidence level.

Table 4.14: t test for minimum temperature

	Paired differences					T	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Years – MinT	1.41500	11.21511	1.77326	-2.17177	5.00177	.798	39	.430

Table 4.15 showed the regression analysis of the mean temperature on years during 1971-2010 climatic periods. The result revealed an upward trend of mean temperature of 0.720^{o}C/yr during the climatic periods. This also signified that the area recorded increase in maximum temperature of 7.20^{o}C/decade. In order to established the statistical significance of the upward trend in the mean temperature, t test was carried out and result is shown in Table 4.16

Table 4.15: Regression analysis of mean temperature on years

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	24.735	.142		173.608	.000
Years	.039	.006	.720	6.404	.000

The t test result shown in Table 4.16 revealed the statistical significance of the upward trend in the mean temperature. The absolute computed t value obtained in the Table is 2.829, which is greater than the critical value of t (1.685) at 95% confidence level. This implied that the computed mean temperature trend of 7.20^{o}C/decade obtained in Table 4.15 is statistically significant at 95% conference level.

Table 4.16: t test for the mean temperature

	Paired differences					T	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Years - MeanT	-5.03000	11.24556	1.77808	-8.62651	-1.43349	-2.829	39	.007

4.7.2 Non Parametric Test

Table 4.17 depicted the Sen's estimator slope of the annual rainfall, annual maximum, minimum and mean temperatures during the 1971-2010 climatic periods. The result showed that the rainfall recorded a downward trend of 94mm/yr during 1971-1980 decade, while in the 1981-1990, 1991-2000 and 2001-2010 decades, the rainfall recorded upward trends of 90mm/yr, 30mm/yr, and 118mm/yr, respectively. On the other hand, the maximum temperature recorded

downward trend of 0.1℃/yr in 1971-1980 decade; while it recorded upward trend of 0.1℃/yr in 1991-2000 decade. The remaining two decades (1981-1990 and 2001-2010) recorded no trend in the maximum temperature. Similarly, the minimum temperature recorded upward trend of 0.1℃/yr in 1981-1990 periods, while 1971-1980, 1991-2000 and 2001-2010 decades recorded no trend. The mean temperature was associated with upward trend of 0.2℃/yr, 0.2℃/yr, 0.1℃/yr, and 0.2℃/yr, respectively during 1971-1980, 1981-1990, 1991-2000 and 2001-2010 decades. The Mann Kendall test was carried out to further ascertain the trend in the climatic variables and also to determine its statistical significance using the Z statistics.

Table 4.17: Sen's estimator slope of the climatic variables

Periods	Climatic variables Trends			
	Rainfall (mm/yr)	Max T (℃/yr)	Min T (℃/yr)	Mean T (℃/yr)
1971-1980	-94	-0.1	0.0	0.2
1981-1990	90	0.0	0.1	0.2
1991-2000	30	0.1	0.0	0.1
2001-2010	118	0.0	0.0	0.2

The Mann Kendall test for the annual rainfall, maximum, minimum and mean temperatures are shown in Table 4.18. The result revealed that the annual rainfall recorded Mann Kendall of -3.0, 1.0, 1.0 and 1.0 during 1971-1980, 1981-1990, 1991-2000 and 2001-2010 decades. This implied a downward trend in the 1971-1980 and upward trends in 1981-1990, 1991-2000 and 2001-2010 periods, but they are not statistically significant at 95% confidence level as the computed Z value is less than 1.96. Similarly, maximum temperature had Mann Kendall of -1.0 and 1.0 in 1971-1980 and 1991-2000, respectively implying decreasing and increasing trends, respectively but they are not statistically significant at 95% confidence level. Moreover, the minimum temperature recorded Mann Kendall of 2.0 in 1981-1990 decade but it was not statistically significant at 95% confidence level. On the other hand, the mean temperature recorded positive

Mann Kendall values of: 1.0, 3.0, 1.0 and 2.0, respectively in 1971-1980, 1981-1990, 1991-2000 and 2001-2010 decades. This signified that all the decades were associated with upward trend in the mean temperature, but none is statistically significant at 95% confidence level. This result signified that the area recorded upward trend in rainfall during the last three decades and also upward trend in mean temperature in all the decades during 1971-2010 periods, implying that the area is becoming warmer which can impair with the growth and development of crops, reduces soil water availability, thereby affecting the yields (Ramirez et al, 2003).

Table 4.18: Mann Kendall (*S*) of the climatic variables

	Climatic variables			
	Rainfall	Maximum Temp	Minimum Temp	Mean Temp
Periods	1971-1980	1971-1980	1971-1980	1971-1980
Mann Kendall (*S*)	-3.0	-1.0	0.0	1.0
Z statistics	-0.179	0.00	0.00	0.00
Periods	1981-1990	1981-1990	1981-1990	1981-1990
Mann Kendall (*S*)	1.0	0.0	2.0	3.0
Z statistics	0.00	0.00	0.092	0.179
Periods	1991-2000	1991-2000	1991-2000	1991-2000
Mann Kendall (*S*)	1.0	1.0	0.0	1.0
Z statistics	0.00	0.00	0.00	0.00
Periods	2001-2010	2001-2010	2001-2010	2001-2010
Mann Kendall (*S*)	1.0	0.0	1.0	2.00
Z statistics	0.00	0.00	0.00	0.174

4.8 Annual Yields of Maize, Sorghum and Millet

Tables 4.19 contain the yields of the Maize, Millet and Sorghum in the area between 2001 and 2011. The Table revealed that the mean yield of maize, millet and sorghum are: 2.311, 0.260 and 0.216, respectively. The corresponding standard deviations of the maize, millet and sorghum are: 0.456, 0.260 and 0.216, respectively. The standard deviation values of the three crops implied

that the maize yield recorded higher variations than millet and sorghum during the 2001 to 2011 periods. It was followed by millet, while sorghum recorded least variations during the periods.

Table 4.19: Annual yields of the Maize, Millet and Sorghum

Years	Maize yields (tonnes/ha)	Sorghum yields (tonnes/ha)	Millet yields (tonnes/ha)
2001	2.870	2.010	2.090
2002	1.704	1.879	1.408
2003	1.728	1.865	1.371
2004	2.970	1.860	1.765
2005	2.010	1.870	1.380
2006	2.646	1.917	1.380
2007	2.832	2.006	1.400
2008	2.239	1.271	1.249
2009	2.232	1.616	1.228
2010	2.255	1.618	1.233
2011	1.938	1.789	1.344
Mean	2.311	1.791	1.441
Std	0.456	0.216	0.260

Source: NAERLS (2012)

4.9 Multiple Non Linear Regressions Analysis

The multiple non linear regression analysis for maize on the annual rainfall and annual mean temperature is shown in Table 4.20. The result revealed that the coefficient of determination (R^2) is 0.289, implying that about 28.9% of the variation in the annual yield of maize can be accounted for by the annual rainfall and mean temperature. The R^2 value also revealed that the yield of crops do not depend only on the climatic variables because non-climatic (agronomic) variables also affect the crop yield, but only two climatic variables (annual rainfall and annual mean temperature) were captured in this study. However, Adebayo and Adebayo (1997); Folorunsho et al, (1998) reported that the climatic factors that influence the crops yield include: radiation, wind, onset and cessation dates of the rains, length of the rainy season, quantity of rainfall in the months of the growing season, total amount of rainfall during the growing season,

the spread of the rains, number of rainy days, rainfall intensity. The agronomic factors that influence the crops yield include: seed varieties, use of fertilizers, differences in soil fertility, weeding practices, occurrence of pests and diseases, harvesting time and government policy (Folorunsho et al, 1998). The length of the rainy season in Samaru-Zaria had been found to be on the decrease which also affected the yield of maize, millet and sorghum from 1976 to 2005 as reported by Sawa and Adebayo (2010).

Table 4.20: Multiple non linear regression of maize yield on rainfall and mean temperature

	Coefficient	Std. Error	T	P	VIF
Constant	-4.709	4.369	-1.078	0.313	
Col 1	0.683	0.407	1.678	0.132	1.002
Col 2	2.121	2.923	0.726	0.489	1.002

N = 11, R = 0.537, Rsqr = 0.289, Adj Rsqr = 0.111 and Standard Error of Estimate = 0.082

The Eq. of the regression generated by the sigma plot software is shown as Eq. 4.1

Col 3 = -4.709 + (0.683 * Col 1) + (2.121 * Col 2) (4.1)

Where Col 3 is the natural logarithm of maize yield, Col 1 is the natural logarithm of the annual rainfall and Col 2 is the natural logarithm of annual mean temperature. Eq. 4.1 can therefore be written as:

$$\log M_{zy} = -4.709 + 0.683\log R + 2.121\log T \quad (4.2)$$

Table 4.21 depicts the analysis of variance of the maize yield with respect to annual rainfall and annual mean temperature. The Table revealed the significance of the maize yield variation with annual rainfall and annual mean temperature. From the Table, the computed F value is 1.625

which less than the critical F value of 4.46, implying that the variation of the maize yields with the climatic variables is not statistically significant at 95% confidence level.

Table 4.21: Analysis of variance of maize yield with climatic variables

	DF	SS	MS	F	P
Regression	2	0.0216	0.0108	1.625	0.256
Residual	8	0.0532	0.00665		
Total	10	0.0748	0.00748		

Table 4.22 showed the contribution of each climatic variable to the variation in the annual yield of maize. The Table revealed that the annual rainfall (Col 1) contributed more to the variation in the yield of maize than the annual mean temperature. This is because the sequential sum of square (SSI) of 0.0181 of rainfall is higher than that of mean temperature (Col 2) of 0.00350 as shown in Table 4.22. This also implied that the rainfall contributed more to the regression sum of square of 0.0216 shown in Table 4.21.

Table 4.22: Contribution of the climatic variables on maize yield variation

Column	SSI	SSM
Col 1	0.0181	0.0187
Col 2	0.00350	0.00350

Table 4.23 showed the observed yield as well as the predicted maize yield obtained from the multiple non linear regression models. The Table also contained the absolute error, mean absolute error, total error and mean square error. The evaluation revealed that the absolute error,

mean absolute error, total error and mean square error recorded for the prediction of maize yields from the model are: 3.184, 0.287, 1.457 and 0.132, respectively. These errors measured the validity, reliability and fitness of the statistical model in predicting the maize yield.

Table 4.23: Model validation and statistical evaluation for Maize yields

Years	Observed Yield	Predicted Yield	E	$\lvert Y_i - Y_o \rvert$	E^2
2001	2.870	2.367	0.503	0.503	0.253
2002	1.704	1.959	-0.255	0.255	0.065
2003	1.728	2.504	-0.776	0.776	0.602
2004	2.970	2.401	0.569	0.569	0.324
2005	2.010	1.972	0.038	0.038	0.001
2006	2.646	2.497	0.167	0.167	0.028
2007	2.832	2.679	0.153	0.153	0.023
2008	2.239	1.984	0.255	0.255	0.065
2009	2.232	2.215	0.017	0.017	0.000
2010	2.255	2.395	-0.14	0.14	0.020
2011	1.938	2.213	-0.275	0.275	0.076
				AE = 3.184	E^2 =1.457
				MAE = 0.287	MSE = 0.132

The multiple non linear regression analysis for millet yield on the annual rainfall and annual mean temperature is shown in Table 4.24. The result revealed that the coefficient of determination (R^2) is 0.452, implying that about 45.2% of the variation in the annual yield of millet can be accounted for by the annual rainfall and mean temperature. The R^2 value also revealed that yield of the crop do not rely only on the climatic variables due to the fact that other non-climatic variables also affect the yield of the crops (Folorunsho et al, 1998). The remaining 54.8% that could not be accounted for by the regression model as shown by the R^2 value of 45.2% could be attributed to other climatic variables as well as agronomic variables that were not considered in this study because they were beyond the scope of this study.

Table 4.24: Multiple non linear regression of millet yield on rainfall and mean temperature

	Coefficient	Std. Error	T	P	VIF
Constant	4.140	3.106	1.333	0.219	
Col 1	0.492	0.289	1.700	0.128	1.002
Col 2	-3.857	2.078	-1.856	0.100	1.002

N = 11, R = 0.672, Rsqr = 0.452, Adj Rsqr = 0.315 and Standard Error of Estimate = 0.058

The Eq. of the regression analysis generated by the sigma plot software is shown as Eq. 4.3

Col 3 = 4.140 + (0.492 * Col 1) - (3.857 * Col 2) (4.3)

Where Col 3 is the natural logarithm of millet yield, Col 1 is the natural logarithm of the annual rainfall and Col 2 is the natural logarithm of annual mean temperature. Eq. 4.3 can therefore be written as:

$$\log M_{ly} = 4.140 + 0.492\log R - 3.857\log T \quad (4.4)$$

Table 4.25 depicts the analysis of variance of the millet yield with respect to annual rainfall and the annual mean temperature. The Table showed the significance of the variation in millet yield with rainfall and mean temperature. From the Table, the computed F value is 3.299 which is less than the critical F value of 4.46, implying that the variation of the millet yield with the climatic variables is not statistically significant at 95% confidence level.

Table 4.25: Analysis of variance of millet yield and climatic variables

	DF	SS	MS	F	P
Regression	2	0.0222	0.0111	3.299	0.090
Residual	8	0.0269	0.00336		
Total	10	0.0491	0.00491		

Table 4.26 showed the contribution of each climatic variable to the variation in the annual yield of millet. The Table revealed that the annual mean temperature (Col 2) contributed more to the variation in the millet yield than the annual rainfall (Col 1). This is because the sequential sum of square (SSI) of mean temperature of 0.0116 is higher than that of annual rainfall of 0.0106 as shown in Table 4.26. This also implied that the mean temperature contributed more than the rainfall to the regression sum of square of 0.0222 shown in Table 4.25.

Table 4.26: Contribution of the climatic variables on millet yield variation

Column	SSI	SSM
Col 1	0.0106	0.00971
Col 2	0.0116	0.0116

Table 4.27 showed the observed yield as well as the predicted millet yield obtained from the multiple non linear regression models. The Table also contained the absolute error, mean absolute error, total error and mean square error. The evaluation revealed that the absolute error, mean absolute error, total error and mean square error recorded for the prediction of millet yields are: 1.619, 0.147, 0.335 and 0.030, respectively. These errors measured the validity, reliability and fitness of the statistical model in predicting the millet yield.

Table 4.27: Model validation and statistical evaluation for Millet yields

Years	Observed Yield	Predicted Yield	E	$\lvert Y_i - Y_o \rvert$	E^2
2001	2.090	1.726	0.364	0.364	0.132
2002	1.408	1.414	-0.006	0.006	0.000
2003	1.371	1.553	-0.182	0.182	0.033
2004	1.765	1.603	0.162	0.162	0.026
2005	1.380	1.229	0.151	0.151	0.023
2006	1.380	1.215	0.165	0.165	0.027
2007	1.400	1.413	-0.013	0.013	0.000
2008	1.249	1.313	-0.064	0.064	0.004
2009	1.228	1.363	-0.135	0.135	0.018
2010	1.233	1.442	-0.209	0.209	0.044
2011	1.344	1.512	-0.168	0.168	0.028
				AE = 1.619	E^2 = 0.335
				MAE = 0.147	MSE = 0.030

The multiple non linear regression analysis of sorghum on the annual rainfall and annual mean temperature is shown in Table 4.28. The result revealed that the coefficient of determination (R^2) is 0.242, implying that about 24.2% of the variation in the annual yield of millet can be accounted for by the annual rainfall and mean temperature. The R^2 value revealed that the yield of crops do not depend only on the climatic variables as non-climatic (agronomic) variables also affects the yield of the crops (Folorunsho et al, 1998). The remaining 75.8% that could not be accounted for by the regression model as shown by the R^2 value of 24.2% could be attributed to other climatic variables as well as agronomic variables that were beyond the scope of this study.

Table 4.28: Multiple non linear regression of sorghum yield on rainfall and mean temperature

	Coefficient	Std. Error	T	P	VIF
Constant	-1.590	3.004	-0.529	0.611	
Col 1	0.446	0.280	1.595	0.149	1.002
Col 2	0.349	2.010	0.174	0.866	1.002

N = 11, R = 0.492, Rsqr = 0.242, Adj Rsqr = 0.0526 and Standard Error of Estimate = 0.056

The Eq. of the regression generated by the sigma plot software is shown as Eq. 4.5

Col 3 = -1.590 + (0.446 * Col 1) + (0.349 * Col 2) (4.5)

Where Col 3 is the natural logarithm of sorghum yield, Col 1 is the natural logarithm of the annual rainfall and Col 2 is the natural logarithm of annual mean temperature. Eq. 4.5 can therefore be written as:

$$\log S_{gy} = -1.590 + 0.446\log R + 0.349\log T \quad (4.6)$$

Table 4.29 depicts the analysis of variance of the sorghum yield with annual rainfall and the annual mean temperature. The Table revealed the significance of the variation in the sorghum yield with rainfall and mean temperature. From the Table, the computed F value is 1.278 which is less than the critical F value of 4.46, implying that the variation of the sorghum yield with the climatic variables is not statistically significant at 95% confidence level.

Table 4.29: Analysis of variance of sorghum and climatic variables

	DF	SS	MS	F	P
Regression	2	0.00803	0.00402	1.278	0.330
Residual	8	0.0252	0.00314		
Total	10	0.0332	0.00332		

Table 4.30 showed the contribution of each climatic variable to the variation in the annual sorghum yield. The Table revealed that the annual rainfall (Col 1) contributed more to the variation in the sorghum yield than the annual mean temperature (Col 2). This is because the sequential sum of square (SSI) of rainfall of 0.00794 is higher than that of mean temperature

(Col 2) of 0.0000949 as shown in Table 4.30. This implied that the rainfall contributed more to the regression sum of square of 0.00803 shown in Table 4.29.

Table 4.30: Contribution of the climatic variables on sorghum yield variation

Column	SSI	SSM
Col 1	0.00794	0.00800
Col 2	0.0000949	0.0000949

Table 4.31 showed the observed and predicted sorghum yield obtained from the multiple non linear regression models. The Table also contained the absolute error, mean absolute error, total error and mean square error. The evaluation revealed that the absolute error, mean absolute error, total error and mean square error recorded for the prediction of sorghum yields are: 1.568, 0.143, 0.349 and 0.032, respectively. These errors measured the validity of the statistical model in predicting the sorghum yield. However, amongst the three models, millet model is the most valid as it has the lowest total error and mean square error; it was followed by sorghum model, while the maize model is the least as it had the highest statistical errors.

Table 4.31: Model validation and statistical evaluation for Sorghum yields

Years	Observed Yield	Predicted Yield	E	$\lvert Y_i - Y_o \rvert$	E^2
2001	2.010	1.879	0.131	0.131	0.017
2002	1.879	1.640	0.239	0.239	0.057
2003	1.865	1.895	-0.030	0.030	0.001
2004	1.860	1.866	-0.006	0.006	0.000
2005	1.870	1.603	0.267	0.267	0.071
2006	1.917	1.805	0.112	0.112	0.013
2007	2.006	1.927	0.079	0.079	0.006
2008	1.271	1.628	-0.357	0.357	0.127
2009	1.616	1.736	-0.120	0.120	0.014
2010	1.618	1.826	-0.208	0.208	0.043
2011	1.789	1.770	0.019	0.019	0.000
				AE = 1.568	E^2 = 0.349
				MAE = 0.143	MSE = 0.032

4.10 Results of the Administered Questionnaires

The results of the 1000 Questionnaires that were self- administered are presented in Tables 4.32 – 4.65 the discussions accompany the Tables. However, all the 1000 questionnaires administered were retrieved.

Tables 4.32 – 4.36 contain the Bio-data of respondents in the area. It can be seen that 67.1% are male; while 32.9% are female (Table 4.32), implying that majority of the respondents are male as they are more accessible. In terms of age, 38.3% are 30-40 years, 28.5% are 40-50 years; 19.1% are 50-60 years, while 14.1% are above 60 years (Table 4.33), implying that majority of the respondents are between the ages of 30 to 40 years. Meanwhile, 30.6% are single; while 69.4% are married (Table 4.34). With regards to education, majority of the respondents (42.9%) have tertiary education, 23.4% have secondary education; 13.5% have primary education; while 20.2% have no formal education (Table 4.35). However, in terms of occupation, 26.5% are civil servants; 16.1% are students; 14.8% are business men or women; 14.0% are farmers; 3.5% are fishermen; while others are 25.1% (Table 4.36).

Table 4.32: Sex

	Frequency	Percent	Valid Percent	Cumulative Percent
Male	671	67.1	67.1	67.1
Female	329	32.9	32.9	100.0
Total	1000	100.0	100.0	

Table 4.33: Age

	Frequency	Percent	Valid Percent	Cumulative Percent
30-40	383	38.3	38.3	38.3
40-50	285	28.5	28.5	66.8
50-60	191	19.1	19.1	85.9
Above 60	141	14.1	14.1	100.0
Total	1000	100.0	100.0	

Table 4.34: Marital Status

	Frequency	Percent	Valid Percent	Cumulative Percent
Single	306	30.6	30.6	30.6
Married	694	69.4	69.4	100.0
Total	1000	100.0	100.0	

Table 4.35: Educational qualification

	Frequency	Percent	Valid Percent	Cumulative Percent
No formal education	202	20.2	20.2	20.2
Primary education	135	13.5	13.5	33.7
Secondary education	234	23.4	23.4	57.1
Tertiary education	429	42.9	42.9	100.0
Total	1000	100.0	100.0	

Table 4.36: Occupation

	Frequency	Percent	Valid Percent	Cumulative Percent
Student	161	16.1	16.1	16.1
Business man/woman	148	14.8	14.8	30.9
Civil servant	265	26.5	26.5	57.4
Farmer	140	14.0	14.0	71.4
Fisherman	35	3.5	3.5	74.9
Others	251	25.1	25.1	100.0
Total	1000	100.0	100.0	

Table 4.37 shows how long the respondents have been residing in the area. It was discovered that 62.9% have been residing in the area for more than 20 years; 13.1% have spent 15-20 years, 10.0% have spent 10-15 years, 7.7% have spent 5-10 years and 6.3% have spent less than five years in the area. This implies that majority of the respondents have been familiar with the area. This plays a significant role in getting reasonable response from the respondents, because majority of them have reasonable experience on the area.

Table 4.37: How long have you lived here?

	Frequency	Percent	Valid Percent	Cumulative Percent
<5yrs	63	6.3	6.3	6.3
5-10yrs	77	7.7	7.7	14.0
10-15yrs	100	10.0	10.0	24.0
15-20yrs	131	13.1	13.1	37.1
>20yrs	629	62.9	62.9	100.0
Total	1000	100.0	100.0	

Tables 4.38 - 4.40 present their awareness or understanding as well as their perceptions of climate change. Majority (71.8%) know what climate change is; 26.8% do not know what climate change is; while 1.4% did not respond (Table 4.38). Similarly, 71.8% think that the climate is changing; 26.8% think that the climate is not changing; while 1.4% did not respond (Table 4.39). This implies that most of the residents of the area have already known climate change and they believe that the climate is currently changing. In terms of their views on why they think that the climate is changing, 27.7% related climate change with the occurrences of flooding; 8.9% had the view that the variation in rainfall they experienced is attributed to climate change; 16.8% responded that the increase in hotness or mean air temperature is an indication according to them that the climate is changing; 6.3% had the perceptions that climate is changing but it is a natural issue; 12.1% had other views; while 28.2% did not respond (Table 4.40).

Table 4.38: Do you know what climate change is?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	718	71.8	71.8	71.8
No	268	26.8	26.8	98.6
No response	14	1.4	1.4	100.0
Total	1000	100.0	100.0	

Table 4.39: Do you think Climate is changing?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	718	71.8	71.8	71.8
No	268	26.8	26.8	98.6
No response	14	1.4	1.4	100.0
Total	1000	100.0	100.0	

Table 4.40: If yes, why do you think so?

	Frequency	Percent	Valid Percent	Cumulative Percent
Occurrence of flooding	277	27.7	27.7	27.7
Variation in rainfall	89	8.9	8.9	36.6
Increase in hotness	168	16.8	16.8	53.4
Natural	63	6.3	6.3	59.7
Others	121	12.1	12.1	71.8
No response	282	28.2	28.2	100.0
Total	1000	100.0	100.0	

With regard to their observations on climate change in their area, 71.8% of the respondents said they have noticed some elements of climate change in their area; 25.6% said they have not noticed any climate change in their area; while 2.6% did not respond (Table 4.41). This further revealed the evidence that they know climate change; they believe that it is changing and there are some basic aspects of climate change that they do observe in their environment. This will help in taking the proper mitigation measures of climate change as the people know that the climate is changing.

Table 4.41: Do you notice Climate change in your area?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	718	71.8	71.8	71.8
No	256	25.6	25.6	97.4
No response	26	2.6	2.6	100.0
Total	1000	100.0	100.0	

Tables 4.42 and 4.43 show the source of heat they use for cooking and the reason for using any of them. It was discovered that 62.8% of them use firewood for cooking; implying that majority of them rely on firewood for cooking as a source of heat energy; 24.0% use kerosene for cooking; 7.1% use cooking gas; while only 6.1% use charcoal for cooking (Table 4.42). This implied heavy dependence on firewood for cooking which will consequently be associated with cutting down of trees, that serve as sinks for atmospheric CO_2. This can increase the effect of global warming. Similarly, 31.4% use any of the above for convenience; 29.8% use it for cost; 20.5% use it because they could afford it; while 18.3% use it because it is readily available (Table 4.43). However, the firewood is cheaper and readily available that is why most of the respondents rely on it for cooking at the expense of the environment.

Table 4.42: What do you use for cooking in your area?

	Frequency	Percent	Valid Percent	Cumulative Percent
Firewood	628	62.8	62.8	62.8
Charcoal	61	6.1	6.1	68.9
Kerosene	240	24.0	24.0	92.9
Cooking gas	71	7.1	7.1	100.0
Total	1000	100.0	100.0	

Table 4.43: Why do you use any of the above?

	Frequency	Percent	Valid Percent	Cumulative Percent
Availability	183	18.3	18.3	18.3
Cost	298	29.8	29.8	48.1
Convenience	314	31.4	31.4	79.5
Affordability	205	20.5	20.5	100.0
Total	1000	100.0	100.0	

Nevertheless, majority of the respondents (92.7%) said that there has been change in the number of vehicles such as cars, vans, motorcycle and so on; 7.0% said there is no change in the number of vehicles; 0.3% did not respond (Table 4.44). Out of the 92.7% that said there is change in the

number of vehicles; 91.4% said there is increase in the number of vehicles; while only 1.3% said there is decrease in the number of vehicles (Table 4.45). The increase in the number of vehicles as noticed by the majority of the respondents is in turn associated with the increase in the vehicular emissions which plays great role in causing climate change. The vehicular emissions are said to contribute negatively to the environment, thereby leading to environmental pollution, depletion of ozone layer, human health consequences and climate change.

Table 4.44: Since you started living here, has there been a change in the number of vehicles?- cars, vans, motorcycles e.t.c

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	927	92.7	92.7	92.7
No	70	7.0	7.0	99.7
No response	3	0.3	0.3	100.0
Total	1000	100.0	100.0	

Table 4.45: If yes, what is the change?

	Frequency	Percent	Valid Percent	Cumulative Percent
There is an increase in the number of vehicles	914	91.4	91.4	91.4
There is a decrease in the number of vehicle	13	1.3	1.3	92.7
No response	73	7.3	7.3	100.0
Total	1000	100.0	100.0	

Majority of the respondents (87.0%) said they have noticed some changes in the quality of air; 11.3% said they have not noticed any change in the quality of air; while 1.7% made no response (Table 4.46). Meanwhile, out of the 87.0% that said there is change in the quality of air which is associated with the increase in the number of vehicles and in turn vehicular emissions, 47.3% said there is increase in smoke in their environment; 3.8% said there is increase in noise in their area; 4.7% said there is increase in accidents; 1.3% said there is increase in smoke and noise; while 29.9% said there is increase in smoke, noise and accident due to the rise in the number of

vehicles coupled with higher vehicular emissions in the area (Table 4.47). The effect of the change in air quality is detrimental to human health, environmental quality and as a result, it can lead to global warming.

Table 4.46: Is there any change you have noticed in the quality of air?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	870	87.0	87.0	87.0
No	113	11.3	11.3	98.3
No response	17	1.7	1.7	100.0
Total	1000	100.0	100.0	

Table 4.47: If yes, what kind of change?

	Frequency	Percent	Valid Percent	Cumulative Percent
Increased smoke	473	47.3	47.3	47.3
Increased noise	38	3.8	3.8	51.1
Increased accidents	47	4.7	4.7	55.8
Increased smoke, noise and accidents	299	29.9	29.9	85.7
Increased smoke and noise	13	1.3	1.3	87.0
No response	130	13.0	13.0	100.0
Total	1000	100.0	100.0	

Most of the respondents (86.6%) said there is change in land use; 12.4% said there is no change in land use; while 1.0% made no response (Table 4.48). However, out of the 86.6% that said there is change in land use, 44.2% said farmlands are developed to houses; 8.8% said some available trees have been removed due to road construction; while 33.6% said farmlands are developed to houses and some trees are removed for road constructions (Table 4.49). The land use change has been known to be amongst the causes of climate change because the available vegetation that can absorb the atmospheric carbon (iv) oxide are removed as a results of constructions and other purposes.

Table 4.48: Have you noticed change in how land is used in your area?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	866	86.6	86.6	86.6
No	124	12.4	12.4	99.0
No response	10	1.0	1.0	100.0
Total	1000	100.0	100.0	

Table 4.49: If yes, what is the change?

	Frequency	Percent	Valid Percent	Cumulative Percent
Farmlands have been converted to houses	442	44.2	44.2	44.2
Some available trees have been removed for road construction	88	8.8	8.8	53.0
All of the above	336	33.6	33.6	86.6
No response	134	13.4	13.4	100.0
Total	1000	100.0	100.0	

Tables 4.50 - 4.51 show activities like cutting of trees for firewood and bush-burning in the area. Majority of the respondents (82.9%) said cutting of trees for firewood occur in the area; 15.2% said cutting of trees for firewood do not occur; while 1.9% did not respond (Table 4.50). Nevertheless, 80.5% said bush-burning occur; 17.4% said it did not occur; while 2.1% did not respond (Table 4.51). These two activities play a major role in contributing to climate change. This is because the trees are known to be the natural reservoirs or sinks for CO_2 that contributes about 76.7% of greenhouse gases in the atmosphere (Odjugo, 2010). The trees absorb the CO_2 thereby preventing it from polluting the environment; while bush burning also release GHGs to the atmosphere thereby causing global warming.

Table 4.50: Have you observed any cutting of trees for firewood in your area?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	829	82.9	82.9	82.9
No	152	15.2	15.2	98.1
No response	19	1.9	1.9	100.0
Total	1000	100.0	100.0	

Table 4.51: Do you noticed bush-burning by farmers in your area?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	805	80.5	80.5	80.5
No	174	17.4	17.4	97.9
No response	21	2.1	2.1	100.0
Total	1000	100.0	100.0	

With regards to change in air temperature, 81.4% said there is change in the air temperature around them; 15.4% said they noticed no change in the air temperature; while 3.2% did not respond (Table 4.52). However, out of the 81.4% that said there is change in air temperature, 50.7% said there is increase in the air temperature around them; 12.7% said there is decrease in the air temperature; while 18.0% said the air temperature fluctuates (Table 4.53). According to the temperature anomalies, some years recorded mean temperature above normal; while some recorded mean temperature below normal. It has been shown that 24 years recorded mean temperature above normal; 13 years recorded mean temperature below normal; while 3 years recorded normal mean temperature. From 1993 - 2010, all the years recorded mean temperature above normal. However, on the decadal basis, there is general increase in the mean temperature, with last decade (2001-2010) being higher than the other decades and all the years in the last decades recorded mean temperature above normal.

Table 4.52: Have you noticed change in air temperature around you?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	814	81.4	81.4	81.4
No	154	15.4	15.4	96.8
No response	32	3.2	3.2	100.0
Total	1000	100.0	100.0	

Table 4.53: If yes, what is the change?

	Frequency	Percent	Valid Percent	Cumulative Percent
There is increase in air temperature	507	50.7	50.7	50.7
There is decrease in air temperature	127	12.7	12.7	63.4
The air temperature increases and sometimes decreases	180	18.0	18.0	81.4
No response	186	18.6	18.6	100.0
Total	1000	100.0	100.0	

Table 4.54 contains their perceptions on climate related illnesses such as cerebral meningitis and cholera in the area. Majority of the respondents (75.0%) said that meningitis and or cholera have occurred in the area; 20.8% said that climate related illnesses have never occurred; while only 4.2% did not respond. According to NIMET (2010) report, climate-related illnesses such as cholera have infected 40,000 people and killed more than 1,500 in some part of the country in October, 2010 and there was outbreak of cholera in the country for nearly two decades.

Table 4.54: Have you ever noticed climate-related illnesses such as meningitis and or cholera as a result of excessive hotness and or flooding in your area?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	750	75.0	75.0	75.0
No	208	20.8	20.8	95.8
No response	42	4.2	4.2	100.0
Total	1000	100.0	100.0	

In terms of the onset of rainfall, 79.4% said they have noticed change in the onset of rainfall; 17.0% said they noticed no change in the onset of rainfall; while 3.6% did not respond (Table 4.55). Meanwhile, out of the 79.4% that have noticed change in the onset of rainfall, 47.5% said that the rainfall starts early and stops late; 12.7% said that the rainfall starts late and stops early; 11.5% said the rainfall starts early and stops early; while only 7.7% said the rainfall starts late and stops late (Table 4.56). On the other hand, Sawa and Adebayo (2010) found that rainfall in

Samaru- Zaria starts late and stops early which in turn causes shortening of the rainy season and that also tallied with the NIMET observation of the late onset and quick cessation rainfall which can affect water availability, thereby affecting agriculture yields.

Table 4.55: Have you noticed any change in the onset of rainfall in your area?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	794	79.4	79.4	79.4
No	170	17.0	17.0	96.4
No response	36	3.6	3.6	100.0
Total	1000	100.0	100.0	

Table 4.56: If yes, what is the change?

	Frequency	Percent	Valid Percent	Cumulative Percent
The rainfall starts early and stops early	115	11.5	11.5	11.5
The rainfall starts early and stops late	475	47.5	47.5	59.0
The rainfall starts late and stops late	77	7.7	7.7	66.7
The rainfall starts late and stops early	127	12.7	12.7	79.4
No response	206	20.6	20.6	100.0
Total	1000	100.0	100.0	

Tables 4.57 and 4.58 present their responses on the change in rainfall in their area, in which 81.6% said there is change in rainfall; 15.8% said there is no change in rainfall; while 2.6% did not respond. Out of the 81.6% that said there is change in rainfall, 65.0% said there is increase in rainfall; while 16.6% said there is decrease in rainfall. Meanwhile, the rainfall anomaly showed that some years recorded higher rainfall than normal; while some recorded lower rainfall than normal. The result revealed that 19 years recorded wets, while 21 years recorded dry. Nevertheless, on decadal basis, there is increase in rainfall. Out of the four decades, only one decade encountered deficits of rainfall.

Table 4.57: Have you noticed change in rainfall in your area?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	816	81.6	81.6	81.6
No	158	15.8	15.8	97.4
No response	26	2.6	2.6	100.0
Total	1000	100.0	100.0	

Table 4.58: If yes, what is the change?

	Frequency	Percent	Valid Percent	Cumulative Percent
There is increase in rainfall	650	65.0	65.0	65.0
There is decrease in rainfall	166	16.6	16.6	81.6
No response	184	18.4	18.4	100.0
Total	1000	100.0	100.0	

Tables 4.59 assess their perceptions on the impact of climate change on agricultural activities, in which 50.4% said there is decrease in the agricultural yield; 26.7% said there is increase in the agricultural yield; 7.1% said there is no change in the agricultural yield; while 15.8% did not respond. The agricultural yields of an area or region are affected by both climatic and non climatic factors (Folorunsho et al, 1998).

Table 4.59: How does climate change affects agricultural yield?

	Frequency	Percent	Valid Percent	Cumulative Percent
There is increase in the agricultural yield	267	26.7	26.7	26.7
There is decrease in agricultural yield	504	50.4	50.4	77.1
There is no change in agricultural yield	71	7.1	7.1	84.2
No response	158	15.8	15.8	100.0
Total	1000	100.0	100.0	

Table 4.60 - 4.63 studied flood occurrences in the area, in which 65.8% said flood occurred, 33.4% said it did not occur, while 0.8% did not respond. Out of the 65.8% that said flood occurred; 31.3% said the flood destroyed few houses; 11.4% said it destroyed many houses;

20.3% said houses were not destroyed; while 2.8% related the flood with destructions of other properties. Similarly, out of 65.8% that said flood occurred, 43.1% said bridge(s) had been destroyed by flooding; while 22.7% said no bridge(s) had been destroyed. More so, 31.8% said some schools were closed due to the flooding; 34.0% said it did not occur. According to the Premium Times News paper of Friday of 7th December 2012, the National Emergency Management Agency (NEMA) said that over seven million people in Nigeria were affected in various ways by the flooding that ravaged many parts of the country; while 353 were killed in the year 2012 as a result of various natural or man-made occurrences between July and October, 2012. The flooding is one of the impacts of climate change with negative consequences as the rainfall become higher than normal for an area and also becomes unpredictable.

Table 4.60: Is there flooding in your area?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	658	65.8	65.8	65.8
No	334	33.4	33.4	99.2
No response	8	0.8	0.8	100.0
Total	1000	100.0	100.0	

Table 4.61: If yes, what were the results of the flood?

	Frequency	Percent	Valid Percent	Cumulative Percent
Many houses were destroyed	114	11.4	11.4	11.4
Few houses were destroyed	313	31.3	31.3	42.7
No houses destroyed	203	20.3	20.3	63.0
Others	28	2.8	2.8	65.8
No response	342	34.2	34.2	100.0
Total	1000	100.0	100.0	

Table 4.62: Is there any case(s) of bridge breakage or destruction as a result of flood in your area?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	431	43.1	43.1	43.1
No	227	22.7	22.7	65.8
No response	342	34.2	34.2	100.0
Total	1000	100.0	100.0	

Table 4.63: Is there any case of school closure due to flooding of the road leading to the school in your area?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	318	31.8	31.8	31.8
No	340	34.0	34.0	65.8
No response	342	34.2	34.2	100.0
Total	1000	100.0	100.0	

Tables 4.64 and 4.65 show their responses with regard to drought, in which 74.5% said that they have encountered drought in the area; 24.1% said they have never witnessed drought in the area; while 1.4% did not respond. In addition; out of the 74.5% that said they have witnessed drought, 54.5% said the drought was accompanied with the reduction in water supply and food production; 6.5% said the drought was accompanied with increase in water supply and food production; 4.6% said there was no change in water supply and food production; while 8.9% related the results of the drought with others issues. Meanwhile, the rainfall anomaly results obtained, revealed that 21 years out of 40 years recorded drought and 1981-1990 was associated with deficit of rainfall. The drought is one of the impacts of climate change as the area record precipitation below normal thereby impacting negatively on agriculture and water availability. The planted crops could encounter insufficient water for their optimum growth, there affecting the yield of the crops.

Table 4.64: Have you noticed drought now or previously in your area?

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	745	74.5	74.5	74.5
No	241	24.1	24.1	98.6
No response	14	1.4	1.4	100.0
Total	1000	100.0	100.0	

Table 4.65: If yes, what were the results of the drought?

	Frequency	Percent	Valid Percent	Cumulative Percent
There were reductions in water supply and food production	545	54.5	54.5	54.5
There were increase in water supply and food production	65	6.5	6.5	61.0
The water supply and food production remained the same	46	4.6	4.6	65.6
Others	89	8.9	8.9	74.5
No response	255	25.5	25.5	100.0
Total	1000	100.0	100.0	

4.11 Focus Group Discussions (FGD)

The Focus Group Discussions conducted with farmers were carried out in such a way that each question was accompanied by the answer and then the next question followed it up. The results are presented as follows:

(1) What kind of change in climate did you notice in the recent years?

In recent years, there has been noticeable increase in wind speed, rainfall, temperatures and fast rate at which soil moisture is drained after a rainfall event;

(2) Has there been change in rainfall pattern?

There is reduction in rainfall in terms of start, end, poor distribution and duration of the rainfall and such are some of the problems we face in our agricultural activities;

(3) How does climate variability affect your agricultural activities?

Climate variability affects our agricultural activities because the planting dates as well as the harvesting dates for crops are affected due the unpredictability of the onset and cessation dates of rainfall;

(4) What effects do climate variability has on your agricultural yield?

Climate variability affects our agricultural yield because some years do record rainfall below the normal requirements of some crops and that affects the crop yield. On the other hand, some years do record rainfall above normal and that causes flooding thereby washing away the agricultural produce;

(5) What are the other factors that affect your agricultural yield other than climate variability?

Non-climatic factors such as seed quality, availability of fertilizer and its application, differences in soil fertility, occurrences of pests and diseases also affect their agricultural yield;

(6) Do you have climate forecasting tools to guide you?

We do not have climate forecasting tools that enable us to forecast climate which can help guide us on the onset or cessation of rainfall.

4.12 Key Informant Interviews (KII)

Interviews with Dr. M. K. Othman, Assistant Director Extension and Training, National Agricultural Extension Research and Liaison Services (N.A.E.R.L.S), Ahmadu Bello University, Zaria on 16th January, 2013.

(1) What are the variables that affect agricultural yield?

Basically, there are climatic variables and also non-climatic variables that affect agricultural yield;

(2) What are the climatic variables that affect agricultural yield?

The climatic variables that affect agricultural yield include: rainfall, mean air temperature, relative humidity and wind speed;

(3) What are the non-climatic variables that affect agricultural yield?

The non-climatic variables include: fertilizer, seed characteristics, soil fertility, pest and diseases amongst others;

(4) How do climate change and variability impacts affect agricultural activities?

Consequences of climate variability and change such as floods and droughts coupled with unpredictable rainfall play significant roles in determining agricultural performance and as such most stages of agriculture from planting to harvesting are affected directly or indirectly by climate change and variability;

(5) How does drought, in particular affects agricultural yield?

Drought can affect crop yield because each crop has its own water requirement and when the rainfall is below normal and coincidentally it is below the water requirement of a particular crop, the crop yield can be affected. Drought affects water loving crops such as maize and rice; while sorghum is a drought resistant crop. The crop water requirement of maize is about 500-800mm per season and if the water is below this range, the growth of maize could suffer some set back in an area.

Interviews with Dr. E.M. Shaibu-Imodagbe, Head of Department Science, Division of Agricultural Colleges, Ahmadu Bello University, Zaria on 7th January, 2013.

(1) What are some basic indicators of climate change and variability?

Among the basic indicators of climate change and variability are increase in mean air temperature and change in rainfall pattern as well as amount. The increase in mean air temperature can be accompanied by either increase or decrease in rainfall;

(2) How does climate change and variability affect agricultural activities?

The change in the onset and cessation dates of rainfall which leads to decrease in the length of the rainy season affects agricultural activities. Some crops could be destroyed when there sudden is cessation of rainfall and their optimum water requirements have not been reached;

(3) How does flood affect crops?

Flood is one of the impacts of climate change and it can cause the emergence of pests and diseases to crops and that can destroy the crops.

Interviews with Mr. Aliyu M. Yamusa, Officer-in-Charge of Meteorological Section, Institute for Agricultural Research, Ahmadu Bello University , Zaria on 14th January, 2013.

(1) Is climate changing?

Actually, climate is changing as it can be observed that there has been increase in the mean air temperature over the years. Zaria is not an exception because there is increase in the mean temperature recorded over the years and that tallied with the IPCC (2007) report;

(2) What do you observe about the rainfall based on the measurement you do in I.A.R?

The rainfall amount is higher than normal in recent years but the spatial distribution of the rainfall is lower and that could be one of the reasons

flooding was recorded in some parts of Zaria Local Government Area in 2013 as well as other parts of the country;

(3) Do you record drought in some years?

Really, in some years, we do record rainfall below normal and such could affect agricultural activities.

Interviews with Dr. A. G. Bakari (Associate Professor/ Consultant in Department of Medicine), Ahmadu Bello University Teaching Hospital Zaria on 22nd December, 2012.

(1) What are the types of climate change impacts on the health of people?

The types of climate change impacts on health could be classified as direct and indirect impact;

(2) What are the direct impacts of climate change on health of people?

The direct impacts of climate change on health arises from extreme events such as heat waves, floods, droughts, windstorms, wildfires, persistence and resistance of diseases to treatment that were not experienced before;

(3) What are the indirect impacts of climate change on health of people?

Indirect impacts of climate change on health may arise from malnutrition due to reduced food production, spread of infectious diseases and food- and water-borne illnesses, and increased air pollution;

(4) How do drought and flood affect the health of people?

Drought causes food shortages which in turn results to malnutrition and such can weaken the body defense mechanisms. Flood, on the other hand, can cause the emergence of some water-borne diseases, because sewage can combine with

water and such can result to the outbreak of diseases such as cholera, diarrhea, and typhoid fever amongst others;

(5) What is the impact of excessive air temperature on the health of people?

Excessive mean air temperature can cause climate-related illness such as meningitis and also extreme weather events are known to exacerbate some cardiovascular diseases such as asthma.

4.13 Mitigation Measures of Climate Change

Mitigation measures of climate change require policies, strategies and interventions to minimize GHGs emissions or improve their reservoirs or sinks that clears them from the atmosphere (for example, trees and vegetations). The various climate change implications can be minimized, removed or prevented by proper mitigation actions (IPCC, 2007a). However, effective attention on mitigation and investments in the future decades will play a vital role in reducing climate change effects and on chances to attain minimum degree of emissions. Additionally, failure to employ quick actions on emission minimization can immensely limit the chances to reach minimum degree of stabilisation and pose the danger of more fatal climate change consequences (IPCC, 2007a). It is clear that CO_2 is the most significant contributor to the GHGs. It contributes about 76.7% of the GHGs (Odjugo, 2011). Its annual release has been increased by about 80% between 1970 and 2004. However, because fossil fuels are the basic source of energy for the current global economy, removing the emission of GHGs altogether is impossible.

There is great believe that neither adaptation nor mitigation alone can prevent all climate change effects; but they can be use together to effectively minimize the negative effects of climate change and variability. However, prolong unmitigated climate change, would certainly became

higher that human systems would not be able adapt (IPCC, 2007a). The time at which such stage could be attained vary between sectors and areas. Additionally, early mitigation actions would prevent further locking in carbon intensive infrastructure and minimize climate change and related demand for adaptation. Moreover, further GHGs emissions at the present level or higher would lead to more warming and create a lot of changes in the global climate system during the 21st century that would be higher than those experience during the 20th century (IPCC, 2007b).

The following mitigation measures will help in the reduction of GHGs in the atmosphere or enhancing their sinks:

a. Embarking upon renewable energy;
b. Adopting standards for emissions per time for engines;
c. Application of carbon capturing and storage;
d. Livestock-methane management;
e. Trees planting

4.13.1 Embarking upon Renewable Energy

Renewable energy is the energy that will not be exhausted and can be suitably apply to generate electricity and heat required in our homes, schools, offices and factories. In several areas of the globe, individual are employing renewable energy, because it is a better way of protecting the environment. They have less effect than other types of energy sources such as coal, oil and gas. Renewable energies include: wind, solar, biomass, geothermal (heat of the earth). They are "renewable" because they are continually renewed by natural processes and as such they have unlimited availability. Similarly, technologies have been created to strengthen these energies and such technologies are called "clean technologies" or "green energy". On the other hand, wind

energy requires various wind turbines placed in an area expected to be permanent for mechanical or electrical power generation. Photovoltaic cells production to strengthen solar energy for power development is also significant. With research, knowledge and progresses, those to be created in the coming years should be stronger, cost effective and more reliable. These strategies would in a long way reduce the dependence of fossil fuel for energy generation that usually pollutes the environment exacerbates effect of global warming.

In transportations, there should be more fuel-efficient vehicles, bio-fuels, modal shift from road transportation to rail and public transport systems, non-motorised transport in relatively short distances (cycling and walking), land-use and transport planning, higher efficiency aircrafts, advanced and hybrid vehicles with more powerful and reliable batteries should be adopted.

The following are the advantages of renewable energies:

(a) Their frequency of usage does not reduce their subsequent amount because they are endless in supply;

(b) They are spread throughout the globe, even though some variations happen.

(c) They are clean, reliable and do not pollute the environment;

(d) They are cost effective and can be continuously generated (Uyigue et al, 2007).

4.13.2 Adopting Standards for Emissions per time for Engines

This should be employed at the local, state and the regional level because the fossil engines are utilized throughout the country. Vehicular emission from transportation is one of the sources of CO_2 in Nigeria. FME (2003) reported that transportation contribute about 20% of the atmospheric CO_2 emissions which is the major amongst the GHGs. Nigeria being developing country, depends on the supply of fossil fuel engines from developed country that are vast in technology. The fossil engines include: cars, generators, motor cycle and so on which contributes

heavily to environmental pollution and climate change and variability because of the GHG emissions they release to the environment. Additionally, Sea transport control authorities responsible for the regulation of the importation of the fossil fuel engines should develop limit for engine emissions for the various products supplied into the country. The agencies responsible for environmental regulation should also embark upon some measures to minimize the vehicular emissions from petrol as well as diesel engines. This will assist in improving the air quality and pave way for the annual checkup for vehicles for harmful air emissions as well as inclusion of emission control devices in the vehicles. However, vehicle emission checking places should be generated at the local, state and national level and also all the fossil fuel vehicles need to be in cooperated with emission minimization technology. These measures will in the long term help in the GHGs emission reduction thereby controlling climate change and variability.

4.13.3 Application of Carbon Capturing and Storage

Carbon capturing and storage implies separating CO_2 its source and taking it to be kept at a location to prevent it from escaping into the atmosphere by isolating it. The location is normally a geologic formation, either deep ocean or underground. This is because the release of CO_2 to the atmosphere has negative consequences as it causes global warming and climate change. Carbon dioxide is significant for improved oil recovery for oil producing companies having a market for carbon storage close to oil fields. This type of emission sequestration is costly but with contribution from Government in organization and capital in the long term will help in achieving it. Additionally, strengthen and making available the carbon capturing and storage devices for industries by the government will help to enhance their utilization. This will reduce the amount of emission in the environment by a higher portion in subsequent years there by minimizing the climate change and variability.

4.13.4 Livestock-Methane Management

Methane that is generated from livestock contributes immensely to the quantity of GHG emissions in any country or region that engages in livestock practices and it occurs in the area and the country. Methane is a strong gas with a short life that last in the atmosphere from 9-15 years, implying it is 20 times more potent than CO_2 over a period of 100 years (Savory institute, 2013). The domestic ruminant such as cattle, sheep and goats release methane due to the bacterial breakdown of cellulose in the rumen. The methane emissions differ with size, breed and feed but for beef and dairy cattle, release methane of 164 – 345 mg/day (Savory institute, 2013).

However, healthy soil condition when properly practiced is very vital in controlling the methane release by the livestock. This is because a well-aerated soil plays a significant role in sequestration of methane, thereby reducing its greenhouse effect. The soil-based breakdown of methane could be the same or higher than the methane generated by the livestock but depends upon the animal weight, soil characteristics and condition (Savory institute, 2013). However, appropriate management of the dung cattle released by cattle herdsmen is important because the decomposed dung can lead to the release of methane to the environment thereby adding methane load to the environment. The employment of safe waste bags to the cattle herdsmen to clear the dung of their livestock in such bags would minimize the release of methane that would result from stark disposal. However, effective manure management in agricultural practices will also help in the reduction of CH_4 emission which will in the long term lower the greenhouse effect.

4.13.5 Trees Planting

Trees within cities and forest have a high significance in supplying the environment with more oxygen after the intake of CO_2; this is a natural carbon-capture or sequestration. Trees assimilate

CO_2 to produce their own food when combined with sunlight and water through the process of photosynthesis. This process is continuous throughout the development and mature life of the plants. The afforestation which refers to the establishment of forest or stand of trees where there is no forest (wikipeida, 2013c) and the reestablishment of forest cover, either naturally (by natural seeding, coppice, or root suckers) or man-made through seeding or planting (reforestation) are very crucial in supplying the environment with a fresh oxygen thereby acting as natural sink or reservoirs to the release CO_2 by vehicles and other industrial processes. This practices when embark upon in the long term, would reduce the level of environmental pollution and minimized the impact of climate change and variability. However, vehicles are said to produce about 20% of the global carbon release; with rapid population growth in the country and traffic in cities, some plants suitable to our environment and conditions can be incorporated around the cities to improve human health and also absorb emissions. Similarly, the broad leaves of banana trees, well-conditioned are capable of absorbing about 0.0005 ppm by volume of CO_2 on a sunny day (Stephen, 2011).

4.14 Adaptation Options of Climate Change

Adaptation involves the modification in practices, processes or structures in reaction to the forecasted or real change climate change, with the aim of retaining the ability to withstand the present and subsequent changes. However, adaptation to climate change also refers to activities that minimize the disastrous effect of change in climate and/or new chances that may be available (IPCC, 2007c). There is significant believe that adaptation can reduce risk, particularly in the short term. Similarly, adaptive capacity is highly depends upon the social and financial capability, but it is not equally spread amongst communities (Kolawale et al, 2011).

However, even if emphases to minimize the GHGs emissions are attained, it is no longer feasible to prevent certain level of global warming and climate change (Ifeanyi-obi et al, 2012). IPCC (2007b) reported that due to GHGs that have been in the atmosphere from past and present release, our planet has been induced to more warming over the 21st century as it has encountered over the 20th century of 0.75^{o}C. This signifies that apart from the mitigation efforts being developed to tackle climate change, adaptation to the expected climate change is also vital.

However, while mitigation is compulsory to minimize the frequency and degree of climate change, adaptation is significant to lower the effects of climate change that their preventions prove abortive. The Nigerian Agricultural sector in the 21st century will be encountering two notable obstacles, due to the demand to upgrade the country's food availability and withstanding variation in climate.

Additionally, by virtue of the fact that Agricultural practices are affected by climate and changes in climate could not be prevented in the nearest future; embarking upon some adaptation options to adjust to the varying climate becomes the most attainable option for farmers to apply in overcoming climate change risk. The following adaptations options can be used:

On crop production:

(a) changing the timing or area of agricultural activities;

(b) enhanced water management through the application of water harvest method; retain soil moisture (through use of crop residue) and effective transportation of water;

(c) changing the inputs or crop varieties to one's with more thermal resistance;

(d) application of drought resistant crop varieties;

(e) employment of enhanced and early maturing crops;

(f) upgrading the efficiency of pest, disease and weed management practices through higher use of combined pest and pathogen management;

(g) development and employment of varieties and species that withstand pests and diseases and upgrading supervision programmes; (Ifeanyi-Obi et al, 2012)

(h) enhanced nitrogen fertilizer usage mechanisms to control N_2O emissions;

(i) application of climate forecasting devices to minimize production instability;

(j) application of irrigation facilities to enhance water availability and improve production;

(k) assistance to farmers affected by the climate change and variability;

(l) extending sources of income to farming and non-farming activities;

However, the above stated adaptation options can be use by farmers and they can apply two or more options where required so as to obtained the targeted output.

On livestock practices:

(a) altering the time of grazing;

(b) changing the animal feed and animal species;

(c) modifying the composition in combined livestock and crop systems and employment of adapted forage crops;

(d) provision of enough supply of water and application of additional feeds and concentrate;

Control of floods involves the techniques employ to minimize the negative results of flood. The following methods can be employed in the flood control:

(a) planting vegetation to hold excess water;

(b) terracing hillsides to reduce water flow down hills;

(c) provision of man-made channels to transport flood water;

(d) building up of levees, dams, reservoirs or retention ponds to keep excess water in a situation of flooding;

(e) prevention of erosion and effective drainage channels for flood controls;

(f) flood warning, that is, notification of conditions that are liable to results to flooding. This should be applied to protect life by allowing people and emergency services time to prepare for flooding. It will also minimize the effects of flooding;

(g) effective town planning in order to provide channel drainage;

(h) use of overland flow for groundwater recharge;

(i) provision of resettlement camps in case of flood disasters;

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Based on the results obtained in this study, the following conclusions are drawn:

(a) The normal rainfall, normal maximum temperature, normal minimum temperature and normal mean temperatures are respectively: 1009 mm, 31.6, 18.9 and 25.3^{o}C; any deviations from these normal signify climate variability;

(b) There was variability of 7 mm, 0.50, 0.30 and 0.40^{o}C in rainfall, maximum temperature, minimum temperature and mean temperature, respectively using the differences between the two means of equal-length time scales of 1971-2000 and 1981-2010;

(c) Out of the forty years, 21 years (52.5%) recorded rainfall below normal (dry); while 19 years (47.5%) recorded rainfall above normal (wet); 1983 having the highest dry of 323 mm; while 1972 had the lowest dry of 15 mm. On the other hand, the highest wet of 340 mm occurred in 1978; while the lowest wet of 9 mm occurred in 1971; as revealed by rainfall anomalies;

(d) Out of the forty years, 24 years (60.0%) recorded higher mean temperatures than normal; 13 years (32.5%) recorded lower mean temperatures than normal; while 3 years (7.5%) recorded normal mean temperature. However, 2006 was the warmest year during the four decades which was higher than normal by 2.0^{o}C; while 1983, 1994, 2000 and 2001 were associated with the least warming of 0.1^{o}C each. Moreover, 1980 and 1989 had the highest deficit of mean temperature of 0.8^{o}C each; 1976, 1979 and 1984 had the least deficit of 0.2^{o}C each;

(e) The Sen's estimator slope revealed that the rainfall recorded downward trend of 94mm/yr in 1971-1980 decade; while it recorded upward trends of 90mm/yr, 30mm/yr and 118mm/yr, respectively during 1981-1990, 1991-2000 and 2001-2010 decades, but none is statistically significant at 95% confidence level;

(f) The mean temperature recorded upward trends of: 0.2^{o}C/yr, 0.2^{o}C/yr, 0.1^{o}C/yr and 0.2^{o}C/yr, respectively during 1971- 1980, 1981-1990, 1991-2000 and 2001-2010 decades, but all are not statistically significant at 95% confidence level;

(g) The multiple non linear regression analysis revealed that 28.9% of the annual maize yield variation could be accounted for by the annual rainfall and mean temperature; while 45.2% of the annual millet yield variation and 24.2% of the sorghum yield variation could be accounted for by the climatic variables. The rainfall contributed to the variation of maize and sorghum yield more than the mean temperature; while the mean temperature contributed more to the variation of millet yield than the rainfall;

(h) Based on the three statistical models developed, the millet model was the most fitted and valid as it recorded lowest total and mean square errors of: 0.335 and 0.030, respectively; it was followed by sorghum model with total and mean square errors of: 0.349 and 0.032; while maize was the least with total and mean square errors of: 1.457 and 0.132, respectively.

5.2 RECOMMENDATIONS

Based on the results obtained in this study, the following recommendations were made:

(a) More researches on climate variability and change should be carried in the subsequent decades considering more meteorological variables, in particular, wind velocity and relative humidity.

(b) Agricultural yield data for crops should be properly and reliably documented in order to have more effective future researches on the impact of climate change and variability on agriculture;

(c) Future researches on the impact of climate change on the non cereal crops should be embark upon as this study was limited to only cereal crops;

(d) Climate forecasting devices should be provided in various meteorological stations and the information should made available to farmer for proper and effective adaptation purposes.

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APPENDIX

Appendix A

Climatic Data

Appendix 1A: Total monthly rainfall in mm (1971-2010)

Years	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
1971	0.0	0.0	2.0	0.0	107.7	49.2	251.5	392.3	203.8	11.9	0.0	0.0	1018.4
1972	0.0	0.0	0.0	16.6	220.3	101.7	148.9	303.2	150.4	52.9	0.0	0.0	994.0
1973	0.0	0.0	0.8	5.7	34.3	168.2	255.9	223.2	212.7	0.0	0.0	0.0	900.8
1974	0.0	0.0	5.3	82.1	53.7	126.8	399.3	226.5	181.9	62.5	0.0	0.0	1138.1
1975	0.0	0.0	0.0	89.3	129.1	97.4	240.2	179.4	202.2	11.4	0.0	0.0	949.0
1976	0.0	0.0	0.0	61.7	103.4	124.9	187.2	217.3	175.2	230.4	0.0	0.0	1100.1
1977	0.0	0.0	1.3	0.0	93.4	125.5	155.0	270.6	216.2	17.3	0.0	0.0	879.3
1978	0.0	0.0	5.1	145.1	162.4	192.2	211.4	406.4	199.9	26.5	0.0	0.0	1349.0
1979	0.0	0.0	11.4	67.0	66.5	169.7	363.2	261.7	116.8	32.4	0.0	0.0	1088.7
1980	0.0	0.0	0.0	20.2	101.0	111.4	268.0	221.5	61.6	43.9	0.0	0.0	827.6
1981	0.0	0.0	0.0	70.5	107.7	89.1	256.5	305.2	149.4	0.0	0.0	0.0	978.4
1982	0.0	0.0	0.0	54.3	77.5	112.3	193.8	238.5	94.3	113.2	0.0	0.0	883.9
1983	0.0	0.0	0.0	0.0	62.7	129.3	132.5	287.3	73.4	0.4	0.0	0.0	685.6
1984	0.0	0.0	43.2	45.7	104.2	97.6	237.4	155.1	172.0	126.2	0.0	0.0	981.4
1985	0.0	0.0	64.3	0.0	122.4	87.2	350.2	250.8	190.9	5.8	0.0	0.0	1071.6
1986	0.0	0.0	0.0	6.5	42.4	69.3	256.6	298.9	149.7	1.7	0.0	0.0	825.1
1987	0.0	0.0	1.0	0.0	91.1	149.1	247.4	356.1	98.3	35.0	0.0	0.0	978.0
1988	0.0	0.0	0.0	23.4	136.0	157.9	177.8	398.7	209.3	11.4	0.0	0.0	1114.5
1989	0.0	0.0	0.0	21.5	110.1	89.3	146.4	286.1	68.1	64.9	0.0	0.0	786.4
1990	0.0	0.0	0.0	2.3	164.1	152.6	202.7	192.9	156.9	12.0	0.0	2.7	886.2
1991	0.0	0.0	42.2	75.5	323.1	100.3	225.3	366.5	75.9	30.7	0.0	0.0	1238.5
1992	0.0	0.0	0.0	36.6	115.3	81.4	274.8	216.7	242.4	6.2	0.0	0.0	973.4
1993	0.0	0.0	1.3	38.9	83.6	88.0	244.0	281.9	199.7	19.8	0.0	0.0	957.2
1994	0.0	0.0	0.0	33.1	78.7	137.1	125.5	352.4	203.7	166.1	0.0	0.0	1096.6
1995	0.0	0.0	0.0	59.1	103.0	153.7	235.5	294.3	112.0	32.9	0.0	0.0	990.5
1996	0.0	0.0	0.0	8.9	149.6	186.3	184.3	267.0	173.5	59.9	0.0	0.0	1029.5
1997	0.0	0.0	0.0	29.4	176.9	146.8	232.8	355.7	192.3	64.9	0.0	0.0	1198.8
1998	0.0	0.0	0.0	33.4	123.3	144.0	184.3	473.1	236.8	71.4	0.0	0.0	1266.3
1999	0.0	0.0	6.9	10.5	7.2	229.5	245.7	144.7	268.2	78.0	0.0	0.0	990.7
2000	0.0	0.0	0.0	17.8	107.6	157.1	268.0	298.4	177.7	63.3	0.0	0.0	1089.9
2001	0.0	0.0	0.0	99.8	100.4	189.0	255.7	244.9	312.6	0.0	0.0	0.0	1202.4
2002	0.0	0.0	26.4	35.0	10.9	85.9	181.2	210.2	200.1	128.7	0.0	0.0	878.4
2003	0.0	0.0	0.0	55.7	107.3	74.5	254.3	407.2	238.2	62.5	0.0	0.0	1199.7
2004	0.0	0.0	0.0	34.8	103.9	239.0	284.4	296.9	186.3	23.9	0.0	0.0	1169.2
2005	0.0	0.0	0.0	28.1	62.1	179.5	168.6	281.6	85.7	10.7	0.0	0.0	816.3
2006	0.0	0.0	0.0	1.5	84.1	125.5	235.8	207.4	356.0	28.2	0.0	0.0	1038.5
2007	0.0	0.0	7.0	44.9	239.6	210.2	213.5	457.8	42.9	3.8	0.0	0.0	1219.7
2008	0.0	0.0	0.0	36.0	66.0	90.1	120.2	250.7	274.0	16.1	0.0	0.0	853.1
2009	0.0	0.0	0.0	14.0	79.6	156.9	191.8	342.7	138.0	55.8	0.0	0.0	978.8
2010	0.0	0.0	0.0	41.4	105.9	134.0	219.3	307.4	205.3	83.7	0.0	0.0	1097.0
2011	0.0	0.0	0.0	21.0	136.0	93.3	317.0	262.0	184.0	24.8	0.0	0.0	1038.1

Source: Nigeria Meteorological Agency (NIMET), Zaria

Appendix 2A: Average monthly maximum temperatures in ^{o}C (1971-2010)

Years	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Mean
1971	28.8	33.4	37.0	36.8	35.9	32.2	28.5	27.9	28.2	32.1	32.2	29.6	32.0
1972	30.6	33.7	36.7	36.3	33.5	30.6	30.3	29.3	31.2	32.1	30.8	30.9	32.2
1973	32.4	35.4	36.1	37.8	36.1	33.2	29.9	29.1	30.1	33.3	31.4	32.8	33.1
1974	28.2	33.3	36.1	36.7	33.7	32.4	27.9	28.5	28.9	31.5	30.9	27.8	31.3
1975	26.9	32.6	35.5	35.9	32.1	31.3	28.3	27.7	29.0	31.7	32.6	29.6	31.1
1976	29.9	34.7	35.5	35.8	32.6	30.0	28.3	28.2	29.8	29.9	30.4	30.3	31.3
1977	30.0	31.1	32.6	36.8	34.4	30.4	29.0	28.0	30.1	31.4	31.0	28.0	31.1
1978	29.5	33.6	35.6	33.4	31.8	29.6	27.4	28.8	29.7	31.9	30.5	30.0	31.0
1979	30.6	33.6	35.6	36.0	32.6	30.4	29.2	29.0	30.0	32.3	32.6	28.6	31.7
1980	32.3	32.5	35.7	36.9	24.7	30.7	28.8	28.5	30.7	32.3	32.7	29.1	31.2
1981	28.5	33.0	35.8	36.6	32.1	31.1	28.5	29.3	30.4	33.3	30.1	30.7	31.6
1982	30.0	31.6	35.0	35.6	33.4	31.4	29.7	28.3	30.0	31.7	30.5	30.7	31.5
1983	23.7	33.3	33.5	38.1	35.4	31.5	29.4	29.2	30.3	32.7	32.7	31.4	31.8
1984	28.9	31.3	36.1	35.6	32.5	31.5	28.8	29.9	30.0	31.0	32.0	28.0	31.3
1985	32.4	30.0	36.0	34.4	33.8	30.5	28.2	29.0	29.2	31.5	32.5	28.2	31.3
1986	29.9	34.7	35.7	37.3	34.0	31.4	28.8	29.3	29.4	31.7	31.6	27.2	31.8
1987	30.9	33.5	35.5	33.0	37.3	30.9	30.5	28.9	30.7	31.4	32.0	30.4	32.1
1988	29.2	32.2	36.1	36.7	34.8	30.5	28.3	27.6	29.3	31.5	32.2	28.7	31.4
1989	25.6	28.7	35.3	37.0	33.3	31.1	29.7	28.1	29.6	30.9	31.5	28.3	30.8
1990	31.3	30.4	33.6	37.7	32.9	31.0	29.0	29.2	30.5	33.3	34.1	33.4	32.2
1991	29.6	36.0	35.6	35.9	31.5	31.1	28.7	28.8	31.3	32.2	32.2	28.6	31.8
1992	27.1	30.3	35.5	36.0	33.4	31.2	29.0	28.2	29.7	32.0	30.2	30.3	31.1
1993	27.5	33.0	35.1	36.9	34.3	31.8	27.9	28.7	30.4	32.9	33.9	29.6	32.0
1994	30.1	32.3	37.7	35.4	34.4	31.7	29.8	27.7	29.7	31.3	30.2	27.2	31.5
1995	28.3	31.1	36.5	36.2	33.8	31.5	29.3	28.6	30.0	32.2	31.5	32.0	31.8
1996	32.2	34.8	36.9	37.0	33.7	30.2	29.3	28.7	29.6	31.1	30.0	31.1	32.1
1997	31.5	28.8	35.0	35.5	33.0	30.8	29.5	29.0	30.9	32.2	33.3	30.6	31.7
1998	29.5	33.7	34.2	37.4	33.8	31.3	29.3	28.4	29.8	31.1	32.8	30.5	31.8
1999	31.0	34.4	35.7	36.7	35.5	32.1	28.6	27.9	29.1	31.0	32.1	29.7	32.1
2000	31.3	29.0	35.0	38.5	35.6	30.5	28.9	28.0	29.6	31.3	32.0	29.6	31.6
2001	29.9	31.0	36.0	35.0	34.0	30.7	29.0	28.3	30.0	33.3	32.8	31.6	31.8
2002	26.8	32.2	36.0	36.4	36.4	32.2	30.2	29.1	30.3	30.5	32.0	30.3	31.9
2003	31.4	34.9	35.4	36.4	36.3	31.1	29.8	28.9	29.9	32.4	33.1	30.1	32.5
2004	31.0	32.1	34.5	37.1	33.5	30.9	29.4	28.2	30.1	32.4	33.0	31.7	32.0
2005	28.7	35.8	37.5	37.5	34.9	34.8	34.3	34.0	33.8	31.0	30.9	30.7	33.7
2006	31.7	34.5	35.9	37.6	37.0	36.8	36.0	35.7	35.6	35.4	31.2	28.2	34.6
2007	28.6	32.3	35.3	35.9	37.4	35.7	35.6	35.3	35.8	34.6	33.1	29.6	34.1
2008	28.6	29.6	36.2	36.6	37.6	36.6	35.5	28.0	30.0	32.2	32.7	31.5	32.9
2009	32.4	34.6	36.4	36.3	34.6	31.8	29.5	28.7	30.8	31.4	31.4	32.3	32.5
2010	32.5	35.9	36.0	36.0	33.8	31.0	28.7	28.9	30.0	31.7	33.5	30.9	32.5
2011	29.0	35.4	37.3	36.8	34.5	31.2	29.5	29.0	30.6	31.8	33.4	30.7	32.4

Source: Nigeria Meteorological Agency (NIMET), Zaria

Appendix 3A: Average monthly minimum temperatures in ^{o}C (1971-2010)

Years	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Mean
1971	12.6	16.2	21.0	21.8	22.1	20.9	19.7	19.1	19.0	17.7	14.4	12.7	18.1
1972	13.6	16.2	19.8	22.5	21.8	20.4	20.0	19.4	20.1	19.4	14.3	14.5	18.5
1973	15.3	17.6	20.3	22.9	23.0	21.3	20.7	19.6	20.0	19.2	14.9	14.5	19.1
1974	13.8	16.1	19.7	22.9	21.7	20.9	19.7	20.4	19.8	19.3	14.8	12.2	18.4
1975	11.5	16.4	19.9	22.1	21.8	20.8	19.7	19.7	19.6	19.5	16.6	13.3	18.4
1976	13.8	18.7	20.2	22.1	22.0	20.3	19.7	19.7	20.0	19.6	15.5	13.6	18.8
1977	13.9	14.5	18.1	21.7	22.3	20.4	20.3	20.2	19.7	18.8	14.3	12.5	18.1
1978	12.8	16.6	20.4	22.3	20.7	20.3	20.2	19.8	19.7	20.2	15.6	13.5	18.5
1979	14.1	16.8	21.3	21.7	20.2	19.0	19.6	20.2	19.3	19.3	16.7	12.1	18.4
1980	13.1	15.6	19.1	22.3	15.1	20.0	19.2	19.2	19.9	19.5	15.7	13.2	17.7
1981	11.4	15.4	19.5	20.7	21.0	20.3	19.1	19.5	19.3	19.7	14.3	12.5	17.7
1982	13.4	15.3	20.3	21.2	21.4	20.2	19.9	20.5	20.5	20.4	15.2	14.1	18.5
1983	12.3	17.4	18.5	23.2	23.4	21.7	20.8	20.4	20.7	18.0	15.6	15.0	18.9
1984	13.2	18.9	21.6	23.0	21.7	21.0	19.9	20.6	19.8	17.2	15.9	14.0	18.9
1985	16.0	15.5	22.3	23.0	23.1	20.9	20.0	20.4	20.0	19.0	16.6	14.5	19.3
1986	13.5	18.1	21.8	24.2	23.5	21.4	20.4	20.1	20.0	19.4	16.6	13.4	19.4
1987	14.4	17.7	21.4	22.8	23.5	21.5	20.7	20.4	20.5	19.3	15.5	14.3	19.3
1988	14.8	16.7	22.0	23.3	23.0	21.5	20.6	20.1	20.3	18.2	15.3	14.1	19.2
1989	11.3	14.5	18.6	21.7	21.6	21.0	20.4	20.2	20.1	19.1	15.8	14.7	18.3
1990	15.6	15.8	18.9	23.6	22.3	21.5	20.5	20.0	20.3	19.5	17.1	16.6	19.3
1991	15.2	18.6	21.3	22.9	21.4	21.1	20.0	19.7	20.0	19.0	16.1	14.1	19.1
1992	13.7	16.0	21.3	23.1	22.6	21.1	20.2	20.3	20.0	18.7	16.4	13.8	18.9
1993	13.2	16.2	20.7	20.7	25.9	28.9	20.7	20.3	20.3	20.2	16.7	15.0	19.9
1994	15.1	16.8	20.7	23.4	23.0	21.5	21.3	20.3	20.5	20.5	15.7	13.4	19.4
1995	13.6	15.6	21.1	22.8	22.6	21.6	21.1	20.8	20.5	20.6	16.6	15.8	19.4
1996	15.5	18.0	21.6	23.5	22.8	21.1	20.0	20.5	20.4	19.9	15.3	14.6	19.5
1997	15.1	15.4	21.0	23.4	21.9	21.9	20.9	21.0	20.9	21.2	17.9	15.0	19.6
1998	14.3	18.7	20.5	24.2	23.6	21.5	21.4	20.9	21.1	20.6	17.5	15.1	20.0
1999	15.1	18.2	22.0	23.8	23.3	21.8	20.9	20.8	20.5	20.0	17.5	14.4	19.9
2000	16.4	15.0	20.0	23.7	23.0	21.2	21.0	20.0	20.6	19.8	16.0	13.5	19.2
2001	12.8	15.0	20.0	22.0	22.7	21.4	20.6	20.9	21.0	19.3	16.5	15.4	19.0
2002	13.3	16.5	21.5	23.9	24.4	21.6	21.3	20.8	20.8	19.6	16.7	14.5	19.6
2003	14.7	18.2	20.2	23.5	22.5	21.5	20.8	20.7	20.7	20.9	17.6	14.1	19.6
2004	15.3	16.5	20.0	24.3	22.3	20.8	20.7	20.5	20.8	20.2	17.8	15.6	19.6
2005	13.9	21.0	23.3	23.7	20.3	20.2	19.7	19.4	19.2	16.4	16.3	16.1	19.1
2006	17.1	19.9	21.3	23.0	22.4	22.2	21.4	21.1	21.0	20.8	16.6	13.6	20.0
2007	14.0	17.7	20.7	21.3	22.8	21.1	21.0	20.7	21.2	20.0	18.5	15.0	19.5
2008	14.0	15.0	21.6	22.0	23.0	22.0	20.9	20.0	20.8	19.3	16.2	15.8	19.2
2009	16.3	18.6	21.1	23.7	22.6	21.3	20.7	20.3	20.8	21.4	17.7	15.4	20.0
2010	15.3	19.1	22.0	24.2	23.4	21.7	21.0	21.1	20.6	20.4	17.6	14.3	20.1
2011	14.1	16.9	20.6	22.8	22.3	21.3	20.4	20.2	20.3	19.5	16.2	14.2	19.1

Source: Nigeria Meteorological Agency (NIMET), Zaria

Appendix 4A: Monthly mean temperatures in ^{o}C (1971-2010)

Years	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Mean
1971	20.7	24.8	29.0	29.3	29.0	26.6	24.1	23.5	24.1	24.9	23.3	21.2	25.0
1972	22.1	25.0	28.3	29.4	27.7	25.5	25.2	24.4	25.3	25.8	22.6	22.7	25.3
1973	23.9	26.5	28.2	30.4	29.6	27.3	25.3	24.4	25.1	26.3	23.2	23.6	26.2
1974	21.0	24.7	27.9	29.8	27.7	26.7	23.8	24.5	24.4	25.4	22.9	20.0	24.9
1975	19.2	24.5	27.7	29.0	27.0	26.1	24.0	23.7	24.3	25.6	24.6	21.5	24.8
1976	21.9	26.7	27.9	29.0	27.3	25.2	24.0	24.0	24.9	24.8	23.0	22.0	25.1
1977	22.0	22.8	25.4	29.3	28.4	25.4	24.7	24.1	24.9	25.1	22.7	20.3	24.6
1978	21.2	25.1	28.0	27.9	26.3	25.0	23.8	24.3	24.7	26.1	23.1	21.8	24.8
1979	22.4	25.2	28.5	28.9	26.4	24.7	24.4	24.6	24.7	25.8	24.7	20.4	25.1
1980	22.7	24.1	27.4	29.6	19.9	25.4	24.0	23.9	25.3	25.9	24.2	21.2	24.5
1981	20.0	24.2	27.7	28.7	26.6	25.7	23.8	24.4	24.9	26.5	22.2	21.6	24.7
1982	21.7	23.5	27.7	28.4	26.6	25.7	23.8	24.4	25.3	26.1	22.9	22.4	25.0
1983	18.0	25.4	26.0	30.7	29.4	26.6	25.1	24.8	25.5	25.4	24.2	23.2	25.4
1984	21.1	25.1	28.9	29.3	27.1	26.3	24.4	25.3	24.9	24.1	24.0	21.0	25.1
1985	24.2	22.8	29.2	28.7	28.5	25.7	24.1	24.7	24.6	25.3	24.6	21.4	25.3
1986	21.7	26.4	28.8	30.8	28.8	26.4	24.6	24.7	24.7	25.6	24.1	20.3	25.6
1987	22.7	25.5	28.5	27.9	30.4	26.2	25.6	24.7	25.6	25.4	23.8	21.4	25.7
1988	22.0	24.5	29.1	30.0	28.9	26.0	24.5	23.9	24.8	24.9	23.8	21.4	25.3
1989	18.5	21.6	27.0	29.0	27.5	26.1	25.1	24.2	25.0	25.0	23.7	21.5	24.5
1990	23.5	23.1	26.3	30.7	27.6	26.3	24.8	24.6	25.4	26.4	25.6	25.0	25.8
1991	22.4	27.3	28.5	29.4	26.5	26.1	24.4	24.3	25.7	25.6	24.2	21.4	25.5
1992	20.4	23.2	28.4	29.6	28.0	26.2	24.6	24.3	24.9	25.4	23.3	22.1	25.0
1993	20.4	24.6	27.9	29.8	30.1	30.4	25.2	24.5	25.4	26.6	25.3	22.3	26.0
1994	22.6	24.6	29.2	29.4	28.7	26.6	25.6	24.0	25.1	25.9	23.0	20.3	25.4
1995	21.0	23.4	28.8	29.5	28.2	26.6	25.2	24.7	25.3	26.4	24.1	23.9	25.6
1996	23.9	26.4	29.3	30.3	28.3	25.7	25.2	24.6	25.0	25.5	22.7	22.9	25.8
1997	23.3	22.1	28.0	29.5	27.5	26.4	25.2	25.0	25.9	26.7	25.6	22.8	25.7
1998	21.9	26.2	27.4	30.8	28.7	26.4	25.4	24.7	25.5	25.9	25.2	22.8	25.9
1999	23.1	26.3	29.8	30.3	29.4	27.0	24.8	24.4	24.8	25.5	24.8	22.1	26.0
2000	23.9	22.0	27.5	31.1	29.3	25.8	25.0	24.0	25.2	25.6	24.0	21.5	25.4
2001	21.4	23.0	28.0	28.5	28.4	26.1	24.8	24.6	25.5	26.3	24.7	23.5	25.4
2002	20.1	24.1	28.8	30.2	30.4	26.9	25.8	25.0	25.6	25.1	24.4	22.4	25.7
2003	23.1	26.6	27.8	30.0	29.4	26.3	25.3	24.8	25.3	26.7	25.4	22.1	26.1
2004	23.2	24.3	27.3	30.7	27.9	25.9	25.1	24.4	25.5	26.3	25.4	23.7	25.8
2005	21.3	28.4	30.4	30.6	27.6	27.5	27.0	26.7	26.5	23.7	23.6	23.4	26.4
2006	24.4	27.2	28.6	30.3	29.7	29.5	28.7	28.4	28.3	28.1	23.9	20.9	27.3
2007	21.3	25.0	28.0	28.6	30.1	28.4	28.3	28.0	28.5	27.3	25.8	22.3	26.8
2008	21.3	22.3	28.9	29.3	30.3	29.3	28.2	24.0	25.4	25.8	24.5	23.7	26.1
2009	24.4	26.6	28.8	30.3	28.6	26.6	25.1	24.5	25.8	26.4	24.6	23.9	26.3
2010	23.8	27.5	29.0	30.9	28.6	26.4	24.9	25.0	25.3	26.1	25.6	22.6	26.3
2011	21.6	26.2	29.0	29.8	28.4	26.3	25.0	24.6	25.5	25.7	24.8	22.5	25.8

Appendix B

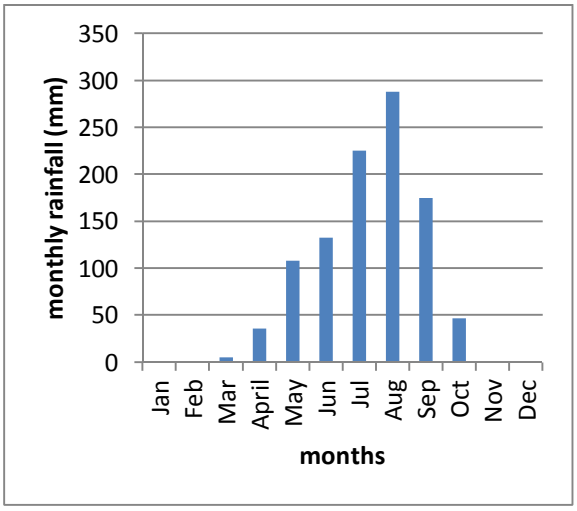
Anomalies Table

Appendix 1B: Anomalies of rainfall, maximum, minimum and mean temperatures (1971-2010)

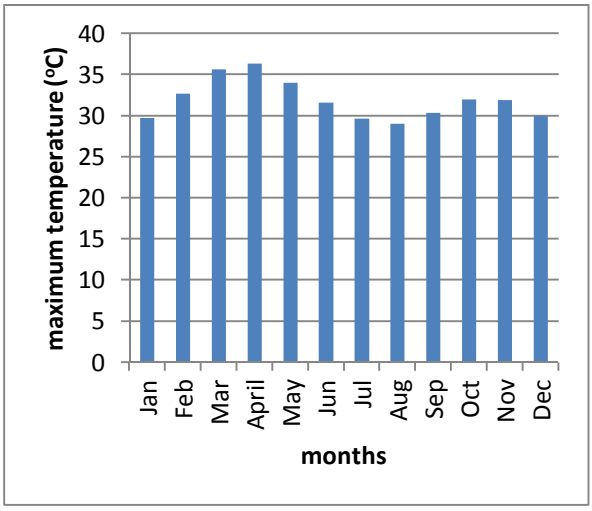
Years	Rainfall	Max. temperature	Min. temperature	Mean temperature
1971	9.45	0.40	-0.80	-0.30
1972	-14.95	0.60	-0.40	0.00
1973	-108.15	1.50	0.20	0.90
1974	129.15	-0.30	-0.50	-0.40
1975	-59.95	-0.50	-0.50	-0.50
1976	91.15	-0.30	-0.10	-0.20
1977	-126.65	-0.50	-0.80	-0.70
1978	340.04	-0.60	-0.40	-0.50
1979	79.75	0.10	-0.50	-0.20
1980	-181.35	-0.40	-1.20	-0.80
1981	-30.35	0.00	-1.20	-0.60
1982	-125.05	-0.10	-0.40	-0.30
1983	-323.35	0.20	0.00	0.10
1984	-27.55	-0.30	0.00	-0.20
1985	62.65	-0.30	0.40	0.00
1986	-183.85	0.20	0.50	0.30
1987	-30.95	0.50	0.40	0.40
1988	105.55	-0.20	0.30	0.00
1989	-222.55	-0.80	-0.60	-0.80
1990	-122.75	0.60	0.40	0.50
1991	229.55	0.20	0.20	0.20
1992	-35.55	-0.50	0.00	-0.30
1993	-51.75	0.40	1.00	0.70
1994	87.65	-0.10	0.50	0.10
1995	-18.45	0.20	0.50	0.30
1996	20.55	0.50	0.60	0.50
1997	189.85	0.10	0.70	0.40
1998	257.35	0.20	1.10	0.60
1999	-18.25	0.50	1.00	0.70
2000	80.95	0.00	0.30	0.10
2001	193.45	0.20	0.10	0.10
2002	-130.55	0.30	0.70	0.40
2003	190.75	0.90	0.70	0.80
2004	160.25	0.40	0.70	0.50
2005	-192.65	2.10	0.20	1.10
2006	29.55	3.00	1.10	2.00
2007	210.55	2.50	0.60	1.50
2008	-155.85	1.30	0.30	0.80
2009	-30.15	0.90	1.10	1.00
2010	88.05	0.90	1.20	1.00

Appendix C

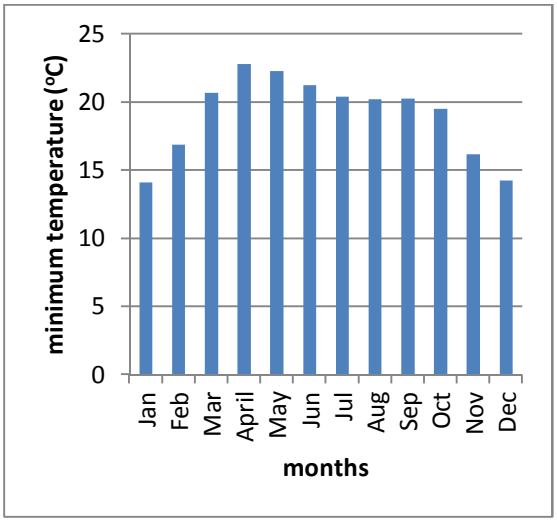
Monthly and decadal variations in the climatic variables



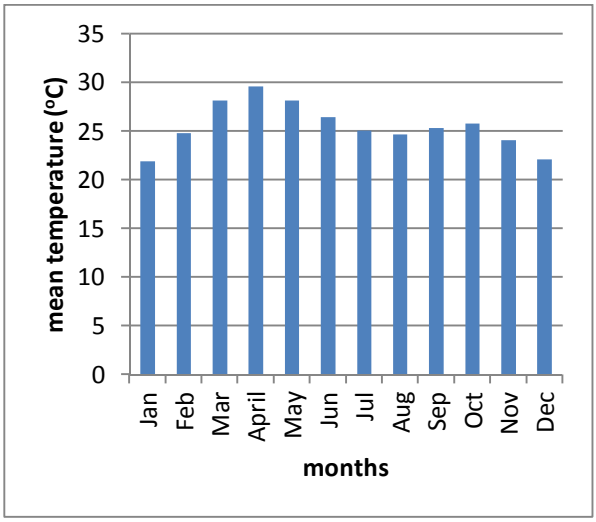
Appendix 1C: Monthly chances in rainfall



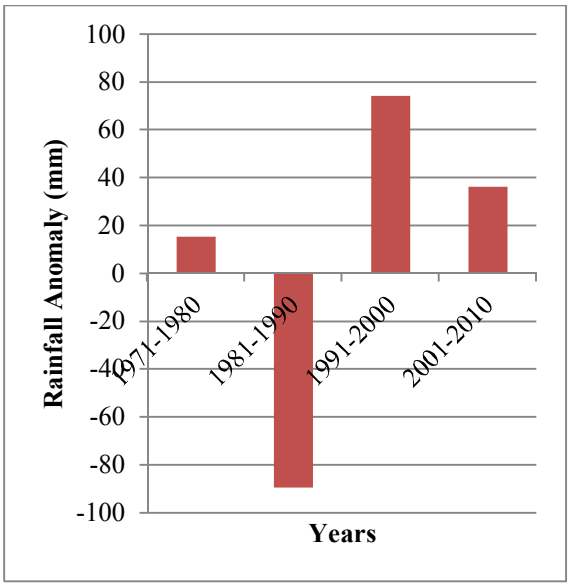
Appendix 2C: Monthly changes in Max. Temp.



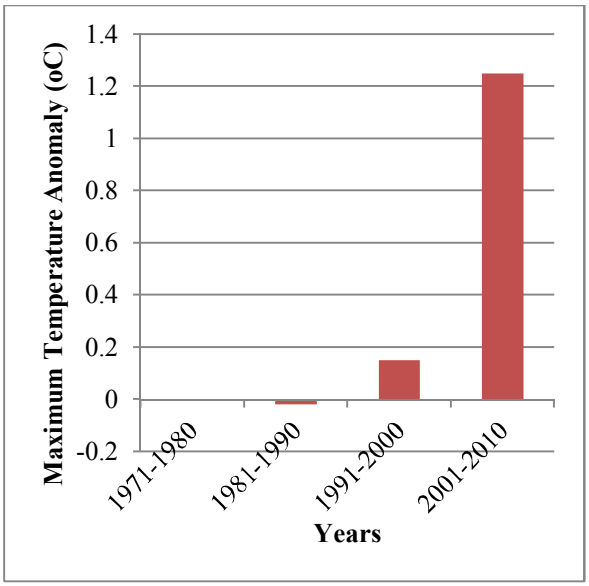
Appendix 3C: Monthly changes in Min. Temp.



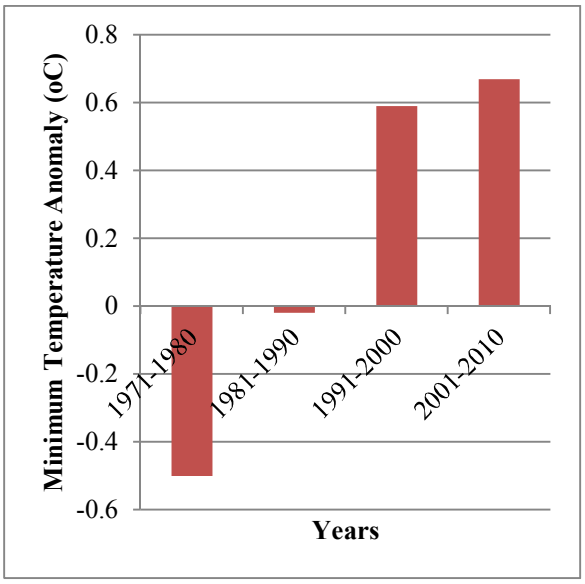
Appendix 4C: Monthly changes in Mean Temp.



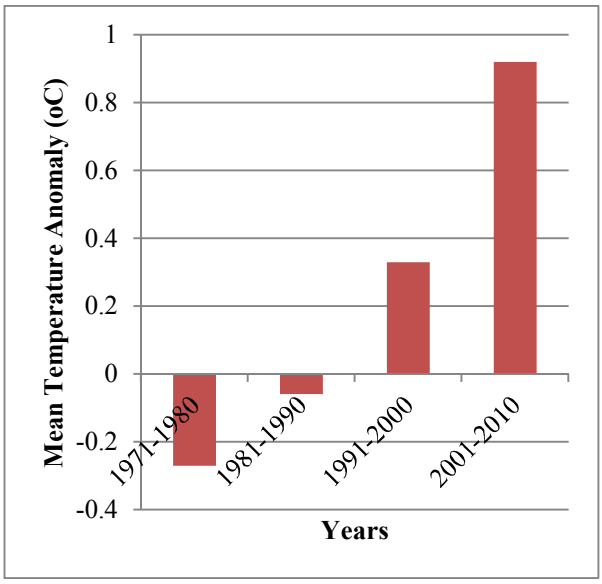
Appendix 5C: Decadal variability of rainfall



Appendix 6C: Decadal variability of Max. Temp.



Appendix 7C: Decadal variability of Min. Temp.



Appendix 8C: Decadal variability of Mean Temp

Appendix D

Questionnaire

Dear respondent,

I am a postgraduate student of the Department of Water Resources and Environmental Engineering, Ahmadu Bello University, Zaria. I am undertaking a research with the title **"ANALYSIS OF CLIMATE CHANGE IMPACT ON AGRICULTURE IN ZARIA LOCAL GOVERNMENT AREA OF KADUNA STATE",** and your community has been chosen for the study.

I shall be grateful if you kindly provide information on the questions below to help in the achievement of the objectives of the study.

Thank you

(1) Sex: Male [ ] Female [ ]

(2) Age: 30-40 [ ] 40-50 [ ] 50-60 [ ] Above 60 [ ]

(3) Marital status: Single [ ] Married [ ]

(4) Educational Qualification: No formal education [ ] Primary education/Arabic education [ ] Secondary Education [ ] Tertiary education [ ]

(5) Occupation: Student [ ] Business man/woman [ ] Civil servant [ ] Farmer [ ] Fisherman [ ] others (Please specify)……

(6) How long have you lived here? < 5 years [ ] 5-10 years [ ] 10-15 years [ ] 15-20 [ ] > 20 years [ ]

(7) Do you know what climate change is? Yes [ ] No [ ] no response [ ]

(8) Do you think climate is changing? Yes [ ] No [ ] no response [ ]

(9) If yes why do you think so? _____

(10) Have you noticed change in climate in your area? Yes [ ] No [ ] no response [ ]

(11) What do you use for cooking in your house? Fire wood [ ] charcoal [ ] kerosene [ ] cooking gas [ ] others (specify)……..

(12) Why do you use any of the above? Availability [ ] Cost [ ] Convenience [ ] Affordability [ ] others (specify)……

(13) Since you started living here, has there been a change in the number of vehicles?-cars, pick up vans, motorcycle e. t. c Yes [ ] No [ ] no response [ ]

(14) If yes, what is the change? There is increase in the number of vehicles [ ] There is decrease in the number of vehicles [ ]

(15) Is there any change you have noticed in the quality of air? Yes [ ] No [ ] no response [ ]

(16) If yes, what kind of change? Increased smoke [ ] Increase noise [ ] Increased accidents [ ] All of the above [ ] others (specify)……

(17) Have you noticed change in how land is used in your area? Yes [ ] No [ ] no response [ ]

(18) If yes, what is the change? Farmlands have been converted to houses [ ] some available trees have been removed for road construction or houses [ ] All of the above [ ]

(19) Have you observed any cutting of trees for fire wood in your area? Yes [ ] No [ ] no response [ ]

(20) Do you notice bush-burning by farmers in your area? Yes [ ] No [ ] no response [ ]

(21) Have you noticed change in air temperature around you? Yes [ ] No [ ] no response [ ]

(22) If yes, what is the change? There is increase in air temperature [ ] there is decrease in air temperature [ ] the air temperature increases and sometimes decreases [ ]

(23) Have you noticed climate-related illnesses such as meningitis and or cholera as a result excessive hotness and or flooding in your area? Yes [ ] No [ ] no response [ ]

(24) Have you noticed any change in the onset of rainfall in your area? Yes [ ] No [ ] no response [ ]

(25) If yes, what is the change? The rainfall starts early and stops early [ ] the rainfall starts early and stops late [ ] the rainfall starts late and stops late [ ] the rainfall starts late and stops early [ ]

(26) Have you noticed change in rainfall in your area? Yes [ ] No [ ] No response [ ]

(27) If yes, what is the change in the rainfall as compare to the past? There is increase in rainfall [ ] there is decrease in rainfall [ ]

(28) How does change in climate affect agricultural yield? There is an increase in the agricultural yield [ ] there is a decrease in the agricultural yield and [ ] there is no change in the agricultural yield [ ] no response [ ]

(29) Is there flooding in your area? Yes [ ] No [ ] no response [ ]

(30) If yes, what were the results of the flood? Many houses were destroyed [ ] few houses were destroyed [ ] no houses destroyed [ ] others (specify)……

(31) Is there any case(s) of bridge breakage or destruction as a result of flood in your area? Yes [ ] No [ ] no response [ ]

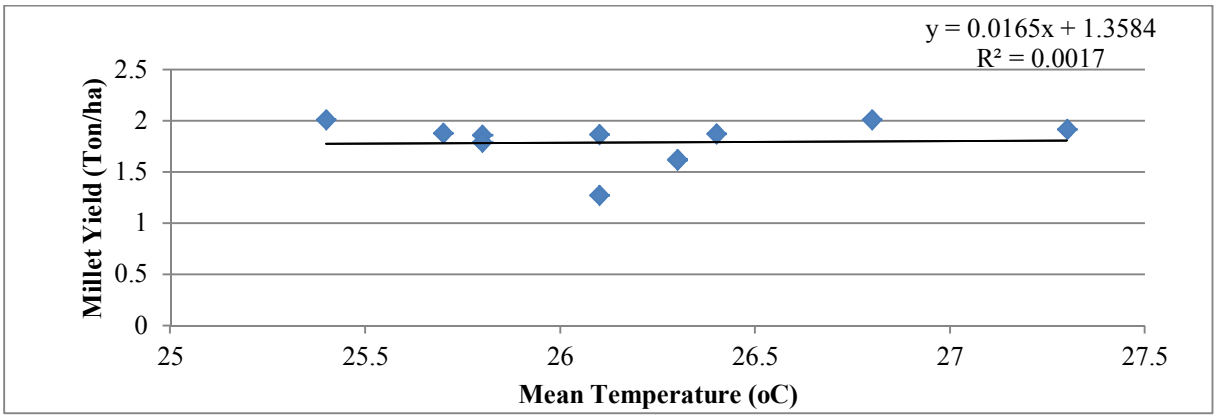
(32) Is there any case of school closure due to flooding of the road to leading to the school in your area? Yes [ ] no [ ] no response [ ]

(33) Have you noticed drought now or previously in your area? Yes [ ] no [ ] no response [ ]

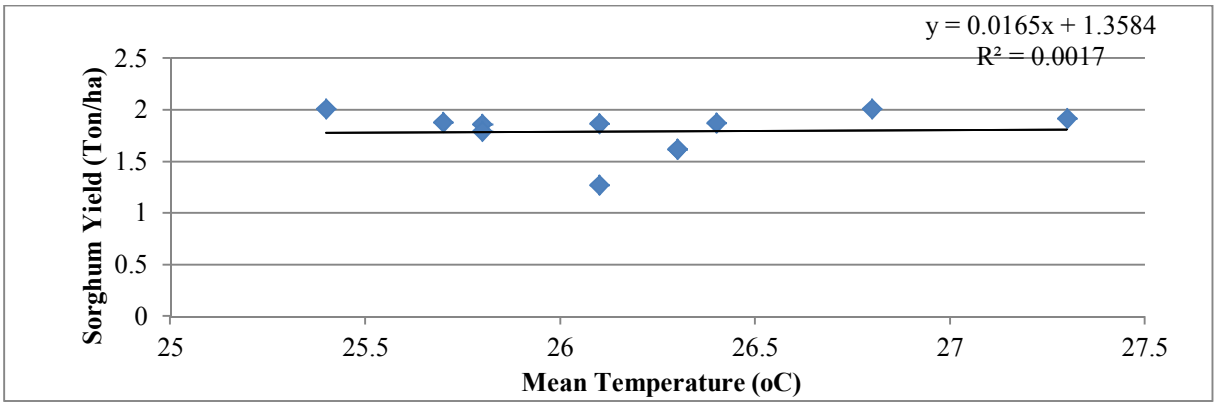
(34) If yes, what were the results of the drought? There were reduction in water supply and food production [ ] there were increase in water supply and food production [ ] the water supply and food production remain the same [ ] others (specify)……

Appendix E

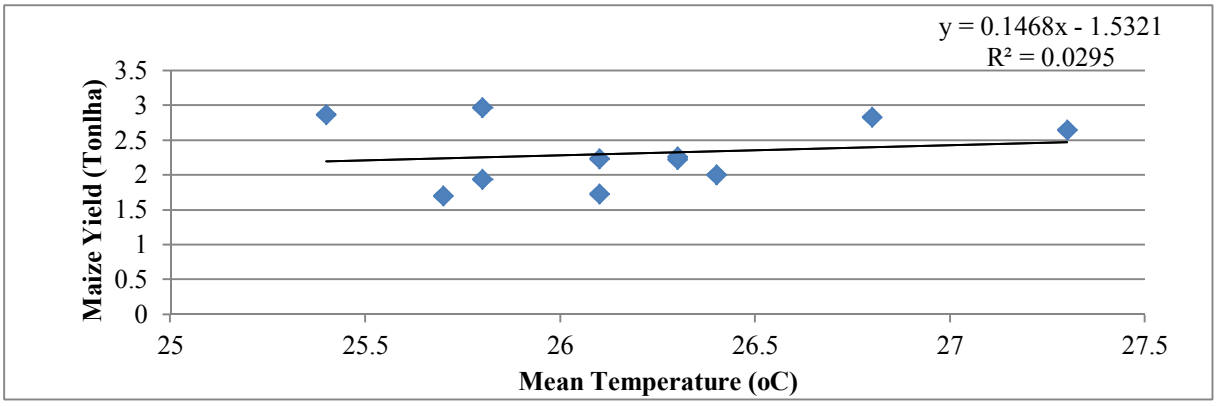
Scattered plots of the crop yields versus climatic variables



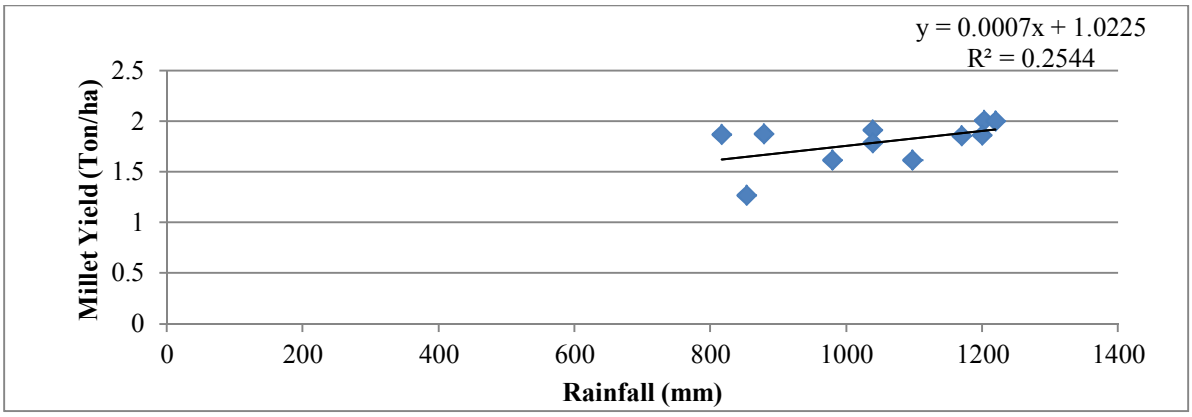
Appendix 1E: Millet yield versus mean temperature



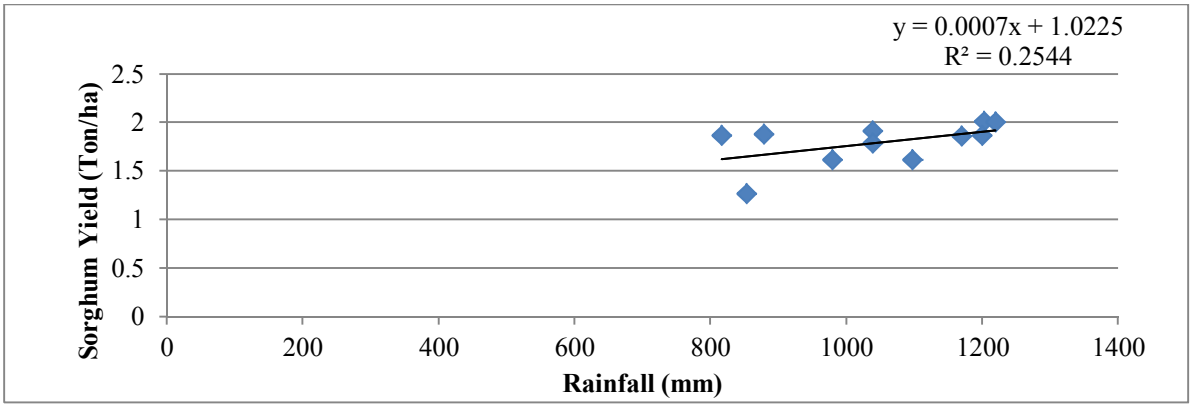
Appendix 2E: Sorghum yield versus mean temperature



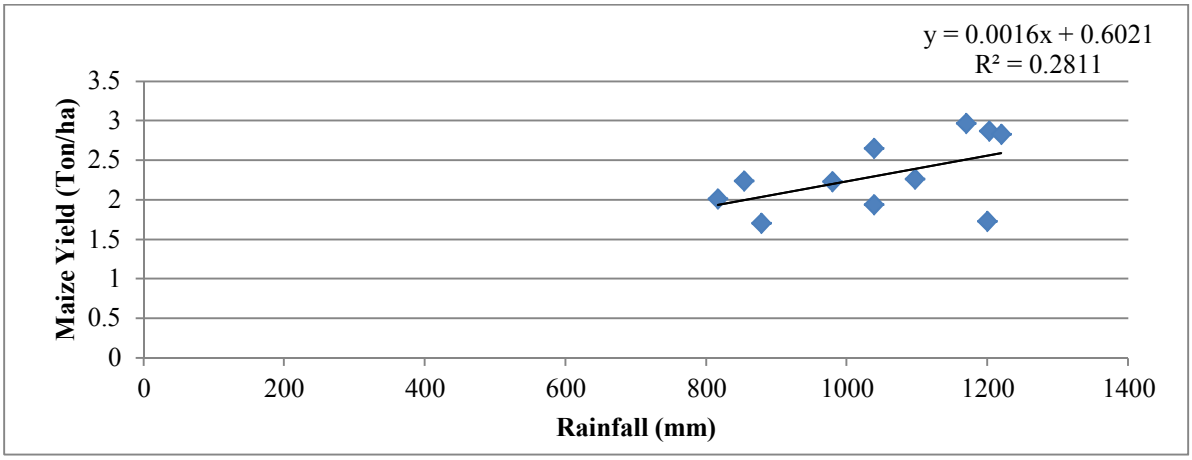
Appendix 3E: Maize yield versus mean temperature



Appendix 4E: Millet yield versus rainfall



Appendix 5E: Sorghum yield versus rainfall



Appendix 6E: Maize yield versus rainfall

Appendix F

Sen's estimator slope and Mann Kendall Tables

Appendix 1F: Sen's estimator slope and Mann Kendall (1971-1980)

Years	Rainfall	$x_{j-}\ x_i$	
1971	1018.4	------	
1972	994.0	-24.4	-1
1973	900.8	-93.2	-1
1974	1138.1	237.3	1
1975	949.0	-189.1	-1
1976	1100.1	151.1	1
1977	879.3	-220	-1
1978	1349.0	469.7	1
1979	1088.7	-260.3	-1
1980	827.6	-261.1	-1
		$T_i = -93.2$	S = -3

Appendix 2F: Sen's estimator slope and Mann Kendall (1981-1990)

Years	Rainfall	$x_{j-}\ x_i$	
1981	978.4	-----	
1982	883.9	-94.5	-1
1983	685.6	-198.3	-1
1984	981.4	295.8	1
1985	1071.6	90.2	1
1986	825.1	-246.5	-1
1987	978.0	152.9	1
1988	1114.5	136.5	1
1989	786.4	-328.1	-1
1990	886.2	99.8	1
		$T_i = 90.2$	S = 1

Appendix 3F: Sen's estimator slope and Mann Kendall (1991-2000)

Years	Rainfall	$x_{j-}\ x_i$	
1991	1238.5	--------	
1992	973.4	-265.1	-1
1993	957.2	-16.2	-1
1994	1096.6	139.4	1
1995	990.5	-106.1	-1
1996	1029.5	30	1
1997	1198.8	169.3	1
1998	1266.3	67.5	1
1999	990.7	-275.6	-1
2000	1089.9	99.2	1
		$T_i = 30$	$S = 1$

Appendix 4F: Sen's estimator slope and Mann Kendall (2001-2010)

Years	Rainfall	$x_{j-}\ x_i$	
2001	1202.4	-----	
2002	878.4	-324	-1
2003	1199.7	321.3	1
2004	1169.2	-30.5	-1
2005	816.3	-352.9	-1
2006	1038.5	222.2	1
2007	1219.7	181.2	1
2008	853.1	-366.6	-1
2009	978.8	125.7	1
2010	1097.0	118.2	1
		$T_i = 118.2$	$S = 1$

Appendix 5F: Sen's estimator slope and Mann Kendall (1971-1980)

Years	Max Temp	$x_{j-}\ x_i$	
1971	32.0	-----	
1972	32.2	0.2	1
1973	33.1	0.9	1
1974	31.3	-1.8	-1
1975	31.1	-0.2	-1
1976	31.3	0.2	1
1977	31.1	-0.2	-1
1978	31.0	-0.1	-1
1979	31.7	0.7	1
1980	31.2	-0.5	-1
		$T_i = -0.1$	$S = -1$

Appendix 6F: Sen's estimator slope and Mann Kendall (1981-1990)

Years	Max Temp	$x_{j-}\ x_i$	
1981	31.6	-----	
1982	31.5	-0.1	-1
1983	31.8	0.3	1
1984	31.3	-0.5	-1
1985	31.3	0	0
1986	31.8	0.5	1
1987	32.1	0.3	1
1988	31.4	-0.7	-1
1989	30.8	-0.6	-1
1990	32.2	1.4	1
		$T_i = 0$	$S = 0$

Appendix 7F: Sen's estimator slope and Mann Kendall (1991-2000)

Years	Max Temp	$x_{j-}\ x_i$	
1991	31.8	-----	
1992	31.1	-0.7	-1
1993	32.0	0.9	1
1994	31.5	-0.5	-1
1995	31.8	0.3	1
1996	32.1	0.3	1
1997	31.7	-0.4	-1
1998	31.8	0.1	1
1999	32.1	0.3	1
2000	31.6	-0.5	-1
		$T_i = 0.1$	$S = 1$

Appendix 8F: Sen's estimator slope and Mann Kendall (2001-2010)

Years	Max Temp	$x_{j-}\ x_i$	
2001	31.8	----	
2002	31.9	0.1	1
2003	32.5	0.6	1
2004	32.0	-0.5	-1
2005	33.7	1.7	1
2006	34.6	0.9	1
2007	34.1	-0.5	-1
2008	32.9	-1.2	-1
2009	32.5	-0.4	-1
2010	32.5	0	0
		$T_i = 0$	$S = 0$

Appendix 9F: Sen's estimator slope and Mann Kendall (1971-1980)

Years	Min Temp	$x_{j-}\ x_i$	
1971	18.1	---	
1972	18.5	0.4	1
1973	19.1	0.6	1
1974	18.4	-0.7	-1
1975	18.4	0	0
1976	18.8	0.4	1
1977	18.1	-0.7	-1
1978	18.5	0.4	1
1979	18.4	-0.1	-1
1980	17.7	-0.7	-1
		$T_i = 0$	$S = 0$

Appendix 10F: Sen's estimator slope and Mann Kendall (1981-1990)

Years	Min Temp	$x_{j-}\ x_i$	
1981	17.7	----	
1982	18.5	0.8	1
1983	18.9	0.4	1
1984	18.9	0	0
1985	19.3	0.4	1
1986	19.4	0.1	1
1987	19.3	-0.1	-1
1988	19.2	-0.1	-1
1989	18.3	-0.9	-1
1990	19.3	1	1
		$T_i = 0.1$	$S = 2$

Appendix 11F: Sen's estimator slope and Mann Kendall (1991-2000)

Years	Min Temp	$x_{j-}\ x_i$	
1991	19.1	----	
1992	18.9	-0.2	-1
1993	19.9	1	1
1994	19.4	-0.5	-1
1995	19.4	0	0
1996	19.5	0.1	1
1997	19.6	0.1	1
1998	20.0	0.4	1
1999	19.9	-0.1	-1
2000	19.2	-0.7	-1
		$T_i = 0$	$S = 0$

Appendix 12F: Sen's estimator slope and Mann Kendall (2001-2010)

Years	Min Temp	$x_{j-}\ x_i$	
2001	19.0	----	
2002	19.6	0.6	1
2003	19.6	0	0
2004	19.6	0	0
2005	19.1	-0.5	-1
2006	20.0	0.9	1
2007	19.5	-0.5	-1
2008	19.2	-0.3	-1
2009	20.0	0.8	1
2010	20.1	0.1	1
		$T_i = 0$	$S = 1$

Appendix 13F: Sen's estimator slope and Mann Kendall (1971-1980)

Years	Mean Temp	$x_{j-}\ x_i$	
1971	25.0	-----	
1972	25.3	0.3	1
1973	26.2	0.9	1
1974	24.9	-1.3	-1
1975	24.8	-0.1	-1
1976	25.1	0.3	1
1977	24.6	-0.5	-1
1978	24.8	0.2	1
1979	25.1	0.3	1
1980	24.5	-0.6	-1
		$T_i = 0.2$	$S = 1$

Appendix 14F: Sen's estimator slope and Mann Kendall (1981-1990)

Years	Mean Temp	$x_{j-}\ x_i$	
1981	24.7	----	
1982	25.0	0.3	1
1983	25.4	0.4	1
1984	25.1	-0.3	-1
1985	25.3	0.2	1
1986	25.6	0.3	1
1987	25.7	0.1	1
1988	25.3	-0.4	-1
1989	24.5	-0.8	-1
1990	25.8	1.3	1
		$T_i = 0.2$	$S = 3$

Appendix 15F: Sen's estimator slope and Mann Kendall (1991-2000)

Years	Mean Temp	$x_{j-}\ x_i$	
1991	25.5	----	
1992	25.0	-0.5	-1
1993	26.0	1	1
1994	25.4	-0.6	-1
1995	25.6	0.2	1
1996	25.8	0.2	1
1997	25.7	-0.1	-1
1998	25.9	0.2	1
1999	26.0	0.1	1
2000	25.4	-0.6	-1
		$T_i = 0.1$	$S = 1$

Appendix 16F: Sen's estimator slope and Mann Kendall (2001-2010)

Years	Mean Temp	$x_{j-}\ x_i$	
2001	25.4	---	
2002	25.7	0.3	1
2003	26.1	0.4	1
2004	25.8	-0.3	-1
2005	26.4	0.6	1
2006	27.3	0.9	1
2007	26.8	-0.5	-1
2008	26.1	-0.7	-1
2009	26.3	0.2	1
2010	26.3	0	0
		$T_i = 0.2$	$S = 2$

Appendix 17F: Homogeneity test using number of Runs

Years	Rainfall		Max. Temperature		Min. Temperature		Mean Temperature	
1971	1018.4		32.0		18.1		25.0	
1972	994.0	-	32.2	+	18.5	+	25.3	-
1973	900.8	-	33.1	+	19.1	+	26.2	+
1974	1138.1	+	31.3	-	18.4	-	24.9	-
1975	949.0	-	31.1	-	18.4	0	24.8	-
1976	1100.1	+	31.3	+	18.8	+	25.1	+
1977	879.3	-	31.1	-	18.1	-	24.6	-
1978	1349.0	+	31.0	-	18.5	+	24.8	+
1979	1088.7	-	31.7	+	18.4	-	25.1	+
1980	827.6	-	31.2	-	17.7	-	24.5	-

Appendix 17F contd.

1981	978.4	+	31.6	+	17.7	0	24.7	+
1982	883.9	-	31.5	-	18.5	+	25.0	+
1983	685.6	-	31.8	+	18.9	+	25.4	+
1984	981.4	+	31.3	-	18.9	0	25.1	-
1985	1071.6	+	31.3	0	19.3	+	25.3	+
1986	825.1	-	31.8	+	19.4	+	25.6	+
1987	978.0	+	32.1	+	19.3	-	25.7	+
1988	1114.5	+	31.4	-	19.2	-	25.3	-
1989	786.4	-	30.8	-	18.3	-	24.5	-
1990	886.2	+	32.2	+	19.3	+	25.8	+
1991	1238.5	+	31.8	-	19.1	-	25.5	-
1992	973.4	-	31.1	-	18.9	-	25.0	-
1993	957.2	-	32.0	+	19.9	+	26.0	+
1994	1096.6	+	31.5	-	19.4	-	25.4	-
1995	990.5	-	31.8	+	19.4	0	25.6	+
1996	1029.5	+	32.1	+	19.5	+	25.8	+
1997	1198.8	+	31.7	-	19.6	+	25.7	-
1998	1266.3	+	31.8	+	20.0	+	25.9	+
1999	990.7	-	32.1	+	19.9	-	26.0	+
2000	1089.9	+	31.6	-	19.2	-	25.4	-
2001	1202.4	+	31.8	+	19.0	-	25.4	0
2002	878.4	-	31.9	+	19.6	+	25.7	+
2003	1199.7	+	32.5	+	19.6	0	26.1	+
2004	1169.2	-	32.0	-	19.6	0	25.8	-
2005	816.3	-	33.7	+	19.1	-	26.4	+
2006	1038.5	+	34.6	+	20.0	+	27.3	+
2007	1219.7	+	34.1	-	19.5	-	26.8	-
2008	853.1	-	32.9	-	19.2	-	26.1	-
2009	978.8	+	32.5	-	20.0	+	26.3	+
2010	1097.0	+	32.5	0	20.1	+	26.3	0

For Rainfall: $R = 26, n = 40, E(R) = 21, Var(R) = 9.74 \; and \; Z = 1.6$

For Max Tempt: $R = 24, n = 38, E(R) = 20, Var(R) = 9.24 \; and \; Z = 1.32$

For Min Tempt: $R = 20, n = 34, E(R) = 18, Var(R) = 8.24 \; and \; Z = 0.69$

For Mean Tempt: $R = 24, n = 48, E(R) = 20, Var(R) = 9.24 \; and \; Z = 1.32$

Appendix G

Published papers by the author in support of the Thesis

(1) **Adamu, A.*,** Adie, D. B., Okuofu, C. A. and Ismail, A. "Variability of Some Climate Elements in Zaria, Nigeria", Book of Proceedings of the 8th Annual National Conference of the Society for the Occupational Safety and Environment Health (SOSEH), Held from November 12-15th, 2012, Ahmadu Bello University, Zaria – Nigeria

(2) **A. Adamu*,** D. B. Adie and C. A. Okuofu, "Study of the Socio-economic Impact of Climate Change in Zaria- Nigeria", A paper presented at 3rd East Africa Young Water Professionals Conference, Nairobi Kenya at the School of Monetary Studies from 9-11th December, 2013.