ASSESSMENT OF FARMERS' ADAPTATION STRATEGIES TO CLIMATE CHANGE IN SOKOTO STATE, NIGERIA

BY

Samuel Uchechukwu OGBONNAYA

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL MANAGEMENT,
FACULTY OF PHYSICAL SCIENCES,
AHMADU BELLO UNIVERSITY,
ZARIA – NIGERIA

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BY

Samuel Uchechukwu OGBONNAYA
HND (Afaka), B.Sc. Agric Ext., MDRM (ABU)
P14SCGS8260

A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES AHAMADU BELLO UNIVERSITY ZARIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER DEGREE IN ENVIRONMENTAL MANAGEMENT

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL MANAGEMENT,
FACULTY OF PHYSICAL SCIENCES,
AHMADU BELLO UNIVERSITY,
ZARIA – NIGERIA

OCTOBER, 2018

DECLARATION

I declare that the work in this dissertation ASSESSMENT OF FARMERS' ADAPTATION STRATEGIES TO CLIMATE CHANGE IN SOKOTO STATE, NIGERIA was performed by me in the Department of Geography, Ahmadu Bello University Zaria, under the supervision of Prof. A.B. Nabegu and Dr. B.A. Sawa. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this project was previously presented for another degree or diploma in any University.

Samuel Uchechukwu OGBONNAYA _____ **Signature** _____ **Date**

CERTIFICATION

This dissertation titled ASSESSMENT OF FARMER'S ADAPTATION STRATEGIES TO CLIMATE CHANGE IN SOKOTO STATE, NIGERIA by Ogbonnaya, Samuel, meets the regulations governing the award of the degree of M.Sc. Environmental Management in Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

Prof. A.B. Nabegu
(Chairman Supervisory Committee) _____ _____
(Signature) **Date**

Dr. B.A. Sawa
(Member Supervisory Committee) _____ _____
(Signature) **Date**

Dr. A.K. Usman
(Head of Department) _____ _____
(Signature) **Date**

Prof. S.Z. Abubakar
(Dean, School of Postgraduate Studies) _____ _____
(Signature) **Date**

DEDICATION

This work is humbly dedicated to Jesus Christ, my Lord who saved me and gave me a reason for life. There can be no me without Him.

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To God immortal, invisible, the only wise God be honour, power, glory, majesty and adoration forever and ever. I am most grateful to my supervisors; Prof. A.B. Nabegu and Dr. B.A. Sawa for their diligence, patience and show of love as they guided me through the process of this work. Special thanks to my boss Prof. M. Mahmud Assistant Director, Monetary & Evaluation, Institute for Agricultural Research, Ahmadu Bello University, for giving me the opportunity to attend this course. Big thanks to my Bishop Rt. Rev. (Dr.) David Bakare and all my pastors in Jesus is Life Church, Zaria, for your prayers. I am indebted to my wife Irene and children, Sharon, Ronald, Praise and Favour, for demonstrating a great sense of understanding and maturity throughout my period in school. Thank you to all my lecturers, students and staff of Department of Geography and Environmental Management, ABU, Zaria, for all your contribution in making this work a reality. Big thank you to Dr. A.M. Yamusa, sectional head, meteorological section, Institute For Agricultural Research, Ahmadu Bello University, Zaria and to all the staff of the section for putting me through in most of the core areas of the work.

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ABSTRACT

The uncertainty about future climate changes, low resource base of semiarid tropics and the dominant traditional methods of adaptation in the study areas has made it imperative to invest in adaptation in order for nations to be fully prepared to cope with adverse changes with possible increase in severe consequences. Hence this research aimed at assessing farmers adaptation strategies to climate change in Sokoto State. This was achieved by a set of objectives which include to characterize the climate of the study area, assess the awareness of farmers on climate change and examine the impact of climate change on agriculture as well as adaptation strategies adopted by the farmers in the study area. Rainfall and temperature data of the study area for a period of 30 years (1986 – 2015) were obtained from the Nigerian Meteorological Agency (NiMET) in Sokoto state and used to characterize the climate of the study area. Total annual rainfall, length of rainy season, onset, cessation, mean maximum and minimum temperature (important parameters to plant growth and development) were derived using time series analysis. A total of 384 close ended questionnaire were used to generate data to address other objectives such as assessment of farmers awareness to climate change in the study area, examine the perceived effect of climate change on crop yield and animal production in the study area, identify the adaptation strategies to climate change adopted by farmers in the study area and examine factors hindering adaptation of modern techniques in the study area. Krejcie and Morgans (1970) method of sample size determination was used to determine the sample size and purposive sampling was applied to administer the interview based questionnaire. Statistical techniques such as regressional analysis were used to analyse the data. The result showed an increasing annual rainfall amount. The mean annual rainfall for the period under study was 679.4mm. The highest rainfall was recorded in 2010 (1146.7mm). The

mean length of rainy season was 120 days. The study showed an increasing trend in the onset of rains. The mean onset date is 5th June. However, the trend line for the cessation of rainfall is showing late cessation. The average cessation date of rain in the study area within the thirty years study is 5th October. The mean maximum temperature is 35.6^0C. The study revealed that 91% of farmers in the study area were aware of climate change. Eighty percent agreed that millet was the most cultivated crop in the study area, while over 85% are involved in rearing cattle and donkeys because they are valuable in farming operations. To cope with the changing climate change, 57% of farmers in the study area adopted mix-cropping, while 42% adopted mixed farming. The study finally revealed that 49% of farmers agreed that inadequate knowledge of modern adaptation techniques was major hindering factor to adaptation strategies as well as lack of information on climate issues via extension services, lack of credit/loan facilities, lack of access to water for irrigation and lack of access to farm inputs. The study concludes that the fluctuations in climate characteristics of the study area affected agricultural production negatively and that adaptation strategies have significantly contributed to agricultural production in the study area. Based on the findings of the research, the study recommends that farmers should in addition to the present adaptation strategies adopt more viable and modern adaptive strategies such as, building water harvesting schemes, water storage ponds and improved irrigation system so as to maximize the available land and the climate conditions that favours their agricultural production. Farmers should concentrate on the production of millet and rearing of cattle and donkeys to maximize crop yield and animal production. Government should enhance the introduction of agrometeorological information to farmers as well as formulate policies that will ensure the supply of farm inputs (seed, insecticide, and fertilizer), credit and loan facilities as well as fund specialized research on crops and animal that

will take advantage of new environmental conditions created by climate change in the study area.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Climate change is a long term shift in the climate of a specific location, region or planet. The shift is measured by changes in features associated with average weather, such as temperature, wind patterns and precipitation. According to the Intergovernmental Panel on Climate Change [IPCC] (2007) in the fourth assessment report, climate change is a change in the state of the climate that can be identified (using statistical tests) by the changes in the mean of temperature, precipitation and wind pattern and that persists for an extended period typically decades or longer. Climate change is therefore the statistically significant deviation or shift from the average weather conditions of climatic elements.

Climate change poses a serious danger to livelihoods and food security as well as aggravating risks and vulnerabilities through the incidence of environmental disaster and extreme weather events (Umar, 2012). As a result of this, global attention is being drawn to the issue of climate change as an environmental problem threatening the survival of the entire human race. According to Nigerian Environmental Study/Action Team [NEST] (2004), every part of the earth will be affected by climate change but the degree to which such impact will cause damage will differ depending on demographic circumstances, capacity to withstand the impact and the nature of the economy. The report noted that developing countries will be the most vulnerable to the impact of climate change due to low capacity to reduce the magnitude of economic, social and human effects of adverse weather condition.

IPCC (2007) further predicted that Africa is highly vulnerable to the various manifestations of climate change and had affirmed that reservations about climate change are inappropriate considering apparent evidences from scientific observations of increase in global average air and ocean temperatures. Ayoade, (1995) affirmed that the resultant increase in temperature have plunged some localities in experiencing excessive weather conditions in the form of floods, droughts, famine and heat waves, ensuring devastating effects on human existence, agricultural productivity and food security, with many households affected by low economic status.

Adaptive capacity to climate change is the ability of a system to adjust or cope with the actual or expected climate stress. Sensitivity is the degree to which a system is either adversely affected or beneficial by climate change stimuli, whereas exposure to climate vagaries is the nature and degree to which a system is exposed to climate variations (IPCC, 2001). IPCC, (2001) defined adaptation as the adjustment in natural or human systems in response to actual or expected climate stimuli or their effects, which moderate harm or exploits beneficial opportunities. IPCC (2007) noted that adaptation alone is not expected to cope with all the projected effects of climate change, and especially not over the long term as most impacts increase in magnitude. Adaptation therefore could be proactive or planned. This requires assessing the vulnerability of natural and man-made systems as well as costs benefits of actions versus inactions, and planning alternatives accordingly.

Adaptation could also be reactionary which means actions are taken to reduce the impact or take advantage of the opportunities presented (Omolola, 2009). Already, climate change rate is gradually exceeding the adaptive capacity of a broad range of crops and tree population used in Nigeria ten years earlier than the prediction of the IPCC's climate model prediction of 2020 (IPCC, 2007). It is evident that food

production and access to food in many dry parts of the country is becoming more expensive and in some cases scarce. According to the (Commission for Sustainable Development [CDC] (2008), exacerbating food scarcity problems, malnutrition, poverty, hunger, diseases and communal conflicts, desertification and drought are all evidence of climate change and the need for sustainable adaptation strategies.

The Sokoto Area, North-West Nigeria has long lived with uncertainty and the threat of unsustainability where moisture is scarce for major parts of the year and soils for the most part are infertile (Onyenechere, 2010). Many of the people in this area have developed resilience under hardship, variability and risk that is based on historic and current adaptive knowledge and skills. Even though such skills are increasingly being recognized, it is commonly claimed that such capacities are not sufficient to cope with the speed of change, especially in the climate. Nevertheless, if better known and understood, they may contribute to development (Adger, Grawala, Mirza, Conden, O'Brrians, Palhin, Palwarty and Takahashi, 2007). Resource limitation and poor infrastructure have limited the ability of most rural farmers to take up adaptation measures in response to climate changes. In the same vain Anselm and Taofeeq, (2010) observed that since most small scale farmers are operating under resource limitations, farmers fail to meet transaction cost necessary to acquire adaptation measures. There is therefore need to critically assess the adaptation strategies currently in use in the study area with a view to enhancing their sustainability.

1.2 Statement of the Research Problem

Climate change has caused an increase in the frequency and intensities of extreme events like flooding, heat wave, drought, desertification and wind storm. This is expected to continue to varying degrees under different climate scenarios due to

increase in greenhouse gas emissions. The need to respond to these changes is quite urgent as the climate change related impacts are emerging more rapidly than predicted.

Measurements by World Data Centre (2011) for Greenhouse Gases (WD-CGC) show that on the average over the globe, the earth's surface has warmed by about 0.8^0C since 1800. This warming has not been gradual, it has been largely concentrated in two periods – from around 1910 – 1940 and from around 1975 – 2000. Since 2000, this warming trend has continued – the decade 2000 – 2009 was globally around 0.15^0C warmer than the decade 1990 – 1999.

Likewise, rainfall trend in Nigeria between 1901 and 2012 shows a general decline. Within the past 105 years rainfall amount in Nigeria dropped by 81mm. The declining rainfall became worst from the early 1970s. However, they seem to have changed from 2013 as rainfall amount have increased whereas the duration is decreasing Odjugo (2010). This evidence and problems of climate change is corroborated by several studies carried out by scientists (Adetola 2007; Ayinde, 2010) especially in the semi-arid regions of Nigeria to assess the biophysical vulnerability as well as strategies and/or adaptation strategies to climate change. Research studies have shown that the Sudano-Sahel zone of northern Nigeria especially, has suffered decrease in rainfall in the range of 30 – 40% per decade since the beginning of the nineteenth century (Apata, Ogunyinka, Sanusi, Ogunwande, 2010). The increasing temperature and decreasing rainfall in the semi-arid region of northern Nigeria – Zamfara, Katsina, Kano, Yobe and Borno may have resulted in increase evaporation, drought and desertification in the region (Odjugo, 2010).

Ikehi (2015) carried out a study on mitigation and adaptation strategies on the environment and agriculture in Nigeria. The study found out that climate change is an

adverse change in weather which impinges on human activities. The study observed that some of the consequences on livelihood are drying of streams, flooding occasions, damage of roads and general damage to the ecosystem. The focus was mainly on the environment.

Umar, Isah, Bello and Abubakar (2014) equally assessed farmers' perception on climate change in Sokoto State Nigeria. The result indicated that farmers were aware that the area is getting warmer and drier with change in the time of rains. The emphasis here was exclusively on farmers perception. Little or nothing was said on the adaptation strategies to mitigate or cope with the perceived negative changes.

In a study conducted by Atedhor (2013) on agricultural vulnerability to climate change in Sokoto State Nigeria, the researcher adopted the integrated approach which combines environmental and socio-economic determinants and found out that unreliable rainfall, desertification, increasing temperature, scarcity of pasture and inaccessibility to credit facilities accounted for 86% of the variation of agricultural vulnerability to climate change in selected areas in Sokoto State. This study was limited to agricultural vulnerability to climate change and therefore did not address adaptation strategies by farmers.

Similarly, Farauta, Egbulen, Idrisa and Agu, (2011) carried out a research on farmers' adaptation initiatives, to impact of climate change on agriculture in northern Nigeria. Quantitative and qualitative approaches were used. The researchers observed that majority of the farmers were aware of the vagaries of weather occasioned by climate change and major initiatives undertaken by them include intensive manure application, change in planting dates, multiple cropping and land rotation.

Umar (2012) also conducted a study on climate change and forestry practices: perception and strategies by rural community in Sokoto State. The result indicated increased loss of trees for firewood and exposure of the soil to direct rain drops leading to both water and wind erosion. This study was restricted to forestry practices and climate change.

Further more, Akeem (2014) investigated the effect of climate change on household agric-economy and adaptive responses among agricultural households in Nigeria. The study used the Fadama III baseline data. Fadama III is a follow up to the successful Fadama II project, sponsored by the World Bank; with the aim of improving livelihood condition of rural farmers through the provision of improved imputs, credits and infrastructure. The research focused on the effect of climate change on household. The result showed that climate change affects all members of the household; men, children and women in that order. While the most negative effect of the climate change include delayed onset of rainfall, long dry spell in between rains and less rain. However not much attention was given to sustainable adaptation strategies.

Also, Ekpoh (2010) carried out a research on adaptation to the impact of climate variations on agriculture by rural farmers in North-west Nigeria. In this study modeling approach and farm surveys were used. Accordingly, regression models which relate climate data to crop yields were constructed. The result showed that rainfall has a positive relationship with crop yields in the region and explained that over 70 percent of the variations in the yields of sorghum, millet and maize was accounted for by variations in rainfall. The study found that rural farmers in north-west Nigeria were quite innovative when it comes to adapting to drought but emphasized the need to update farmers adaptive strategies as the impact of climate variations on crop yields in north-western Nigeria can be sustainable especially under drought conditions. This

study was however limited to a few selected states in Northwest Nigeria (Kano, Katsina, Jigawa) excluding the study area which is Sokoto State.

The location of the study area at the brink of the Sahara desert (making it much more vulnerable to the impact of climate change) makes it imperative to assess their coping adaptation strategies as no previous studies has concentrated on that area. In addition to this, most studies before now were conducted before 2010, but this study covers a period of 30 years up to 2015. These facts added a new perspective to previous studies on adaptation to climate change in Sokoto State.

From the studies cited so far and the semi-arid location of the study area, it is important to note that despite the increasing insufficiency of rainfall for agricultural production in the study area, increasing temperature with its attendant high evapotranspiration, increasing desertification and incessant dry spells in the study area, the people are still engaging in farming. What are those things they do in order to adapt to the changing environment? These issues are inadequately documented hence constitute a gap in our knowledge of adaptation strategies.

This is the research gap that this study intends to fill.

Stemming from the problem are questions the research intends to answer.

i. What is the pattern of rainfall and temperature in the study area between 1986 to 2015?
ii. What is the level of awareness and perception of climate change by farmers in the study area?
iii. What are the effects of climate change on crop yields and animal production in the study area?

iv. What are the adaptation strategies to reduce the effect of climate change in the study area?
v. What are the factors hindering adaptation techniques to reduce climate change in the study area?

1.3 Aim and Objectives of the Study

The aim of this research is to assess the farmers' adaptation strategies to climate change in parts of Sokoto state Nigeria with a view to enhancing their sustainability. The aim of the study was achieved through the following specific objectives which include to:

i. characterize the pattern of rainfall and temperature in the study area between 1986 to 2015;
ii. assess the awareness of farmers to climate change in the study area.
iii. examine the perceived effects of climate change on crop yield and animal production in the study area;
iv. assess the adaptation strategies to climate change adopted by famers in the study area; and
v. examine factors hindering adaptation techniques to mitigate climate change in the study area.

1.4 Scope of the Study

The spatial scope of the study is limited to four Local Government Areas of Sokoto East Senatorial district. These Local Government Areas were chosen because they are closer to the Sahara desert and therefore more prone to some of the negative effect of climate change such as drought, aridity, desert encroachment, wind storm etc. The scope of the study in terms of content is to characterize rainfall and temperature,

examine awareness of farmers to climate change, examine how climate change has affected agriculture, examine the adaptation strategies to climate change and examine factors hindering adoption of adaptation technique to mitigate climate change in Sokoto State.

The study covers a period of thirty years from 1986-2015. Rainfall and temperature variability and how they affect agricultural land-use and animal production are the main climate change indicators for the study.

1.5 Justification of the Study

Farming in northern Nigeria is predominantly rural, with over 80 percent of the farming communities practicing rain-fed subsistent agriculture. These peasant farmers produce for subsistence rather than for commercial. Thus, the aim of crop and animal production is not to maximize profit but to feed one's family. However, in the process of meeting family nutritional needs, surplus agricultural products are disposed-off in the local markets for money. Climatic factors have serious consequences for numerous farmers and non farmers whose livelihoods are heavily dependent on the vagaries of climate. On a general note, climate plays an important role in the agricultural productivity of many parts of northern Nigeria; including the study area and with very low level of technology and rigid adherence to traditional ways of farming, recent variations in the weather and climate of the region have taken severe toll on crop production.

Since the 1970s' drought has affected many parts of northern Nigeria including the study area with agricultural outputs varying widely from year to year and from one location to the other. The constraints posed by climate change to agriculture have ranged from pronounced seasonality of rainfall (which confines cultivation to short

periods of three to five months) to severe and recurrent droughts (which disrupt the usual pattern of seasonal water availability). False onset of rains, late onset of the rains, pronounced break during the rainy season and early cessation of the rains are some of the characteristics leading to drastic alterations in the pattern of seasonal rainfall distribution (Adefolalu, 2007).

Understanding the nature and level of adaptation to the negative effects of climate change had become absolutely imperative in developing local appropriate, effective, and sustainable adaptation strategies in the study area. There is therefore, need to comprehensively assess the existing initiatives in the light of current and expected climate change to ensure that development, being supported and encouraged are sustainable. Hence, the study addressed climate trends in the study area and how the people are adapting to its negative impact. The findings of the study and subsequent recommendations will not only assist both the people and other stakeholders (e.g. Government, NGOs and International Research Institutes) on the successful mitigation and response to climate variations, it will also be a valuable source of information for future studies on related subjects.

CHAPTER TWO

2.0 CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 Introduction

This chapter set out to discuss concepts and reviewed related literature that are relevant to the study; concept of climate change, causes of climate change, impact of climate change and various approaches to address climate change including mitigation and adaptation were fully reviewed and discussed.

2.2 Concept of Climate Change

Emeka (2008), defined climate change as a deviation from normal weather conditions of an area over time, whether due to natural conditions or as a result of human activities which result in degradation of an environment. Cramer, Bandeau, Woodward, Lam, Colin and Richard, (2001) stated that climate change is the statistical distribution of weather over a long period of time that ranges from decades to millions of years. Therefore, a sustained climatic anomaly over a long period of time will contribute to climate change. The most widely acceptable definition of climate change is that climate change is the variation in the statistical distribution of the average weather conditions over a prolonged period of time (Ikechi and Zimoghen, 2014).

Climate change has been threatening the global environment and in particular agricultural sustainability in Nigeria and other vulnerable regions of the world. According to Onu and Ikechi (2015), climate change affects not only agricultural production and prices, trade and food sufficiency but also environmental conditions like water resources, land use and coastal infrastructure among others. Emeka (2008), referred to climate change as one of the global threats with serious implications on agriculture. Nwosu (2012) on his part defined climate change as a deviation from the

normal weather conditions of an area over time whether due to natural conditions or as a result of human activities which results in degradation of an environment. Ikechi and Zimoghen (2014), see climate change as the variation in the statistical distribution of the average weather conditions over a prolonged period of time. It refers to weather changes including steady alteration in usual temperature (rise or fall), rainfall regime (pattern or intensity), wind, relative humidity and solar radiation over time.

Similarly, the Intergovernmental Panel on Climate Change [IPCC], (2007) and Food and Agricultural Organization [FAO], (2007) referred to climate change as any change in climate overtime, either due to natural variability or as a result of human activity. The IPCC and FAO reports noted that change in climate occur due to variation in different climatic parameter such as cloud cover, precipitation, temperature and increase in Green House Gases (GHS) emission through human activities. Kandi, and Mackeson, (2006) in their study noted that climate change will have main impact on agriculture, economy and livelihood of the population of underdeveloped world. They noted that adverse impact of climate change in most developing countries, Nigeria; inclusive would include frequent drought, increased rural-urban migration, increased biodiversity loss, depletion of wild and other natural resources base, changes in vegetation types, increased health risk and the spread of infectious diseases and changing livelihood systems.

In Nigeria in general and in the North-western part in particular, severe impacts of climate change have been noticeable over the past two decades. The most serious among the climate related catastrophes have been dry spells, seasonal drought, intense rainfall, floods etc (Action Aid International, 2006).

The Intergovernmental Panel on Climate Change Assessment Report (2007) revealed that between 75 and 250 million people in Africa may be exposed to increased water stress due to climate change by 2020 and this will adversely affect livelihoods in the region. The report further stated that the area suitable for agriculture, the length of growing seasons and yield potentials, are expected to decrease due to climate change, and yields from rain-fed agriculture in most countries could be reduced by up to 50%.

Furthermore, De Chavez and Tauli-Corpus (2008), described climate change as a change in climate that is attributed directly or indirectly to human activities, it affects the atmospheric conditions of the earth, thereby leading to global warming. According to them, climate change has the potential to affect all natural systems thereby becoming a threat to human development and survival, socially, politically and economically.

The United Nations Framework Convention on Climate Change (UNFCCC, 2007) defines climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. Thus, the UNFCCC makes a distinction between climate change attributed to human activities altering the atmospheric composition and climate change attributed to natural causes. The convention concluded that climate change may be due to natural internal processes or external forces, or due to persistent anthropogenic changes in the composition of the atmosphere or in land use. This therefore implies that climate change has both anthropogenic and natural causes.

2.2.1 Causes of climate change

Human societies over the years have depleted natural resources and degenerated their local environments. Due to population increase, man has modified their local climates by cutting down trees and building cities. It is now apparent that human

activities are perturbing the climate system at the global scale (Forest, Wolfe, Molner, Emmanuel, 1999). According to the summary of the International Governmental Panel on Climate Change (IPCC) 4th Assessment Report (2007), human actions are very likely the major cause of global warming; meaning a 90% or more greater probability is attributed to human actions. After a comprehensive assessment by the IPCC of the scientific evidence suggest that human activities are contributing to climate change, and that there has been a discernible human influence on global climate. Climate change caused by human activities most importantly the burning of fossil fuels (Coal, oil and natural gas) and deforestation are superimposed on and to some extent marked by natural climate fluctuations and building up of greenhouse gases.

Climate change and global warming are caused by the buildup of greenhouse gases (GHGS) such as carbon dioxide, nitrous oxide, chlorofluorocarbons (CFCS) and methane in the atmosphere as a result of human activities, among them, the burning of fossil fuel, cooking etc. Daily Trust 16th March, 2013. The burning of fossil fuels emits GHGs into the atmosphere while deforestation and land-use changes removes trees and other kinds of vegetation that store ("sequester") carbon dioxide.

According to De Chavez and Taulin-Corpus (2008), GHGs are chemical compounds such as water vapor, carbon dioxide, methane and nitro oxide found in the atmosphere. These gases are able to absorbs and radiate heat. Many green house gases occur naturally such as water vapor, carbon dioxide (CO_2), Methane (CH_4), Ozone (OZ) and nitrone oxide. Others such as hydroflouro carbons (HFCS), perflourocarbons (PFCs) results exclusively from human industrial processes. All these gases are responsible for the greenhouse effect, but water vapour and CO_2 contributed 90% of the total GHG emissions. In terms of direct contribution of these greenhouse gases, CO_2 contributes 55%, methane 15%, CFCs 7%, CFC (11 & 12) 17% and N20, 6% (www.gerio.org

Retrieved on 2nd January, 2010). Carbon dioxide is produced when coal, oil and natural gas (fossil fuel) are burnt to produce energy used for transportation, manufacturing, heating, cooling, electricity generation, and other applications. They presently account for 80% to 85% of carbon dioxide being added to the atmosphere. Clearing land for logging, ranching and agriculture also, leads to carbon dioxide emission Beyioku (2016). Methane (natural gas) is second most important of the greenhouse gases resulting from human activities Beyioku (2016). It is produced by rice cultivation, cattle and sheep ranching and by decaying material in landfills. Methane is also emitted during coal mining and oil drilling and by leaking gas pipelines. Nitrous oxides is produced by various agricultural and industrial practices. Chlorofluorocarbon (CFCs) has been used in refrigeration, air conditioning, and as solvent).

Natural contributors to climate change include changes in the earth's orbit, the sun's intensity, the circulation of the ocean and the atmosphere, and the volcanic activity. IPCC (2007) in summary concluded that the causes of climate change can be linked basically to factors such as;

1. Industrial revolution (activities of automobiles and other industries).
2. Burning of fossil fuels by oil producing companies and refineries.
3. Land use changes such as deforestation, desertification etc. and
4. Agricultural activities such as bush burning, fertilizer application, ranching etc.

2.2.2 Types of green house gases and their occurrence

Schneider, Llull and Havliks, (2008), categorized greenhouse gases into two. Those that occur naturally in the environment, this includes carbon-dioxide, methane, nitrous oxide, ozone, synthetic chemicals. Other greenhouse gases do not occur naturally at all and are produced only through industrial processes e.g. aerosol.

1. Carbon dioxide

This is the most abundant greenhouse gas after water vapor. Carbon dioxide circulates the environment in a process called carbon cycle. It is released to the environment through a number of ways which include volcanic eruption, animal respiration, which breathes in oxygen and exhales carbon dioxide, and the burning or decay of plants and other organic matter. Carbon-dioxide leaves the atmosphere when it is absorbed into water, especially the oceans, and by plants, especially trees through a process called photosynthesis.

Man contributes immensely to the release of carbon dioxide releases through burning of fossil fuels (such as coals, oils and natural gas), solid wastes, wood and wood products for heat, building etc. At the same time, the number of trees available to absorb carbon dioxide through photosynthesis is being greatly reduced by deforestation, and wide spread cutting of trees for lumber or to clear land for agriculture (IPCC, 2004). The IPCC report of (2007) indicated that levels of carbon dioxide had risen to a record high of 379ppm and are increasing at an average of 1.9ppm per year. The report recommended that to stabilize atmospheric concentrations of carbon dioxide, global emissions would need to be cut significantly in order of 70 to 80 percent.

2. Methane

Another very important greenhouse gas is methane which is emitted into the atmosphere during mining of coal. Methane also comes from rotting organic matter in landfills, rice paddies and wet lands as well as from certain animals especially cows and sheep as by-product of digestion (Boucher, Firedlingteen, Colling, and Shune, 2009). According to them, since the beginning of the industrial revolution, the amount of methane in the atmosphere has more than doubled. Methane traps nearly 30 times more heat than the same amount of carbon dioxide. It appears in lower concentration in

the atmosphere compared to carbon dioxide, it however remained in the atmosphere for a shorter period than carbon dioxide. In total, methane contributes about a third as much as carbon dioxide to global warming (Forest, Wolf, Molnar and Emmanuel, 1999).

3. Nitrous oxide

According to IPCC, (2007) nitrous oxide is a potent greenhouse gas that is released primarily by burning fossil fuels. Nitrous oxide taps about 300 times more heat than does the same amount of carbon dioxide. The concentration of nitrous oxide in the atmosphere has increased 18percent over preindustrial levels. It contributes about a tenth as much as carbon dioxide to global warming (Forest *et al.,* 1999).

4. Ozone

Ozone is both natural and human-made greenhouse gas. Ozone in the upper atmosphere is known as the ozone layer and shields life on earth from the sun's harmful ultraviolet radiation. This ozone is formed by the action of ultraviolet light from the sun on molecular or ordinary oxygen. Some chemical components are known to destroy ozone molecules in the upper atmosphere. These compounds breakdown or deplete the ozone layer. This breakdown or "Depletion" of the ozone layer results in high ultraviolet rays reaching the earth surface. This is called global warming (Houghton, 2001).

Ozone is a colorless gas which is found in the stratosphere of our upper atmosphere. The layer of ozone gas is what protects us from the harmful ultraviolet radiations of the sun. The ozone layer absorbs these harmful radiations and thus prevents these rays from entering the earth atmosphere. Increase in the level of chlorine and bromine gases in the upper stratosphere are some of the reasons that leads to ozone layer depletion. Coupled with this, is the production and emission of chlorofluorocarbon (CFCs). This is what

which leads to almost 80percent of the total ozone layer depletion. There are many other substances that lead to ozone layer depletion such as hydro chlorofluorocarbons (HCFCs) and volatile organic compounds (VOCs). According to Houghton (2001), some of the immediate effect of ozone layer depletion on man includes eye damage; skin cancers, damage of immune system, ageing of skin etc. On plants, UV rays due to ozone layers depletion can alter time of flowering in some plant species, as well as affect other physiological and developmental processes of the plants.

On the environment, ozone layer depletion lead to decrease in the stratosphere and increase in ozone present in the lower atmosphere. Because of this, the ozone in the lower atmosphere is considered as a pollutant and a greenhouse gas. Ozone in the lower atmosphere contributes to global warming and climate change which in turn leads to melting of polarize, which leads to rising sea levels and climate change around the world (Anderson, Prescott, Pekham and Seaton, 2001).

5. Aerosols

According to Vogel, Tatchell, Furnis, Hannaford and Smith (1996), aerosols are tiny solid and liquid particles that remain suspended in the atmosphere that form through fuel combustion and to a lesser extent agricultural and industrial processes. Although aerosols are not considered greenhouse gases, they do affect global warming in several ways. Puspham and Uwe (2008) observed that diesel engine and some types of biomass burning produce black aerosol such as soot, which absorbs the sun's energy and therefore contribute to warming of the atmosphere.

Conversely, coal fire powder, plants burning and high sulfur coal emit sulfate aerosols, which are light colored aerosols that reflect incoming solar energy back to space. Aerosol particles also have an indirect cooling influence by acting as seeds for the

condensation of water vapour into cloud masses. The addition of greenhouse gasses and aerosols has changed the composition of the atmosphere. This change in the atmosphere has likely influenced temperature, precipitation, storm and sea level (IPCC, 2005).

2.2.3 The state of greenhouse gases in the atmosphere

According to World Meteorological Organization WMO– Global Atmosphere Watch (GAW) Annual Greenhouse Gas Bulletin report (2004), systematic and reliable observation of the global atmospheric environments of CO_2, CH_4, N_2O has been showing increasing trend relative to the beginning of industrial age (1750). The observations which are promoted by the Global Atmosphere Watch (GAW) programme of the (WMO) reports measurement data by participating countries are archived and distributed by the World Data Centre for Greenhouse Gases (WD – CGG).

The global abundance of key greenhouse gases as well as their percentage increase relative to year 1750 is presented in Table 2.1.

Table 2.1: The Global Abundances of Key Greenhouse Gases as well as their Percentage Change Relative to Year 1750

	CO_2 (ppm)	CH_4 (ppb)	N_2O (ppb)
Global abundance prior to 1750	**= 280ppm**	**= 700ppb**	**= 270ppb**
Global abundance in 2004	377.1	1783	318
2004 abundance relative to 1750	**+ 35%**	**+ 55%**	**+ 18%**
Global abundance in 2005	379.1	1783	118.2
2005 abundance relative to 1750	**+ 35.4%**	**+ 55%**	**+ 18.2%**
Global abundance in 2006	381	1783	320.1
2006 abundance relative to 1750	**+ 36%**	**+ 55%**	**+ 19%**
Global abundance in 2007	383.1	1789	320.9
2007 abundance relative to 1750	**+ 37%**	**+ 56%**	**+ 19.1%**
Global abundance in 2008	385.2	1797	321.8
2008 abundance relative to 1750	**+ 38%**	**+ 57%**	**+ 19.2%**
Global abundance in 2009	386.8	1803	322.5
2009 abundance relative to 1750	**+ 38%**	**+ 58%**	**+ 19.4%**
Global abundance in 2010	389	1808	323.2
2010 abundance relative to 1750	**+ 39%**	**+ 58%**	**+ 20%**

Source: World Data Centre for Greenhouse Gases (WD-CGG) 2011.

2.2.4 Impacts of climate change

The IPCC's (2007) Fourth Assessment Report summary for Africa describes a trend of warming at a rate faster than the global average, and increasing aridity in many countries. Climate change exerts multiple stresses on the biophysical as well as the social and institutional environments that underpin agricultural production (IPCC, 2007). That is, socio-economic factors, international competition, technological development as well as policy choices will determine the pattern and impact that agro-

climatic changes will have on agriculture Brussel, (2009) cited in Anselm and Taofeeq, 2010). In all, Khanal (2009) classified the patterns of impact of climate change on agriculture into biophysical and socio-economic impact. The biophysical impacts include; physiological effects on crop and livestock, change in land, soil and water resources, increased weed and pest challenges, shifts in spatial and temporal distribution of impacts, sea level rise and changes to ocean salinity and sea temperature rise causing fish to inhabit in different ranges. The socio-economic impacts result in decline in- yield and production, reduced marginal GDP from agriculture, fluctuation in world market price, changes in geographical distribution of trade regime, increased number of people at risk of hunger and food insecurity, migration and civil unrest.

One of the greatest impacts of climate change is the worsening condition of extreme weather events like drought, flood, rainstorms, windstorms, thunderstorms, landslides, avalanches and tsunamis, among others (Odjugo, 1999; 2001). Odjugo (2008) noted that the frequency and magnitude of wind and rainstorms did not only increase, they also killed 199 people and destroyed property worth N85.03 billion in Nigeria between 1992 and 2007. Odjugo (2010) shows that climate change has led to a shift in crops cultivated in northern Nigeria. Odjugo (2008) quoted Ahmed (1978) that as at 1978, the preferred crops the farmers cultivated in Northern Nigeria were guinea corn followed by groundnut and maize, but due to increasing temperature and decreasing rainfall amount and duration occasioned by climate change, the farmers as a means of adaptation in 2007 shifted to the production of millet followed by guinea corn and beans. Another major problem to agriculture in Nigeria due to climate change is the reduction of arable lands. While the sea incursion is reducing the arable land of the coastal plains, the desert encroachment with its associated sand dunes is depriving farmers of their agricultural farmlands and grazing rangelands in the arid region.

Moreover, the frequent droughts and lesser rains have started shortening the growing season thereby causing crops failure and food shortage. It has been shown that drought, desert encroachment and coastal inundation have started affecting the country's ecosystem leading to ecological destabilization due to climate change impact in the semi-arid region of Northern Nigeria (Odjugo and Ikhuoria, 2003; Ayuba, Maryah and Gwary, 2007).

When temperatures exceed the optimal level for biological processes, crops often respond negatively with a steep drop in net growth and yield. Khanal (2009) stated that heat stress might affect the whole physiological development, maturation and finally reduces the yield of cultivated crop. The negative effects on agricultural yields will be exacerbated by more frequent weather events. Brussel (2009) cited in Anselm and Taofeeq, (2010) stated that rising atmospheric CO_2 concentration, higher temperatures, and changes in annual and seasonal precipitation patterns and the frequency of extreme events will affect the volume, quality, quantity, stability of food production and the natural environment in which agriculture takes place. Climatic variations will have consequences for the availability of water resources, frequency of pest and diseases, and soil quality, leading to significant changes in the conditions for agriculture and livestock production. In extreme cases, according to Brussel (2009), the degradation of agricultural ecosystems could mean desertification, resulting in a-total loss of the productive capacity of the land in question. This is likely to increase the dependence on food importation and the number of people at risk of famine.

In Africa, climate change is expected to alter the dynamics of drought, rainfall and heat waves, and trigger secondary stresses such as the spread of pests, increased competition for resources, and attendant biodiversity losses. Predicting the impact of climate change on complex biophysical and socio-economic systems that constitute agricultural sectors

is difficult. In many parts of Africa it seems that warmer climates and changes in precipitation will destabilize agricultural production. This is expected to undermine the systems that provide food security. Whilst farmers in some regions may benefit from longer growing seasons and higher yields, the general consequences for Africa, are expected to be adverse, and particularly adverse for the poor and the marginalized, which do not have the means to withstand drastic changes. Evidence from the IPCC suggests that areas of the Sahara are likely to emerge as the most vulnerable to climate change by 2100, with likely agricultural losses of between 2 and 7% of affected countries' GDP. Western and Central Africa are expected to have losses ranging from 2 to 4% and Northern and Southern Africa are expected to have losses of 0.4 to 1.3% (Mendelsohn, Dinar and Williams, 2006). Maize production is expected to decrease under possible increased El Nino-Southern Oscillation (ENSO) conditions which are expected in southern Africa (Stige, 2006).

Climate Change would also directly or indirectly affect population and human settlements in Nigeria. In general, about 15% of the country's population is presently affected by climatic variation and sea level changes. With climate change, between 50% and 60% of the population would be affected, the excessive heat, increasing water stress, air pollution and suppressed immune system occasioned by climate change will result in increasing incidence of excessive death due to heat exhaustion, famine, water related diseases (diarrhea, cholera and skin diseases), inflammatory and respiratory diseases (cough, and asthma), depression, skin cancer and cataract (Odjugo 2010 and Deweerd, 2007).

World Health Organization WHO (2014) gave the following as the potential effects of climate change on human health:

1. High temperatures that raise the levels of ozone and other pollutants in the air that exacerbate cardiovascular and respiratory disease.
2. Pollen and other aeroallergen levels are also higher in extreme heat. These can trigger asthma, which affects around 300 million people. Ongoing temperature increases are expected to increase this burden.
3. Natural disasters (such as hurricane, typhoon, severe drought and floods), and variable rainfall patterns globally, where the number of reported climate change-related natural disasters has more than tripled since the 1960s. Every year, these disasters result in over 60 000 deaths, mainly in developing countries.
4. Rising sea levels and increasingly extreme weather events will destroy homes, medical facilities and other essential services. More than half of the world's population lives within 60 km of the sea. People may be forced to move, which in turn heightens the risk of a range of health effects, from mental disorders to communicable diseases.
5. Increasingly variable rainfall patterns are likely to affect the supply of fresh water. A lack of safe water can compromise hygiene and increase the risk of diarrhoea disease, which kills approximately 760 000 children aged less than 5 years, every year. In extreme cases, water scarcity leads to drought and famine. By the late 21st century, climate change is likely to increase the frequency and intensity of drought at regional and global scale.
6. Floods are also increasing in frequency and intensity, and the frequency and intensity of extreme precipitation is expected to continue to increase throughout the current century. Floods contaminate freshwater supplies, heighten the risk of water-borne diseases, and create breeding grounds for disease-carrying insects such

as mosquitoes. They also cause drowning and physical injuries, damage homes and disrupt the supply of medical and health services;

7. Rising temperatures and variable precipitation are likely to decrease the production of staple foods in many of the poorest regions. This will increase the prevalence of malnutrition and under-nutrition, which currently cause 3.1 million deaths every year.
8. Extreme heat occasioned by extreme high air temperatures contribute directly to deaths from cardiovascular and respiratory disease, particularly among elderly people. In the heat wave of summer 2003 in Europe for example, more than 70,000 excess deaths were recorded;
9. Changes in the patterns of infection could also result from climate change impacts. Climatic conditions strongly affect water-borne diseases and diseases transmitted through insects, snails or other cold blooded animals. Change in climate are likely to lengthen the transmission seasons of important vector-borne diseases and to alter geographic range. For example, Malaria (transmitted by Anopheles mosquitoes) kills almost 600,000 people every year – mainly African children under 5 years old.

2.4 Climate Change Awareness

Climate change remains a threat to human societies and natural ecosystems, yet public opinion research finds that public awareness and concern vary greatly. In a global survey on climate survey on climate change awareness publish in nature Climate Change based on the results of a Gallup World Poll undertaken in (2000 – 2008) by which collected responses in 119 countries, it showed that more than a third of the world's adult have never heard of climate change. During the survey, the poll asked people How much do you know about global warming or climate change? The

researchers analyzed the responses in relation to social, financial and behavioural factors such as age, education level, urban or rural location, income, access to tailored climate communication and engagement in civic and environmental matter, to see if they were linked to climate change awareness, followed by access to communication. The report concluded that education is an important tool to help speed up the process of fostering awareness and concern for climate change. It recommended awareness raising campaigns to stimulate consciousness.

According to Jamison (2015), awareness raising is an important component of the adaptation process to manage the impact of climate change, enhance adaptive capacity, and reduce overall vulnerability. Public awareness of climate change is important to increase enthusiasm and support, stimulate self-mobilization and action and mobilize local knowledge and resources. Raising political awareness is equally important as policy makers and politicians are key actors in the policy process of adaptation. Awareness raising requires strategies of effective communication to reach the desire outcome. Jamison (2015). Generally, the aim of awareness raising includes increase concern, informing the targeted audience, creating a positive image, and attempts to change their behaviour. For awareness campaigns to be successful, it should address groups of people in a region affected by a particular climate threat, group of stakeholders, the general public in order to achieve long-term lasting behavioural changes (Weber 2016). Several ways of communication can be deployed to reach targeted audience effectively such as dissemination of printed materials, organization of public meetings and training, use of mass media etc.

In Africa, agriculture provides over 85 percent of the exports, employs 85 percent of the workforce, contributes 75 percent of foreign exchange earnings and contribute about 25.8 percent to most National Gross Domestic Product (URT 2008). To improve

agricultural production, cropping and adaptation to climate change and variability, farmers need timely, relevant and reliable information. Information with such qualities has the potential of facilitating the farmers' choices and decision making. The understanding of climate change and variability is essential for adopting innovations and embracing initiatives developed for coping and adapting to climate change and variability (Dhaka, Chanyal and Poonta 2010). Considering that over 70 percent of the income from rural areas of Africa (who mostly are farmers) depend on agriculture (URT 2012). Climate change variability awareness and understanding is critical for the livelihood existence. Jamison (2016) noted that climate change first emerged as an issue of public concern in the 1970s, 1980s and grew into political significance in the 1980s and 1990s. it became a topic on the international political agenda in 1992 at the United Nations Conference on Environmental and Development in Rio de Janerio where it was declared an environmental problem. From the 1990s to 2000s the International Panel for Climate Change (IPCC) through its assessment reports, raised more awareness and draw the attention of the public to climate change which had become an expensive political problem. Ensor and Berger (2011) further noted that climate change become a crucial element in development in the early part of the twenty first century. To promote education, awareness and understanding on climate change globally, the United Nations Framework Convention on Climate Change (UNFCC) formed a legal framework to ensure that countries adhere to the laws and regulations set and agreed upon by member states. Article six of the UNFCC and article ten(e) of the Koyoto protocol exemplify the commitment of members states to espouse climate change and variability. The two articles stressed the need for developing and implementing educational and public awareness programmes on the effect of climate change, promoting information on climate change and affects, strengthening national

institutions and training scientific and managerial personnel (UNFCC 2012). Ensor and Berger (2011) noted that farmers' ability to adapt to changed circumstances and adopt different livelihood strategies is limited because they have little access to resources, new knowledge and apportunities for learning new skills. To increase harvests, improve farming and hasten efforts in adaptation and fathoning climate change and variability frequent education, awareness, knowledge become critical components in improving farmers' understanding (Lorenzoni, Michalso, Whitmarsh 2012).

Despite the role of awareness and understanding in adaptation, there are contradictory finding on farmers' awareness in Africa. Deressa, Hassan, Ringler, Alemu and Yesuf (2010) and Orindi and Mufray (2012) observed that awareness of climate change and variability was generally low in Ethiopia and East Africa respectively. Contrary to the findings of these studies, other studies such as the BCC. World Service Trust (2014), Jonge (2010) and Mertz *et al.,* (2016) indicated that farmers were aware of changes in climate in respective African countries. The farmers in Sokoto East Senatorial District of Sokoto State receive information on climate change and variability through personal observations and electronic media, their level of awareness, understanding and factors affecting their awareness and understanding of climate change had not been ascertain. This study therefore investigated the farmers awareness to climate change and variability and adaptation strategies employed by the farmers in the study area.

Literature on adaptation to different environmental changes (such as climate change) makes it clear that awareness and perception are the necessary pre-requisites for successful adaptation (Udeh, 2014). Brooks (2009) define awareness as it relates to environmental studies as "the ability to directly know, perceive, or be conscious of an event, object or emotion. He further stressed that in this level of consciousness, sense data can be confirmed without necessarily implying understanding. In other words, it

simply refers to the knowledge that something exists, or understanding of a situation or subject at the present time based on information or experience. That is, the ability to know, feel or be conscious of events, objects, thoughts or emotions. However, to be conscious or have an idea or information that something exists, and not necessarily having the knowledge of its causes, potential impacts, magnitude or its spatio-temporal patterns is not complete.

There exists substantial consensus amongst scientists and other stakeholders in climate change related issue to the fact that climate change awareness plays an important role in any effort to increase resilience of any system to the impacts of climate change. Studies on climate change awareness by different researchers, at different levels/scales and in different parts of the world were conducted. For instanc, Leiserowitz, Tien, Ezra, Peter, Chia-Yiang (2015) conducted a research on determinants of public climate change awareness and risk perception in the world. The study was conducted in 119 countries, using 2007-2008 Gallup World Poll Data via phone or in person with 195,000 randomly selected, nationally representative samples. The study revealed that climate change awareness level is generally low and unevenly distributed globally, with the highest level recorded in the developed countries of Europe, North America and Japan, whereas countries in Africa, Middle East and Mainland Asia had extremely low awareness. The study also revealed that, climate change awareness was driven by different factors in different parts of the world. The study further revealed that educational level and beliefs about the causes of climate change stand as the strongest and most common determinants of both awareness and risk perception of the change across the globe. However, beyond educational level and beliefs about causes of the change, the study further says each country has its own set of factors awareness. For instance, in United States of America (USA), the most important predictors of climate

change awareness were civic engagement, media access, attitude towards government and education. By contrast, in China the strongest predictors of climate change awareness were education, geographic location household income level. The study therefore stressed the need for programmes aiming to increase people's awareness and engagement, should be tailored to the unique context of each country.

2.4 Climate Change Perceptions

Perception is another important concept that often appears in climate change related studies. According to IPCC (2007) the term perception refers to the process by which we ‘digest’ and transform information or stimuli received from our environment, into psychological awareness for proper understanding of the situation at hand. Berber, Smith, Ann and Williams (2003) describe perception an extremely complex concept and confines to 'social perception' which has to do with the effects of our social and cultural factors to cognitive structuring of our physical and structural environment. That is, our socio-cultural factors that always guide our understanding of an event, object, thought or emotion. And the way we perceive something often go a long way with how we react or respond to it. According to Niles and Muller (2016), how individuals perceive climate change is linked to whether individuals support climate policies and whether they alter their own climate related behaviours.

Most studies on people s perceptions or climate change/variability focus on how local people's perceptions fit available meteorological data. This is because, the way we perceive something often go a long way with how we respond to it. Perception and awareness are often used interchangeably in climate change literature, but they are different. Climate change awareness simply refers to the knowledge or belief that climate change exists, based on information, personal experience or belief. That is, one

can be aware of climate change, without necessarily understanding its causes or effects (Ajuang, et. al., 2016). In other words, knowing climate change is real is not the same as understanding it to be a real risk and can pose serious problems for humans in the future. Therefore, climate change perception is the ability of an individual to be aware and understand the change, by attributing it to either natural or anthropogenic or even supernatural causes as the case may be, and perceived some of its impacts based on experience or information. Therefore, local people's perception of climate change is unavoidably important in any adaptation and mitigation efforts, as well as policy formulation towards that end. This is because "if you don't know you are at risk, you are even more at risk, as you cannot possibly be taking the necessary actions to prepare" (Leiserowitz, *et. al.,* 2015).

2.5 Climate Change Adaptation

2.5.1 Definition of adaptation

Many definitions of the term adaptation abound in literature, but perhaps the most quoted is that provided by the IPCC, Third Assessment Report, (2007) which defines adaptation as ecological, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts. This term refers to changes in processes, practices or structures to moderate or offset potential damages or to take advantage of opportunities associated with climate (IPCC, 2001, Jan and Aja, 2007).

United Nations Framework Convention on Climate Change (UNFCCC, 2008) defined adaptation as the adjustment in natural or human systems in response to actual or expected climate stimuli or their effects, which moderates harm or exploits beneficial opportunities (UNFCCC, 2008). The European Environmental Agency (EPA) defined adaptation as policies, practices and projects with the effect of moderating damages and

or realizing 'Opportunities associated with climate change. Smith and Pilifosova (2000), define adaptation to climate as adjustment in ecological, social and economic systems in response to the effects of changes in climate.

The IPCC broad definition of adaptation to climate change puts it as an adjustment in natural or human system to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. In practical and operational terms, adaptation involves a process of sustainable and permanent adjustment in response to new and changing environmental concerns or circumstances. This means adjusting behaviour, livelihoods, infrastructure, laws and policies and institutions in response to experienced or expected climatic events. African Ministerial Conference on the Environment [AMCEN], (2008) described adaptation as a process, beginning with understanding current vulnerability, building capacity to support adaptation planning and implementation, learning from pilot actions and deploying strategies and measures to operationalise climate change adaptation in vulnerable regions, sectors and populations. In all ramifications, adaptation is closely linked with development and this linkage is critical to reducing vulnerability (or increasing resilience) to climate change. Sustainable development in particular can reduce vulnerability to climate change. A summary of adaptation definitions is given in Table 2.2.

Adaptation occurs at a range of interlocking scales, and can occur in anticipation of change (anticipatory adaptation), which may also be a response to those changes occurring in the environment also referred to as reactive. However most adaptations being implemented at present are responding to current climate trends and variability (climate change 101). Reactive or autonomous adaptation refers to the capacity of natural and human system to naturally adapt to external shocks. The former therefore

includes activities explicitly aimed at reducing or canceling the negative impacts of climate change (IPPCC, 2001).

Table 2.2: Summary Definitions of Adaptation

Source	Definition
Burton *et al* (2002)	Refers to all those responses to climate change that may be used to reduce vulnerability.
Burton, (1996)	Adaptation to climate is the process through which people reduce the adverse effects to climate on their health and well-being and take advantage of the opportunities that their climatic environment provides
Downing *et al* (1999)	Adaptation is synonymous with "downstream coping"
Frairkhouse, (1996)	All changes in a system, compared to a reference ease, that reduce the adverse effects of climate change.
IPCC, (2001)	Adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. This term refers to changes in process, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate. It involves adjustments to reduce the vulnerability of communities, regions, or activities to climate change and variability.
Pielke (l998)	Refers to adjustment in individual, group and institutional behaviour in order to reduce society's vulnerabilities to climate.
Rosenberg (1992)	Adaptive strategies arc ways in which local individual, households and communities have changed their mean of productive activities, and modified their community rules and institutions in response to vulnerabilities, in order to meet their livelihood needs.
Scheraga and Gramsch (1998)	Adaptive actions are those responses or actions taken to enhance resilience of vulnerable systems, thereby reducing damages to human and natural systems from climate change and variability.
Smith (I996)	Involves adjustments to enhance the ability of social and economic activities and to reduce their vulnerability to climate, including its current variability and extreme events as well as longer term climate change.
Smith and Lenhert (1996)	Means any adjustments, whether passive, reactive or anticipatory, that is proposed as a means for ameliorating the anticipated adverse consequences associated with climate change.

Source: Oladipo, 2012

2.5.2 Concepts in adaptation

The following concepts are germane to the understanding of adaptation:

Vulnerability: Nearly all human societies and activities are sensitive to climate in some way or other- This is because in large measure how people generate livelihood and wealth is influenced by the ambient of climate (Adger *et al* 2003). Human societies have always and everywhere had to develop coping strategies in the face of unwelcome variation in climate or weather extremes. Vulnerability therefore can be seen as the context in which adaptation takes place. Vulnerability refers to a state of defenselessness, insecurity, exposure to risk and shock (Chamber, 1989). Vulnerability is also the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climatic variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity, and adaptive capacity. Magnitude means asking the question about the scale of impact. For example, does the change affect a high number of people or species? Is there loss of life? Loss of biodiversity or ecosystem? (IPPC 2015).

Timing: Impacts are explained in short term and unavoidable in the long term if not addressed. The vulnerability or security of individuals and societies is determined, not only by the likely responses of the resources on which individuals depend, but by the availability of resources and, crucially, by the entitlement of individuals and groups to call on these resources. This is well documented across a wide range of political and economic circumstances and development processes (Sen, 1981; Watts and Bohle, 1993; Ribot *et al,* 1996: Adger, 1999, Smit and Wandel 2006). Vulnerability is therefore a socially constructed phenomenon influenced by institutional and economic dynamic. (Adger, *et al,* 2003), Cannon (1994) has suggested that poverty and

marginalization are driving forces of vulnerability and constraints to individuals in their coping and long-term adaptation. Vulnerability is conceived simply as a function of exposure, sensitivity and adaptive capacity. V= f (exposure, sensitivity, adaptive capacity (IPPC, 2001). This means that vulnerability is a function of adaptive capacity + potential impacts (sensitivity + exposure).

Adaptive capacity: refers to the potential, capacity, or ability of a system to adapt to climate change stimuli or their effects or impacts. Adaptive capacity greatly influences the vulnerability of communities and regions to climate change effects and hazards (Downing *et al*, 1999; Kelly and Adger, 1999; Mileti, 1999; Kates. 2001).

Sensitivity: This is the degree to which a system is affected, either adversely or beneficially by climate-related stimuli. It encompasses all the elements of climate change, including mean climate characteristics, climate variability and the frequency and magnitude of extremes. The effect may be direct (e.g. a change in crop yield in response to change in the mean, range or variability of temperature) or indirect (e.g. damages caused in the frequency of coastal flooding due to sea-level rise).

2.5.3 Purpose of adaptation

Adaptation is considered an important response option or strategy, along with mitigation, Cooper, Stern, Noger, Gatherngo (2013). Adaptation strategies became prominent in literature from the 1990s and often associated with climate change by American National Academy of Science. IPCC report (2007) stated that adaptation will be necessary to address impacts resulting from the warming which is already unavoidable due to past emission. Adaptation is necessary because setting limits on emissions will not be enough, or happen soon enough, to avoid all impacts of climate change. Adaptation is imperative because the world climate is changing and will

continue to change at rates unprecedented in recent human history. The risks associated with those changes are real but highly uncertain. Risks are apparent in every area which will affect development goals especially in developing nations. Sadly however these nations have been declared most vulnerable to climate change. Furthermore, adaptation efforts are necessary to reduce both the costs and severity of both mitigation and climate change impacts for decades to come. The IPCC working groups II have suggested that mitigation and adaptation should be complementary.

Adaptation is necessary strategy at all scales:

Those with the least resources have the least capacity to adapt and are the most vulnerable. Adaptation, sustainable development and enhancement of equity can be mutually reinforcing. It is expected: that the climate will continue to change as a result of both the natural climatic variation and human activities (Scheraga and Grammbsch, 1998). Therefore while there is uncertainty about future climatic changes, failure to invest in adaptation may leave a nation poorly prepared to cope with adverse changes and increase the probability of severe consequences (Nzuma, Waithaka, Mbithi 2010).

Adaptive capacity may also be defined as the ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. Adaptive capacity is driven by physical constraints, social drives, economic and political process, and social network within the community. For example a farmer's adaptive capacity will not only depend on access to resources (both physical and social) within the community which allows a crop to be grown successfully but also the effect of macro-scale economic processes on the received crop, (Fussel 2007).

Gender is another factor; women may participate or be hindered by levels of education. There is also temporal and spatial aspect of adaptation. Bello, Ganiyu, Wahab, Afolabi (2012) have suggested that adaptation to climate change and risks takes place in a dynamic social, economic, technological, biophysical, and political context that varies over time, location and sector. They therefore argued that this complex mix of conditions determine the capacity of a system to adapt.

These determinants include the following: economic resources with regards to institutions, technology, and infrastructure (with regards to institutions and equity). It is accepted that wealthy or developed nations are better prepared to bear the cost of adaptation to climate change impacts and risks than poorer nations. Bello *et al.* (2012) have been able to prove that poverty influence a region's coping capacity. Moreover from empirical studies it is evident that poorer nations and disadvantaged group within nations are especially vulnerable to disasters, Bello *et al.* (2012).

Technology has also been identified to play a significant role in adaptive capacity. For instance, warning system, protective structures, crop breeding, irrigation are all technology dependent. The lack of technology may seriously impede a nation's ability to implement adaptation options by limiting the range of possible responses (Scheraga and Grambsch, 1998).

Information and skills is imperative in effective adaptation. An effective information dissemination system must be in place (Gupta and Hisschemoller, 1997). This is necessary as Tol (1998) has suggested, because successful adaptation requires recognition of the necessity- to adapt knowledge about available options, the capacity to assess them and the ability to implement the most suitable ones.

Infrastructure: Adaptation capacity is likely to vary with social infrastructure. Availability of good and well planned infrastructure enhances ability to adapt. For instance in the coastal areas of Hong Kong, the capacity to adapt to risk of typhoons differs for existing urban areas, and for new coastal land reclamation (Yim, 1996), In. addition institution hold society together giving it sense and purpose and enabling it to adapt (O' Riordan and Jordan, 1999). Studies have demonstrated that institutional role in adaptive capacity is very important. The presence of or the lack of institutional support could make a great difference in the ability of a society to adapt to climate change, (Kelly and Adger, 1999; Smith and Lenhart, 1996; Huq, *et al,* 1999; and Ahmed *el al,* 1999). Smith and Pilifosov, (2001) posit that established institutions in developed countries not only facilitate management of contemporary climate-related risks but also provide an institutional capacity to help deal with risks associated with future climate change.

Finally, equity, which guarantees equal access, enhances adaptive capacity. When resources are equitably distributed by the social institutions governing the allocation of such resources, society will participate in adaptation actions (Adger, 1999).

2.5.4 Adaptation and adaptive capacity

Adaptation has the potential to reduce adverse impacts of climate variability and to enhance beneficial impacts, but will incur costs and will not prevent all damages (IPCC, 2001). IPCC states that human and natural systems will, to some extent, adapt autonomously and that planned adaptation can supplement autonomous adaptation (IPCC, 2001). "Options and incentives, however, are greater for adaptation of human systems than for adaptation to protect natural systems" (IPCC. 2001). The propensity of systems (e.g. socio-economic systems) to adapt is influenced by certain systems characteristics that have been called "determinants of adaptation" in the literature

(Smith, Burton, Tol, Klein and Wandel, 2000). These include sensitivity, vulnerability, resilience, susceptibility and adaptive capacity (Smith *et al,* 2000).

The term adaptive capacity has many definitions. “Adaptive capacity may be described as the ability or capacity of a system to modify or change its characteristics or behaviour so as to cope better with existing or anticipated external stresses” (Adger *et al,* 2003). Therefore, society has inherent capacities to adapt to change. Burton, Hoa, Lim, Pilifosova and Schiper (2002) argued that capacities are bound up in the ability of society to act collectively. Individuals groups within society, organizations and governments on behalf of society, make decisions on adaptation (Burton *et al,* 2002). "The examination of the social dynamics and outcomes of adaptation moves beyond simply accounting for the economic costs and benefits of adaptation to climate variability”. Research carried out in the coastal environments, shows that coastal urban communities are particularly at risk to climate variability hence, social capital is an important element for coping with climate variability and hazards in recent time. Adger *et al.* 2003, for example, carried out a research in the Caribbean coastal area, and showed that communities find strategies to manage risks through strategic and local networks and interactions. Detailed investigations of social capital, illustrate explanations of how-individuals use their relationships to other actors in societies for their own and for the collective good, both in material terms and wider spiritual benefits.

2.5.5 Types of adaptation options in agriculture

This section identifies types of agricultural adaptation to climate change, and gives examples of the types. Agricultural adaptation options are grouped according to four main categories that are not mutually exclusive: (1) technological developments, (2) government programs and insurance, (3) farm production practices, and (4) farm

financial management-Within each category, specific examples are considered in light of the distinctions discussed earlier and farm decision-making in general. The main types of adaptations are summarized in Table 2.2 with examples in each category.

According to USAID (2007), some adaptation responses to climate change impacts on agriculture are:

1. Genetic improvement to produce drought-tolerant crops,
2. Translocation of crops and changes in cropping patterns;
3. Afforestation to condition soils, improve water infiltration, and provide shade,
4. Increased water use efficiency,
5. Diversification into non-farm activities;
6. Crop insurance and micro credit scheme.
7. Adjustment of planting dates and crop varieties
8. Improved land management e.g. erosion control and soil protection through tree planting.

2.5.6 Barriers to adaptation

When people become aware and understand that the climate is changing, they will also be aware of the need to adapt their behavior to reduce the potential cost and take advantage of the available opportunities (Adger *et. al*, 2003). However, there are some factors that serve as barrier to successful adaptation. Stern (2006) identified three factors that hinder or distort adaptive capacity. These are;

1. **Uncertainty and Imperfect Information:** This is especially about the likely consequences of climate change, making it difficult for individuals and businesses to weigh the cost and benefits of investing in adaptation;
2. **Missing and Misaligned Market:** That is, when people are not educated on the benefits of adaptation, they will not be able to capture its full advantages/benefits,

Which make them unable to value a resilient system differently from non-resilient ones, consequently a missing and misaligned market for adaptation;

3. **Financial Constraints:** This is the most felt by especially the most vulnerable individuals or groups. On account of some socioeconomic inequalities in some societies, the ability of certain group or section to effective adaptation is limited than others.

Nigeria like many of the developing countries faces a number of challenges in its preparedness to anticipate and implement climate change adaptation policies and programs. Udeh (2014) identified the following as barriers to adaptation in the country:

1. Absence of or poor national adaptation policy or strategies;
2. Poor or inadequate funding of adaptation programs;
3. Limited human resource and institutional capacity to deal with climate change uncertainty and models
4. Poor understanding of adaptation and inadequate data for evidence-based analysis;
5. Limited practical guidance on adaptation;
6. Low level awareness of the dimension of contemporary environmental problems (e.g. climate change) at all levels of governance in the country; and
7. Poor integration of climate change policies into national development planning and processes.

The table below listed some types and selected examples of adaptation options in agriculture.

Table 2.3: Types and Selected Examples of Adaptation Options in Agriculture

	SELECTED EXAMPLES OF ADAPTATION OPTIONS IN AGRICULTURE
1.	TECHNOLOGICAL DEVELOPMENTS
	2. Crop development: Develop new crop varieties, including hybrids, to increase the tolerance and suitability of plants to temperature, moisture and other relevant climatic conditions. **b) Weather and Climate Information Systems:** Develop early warning systems that provide daily weather Predictions and seasonal forecasts. **c) Resource Management Innovations:** • Develop water management innovations, including irrigation, to address the risk of moisture deficiencies and increasing frequency of droughts. • Develop farm-level resource management innovations to address the risk associated with changing temperature, moisture and other relevant climatic conditions.
2.	GOVERNMENT PROGRAMMES AND INSURANCE
	2. Agricultural Subsidy and Support Programmes • Modify crop insurance programmes to influence farm-level risk management strategies with respect to climate-related loss of crop yields. • Change investment in established income stabilization programmes to influence farm-level risk management strategies with respect to climate-related income loss. • Modify subsidy, support and incentive programmes to influence farm-level production practices and financial management. • Change adhoc compensation and assistance programmes to share publicly the risk of farm. • Modify subsidy, support and incentive programmes to influence farm-level production practices and financial management. • Change adhoc compensation and assistance programmes to share publicly the risk of farm level income loss associated with disasters and extreme events **b) Private Insurance:** Develop private insurance to reduce climate-related risks to farm-level production, infrastructure and income **c) Resource Management Programmes:** Develop and implement policies and programmes to influence farm-level land and water resource use and management practices in light of changing climate conditions
3	FARM PRODUCTION PRACTICES
	2. Farm Production • Diversify crop types and varieties, including crop substitution, to address the environmental variations and economic risks associated with climate change. • Diversify livestock types and varieties to address the environmental variations and economic risks associated with climate change. • Change the intensification of production to address the environmental variations and economic risks associated with climate change. **b) Land Use** • Change the location of crop and livestock production to address the environmental variations and economic risks associated with climate change. • Use alternative fallow and tillage practices to address climate-related moisture and nutrient deficiencies **c) Land Topography:** Change land topography to address the moisture deficiencies associated with climate change and reduces the risk of farm land degradation. **d) Irrigation:** Implement irrigation practices to address the moisture deficiencies associated with climate change and reduce the risk of income loss due to recurring drought **e) Timing of Operation:** Change timing of farm operations to address the changing duration of growing seasons and associated changes in temperature and moisture.
4	FARM FINANCIAL MANAGEMENT
	2. Crop Insurance: Purchase crop shares and futures to reduce the risks of climate-related income loss **b) Crop shares and Futures:** Invest in crop shares and futures to reduce the risks of climate-related income loss **c) Income Stabilization Programmes:** Participate in income stabilization programmes to reduce the risk of income loss due to changing climate conditions and variability **d) Household Income:** Diversify source of household income in order to address the risk of climate-related income loss.

Source: Barry and Skinner, 2002.

2.5.7 Models and theories in climate change adaptation

Several models and theories have been employed by different researchers in the study of adaptation strategies. These are:

1. Impact Assessment Models

These models are based on climate scenarios that focus on adaptation to change average condition and not inter-annual variations and extremes. Mendelsohn, Nordhaus and Dhaw (1999) argued that it is easier to adapt to changes in average conditions than with change related to variability. Some impact models assume 'naive' or 'dumb farmer' assumption (which is not agricultural sector) and which is a term used for any impacted agent that is assumed to anticipate or respond to changed climatic condition but continue to act as if nothing has changed. However, integrated impact models include assumption about adaptation to the impact component (Rosenberg, 1992).

2. Numerical Impact Models

In employing this model, assumption about perception and adaptation are commonly arbitrary or based on principles of efficiency and rationality, and assume full information, though actual and assumed behavior do not necessarily match (Mendelsohn, Nordhaus, and Dhaw, 1999). However, the information available, the rationality of the actors and unconstrained factors all play a major role.

The major feature of numerical impact model is that they tend to use rather than generate information on adaptation to estimate future impacts of climatic stimuli, after the effects of adaptation has been factored in. Hence, they indicate the potential of human system to adapt autonomously to moderate climate change damages (Rosenberg, 1992; Mendelsohn, Nordhaus, and Dhaw, 1999).

3. Social Capital or Collective Action

Social capital or collective action use lessons derived from political ecology and other theoretical insight for present day adaptation processes. It is an integral part of theories of adaptive management in the context of environmental risk, and also allow for a consideration of social practices and collective action in relation to other forms of capital (particularly natural capital) and the performance of institutions in coping with the variability and uncertainty in interaction with the natural world (Adger, *et. Al*, 2003). It is therefore made up of the norms and networks that enable people to act collectively. Thus, it serves as a necessary 'glue' for adaptation capacity, particularly in dealing with an unforeseen and periodic hazardous events, and which require networks and flow of information between individual and groups to oil the wheel of decision making (Burton, Huq, Lim, Pilifosova and Schipper, 2002).

Agrawal (2001) opined that the size of the group undertaking the collective action, boundaries of resources at risk, homogeneity of the decision making group and distribution of management benefits are all important for achieving a successful collective management. However, one criticism of this theory is its confusion of cost and effect, particularly when used in economic performance, educational attainment, or regional economic growth (Sobel (2002).

4. Analogue Models

This models aim to establish how individuals and institutions anticipate or respond to reduce the risk of different types of climatic variability and how policy influenced these actions. Analogue models can be broadly categorized into two, namely: (i) spatial analogue models; (ii) temporal analogue models. The former employs an analogue of past climate change contrast with scenarios, derived from climate model experiments in search for adaptation insights; while the latter involves taking detailed case studies of

past responses to climate variability and extremes. However, the major limitation of this approach to climate change assessment is that the characteristics of future climate change are likely to be different to past variability (particularly in terms of rate and magnitude). This is because many examples exists (in Africa for instance), where the observed variability is greater than suggested by climate model for the next 50 – 100 years (Hulme, 1998).

Researches on especially climate change-Agriculture interactions often use either a "top-down" or "bottom-up" approach. Top-down model is the one that starts with the climate change scenarios and estimates impacts through scenario analysis, based on which possible adaptation practices are identified. And where scenario-based approach adaptation strategies are assumed and invariably treated as primary technical adjustment to the identified impacts. While the bottom-up approach on the other hand, takes on vulnerability perspective, where adaptation strategies are considered as more of a process involving the socioeconomic and policy environment, producers' perceptions and elements of decision-making (Wall and Smith, 2005).

2.6 Climate Change in Nigeria

Nigeria is a country that span across Tropical climates of varying characteristics. This ranges from Tropical Wet (Equatorial/Sub-equatorial) in the coastal south, through Tropical Hinterland in the Middle belt, to Tropical continental/dry associated with the Sudano-Sahelian region in northern part of the country. As such, the country is characterized by strong spatio-temporal climatic variations and an irregular trend of climatic elements of especially rainfall and temperature (Okorie, 2003). However, this Variation is more pronounced in the northern than in the southern part of the country.

2.6.1 Evidence of climate change in Nigeria

At this point, it is important to examine some evidences of climate change in Nigeria. Reports from recent literature point to climate change in Nigeria. Odjugo (2010), IPCC (2001), Nigerian Environmental Study/Action Team (NEST, 2003) and Hengeveld and Fergusson (2005) provided indicators that one could use to assess the evidence of climate change in a region. These include, increasing temperature, increasing evapotranspiration, decreasing rainfall amount in the continental interiors, increasing rainfall in the coastal areas, increasing disruption in climate patterns and increasing frequency and intensity of unusual or extreme weather related events such as; thunderstorms, lightning, landslides, floods, droughts, bush fires, unpredictable rainfall patterns, sea level rise, increase desertification and land degradation, drying up of rivers and lakes and constant loss of forest cover and biodiversity.

The most significant changes are with respect to temperature and temperature related parameters. There has been a tendency to emphasize changes in temperature in the temperate latitudes and to imply that similar changes will occur in tropical areas. Given some of the emission scenarios, changes in minimum and maximum temperatures of the order of 7°C or more could be expected in certain parts of the country. This is likely to create a significantly different world with implications in vulnerability and adaptive capacity. The impacts of such changes will be felt in multiple sectors including: health, water, biodiversity, agriculture and forestry. An increase of 1.7°C in air temperature has been observed in Nigeria over 105 years. The implication is that if the increase continues at this rate, by 2100, Nigeria will fall within the low or medium scenario of global warming of not less than 2.5°C. Should it continue at the 1971-2005 rates, Nigeria will then be placed among areas that will experience high scenario of 2.5 - 4.5°C (Federal Ministry of Environment, 2003).

Another indicator is the increasing frequency and intensity of unusual or extreme weather related events such as erratic rainfall pattern, floods and sea level rise among others. Although these indicators are outside the scope of this study, recent researches (Odjugo, 2000; 2009; Molega, 2000; Nnodu 2007, Umoh, 2007) confirm their existence in Nigeria. A further support of the evidence of climate change in Nigeria by Odjugo (2000; 2009) is the increase in rainfall amount in the coastal areas since the 1970s, and a constant decline in rainfall amount and duration in the continental interior of the semi-arid region of Nigeria. The increasing rainfall in the coastal cities may have partly be responsible for the increasing floods devastating the coastal cities of Warri, Lagos, Port Harcourt and Calabar (Ogundebi, 2004; Ikhile 2007; Nwafor, 2007; Umoh, 2007; Odjugo, 2010). The increasing temperature and decreasing rainfall in the semi-arid region of Northern, Nigeria- Sokoto, Katsina, Kano, Nguru and Maiduguri may have resulted in the increasing evapotranspiration, drought and desertification in the region (Odjugo and Ikhuoria 2003 and Adefolalu, 2007). Constant loss of forest cover and biodiversity in Nigeria is linked to global warming and climate change (NEST, 2003; Ayuba *et al.,* 2007).

The increasing temperature and decreasing rainfall have led to frequent drought and desertification. The Sahara desert is observed to be expanding to all directions trying to engulf the Sahellian region of Africa with annual expansion of 1-3 meters (Odjugo and Ikhuoria, 2003; Yaqub. 2007). Odjugo and Ikhuoria (2003) also observe that Nigeria north of 12°N is under severe threat of desert encroachment and sand dunes are now common land features of desertification in states like Yobe, Borno, Sokoto, Jigawa and Katsina. The migrating sand dunes have buried large expanse of arable lands, thus reducing viable agricultural lands and crops' production. This has prompted massive emigration and resettlement of people to areas less threatened by desertification. Such

emigration gives rise to social effects like loss of dignity and social values. It often results in increasing spate of communal clashes among herdsmen and farmers and such clashes resulted in the death of 186 people in six northern states of Nigeria between 1998 and 2006 (Yugunda, 2002; Yaqub, 2007). Akonga (2001) also shows that most of the destitute that emigrated as a result of drought and desertification usually move to nearby urban areas to beg for alms thereby compounding the already tense urbanization problems.

In Nigeria, many rivers have been reported to have dried up or are becoming more seasonal, while Lake Chad has shrunk in area from 22,902 km^2 in 1963 to a mere 1304 km2 in 2000 Awake (2009). This shows that what is left of Lake Chad in the year 2000 is just 5.7% of 1963 (Odjugo, 2007). Awake, (2009) also confirmed the fact that Lake Chad has shrunk by 95% since the 1960s, Lake Chad and so many rivers in Nigeria, especially in Northern Nigeria, are in the danger of disappearing. The water scarcity will create the tendency- for concentration of users around the remaining limited sources of water. Under such circumstances, there is increased possibility of additional contamination of the limited sources of water and transmission of water borne diseases like cholera, typhoid fever, guinea worm infection and river blindness.

Available evidence also shows that climate change has impacted on agriculture and health in Nigeria (Mshelia, 2005; Adefolalu, 2007). The decreasing rainfall, increasing temperature and evapotranspiration have resulted in either reduction of water levels or total dry up of some rivers and lakes in Northern Nigeria, while lake Chad in Nigeria is reported to be shrinking in size at an alarming rate since the 1970s (Chindo and Nyelong, 2005; Odjugo, 2010). In the coastal region of Nigeria, sea level rise of 0.2 m and incursion of salt water into the coastal plain for about 2016 - 3400 km^2 was reported (NEST, 2003; Nyelong, 2004; Nwafor, 2006).

Spurgeon, wasilawih, Ikpi and Foster (2009) reported 0.05°C change in temperature per decade in Africa throughout the 20th century. Warming was said to be more significant between June to November every year. Similarly, reduction in rainfall occurred in semi arid West Africa. In the Sahel Nigeria, there was 25% reduction in rainfall on the average in the last 30 years. These trends have been supported by other studies that use long term climatic data. Akpodiogaga and Odjugo (2010) and Olaniran, (1991) have shown trends in climate change in Nigeria and also showed evidences of climate change in the Guinea Savanna and Sahel zone of Nigeria by using rainfall data for stations within the zone from 1940-2000. They found that: for most stations, deviation of rainfall from the grand mean is negative. For examples, Birnin Kebbi, Gusau, Kano, Maiduguri, Sokoto, Yola, Nguru, Potiskum and Katsina, with Nguru, Maiduguri and Katsina worst affected. Other stations experience positive deviations. For the six decades covered by the study, there were 3 decades of below the grand mean (1941-1950, 1971-1980 and 1981-1990) and there were 3 decades of mean, above the grand mean (1951-1960, 1961-1970 and 1991-2000). The study by Odjugo (2010) showed a gradual temperature increase between 1901 and 1940s. This dropped slightly between late' 1940s and early 1950s and took a sharp rise till late 1960s. The sharp rise in temperature became evident between early 1970s and 2005. "This sharp rise within this period is in agreement with the global trend" (Odjugo, 2010).

Already, Nigerian urban centers have been feeling the impacts of climate change with incessant annual flooding that affect large areas and large number of people. For example, in 2010, flood in Northern Nigeria affected 2 million people in Jigawa State and another 40, 000 people were displaced in Sokoto State where Usmanu Dan Fodio University was forced to close down for weeks as a result of bridge collapse associated

with the flood. Similar floods were reported in Lagos where 689 people were to be relocated in Ajegunle as a result of flood (Yekken, 2011).

Nigeria, like many parts of the world has witnessed many climatic anomalies, which clearly indicates a changing climate with serious consequences on the environment and the society. For example, Odjugo (2010) observed that the temperature trend in Nigerian since 1901 shows increasing pattern. The increase was gradual until the late 1960s and this gave way to a sharp rise in air temperatures from the early 1970s, which continued till date. The mean air temperature in Nigeria between 1901 and 2005 was 26.6^0C while the temperature increase for the 105 years was 1.1^0C. This is obviously higher than the global mean temperature increase of 0.74^0C recorded since 1860 when actual scientific temperature measurement started (Spore, 2008; IPCC, 2007a). Should this trend continue unabated, Nigeria may experience between the middle (2.5^0C) and high (4.5^0C) risk temperature increase by the year 2100. The increasing temperature together with decreasing rainfall have led to frequent drought and desertification, with the Sahara desert observed to be advancing southwards at an alarming speed of 1-10 km per annum trying to engulf the Sudano-Sahelian region of Africa and Nigeria in particular (Odjugo and Ekhuoria 2003; Yaqub, 2007).

Rainfall trend in Nigeria between 1901 and 2005 shows a general decline. Within the 105 years, rainfall amount in Nigeria dropped by 81mm. The declining rainfall became worst from the early 1970s, and the pattern has continued till date. This period of drastic rainfall decline corresponds with the period of sharp temperature rise (Oladipo, 2012; Spore, 2008; Odjugo, 2010). Although, there is a general decrease in rainfall in Nigeria, there is a significant variation between different regions of the country. For instance, Odjugo, (2005, 2007); Okorie (2003), and Spore (2008) observed that the number of rain days dropped by 53% in the northeastern Nigeria, a 14% drop was

observed in the Coastal areas of the south; while Niger-Delta areas like Warri, Brass and Calabar are observed to be experiencing slightly increasing rainfall in recent times. This is a clear evidence of climate change because a notable impact of climate change is, increasing rainfall in most coastal areas and decreasing rains in the continental interiors (Nigerian Environmental Study/Action Team NEST, 2003). The studies also showed that while the areas experiencing double rainfall maximal is shifting southward, the short dry season (August Break) is being experienced more in July as against its normal occurrence in the month of August prior to the 1970s.

However, in the Sudano-Sahelian zone of Northern Nigeria, recent studies revealed that the Zone has suffered decrease in rainfall in the range of 30-40% since the beginning of nineteenth century (Ojo, 1985; FRN, 2011). These are major disruptions in climatic patterns of Nigeria showing evidences of a changing climate. And according to IPCC report, a rainfall decrease of 29% to 49% has been observed in the Sudano-Sahelian region between 1968 and 1997 period compared to the 1931 to 1960 baseline. And as a result of this inter-annual rainfall variability, it often results in frequent climatic hazards such as floods, severe and widespread droughts (McCarthy, *et. al.,* 2001). Oladipo (1989) established that since the 1969 - 1973 Sudano-Sahelian drought rainfall has been irregular and unpredictably low in the drought prone areas of northern Nigeria. Sawa (2002) and Sawa and Adebayo (2011) also affirmed that even within the period of 1970 - 2000, Sudano-Sahelian zone of Nigeria has been experiencing a general tendency towards a decreasing number of wet spells; and a drier than normal condition as from 1969/1970, thus proving an apparent and real increasing aridity in the region.

Similarly, the climate change-induced increase in temperature and decreasing rainfall together with the erratic pattern of rainfall produce a minimal recharge of groundwater resources, wells, lakes and rivers in most parts of the world especially in Africa. In

Nigeria, many rivers have been reported to have dried up or are becoming more seasonally navigable while Lake Chad shrunk in area from 22,902 km2 in 1963 to a mere 1304km2 in 2000. Awake, (2009) also confirms the fact that Lake Chad has shrunk by 95% since 1960s; and concluded that Lake Chad and so many rivers in Nigeria, especially in Northern Nigeria, are in the danger of disappearing, Hence, climate change is an undeniable reality in Nigeria.

2.6.2 Rainfall characteristics of sudano-sahelian zone of Nigeria

The Sudano-Sahelian zone of Nigeria (which the study area belongs to) is generally characterized by short rainfall periods and long dry season with very high annual temperature range (Otegbeye, 2004). The annual precipitation in this area varies from less than 500mm in the extreme northeastern part (Borno and Yobe states) to about 1000mm in the southern fringes of the zone, around Kaduna state (FRN, 2000). Seasonal variation in rainfall in the region is influenced by the interactions of two air masses. The relatively warm and moist Tropical maritime (mT) air mass, which originate from Atlantic ocean (also known as South-West Trade Wind) and the relatively cool and dry Tropical continental (cT) air mass (also known as North East Trade Wind) which originate from Sahara deseit, associated with cold, dry and dusty storm known as *Harmattan* (Sawa, 2002; Ayoade, 2004). The two air masses always meet to form a *front,* which changes position southwards and northwards according to seasons. This boundary zone between the two is known as Inter-tropical Front (ITF), Inter-tropical Convergence Zone (1TCZ), Inter-tropical Confluence (ITC) or Inter-tropical Discontinuity (ITD) (Ayoade, 2004).

The changing position of the ITD northwards (between January and August) and southwards from the southern fringes of the Sahara desert (from September to December) across the country, makes much of the country to experienced seasonal

rainfall; (Olaniran, 2002; Ati, Iguisi and Afolayan, 2007). Oladipo and Salahu (1993) observed that the surface position of the ITD in the Sudano-Sahelian zone of Nigeria exhibits not only seasonal variation but also day-to-day variations, and its speed of movement is very irregular and vary with season, from about 2° of latitude (about 160km) per month (during its northwards advance) to 5.6° of latitude (320km) per month during its southwards retreat.

2.7 Agriculture and Climate Change

Agriculture is perhaps the most sensitive to climate change related issues of all human economic activities. Changes in the world's climate will bring major shifts in food production. In spite of recent technological and scientific development, weather remains a key variable in agricultural production. Weather and climate affect agriculture and determine the adequacy of food supplies. Climate determines whether or not rainfed agriculture will be successfully cultivated in a given area. All stages of agricultural production from land clearing and preparation, through crop growth and management to harvesting, storage, transportation, and marketing of agricultural products are subject to the influence of weather and climate. Weather and climate act both as a resource and a constraint to agricultural production. The resource value of weather has to be optimized while the hazards posed by weather have to be managed Ayoade (2002).

Although crude oil is now by far the most important source of Nigeria's national revenue, about 60% of the labour force is still employed in agriculture. More than 90% of agricultural production comes from rural-based, small scale farmers. The agricultural sector (crop production, livestock and fisheries) is likely to retain its dominance in terms of total labour force for the economy of the country for a long time. This

indicates that agricultural activities will remain a significant source of methane emission in the long-term. Federal Ministry of Environment (2003).

Many untested assumptions lie behind efforts to project global warming's potential influence on crops. In addition to the magnitude and pace of change, the stage of growth during which a crop is exposed to drought or heat is important. When a crop is flowering or fruiting, it is extremely sensitive to changes in temperature and moisture; but more tolerant during other stages of the growth. Moreover, temperature and seasonal rainfall patterns vary from year-to-year and region-to-region, regardless of long-term trends in climate. Temperature- and rainfall changes induced by climate change likely will interact with atmospheric gases, fertilizers, insects, plant pathogens, weeds, and the soil's organic matter to produce unanticipated responses.

According to Chakeredza, August, Assetau, Makkungwa and Saka (2009) despite these uncertainties, an average global temperature rise of slightly more than one-half degree Centigrade would lengthen the frost-free growing season in the corn-belt by two weeks. However, if temperatures continue to increase beyond a specific threshold, a crop's productive summer growing season could become shorter, thus reducing the yield. Agriculture is a very important sector in the whole of Sub-Saharan Africa in terms of subsistence, contribution to Gross Domestic Product (GDP), employment and foreign exchange earnings (Diao 2006). It is common knowledge that farmers in Sub-Saharan Africa, including Nigeria are struggling to cope with the current climate variability. It is predicted that declining crop yields in Sub-Saharan Africa could leave hundreds of millions without the ability to produce or purchase sufficient food (Chakeredza *et al.*, 2009).

According to Bazzaz and Sombroek (1994), changes in the world's climate will bring major shifts in food production. In some places, temperatures will rise and rainfall will increase; in others rainfall will decrease. In addition, coastal flooding will reduce the amount of land available for agriculture.

According to USAID (2007) "Climate change has the following impacts on agriculture:

1. Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks in warmer areas.
2. Damage to crops; soil erosion; inability to cultivate land due to water logging of soils.
3. Land degradation, lower yields or crop damage or failure; increased livestock deaths; increased risk of wildfire.
4. Salinization of irrigation water, estuaries and fresh water systems.

According to Oladipo (2012), indirect effects of climate change on agriculture include the effects on pests and diseases and the impacts of these on agricultural production, the impacts, on health, and the impacts on agro-related socio-economic activities. Various pests, including rice stink bug, lima-bean pod borer, rice weevil, and soybean pod borer would probably expand their distribution areas in the event of climate change.

In general, the various impacts of climate change on crop production in the country could have tremendous impact on income, employment and food production. There could also be significant impacts on the characteristics of labour, employment and population processes and their characteristics (Oladipo, 2012). Climatic factors affect agriculture and determine the adequacy of food supplies (Ayoade, 2004); hence, the need for adaptive strategies.

2.8 Approaches to Addressing Climate Change

The impacts of climate change will most likely continue well into the next century, due to the inertial in the climate system. It requires both mitigation and adaptation to deal with the potential damage that climate change might inflict on the planet (UNEP, 1998). Mitigation and adaptation may either exhibit synergies, where both actions reinforce each other, or be mutually counter-productive. It may be possible in agriculture and forestry, while in water management it may be counter-productive; this is so because the energy needed to produce more water will equally increase the GHG unless more energy efficient systems are used.

2.8.1 Mitigation

According to 1PCC (2007), mitigation is an anthropogenic intervention to reduce the anthropogenic forces in the climate system, it includes strategies to reduce emissions and enhancing green house sinks. Mitigation has also been defined as steps taken to reduce the amount of green house gases being produced by human societies over the long-term (usually through international policy). It must be noted however, that mitigation can 'deal with manmade causes (Ayoade, 2003). It is also an anthropogenic intervention to reduce the anthropogenic' forces in the climate system. Ayoade. (2003) defines it as measures taken by man to prevent or retard the increase of green house gas concentration in the atmosphere.

Pascala and Socolow (2004), have proposed about fifteen ways to reduce the anthropogenic factors of climate change, among them are; improving the efficiency of today's coal plant from the present 40 to 60 percent, use biomass to make fuel, capture and store carbon, make more efficient cars and a host of others. Other methods

proposed are carbon trading, seeding oceans with iron, GHG remediation and carbon tax.

Integrating mitigation and adaptation into climate change concerns is not a completely new idea in the African Sahel. The African Sahel is characterized by recurrent droughts, the magnitude and intensity of which have been on the increase over the last 100 years and consequently in the destruction caused by it (Elum and Simoyan 2016). Records show that the region has experienced marked rainfall declines and droughts that exceed those predicted by models of future climate (Hulme, Doharter, Ngora, New and Lister, 2001). The fact that the communities in this region have survived till today with a fast population growth rate is an indication that they have developed traditional mechanisms and strategies to cope with these climate anomalies. Some of these actions combine elements of mitigation and adaptation. Traditional knowledge about how local populations have coped with previous droughts has the potential of providing guide for addressing current and future climatic events.

While the importance of traditional knowledge has been realized in the design and implementation of sustainable development projects, little has been done to incorporate this into formal climate change mitigation and adaptation strategies. Climate change cannot be divorced from sustainable development as sustainable development may be the most effective way to frame the mitigation question and a crucial dimension of climate change adaptation and impacts. Incorporating traditional knowledge into climate change policies can lead to the development of effective mitigation and adaptation strategies that are cost-effective, participatory, and sustainable (Saka 2008; Willen, 2009). However, incorporating traditional knowledge into climate change concerns should not be done at the expense of modern/western scientific knowledge.

Traditional knowledge should complement, rather than compare with global knowledge system.

2.9 Literature Review

2.9.1 Pattern of rainfall characterization

Rainfall characterization has been the focus of many studies performed at various scales using direct or indirect rainfall measurement (Kruger 2006; New *et al.,* 2006; Hisali *et al.,* 2011; Ngongondo *et al.,* 2011; Pirre *et al.,* 2011). These studies mostly focused on areas where high quality climatic data are available at the desired temporal scales. According to Trenbert *et al.,* (2007), one of the main challenges in the analysis of risk and vulnerability in hydrological and agricultural studies in Africa lies in the scarcity of accurate long-term rainfall information. In Africa, particularly in the seasonal deserts, grass lands, and savannah that constitute most of the continental area, rainfall is the key environmental constraints for hydrological, biochemical agronomical and cological processes (Dunkerly 2008). While rainfall amount expressed as an annual, monthly or (less frequently) daily precipitation depth is a key variable, other characteristics of rainfall including rainfall intensity and event duration can significantly influence agricultural surface ponding and evapotranspiration.

The sudano-sahelian zone of Nigeria (which the study area belogs to) is generally characterized by short rainfall periods and long dry season with very high annual temperature range (Otegbeye 2004). The annual precipitation in this area varies from less than 500mm in the extreme northeastern part (Borno and Yobe States) to about 1000mm in the southern fringes of the zone, around Kaduna State (FRN 2006). Seasonal variation in rainfall in the region is influenced by the interactions of two air masses. The relatively warm and moist tropical maritime (MT) air mass, which

originate from Atlantic Ocean (also known as South-west trade Wind) and the relatively cool and dry tropical continental (CT) air mass also known as North-east trade wind) which originate from sahara desert associated with cold, dry and dusty storm known as Harmattan (Sawa 2002, Ayoade 2004). The two air masses always meet to form a front, which changes position south wards and north wards according to seasons. This boundary zone between the two is known as inter-tropical front (ITF), Inter-tropical Convergence Zone (ITCZ), Inter- Tropical Confluence (ITC) (Ayoade 2004).

The changing position of ITD north wards (between January and August) and south wards from the southern fringe of the sahara desert from September to December) across the country, makes much of the country to experience seasonal rainfall (Olaniran 2002; Ati, Iguisi and Afolayan 2007). Oladipo and Salahu (2009) observed that the surface position of the ITD in the Sudano-Sahelian zone of Nigeria exhibits not only seasonal variation but also day to day variations, and its speed of movement is very irregular and vary with season, from about 2^0 of latitude (about 160km) per month during its south wards retreat so many studies have been carried out by researchers on the rainfall pattern characterization in Nigeria.

Oyewole, Thomas, Akinpelu and Jegede (2014) carried out a study on the variation of rainfall and humidity in Nigeria. Thirty one year (1997 – 2010) annual rainfall and relative humidity for eight stations scattered over Nigeria was analyzed. The study observed that rainfall is highly variable in both time and space, particularly in sub-humid tropical regions like West Africa. The study showed that coefficient of variation for the rainfall for the period of study is between 0.25 and 5.65, increasing from the areas into the hinterland. The monthly analysis also showed that periods of highest rainfall falls between June or July and August or September for the locations nearest to

the coast and those closer to the Sahara desert respectively. The trend of the rainfall in Nigeria within the study period is 0.654 per annum.

In another related study, by Akinsanola and Ogunjobi (2014) titled Analysis of Rainfall; and Temperature Variability over Nigeria, the study investigated rainfall and temperature variables from 1971 – 2000 (30 years) were investigated. The data were analyzed for the occurrences of abrupt changes in temperature and rainfall values over Nigeria while temporal and spatial trends were also investigated. Statistical approach was deployed to determine the confidence levels, coefficient of Kirtosis, Skewness and coefficient of variations. Analysis of air temperature indicate that in the first decade of 1971 – 1980 nomalies between -0.2 and -1.6 were predominant, in the second decade of 1981 – 1990, only five station (Lokoja, Kaduna, Bida, bauchi and Warri) shows positive anomaly while greater portion of the country were normal with evidence of warming in the third decade of 1990 – 2000. Results further indicate that there has been statistically significant increase in precipitation and air temperature in vast majority of the country. Analysis of long time trends and decadal trends in time series further suggest a sequence of alternately decreasing and increasing trends in mean annual precipitation and air temperature in Nigeria during the study period.

Obot, Chendo, Udo and Ewona (2010) in a related study Evaluated Rainfall trends in Nigeria for 30 years (1978 – 2007). The non-parametric Mann-Kendall test was used to test for significant trend in rainfall in Nigeria through randomly selected locations in the six geopolitical zones within 30 years period. The selected locations are Maiduguri $13^0 10 11^0 50$) in the North East, Kaduna (7^0 27, 10^0 31') in the North West, Lokoja (6^0 45', 7^0 43') IN THE North Central, Ibadan (3^0 53', 7^0 22') in the South West, Enugu (7^0 30', 6^0 27) in the South East and Calabar (8^0 28', 4^0 57') in the South South. During the 30 years period, the yearly average rainfalls (mm) were 580.5, 1187.5, 1228.7,

1317.2, 1753.8 and 2925.6 respectively. While the rest of the locations had no significant trend yet Maiduguri showed an increasing trend at a rate of 9.88mm/year, where formally the trend there from the period 1961 – 1990 was decreasing. This study characterized the rainfall and temperature of the study area for 30 years (1986 – 2015) in order to compare it with the perception of farmers in the study area.

Adesina and Odekunle (2011) conducted a work on Climate Change and Adaptation in Nigeria. The research evaluated some aspect of Nigeria's vulnerability to the impact of climate and potential adaptation strategies that can help in coping with or reducing the impact of the change in the agriculture and forestry sectors. The vulnerability of the various parts of the country were computed using a wide range of socio-economic parameters and physical environmental factors. Time series analysis was used to determine the onset, ceasation dates, length of rainy season and temperature of various parts of the country.

The result showed that there had been important variability in the rainfall and temperature regimes which exposes the country to severe impacts of climate change. The vulnerability assessment further showed that the country's resilience to climate change impact is very weak especially in the Sudano-Sahalian zone. The research proposed a number of adaptation strategies mainly in agriculture and forestry sectors to include, provision of accurate and timely weather forecasting, enhancing agricultural extension services, expanding and optimizing existing irrigation infrastructures, adoption of drought-tolerant and early maturing varieties of crops, diversifying livelihoods to improve income, control of pests-insect and increasing and upgrading storage facilities etc.

2.9.2 Awareness of climate change

Many studies have been conducted at either regional, national or even local levels in different parts of the world to assess or examine public awareness of climate change. Al-Buloshi and Ramadan (2015) undertook a study to assess climate change awareness and perception amongst the inhabitants of Muscat governorate, Oman. The study revealed that climate change awareness is fairly high amongst people of the area, while some limitations in knowledge of the causes, prevention or adaptation measures to climate change were recorded. The study also revealed that gender, educational background and income level were the most significant factors that determine the level of climate change awareness in the study area. Though the study examined climate change awareness and perception, it did not include adaptation as the present study.

Hasan and Akhtar (2015) conducted another study on the determinants of public awareness and attitude on climate change in urban Bangladesh. The study revealed that climate change awareness was relatively high amongst individuals in the study area. It also revealed that, level of formal education, access to media and family past experience of environmental problems, were the strongest determinants of the level of climate change awareness amongst individuals in the study area. Critical to this study is its emphasis on urban centres, leaving the rural area that are mostly nature-dependents. Similarly, Ajuang, Abuom, Bosire, Dida, and Anyona, (2016) examined the determinants of the level of climate change awareness in Upper Nyakach division of Kisumu county, Kenya. The researchers laid emphasis on the common climate change markers viz- rainfall, temperature, drought and floods to collect the data from the sampled respondents. The study revealed that climate change awareness level is generally low in the study area. It further revealed that gender, educational level and age, are the most significant predictors of the level of climate change awareness in the

study area. Though the study was conducted at local level, it failed to examine the issue of perceptions and adaptations to climate change as the present study. In the same vein, Millicent and James (2013) assessed the level of climate change awareness and perception among primary school teachers in Kisumu municipality, Kenya. The study revealed that, there was high level of climate change awareness amongst primary school teachers in the area, but there exist significant gap in their knowledge and understanding of its causes. The study also revealed that, educational level were the most significant determinant of climate change awareness amongst the respondents. This could be attributed to the fact that the respondents were teachers who must have attained a significant level of formal education per se. Critical to the study are its emphasis on educated population (primary school teachers) leaving the uneducated rural people who are usually the first-hand source of information on climatic parameters.

Rughuvanshi, Ansari and Amardeep (2017) in a study on farmers awareness about climate change and adaptation practices in India observed that agriculture is the backbone of Indian Economy and that significantly affects agriculture productivity. The study was conducted in the district of Uttarakhand State in the North Himalayan region of Indian bordering Nepal and China. The study sample comprised 110 farmers selected by using simple random sampling. Study findings indicate that all the farmers were found to be aware if the climate change and majority then reported erratic rainfall, diminishing agricultural yield and increase in temperature as the indicator of climate change. The increasing industrialization, overpopulation and deforestation were perceived by farmers to be the main causes of climate change. Furthermore, the study revealed that most of reported crop failures, migration to other pleaces and flooding as three main consequences (impact) of climate change. The study recommend better

policy formulation and agricultural development programmes to cushion the effect of climate change.

In Nigeria, Adebayo, Onu, Adebayo and Anyanwu, (2015) assessed farmers' awareness, vulnerability and adaptation to climate change in Adamawa state, Nigeria. The study revealed that majority (96.5%) of the respondents is aware of climate change, and opined that it affects them negatively. The study also revealed that age, educational level, years of farming experience and beliefs about the causes of climate change were the major drivers of awareness in the study area.

Other studies include Mings, (2008), Godfrey, Roux-Rutledge, Cooke, and Burton (2009), Cutter, (2009), Tedrera, (2010), Boissiere, *et. al* (2013). Common to these studies, is their findings on the levels of climate change awareness amongst individuals in their respective study areas. All of the studies revealed that climate change awareness level was high, with age, gender, educational level and past experience of environmental problems standing as the strongest determinants of climate change awareness in their respective study areas. Therefore, in light of the above literature, different factors affect the level of climate change awareness in different parts of the world.

In other studies, Khan, Ul-Hassan and Aslam (2012) analyzed peoples' perception about climate change and adaptation in the region of Pakistan using field questionnaire and interview survey method. The students and teachers of the University of Bahawalpure, Peshawar and Quatar were used as population of the study. The study revealed that there was significant increase in climate change awareness as expressed by majority of the respondents, and they believed that temperature is getting warmer in

recent years, while rainfall is decreasing. Over 90% of the respondents pledged to participate in personal actions to reduce their contribution to the problem.

2.9.3 Climate change perception

Several studies have been conducted in different regions of the world to assess the level of awareness, perceptions, biophysical vulnerability, adaptation and/or coping strategies to climate change. Leiserowitz, *et. al*, (2015) assessed the level of public climate change awareness and risk perceptions in the world. The study centered on causes and risk perceptions amongst individuals across the globe. The study revealed that climate change causes and risk perceptions were unevenly distributed globally. It also revealed that majority of the respondents from developed countries of Europe, North America and Japan, perceives the change as having anthropogenic causes. By contrast, in developing countries of Africa, Middle East and Mainland Asia, majority of the people perceives natural and supernatural forces are behind the change. However, the study further reports that in developing countries those that are aware of climate change though are the minority, they generally perceived climate change as a greater threat to their livelihoods and families than elsewhere. Asrate and Simane (2018) carried out another study on farmers' perception of climate change and adaptation strategies in the dabus Watershed North West Ethiopia. The research employed the Heckman sample selection model to analyse the two-step process of adaption to the climate change which initially requires farmers' perception that climate is changing prior to responding to the changes through adaptation measures. Based on the model result, education attainment, the age of the head of the household, the number of crop failures in the past, changes in temperature and precipitation significantly influenced farmers' perception of climate change in the study area. The study recommend any intervention that promotes the use of adaptation measures to climate change may

account for location-specificf factors that determine farmer' perception of climate change and adaptive response thereof.

Hitayezu (2017) in a similar study on assessing farmers' perception about climate change: a double hurdle approach, the study applied a double-hurdle (DH) estimation techniques to assess socio-psychological factors influencing the likelihood of perceiving climate risk and perception among farmers in Kwazulu-Natal, South Africa. The model employed survey collected from 352 small-scale farmers. Dominant perception were analyzed using a principal component analysis techniques and appraisal based on meteorological records. The result pointed to higher probabilities of perceiving climate risk among farmers who experienced more emotive mental imaginary and those with stronger egalitarian values. The study further observed that farmers who perceive climate change based on effective impression and direct personal experience are more likely to suffer cognitive bias in their perception compared to farmers who perceive climate risk based on knowledge and analytic processing of climate information. Based on these results, the study recommended effective climate change communication policy among farmers in the study area.

In another study (Saguye, 2017) assessed farmers perception of climate and variability and its implication for implementation of climate – smart agricultural practices in Geze Gofa District southern Ethiopia. The main purpose of this study was to analyze factors determining the farming communities awareness and perception of climate change and variability and its implication for implementing of climate change – smart farming practices. A multistage sampling procedure was used to select sample respondent households and the total sample size of the study was 138 households. The researcher employed both qualitative and quantitative methods of data collection. Logistic regression model was used to estimate household demographic, socio-economic,

institutional and biophysical factors that determine the farmers' perception of climate change and variability in the area. The results indicted that about 88.7% of farmers believe that temperature in the district had become warmer. Ninety percept of the farmers recognized that rainfall volume, pattern, distribution and timing had changed resulting in increase rate of draught. The study further suggest that local socio-economic, institutional and agro-ecological and information on weather and climate were significant in determining the likelihood of a good perception and knowledge of climate change and variability. The study recommends that more focus should be given to socio-economic (farm experience, education and training, access to weather related information, household size, wealth land ownership-) as a means to enhance rural farmers awareness and adaptation techniques.

Nigeria, like many parts of the world has witnessed many climatic anomalies with serious consequences on the environment and the society. Recent studies, shows that the Sudano-Sahelian Zone of Northern Nigeria has suffered decrease in rainfall in the range of 30-40% since the beginning of nineteenth century (Ojo, 2009). While the temperature and rainfall variability in the semi-arid region of northern Nigeria (Sokoto, Zamfara, Katsina, Jigawa, Yobe, and Borno States) are believed to be climate change related (Odjugo and Ikhuoria, 2013).

Ishaya and Abaje (2008) examined the indigenous people's perceptions on climate change and adaptation strategies in-Jema'a Local Government Area of Kaduna State, Nigeria. The study revealed that indigenous people in the area observed some changes in the environment (climate in particular) over the years. It also revealed that majority of indigenous people in the study area, attributed the change to diverse anthropogenic activities (such as deforestation, bush burning, burning of fossil fuels, overgrazing and environmental pollutions) than having natural causes. The study further revealed that,

the people perceives climate change as a great threat to their livelihoods and families, and that the threat is more on food supply, health, biodiversity lost and forestry. Gender, age, education and beliefs were the strongest determinants of the people's cause and risk perceptions of the change as reported by the study.

In the same vein, Adebayo, Onu, Adebayo and Anyanwu (2012) assessed farmer's awareness, vulnerability and adaptation to climate change in Adarnawa State,'Nigeria. The study revealed that majority of farmers in the state are aware of climate change, and submitted that it has affected their farming in recent years, while mentioning mass media as their main source of information about the change. They also identify reduced crop yield, shortage of water and pasture for animals and frequent dry spells in recent years as the main impacts of the scenario. It further revealed that, the farmers are making efforts to adapt to the change, but they lack adequate information on how to adapt in modern ways.

Egbe, et. al., (2014) assessed the rural people's perception to climate variability and change in Cross River State, Nigeria. The study revealed that, majority (74%) of perceived late onset and early cessation of rainy season in recent years, which corroborates with meteorological data. The study also revealed that, though there was natural causes of the change, majority (66.7%) perceived anthropogenic activities (such as deforestation, bush burning and overgrazing) as the major causes. The study further revealed that, majority (83%) of the respondents perceived climate change as a great threat to their livelihood, occupation, geographic location age as the most significant drivers of their climate change perceptions.

In another study, Abaje, Sawa and Ati (2014) examined local people's perceptions on climate variability and change, and adaptation strategies in Dustin-ma L.G.A of Katsina

State. The study revealed that local people in the area are aware of climate change in terms of increasing temperature, occurrence of extreme weather events such as floods and drought and increase in their variability in recent years, as opined by majority of the respondents. However, in terms of causes, majority (83%) opined that the change has supernatural causes (specifically communities disobeying God). The study also revealed that majority of the respondents perceives climate change as a threat to them and their families. It further revealed that water shortage, decrease in soil fertility, shortage of labour force for agriculture (due to rural-urban migration), and decline in forest resources as the most significant impacts of the change as perceived by majority of the respondents.

It is observed from the literature reviewed so far that people perception on climate variability is high. However, knowledge of the causes of the variability differs from place to place.

2.9.4 Effect of climate change on crop and animal production

Climate change and agriculture are interrelated processes, both of which take place on a global scale. According to the United States research Programm USRP (2016), climate change affects agriculture in a number of ways, including through changes in average temperature, rainfall and xclimate extremes (e.g. heat waves), changes in pests and diseases prevalence, changes in atmospheric carbondioxide, changes in the nutritional quality of some food and changes in sea level.

It is therefore obvious that an important prerequisite for efficient intensification of agricultural production therefore is an understanding of climate crop relationships. Long-term climate variability influences sowing dates, crop duration, management practices and crop yield. (fakorede 2009, Langiyan *et al.*, 2009). According to Fakorede

and Opeke (2012) short-term weather fluctuations especially temperature, potential evaporation and moisture availability also effect crop growth and yield. The degree of vulnerability of crops to climate variability depends mainly on the development stage of the crop at the time of weather observation (Lansigana *et al.,* 2009).

In a study titled the effect of climate factors on maize yield in Obafemi Awolowo University Teaching Research Farm, southwestern Nigeria, rainfall data were obtained with Dynes tilting siphon rain gauge. Temperature data were obtain from mercury thermometers. Data on potential evaporation were obtained from a shielded piche evaporimeter and sunshine hours from a Campbell stokes sunshine recorder, while relative humidity was obtained using dry and wet bulb thermometers. The result of the study showed that relative humidity (RH) generally showed negative correlation with yield, while other weather elements showed positive correlation with yield of maize crop.

Ayinde, O.E., Muchie, M. and Olatunji, G. (2011) carried out a study on the effect of climate change on agriculture in Nigeria. Descriptive and cointergration analysis were used to analyze the time series data used in the study. The findings demonstrates that the rate of agricultural productivity is persistently higher between 1981 and 1995, followed by a much lower growth rate in the 1996 – 2000 sub period. The study also revealed variations the trend pattern of rainfall, while temperature was not relatively constant either. The Augmented Dickey-Fuller test for unit root revealed that agricultural productivity is not stationary and likewise the annual rainfall but become stationary after the differencing. The study recommend environmental and agricultural sensitivity technologies and innovations that can prevent climate fluctuation be encouraged if agricultural productivity was to be increased and sustained. In the same vein, Sajian, Gaughan, and Naquis (2016), carried out a study on the effect of climate

change on livestock productivity. Molecular biotechnology was used to characterize gene expression in order to identify key cellular responses to stress. The study revealed that the most significant direct impact of climate change on livestock production comes from the heat stress. It observed that heat stress results in a significant financial burden to livestock producers through decrease in milk component and milk production, meat production, reproduction efficiency and animal health. The study recommended robust research into breeding of heat tolerance animals. It also advocated a systematic information generation on the impact assessment of climate change on livestock production as a way of developing appropriate adaptation and mitigation strategies to sustain livestock production in the changing climate scenario.

2.9.5 Adaptation strategies to climate change

Hirsch**,** Johnson, Neil, Webber and Williamson (2009) undertook a study of climate change impacts and adaptation strategies for the forest sector in Canada. The study revealed that many forest species are moving to the poles or higher altitudes in response to shift in the habitats to which the species have adapted. Du-Yao, Wang, Yang and Ma (2008) carried out a similar study on impacts of climate change on human health and adaptation strategies in Southern China. The study revealed that the daily mean surface air temperature above or below 27^0C increase the death risk for the people in Guangzhou especially the elderly. The study further revealed that the risk of non-accidental deaths and respiratory disease deaths significantly rise as well. Bruce, El-Ganzori, El-Shinnawy, Joel, McCal, Mohammed, Smith, Paul and Russell (2013) carried out a similar research on climate change vulnerability and adaptation strategies in Egypt's agricultural sector using a partial equilibrium model that simulates crop and livestock production. The study revealed that climate change has damaged the Egyptian agricultural sector and the damages increase over time, as a result, price for agricultural

commodities has increased which has negative impact on the consumers. The study observed that diversitifcation, intensification and or integration of pasture management, livestock adaptation strategies and crop protection, altering time of operations are some of the adaptation strategies adopted in the area.

Franklin, Gifty and Samuel (2014) on their own undertook a study on determinants of choice of climate change adaptation strategies in northern Ghana using a semi-structured questionnaire. The empirical result of the binary logistics regression models revealed that farming experience, farmers income, access to phones, mixed farming, farmers perception on reduction in rainfall amount and access to weather information significantly and positively affects the choice of climate adaptation strategies. According to Odjugo 2010 Nigeria, like many other parts of the world has also witnessed many climatic anomalies with serious consequences on the environment and society. This has necessitated recent studies on climate change impacts, awareness, perception and adaptation strategies in Nigeria especially in the semi-arid regions of Sokoto, Zamfara, Katsina, Kano and Jigawa States respectively. Mohammed (2012) examined the perception and coping strategies to desertification by farmers and pastoralist in Babura Local Government Area of Jigawa State using the interview method. He reported that farming and grazing lands in the study area are gradually being taking over by sand dunes. He identified planting of drought resistant varieties, change in cropping pattern and calendar of planting as some of the adaptation strategies adopted by farmers in the study area. He therefore called on government to intervene with the provision of irrigation facilities as a coping strategy for the farmers. Abubakar (2010) carried out a similar study on farmers coping strategies to climate change in Jibya Local Government Area of Katsina State, using interview method. The researcher found that there were great losses in livestock and significant reduction in crop

production due to climate variations. The study discovered that extensive use of both organic and inorganic fertilizers, use of early maturing seed varieties, mixed cropping and mixed farming are major adaptation strategies employed by farmers in the study area. He recommended the provision of irrigation facilities as coping strategies to climate change in the study area. The farmers also adopted mix livestock farming, use of emergency fodder in times of droughts as coping measure for their animals. Gashua (2005) in the same vain carried out a research on an evaluation of indigenous techniques coping with drought in Bade Local Government Area of Yobe State. The research revealed that farming community of Bade perceives drought as its most serious ecological problem and various measures such as planting of early maturity seeds varieties, drought tolerant varieties, mix farming and mix cropping have been adapted to mitigate the effect. Audu (2012) also undertook a study on adaptation strategies method. Descriptive statistics such as frequency and percentages tables as well as regression analysis were used in analyzing the data. The study revealed that the most effective strategies adapted by the dwellers of the environment are planting of shelter and south ward migration.

Similarly, Solomon (2014) carried out a study on biophysical and socioeconomic vulnerability of climate change on given farmers and the adaptive strategies in shinkafi Local Government Area of Zamfara State. The researcher revealed that rainfall was normally distributed at 95% confidence level and the grain farmers have adopted traditional means of combating climatic stress such as mulching and shifting cultivation.

Elisha (2014) examined on his own the adaptation strategies to climate change among grain farmers in Goronyo Local Government Area of Sokoto State. Rainfall and temperature data of the study area was characterized using time series analysis to

determine onset, cessation dates, length of rainy season and temperature of the study area. The study revealed that millet is the most cultivated crop in the study area. It further revealed that grain farmers in the study area adopted crop rotation, mixed cropping, use of improved seed varieties, shifting cultivation, intensification of irrigation, use of organic and inorganic manure and access to credit loan as adapted strategies to cope with the vagaries of climate change.

Similarly Abaje, Sawa, Iguisi and Ibrahim (2015) carried out a study on impacts of climate change and adaptation strategies in rural communities of Kaduna State. It focused on the impacts of climate change on the livelihood of some selected rural communities of Kaduna State and adaptation strategies employed by the people to ameliorate the scourge of climate change. Data on the study was obtained from direct field study based on the result of 426 questionnaires that were administered to household heads. Descriptive statistics was used to describe the socio-economic characteristics of the respondents. A five point Likert scale was used to determine the impacts of climate change and adaptation strategies employed by the people. Focus group discussion sessions were held in each local government area in order to obtain in-depth information on the changing climate. The study identified decline in crop yields, decline in animals production, increased sickness for man and animals, decrease soil fertility and decline in forestry resources as the most significant impact of climate change in the study area, whereas use of fertilizer/animals dung, water harvesting, planting of economic trees and drought resistant crops as the most significant adaptation strategies adopted by the rural people. It recommended awareness programmes on climate change challenges should be intensified by the three tiers of government.

Ojonuga, Iguisi and Afolayan (2014) undertook another study in climate variability and change, impacts and adaptation strategies in Dutsin-Ma Local Government Area of Katsina State. The study examined local people perception on climate variability and change and strategies adopted in combating the impacts of the changes in the study area. Descriptive statistics such as frequency distribution, percentages, and mean scores were used in the data analysis. The result of the study revealed that majority of the people have a very good knowledge of climate change variability and change in terms of higher temperature, higher rainfall intensity and variability, and the occurrence of extreme weather events such as flood and drought. The study further revealed that deforestation, bush burning, combustion of fossil fuel and pollution were the major causes of climate variability and change as perceived by the respondents. The most significant impact of climate change in the study area according to the study include decline in crop yield, decline in animal production, increase prevalence of pests and insects both in crops and animals, decline in forestry resources, water shortages and decrease in soil fertility. Sustainable adaptation strategies adopted by the people according to study are water harvesting, the use of fertilizer and animal dung to improve crop yield, irrigation agriculture, planting of early maturing and drought resistant crop varieties. It recommends the education of the people on the scientific basis for climate change as well as including traditional and religious beliefs of the people in various efforts at combating climate change in the study area.

2.9.6 Factors affecting adaptation and use of adaptation strategies

An evaluation of the responses to the 1997 – 98 ElNino across 16 developing countries in Asia, Asia Pacific, Africa and Latin America highlighted a number of barriers to effective adaptation, including: spatial and temporal uncertainties associated with forecasts of regional climate, low level awareness among decision makers of the local

and regional impacts of ElNino limited national capacities in climate monitoring and forecasting and lack of coordination in the formulation of responses.

Previous studies have reported that farmers' adaptation to climate change is determined by factors such as education, age, farming experience, gender, access to extension, credit, markets, farm income and farm size (Deressa *et al.,* 2011). The results of these studies showed that education was positive and significantly related to farmers decision to adapt to climate change. They showed that there is a positive relationship between educational level of the household head and adoption of improved technologies. This is particularly so because educated farmers are more knowledgeable due to their ability to access information pertaining to climate change and adaptation options. Also the results showed that the probability of adaptation rises with increased access to information. This implies that farmers with access to timely weather information and other extension services are more likely to adaopt to climate change. Similar findings have been reported in Nepal and southern Africa (Tiwari *et al.,* 2014). In addition, results of the studies indicated that the likelihood of adaptation to climate change was higher with larger household size than with small households. Earlier investigations have shown that the visible tendency of larger households to adapt to climate change is probably due to their higher endowment of labour (Oyekale and Oladele 2012). Increase access to credit facilities as well as household income have all shown the probability of adaptation to climate change rise across Africa/ (Fosu-Mansah *et al.,* 2012). Membership to farmer-based organization (FBOs) and adaptation to climate change have shown positive relationship also (Tiwari *et al.,* 2014; Uddin *et al.,* 2014).

Strauss (2012) in a paper titled vulnerability to climate change in West Africa, Adaptive capacity in the regional context builds on the climate change vulnerability mapping work of Robert S. Strauss (2012) center on international security and law's

Climate Change and African Political Stability (CCAPS) program. The CCAPS program takes data on climate-related hazard exposure, population density, and household, and uses Geographic Information System (GIS) software to identify the areas of highest composite vulnerability. The paper expanded on the CCAPA index by incorporating new data related to the political economy of government as it relates to their willingness and ability to adapt to climate change. Specifically it discovered dependence on oil and mineral extraction, ethnic and religious conflicts, low level education, poor government policy implementations as major hindrances to adopting adaptation strategies in many nations.

Ogbo and Oyedinma (2015) in their study titled climate change adaptation in Nigeria, Problems and Prospects, examined the growing concerns of global climate change manifestation and how the technological system of climate change adaptation can spur Nigeria to greatness among various communities. The research design adopted was the survey method. The population sample was one hundred and nine (109) and the research instruments used were questionnaire and interview guide administered to local communities in Enugu State. The result of the finding revealed that there is a strong relationship between climate change adaptation and effective management technologies. It recommends that the prevailing government policies must encourage and support the contributions to adaptation of individuals, households, communities, organizations and enterprises.

In a paper titled Climate Change Adaptation: Uncovering Constraints to the Use of Adaptation Strategies among Food Crop Farmers in South West, Nigeria by Otitoju (2016), principal component analysis (PCA) was used. The study focused on the constraints to the use of climate variability/change adaptation strategies in Southwest Nigeria. Multistage random technique was employed to select the location and the

respondents. Descriptive statistics were the analytical tools engaged in this study. He found out that the principal constraints that the farmers faced in climate change adaptation were public, institutional and labour constraints, high cost of inputs, technological and information constraints, farm distance, access to climate information off-farm job and credit constraints and poor agricultural programmes and service delivery constraints (Otitoju, 2016).

Ifeanyi, Obi, Etuk and Ojike (2012) reviewed the climate change effects, adaptation strategies and its implication for agricultural extension system in Nigeria. They observed that the extension system in Nigeria has failed in its role to mitigate against climate change and increasing capacity and role of extension agents.

The paper conclude that there is an urgent need for the extension system to rise up to the challenge of climate change by ensuring that extension agents are well groomed in issues of climate change and adaptation strategies relevant to the development of farmers particular environmental need. They recommend that government on her part need to develop policies to back-up institutional efforts to combat threats of climate change and make it easy for farmers to adopt new adaptation strategies.

Ifeanyi Obi and Arokoyo (2017), in a study titled challenges faced by cocoyam farmers in adapting to climate change in southeast Nigeria, examined the challenges faced by cocoyam farmers in adapting to climate change in southeast Nigeria. Three hundred and eighty-four respondents were selected through multi-state sampling technique were used for the study. Data were collected using structured questionnaire and interview scheduled and analyzed using both descriptive and inferential statistical tools. The study identified eight major challenges faced by cocoyam farmers in adapting to climate change namely; lack/high cost of farm inputs and low soil fertility, land and

labour constraints, poor access to information and ineffectiveness of cooperatives, lack of improved varieties of cocoyam, poor value attached to cocoyam and technological know-how and transport constraints. The study recommends enrolment of new cooperatives and revitalizing existing cooperatives as well as provision of improved variety cocoyam and other farm inputs for the farmers by state government.

CHAPTER THREE

3.0 Study Area and Methodology

3.1 Introduction

This chapter presents the physiography, geology, relief, climate and drainage pattern of the study area. It also discussed the methodology used in the study.

3.2 Study Area

3.2.1 Location and size

Illela, Gwadabawa, Gada and Sabon-Birni are four (4) Local Government Areas (LGAs) in Sokoto east senatorial district of Sokoto State. This is an area located at the southern fringes of the sahara desert. It is situated along latitude $12^0$45' to$13^0$25' North and Longitude 5^0 10'E to 6^0 40'E.' The total land area of the four (4) LGAs is 5,476 km^2. The area is boarded to the north by Niger Republic; to the east by Goronyo and Rabah LGAs to the west by Tangaza and Gadu Local Governments and to the south by Kware and Wurno Local Government Areas respectively (See Fig. 3:1).

3.2.2 Climate

The climate is mainly semi arid with alternating wet and dry seasons characterized by low rainfall usually between 400 – 700mm annually Nigerian Meteorological Service (NIMET, 2011) occurring between May and October with peak in August. The dry season starts from October and ends in May. According to the NIMET, (2009), maximum temperatures range from 25^0C to 43^0C. Relative humidity can be less than 5% during the harmattan season. According to Hir (2010), sand dunes and harsh arid climate in Sahel area of Sokoto State are evidence of the climate change reality.

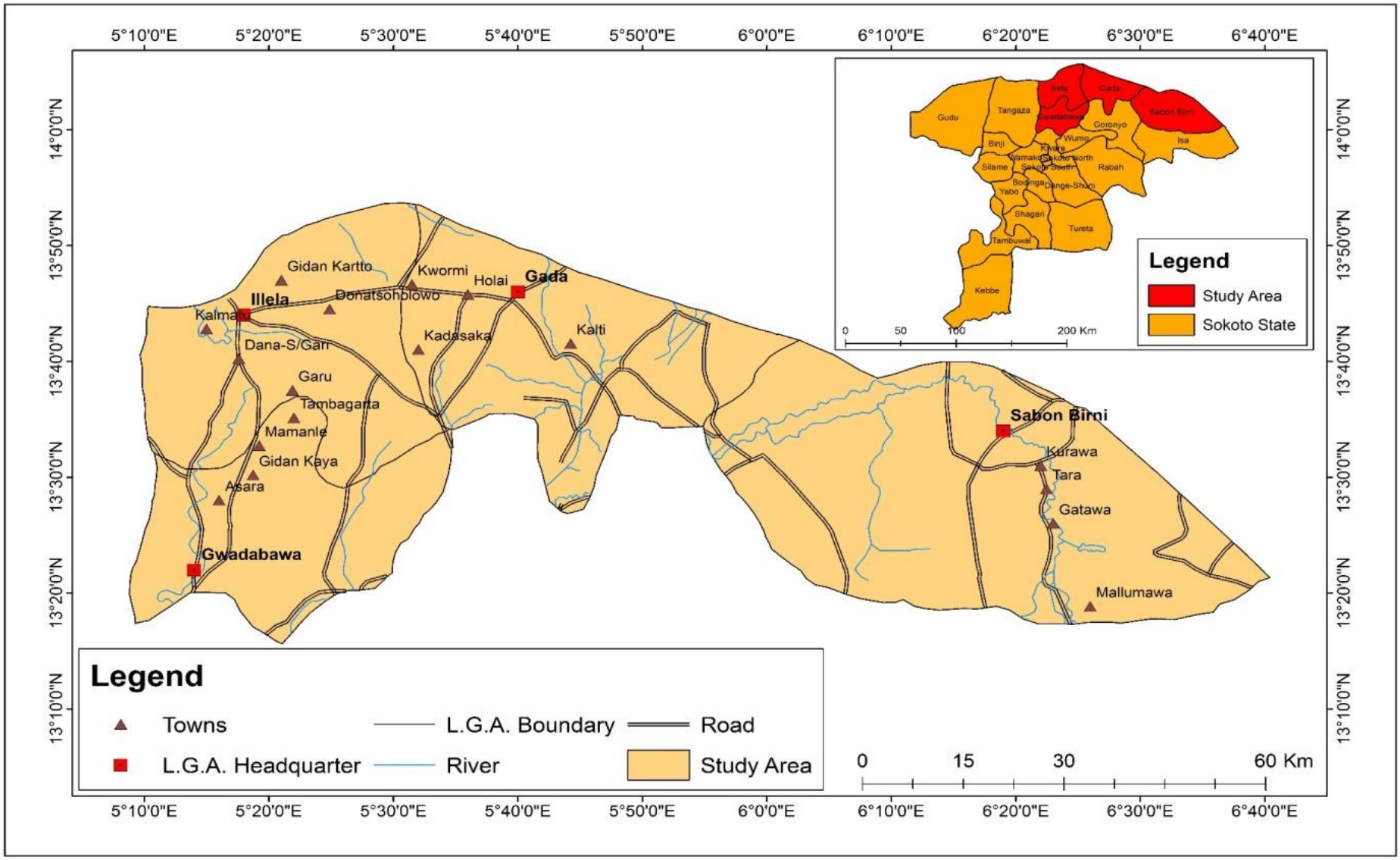

Fig. 3.1: Study area
Source: Modified from Administrative Map of Sokoto State, (2008).

3.2.3 Geology and relief

Sokoto East senatorial district is located within the ilumedan basin, which is underlain to the east and south by the precambrain basement complex. Iyanomo (2002) identified five major groups of rocks in the area covering 176,00km in northwest Nigeria. These rocks include granites, sandstones, basalt pyrolast rocks and gneiss.

The predominant soil is made up of aeolian, alluvial and locustrine sediments deposited over older sediment or on basement complex rock (Ojonuga, 1987). Aeolian deposits constitute the most extensive parent material in northern part of the region. Alluvial deposits are found mainly in the valley of the Sokoto-Rima.

The land is a gentle rolling to undulating plane. Obaje (2009) characterized Sokoto's relief as a monotony of low land interrupted by isolated flat-topped hills (mesas) and escarpments. The escarpments are found in Dange and Kalambaine and, along with the hills, they rise up to 488m.

3.2.4 Drainage

Sokoto East senatorial district is drained by the Rima River. The Goronyo dam located close to the study area impounds the Rima at Goronyo. Most of the tributaries of the Rima River rise in the Northwestern part of the state and in the neighbouring Zamfara State. While the Bunsuru and Gangers Rivers flow in a northerly direction, joining the Rima near Sabon-Birni, the Sokoto, Zamfara and Kebbi tributaries on the other hand flow west wards to join the Rima. Obaje (2009). In their upper reaches all the tributaries flow over basement complex rocks. Their valleys are rather narrow and restricted until the rivers enter where they flow through broad valley.

3.2.5 Soil and vegetation

The soil is sandy topsoil with clayey subsoil which textually can be described as sandy and loamy with very little organic matter. These soils are highly susceptible to wind and water erosion (Driessen and Dydal, 1989).

The natural vegetation of the study area is Sudan Savanna made up of mainly grasses, thorny shrubs and trees. Woody species make up less than 5% of the area on soils formed from aeolian deposits. However on soils formed from sand stones and riverine deposits with temporary puddles due to accumulation of run-off water, coverage can be up to 20% (Bremen and DeWeerdt, 1983). The dominant tree species include: *Azadirachta indica, Parkia bigloboza, Magnifera indica, Khaya senegalenses, Balanites aegyptiaca*. The shrub species include *cumbretum nigricans, combretum molle,* while common grasses include *Andropogon gayanus, Landetia togorensis, Tripogen minimus* etc (Bashir, 1989).

3.2.6 People, population and socio-economic activities

Sokoto East senatorial district is mainly populated by Hausa, Fulani and the Zabarmawa people. According to the 2006 census, the entire senatorial district has a total population of 1,482,254 while the four Local Governments under study have a total population of 838,153. They are essentially agricultural areas with 95% of the population engaged in subsistence farming (Gadzama 1990).

Mortimore (2009) also confirmed that greater proportion of the population in the semi-arid zone including the study area are agrarian and depend on land for their livelihood. The main crops produced in the area are millet, guinea corn, beans and some fruits and vegetables such as onions, lettuce, cabbage, spinach. Large catch of livestock e.g. goat, sheep, is also found here.

Both mixed farming and irrigation farming are practiced in the study area, local crafts such as blacksmitting, weaving, carving and dying are practiced. Leather works also play an important role in the economic life of the people of the state. Along the stretch of the Sokoto and Rima Rivers fishing is practiced and provides a means of additional income to farmers, (Sani 2005).

3.3 Methodology

3.3.1 Reconnaissance survey

A reconnaissance survey was carried out by the researcher in the study area between the 4th and 9th March, 2016. During the survey, the researcher interacted with heads of Agric departments in the respective Local Government Headquarters, village heads, farmers as well as opinion leaders (Sarkin Noma, Sarkin Yaki and area councillors). Observation during the survey and interactions with all the stakeholders confirmed the negative impact of climate change in the study area and hence the need to assess the adaptation strategies by the people over the years.

3.3.2 Types of data

The following data were used for this study

i. Daily rainfall records of the study area (1986 – 2015). The daily rainfall data obtained from NiMET Sokoto were used to characterize trends in total annual rainfall, onset and cessation date, number of rainy days, annual total and length of rainy season. The data was also used to compare recorded data with farmers' perception of climate change in the study area.
ii. Mean monthly maximum temperature records of the study area (1986 – 2015). This was obtained from NiMET Sokoto and was used to determine trends in temperature

fluctuations, whether the temperature of the study area was increasing or decreasing over the years.

iii. Farmers' awareness and adaptation to climate change: farmers awareness to climate change was obtained using well structures questionnaire and helped to determine the sensitivity and knowledge of farmers to the changing climate as well as their adaptive strategies to climate change.

iv. Socio-economic characteristics of farmers such as sex, age, education etc were also obtained using well structured questionnaire and helped to ascertain the farmers capability to adopt certain mitigation measures and those that have lived in the study area long enough to describe the changing climate.

3.3.3 Sources of data

The daily rainfall and temperature records for the period under study were obtained from the Nigerian Meteorological Services (NiMET) Sokoto. Data on farmers awareness and adaption strategies as well as those on socio-economic characteristics were obtained by means of structured questionnaire.

3.3.3.1 The Questionnaire

The questionnaire is divided into five (5) sections, with each section addressing major objectives of the study. Section A shows the profile of biodata of the respondents that are relevant to the study. Information on age, name, educational status, marital status, sex as well as how long the farmer has lived in the study area were collected via the questionnaire.

This is followed by Section B in which questions that addressed farmers crop and animal production as well as reason for their choice of production were ascertained.

Questions in Section C verified farmers awareness to climate change as well as their sources of information about climate change.

Section D questions were targeted towards finding out the effect of climate change on agriculture in the study area. Farmers' perception of climate change was also investigated by questions in this section of the questionnaire. Section E investigated the adaptation strategies adopted by farmers to mitigate the effect of climate change as well as possible hindrance to the adaptation of modern techniques of combating climate change. The section concluded with a question bothering on the recommendation of steps to be taken to enhance the fight against climate change in the study area.

3.3.3.2 Sample size and sampling techniques

The respondents for the questionnaire were farmers in the four (4) Local Government Areas of Sokoto east senatorial district namely Gada, Illela, Sabon-Birni and Gwadabawa. Each of the LGA has eleven wards. Five (5) wards in each LGA were selected using systematic random sampling based on every second ward in alphabetical order (i.e. 2^{nd}, 4^{th}, 6^{th}, 8^{th} and 10^{th}) making a total of 20 wards. It is assumed that the size of the five wards selected in each of the LGA is a fair representation of the entire LGA since all of the wards share common characteristics (dry and agrarian) as revealed during the reconnaissance survey (see Table 3.1).

To determine the sample size for the research, Krejcie and Morgan's (1970) method of determining sample size was adopted. It stated that for an area with a population between 75,000 and 999,999, the sample size to be used is a minimum of 382. Since the population of the study area according to (2006 population) is 838,153 and this falls within the ranges, 384 copies of questionnaire were administered to the respondents within the study area. A purposive sampling technique was used to sample the

respondents within the twenty-one (21) wards spread across the four (4) Local Government Areas. Purposive sampling according to Bernard (2002) is the deliberate choice of an informant due to the quality the informant possesses.

The 384 copies of questionnaire were distributed proportional to the population of the selected wards in each Local Government Area (see Table 3.2).

Table 3.1: Local Government Areas, Wards and selected Wards

LGA/Wards Gada	LGA/Wards Illela	LGA/Wards Sabon-Birni	LGA/Wards Gwadabawa
Dukamaje	Araba	Gangara	Atakwanya
Gada	**Dana-S/Gari**	**Gatawa**	**Asara**
Gilbadi	Danba	Kalgo	Chinola
Holai	**Donatsolowo**	**Kurawa**	**Gidan kaya**
Kadadi	Garti	Laginge	Gigane
Kadasaka	**Garu**	**Makumana**	**Gwadabawa**
Kaddi	Gidan Honma	Takatsaba	Huchi
Kalfi	**Gidan Kartto**	**Tarah**	**Mamande**
Kiri	Illela	Tsamaye	Mammansuka
Kworma	**Kalmalu**	**Sabon Birni**	**Tambagarka**
Kyadawo	Tozai	Unguwan Lale	Salame

The questionnaire were administered to farmers above the age of thirty (30) who must have lived in the study area for at least twenty (20) years. These group of farmers were identified through the “Sarkin Noma” (Head of Farmers) and the village heads. This was done by asking farmers their age and how long they have lived in the study area. This decision become imperative because farmers within this age bracket have information needed about climate change.

The questionnaire were administered with the aid of eight (8) staff of Sokoto State Agricultural Development Project (SADP) who are trained research assistants of the institution. The researcher also spent some time to train them on the questionnaire.

They in turn interacted with the farmers under the supervision of the researcher. The questionnaire were administered to the farmers in their homes. This procedure ensured a hundred percent recovery of the questionnaire. A total period of ten (10) days was used to administered the questionnaire between the 1st and 10th of October, 2016.

Table 3.2: Distribution of questionnaire by wards

LGA	Wards	Population		No. of Respondents	
				Number	Percentage
GADA	Gada			30	
	Holai			28	
	Kadasaka	249051		18	
	Kalfi			23	
	Kworma			16	
			Total	**115**	30
ILLELA	Dana-Sabo				
	Gari			18	
	Donatsoholowo			14	
	Garu	150133		9	
	GidanKarto			13	
	Kalmalu			15	
			Total	**69**	18
SABON BIRNI	Gatawa			19	
	Kurawa			22	
	Makumana	207470		15	
	Tarah			27	
	SabonBirni			13	
			Total	**96**	25
GWADABAWA	Asara			13	
	Gidan Kaya			28	
	Gwadabawa	231569		14	
	Mamamde			21	
	Tambagarta			29	
			Total	**104**	27
			Grand Total	**384**	**100**

3.3.4 Agro-climatological derivations

3.3.4.1 Onset, cessation and length of the rainy season

The daily rainfall data were used in calculating the mean monthly and annual rainfall for Illela, Gada, Gwadabawa and Sabon-Birni LGAs. From the climatic data, the

derived agro climatic parameters of precipitation effectiveness were computed in accordance with the following method.

Various methods abound for the determination of onset, cessation and length of the rainy season. Some of these include Walter (1967), Ilesanmi (1972), Kowal and Knabe (1972), Stern and Coe (1982), Olaniran (1984), Sivakumar, (1988); Stern, Dennett and Dale, (1982) and Adefolalu (2010).

The definition of onset, cessation and length of the rainy season in tropical climates has been problematic due to the intermittent and patchy nature of rainfall in the region. These three terms have been defined in various ways for different purposes by researchers. Onset refers to the time a place receives an accumulated amount of rainfall sufficient for growing of crops. It is not the first day the rainfalls. According to Stewart (1991) cited in Ati, (2002) the onset date is a key variable to which all other seasonal rainfall attributes are related. It is the onset relations that determine how the season rainfall is expected to behave. Cessation means termination of the effective rainy season. It does not imply the last day rain fell, but when rainfall can no more be assured or be effective. Length of the rainy season is the period between the onset dates and the cessation dates of the rainy season.

Walter (1967) computed the start of the rains as follows: the product of the number of days in the month from January whose cumulative rainfall is equal to or greater than 51mm and the difference between 51mm and the total rainfall of the previous month divided by the total rainfall of the month with cumulative rainfall equal to or greater than 51mm.

Mathematically given as:

$$\text{Onset Date} = T\,\frac{(51 - x)}{T_2}$$

Where: T = Number of days and month with cumulative rainfall ≥ 51mm

x = Rainfall of previous month

T_2 = Rainfall of month with cumulative rainfall ≥ 51mm

51mm = Soil moisture index at which crops germinate

The cessation on the other hand follows the same equation as the onset on the opposite direction of the onset i.e. computed from December backward. The value obtained is subtracted from the total number of days in the onset month.

According to Adefolalu (1993), the length of the rainy season is the period between the onset and cessation dates. Length of the rainy season is obtained by subtracting the onset date from the cessation date and using the Julian calendar to get the exact length of the rainy season. This was the approach used for the determination of the length of the growing season in this study.

The mean monthly maximum and minimum temperature is calculated by the summation of the daily temperatures (max and Min) and dividing by the number of days in the month.

3.3.5 Data analysis

Analysis was done to achieve each objective as follows:

1. To achieve objective I: which is to characterize the pattern of rainfall and temperature in the study area between 1986 to 2015, trends in mean annual rainfall, onset, cessation dates, and length of rainy season and temperature were analyzed using time series analysis. Trend lines and trend line equations were fitted to determine the direction of change in these parameters as was used by Elisha (2004) in Goroyo LGA Sokoto State.

2. Objective II: is to assess the awareness of farmers to climate change, as such descriptive statistics (i.e. frequency, average and percentages) was used to analyze the data and results presented in tables.
3. Objective III: is examination of how climate change affects agriculture in the study area. Descriptive statistics (i.e. frequency, average and percentages) were used to analyze the responses of the farmers and presented in tables and charts.
4. Objective IV: To examine the various agricultural adaptive strategies used by the farmers to cope with climate change, descriptive statistics (i.e. frequency, average and percentages) was used and the results presented in tables and charts.
5. Objective V: To examine the factors hindering adaptation strategies, descriptive statistics (i.e. frequency, average and percentages) was used to analyze data collected with structured questionnaire and results presented in tables and charts.

CHAPTER FOUR

4.0 Results and Discussion

4.1 Introduction

This chapter presents and gives detailed discussion of the results obtained at the course of this research. These include rainfall (onset, cessation, length of the rainy season and annual amount) and temperature trends for 30 years (1986 to 2015), farmers' awareness of climate change, farmers' adaptation strategies to climate change and farmers' perceived hindrances to adaptation of modern technique of combating climate changes as well as the impact of climate change on agriculture in the study area.

4.2 Socio-demographic characteristics of the respondents

Farmers' socio-demographic characteristics are very relevant to their agricultural practices. The rate of adoption of innovations and adaptation capacities of farmers are greatly influenced by characteristics such as age, educational qualification, sex and marital status. These characteristics are discussed fully in this section.

4.2.1 Sex of the respondents

The sex distribution of the farmers in Sokoto East Senatorial District is presented in Table 4.2.1.

Table 4.1: Sex of the Respondents

Gender	Frequency	Percentage
Male	376	97.9
Female	8	2.1
Total	**384**	**100**

Source: Author's Analysis (2016).

From Table 4.1, ninety seven percent of the farmers in the study area are male, while about two percent are female. This indicates that male dominate agricultural activities in the study area. It agrees with Adedoyin, Mbada, Awofolu and Obayemi, (2005) that reported that male dominated the agricultural workforce in Sudan Sahel area of Nigeria. The high proportion of male to female may not be unconnected with the religion and custom of the people and the crucial roles they play in the livelihood of the study area. By the custom and religion of the people male have more access to land, labour and cash (which are major resources in agriculture) and participate more in outdoor activities than their female counterpart.

This lack of access by women to the critical resources needed in agricultural production undermines their ability to carry out labour-intensive agricultural innovations (De Groote and Coulibaly, 1988). However, a recent study by Nhemachena and Hassan (2007) indicated that the way gender influences adaptation is location-specific. The study found out that female farmers are more likely to take up climate change adaptation methods than men especially in rural areas where women play more prominent role in agriculture as most men in such areas are town based. Women in such rural areas have more farming experience and information on various management and adaptation strategies to climate change.

4.2.2 Age of the respondents

Age plays a major role in agricultural practices as well as adaptive capacity to climate change. It determines the vibrancy of the workforce as well as affect the rate or speed of adoption of new innovations. According to Adesina and Forson (1995), older farmers are more risk-averse and less likely to be flexible than younger farmers thus, have a lesser likelihood of adopting new technology. On the other hand, older farmers are more experienced in farming and are better able to understand the vagaries of

climate change than younger farmers. Hence, more used to suitable adaptation strategies. Table 4.2 presents the age distribution of the respondents.

Table 4.2: Age of the Respondents

Age	Frequency	Percentage
31 – 40 years	108	28
41 – 50 years	150	39
51 years and above	127	33
Total	**384**	**100**

Source: Author's Analysis (2016).

Table 4.2 shows that 39% of the respondents are within the age bracket of 41 – 50 years; 33% of the farmers are above fifty years of age, while 28% of the respondents are between ages 31 – 40 years. This implies that the agricultural workforce in the study area is characterized mainly by people of less than 40 years of age which indicate a young and vibrant workforce. This has direct bearing on the availability of able-bodied manpower for agricultural production and also on the ease of adoption of climate change adaptation strategies. Age also influences the ability to seek and obtain off-farm jobs and income, which could increase farmers income and could help cope with adverse change of climate.

4.2.3 Marital status of the respondents

Table 4.3 shows the marital status of the respondents.

Table 4.3: Marital Status of the Respondents

Marital status	Frequency	Percentage
Married	359	93.6
Single	3	0.7
Divorced	19	5.0
Widowed	3	0.7
Total	**384**	**100**

Source: Author's Analysis (2016).

As can be seen in Table 4.3, majority of the respondents 393(93.6%) in the study area are married. 3(0.7%) are single, 21(5%) are divorced and 3(0.7%) are widowed. This indicates that majority of the respondent have family responsibilities to cater for which invariably affects their farming activities.

4.2.4 Educational status of the respondents

Table 4.4 shows the spread of the educational status of the respondents as revealed by the study.

Table 4.4: Educational Qualification of the Respondents

Qualification	Frequency	Percentage
Primary	170	44.3
Secondary	27	7.1
Tertiary	14	3.6
Koranic	165	42.9
None	8	2.1
Total	**384**	**100**

Source: Author's Analysis (2016).

Education is an important factor that determines the ability of an individual to understand policies and programmes relating to climate change adaptation. According to Woznaiak (1984), education is expected to increase one's ability to receive, decode, and understand information relevant to making innovative decisions. Table 4.4 reveals that about 44% of the respondents had primary education, 7.1% attained secondary education, about 3.6% attained tertiary education while 42.9% attended Koranic education. Only 2.1% have no formal education. This means that over 50% of the respondents have some form of formal education. This also means that literacy level is above average among the respondents and this could have implications for agricultural production and also for adaptation to change in the climate. Adoption of measures that

could result in climate change adaptation is easier and faster among the educated farmers than the uneducated farmers.

4.2.6 Duration of residency in the study area

The survey found out the duration of stay of the respondents in the study area and it is presented in table 4.5

Table 4.5: Residency of the Respondents in the Study Area

Duration	Frequency	Percentage
20 – 30 years	65	17.0
31 – 40 years	173	45.0
41 years and above	146	38.0
Total	**384**	**100.0**

Source: Author's Analysis (2016).

Table 4.5 clearly indicates that 17.9% of the respondents have lived in the study area between 20 – 30 years, 44% have lived between 31 – 40 years, while 38.1% have lived in the study area for well over forty years. This means that over 80% of the respondents have lived in the study area for more than thirty years. This means that majority of the respondents have lived long enough in the study area and therefore have the necessary experience and reliable information about climate change over the years and adaptation strategies in the study area.

4.3 Characteristics of Rainfall and Temperature of the Study Area

Rainfall and temperature are two major weather elements that greatly influence agricultural activities. Some of the important characteristics of rainfall which are most useful in agricultural decision making are the onset and cessation dates of rainfall. Otherwise known as "beginning and end of growing session". According to Olaniran (1991), the combination of these two determines the length of the rainy season (LRS).

To this effect, the rainfall and temperature of the study area was characterized. Rainfall data was used to determine the onset, cessation, annual rainfall, annual length of rainy season and annual total number of rainy days.

Table 4.6: Shows the rainfall characteristics and mean maximum and mean minimum temperature of the study area including onset and cessation dates as well as total length of rainy season in days.

Table 4.6: Rainfall and Temperature Characteristics of Sokoto East Senatorial District 1986 – 2015

Years	Total annual rainfall (mm)	Onset dates	Cessation Dates	Annual length of rainy season (days)	Mean Max Temp. (^{0}C)	Mean Min. Temp. (^{0}C)
1986	475.8	24 – June	23 – Sept.	89	35.3	23.5
1987	370.9	14 – June	29 – Oct	135	36.2	23.5
1988	667.3	8 – June	1 – Sept.	83	36.6	22.9
1989	522.7	14 – June	4 – Oct	110	34.3	22.9
1990	654.2	28 – May	30 – Sept	122	35.5	22.3
1991	774.8	21 – May	16 – Oct	145	34.9	23.0
1992	549.0	13 – June	15 – Sept	92	34.6	22.8
1993	641.9	1 – July	29 – Sept	88	35.7	22.6
1994	762.1	15 – June	20 – Sept	95	34.8	22.6
1995	509.8	16 – June	27 – Sept	101	35.8	22.6
1996	729.9	20 – May	19 – Oct	149	36.0	22.7
1997	645.4	2 – May	24 – Oct	172	35.7	22.7
1998	845.9	1 – June	13 – Oct	132	36.3	22.5
1999	709.6	23 – May	16 – Oct	143	35.3	23.8
2000	732.6	3 – June	21 – Oct	138	35.5	22.5
2001	731.6	26 – May	29 – Sept	123	35.5	22.0
2002	768.7	3 – June	15 – Oct	132	35.3	22.3
2003	790.1	29 – May	14 – Oct	135	35.7	22.6
2004	992.2	14 – May	30 – Sept	136	36.2	22.5
2005	634.4	30 – May	4 – Oct	124	36.0	23.0
2006	716.9	8 – June	7 – Oct	119	36.1	22.5
2007	636.2	27 – June	21 – Sept	84	36.8	22.7
2008	602.9	12 – May	5 – Oct	143	35.5	22.5
2009	578.9	20 – June	28 – Sept	98	36.5	23.8
2010	1146.7	19 – June	26 – Oct	127	36.5	23.3
2011	557.8	9 – June	10 – Oct	121	36.4	22.5
2012	634.9	29 – May	16 – Oct	137	35.5	22.5
2013	665.7	13 – July	12 – Sept	59	36.3	23.9
2014	675.1	3 – May	17 – Oct	164	35.6	22.3
2015	691.0	25 – June	1 – Oct	96	35.6	22.2
Mean	**676.4**	**5 – June**	**5 – Oct**	**120**	**35.6**	**22.8**

According to the Table 4.6, the highest rainfall during the period under study was in 2010 (1146.7mm) while the lowest rainfall was recorded in 1987 (370.6mm). Mean rainfall for the 30 years of study was 676.4mm. The earliest onset of rainfall was in May 3rd 2014 while the least onset was in July 13th 2013. In the same manner, the earliest cessation date of rainfall during the period under review was in 1st September 1988, and the least cessation date was in 29th October 1987. The length of rainy days was highest in 1997 at 172 days while the lowest length of rainy day was in 2013 at 59 days.

The mean average maximum temperature during the years under study was 35.6^{0}C and the mean minimum temperature was 22.8^{0}C. Highest maximum temperature was recorded in 2007 at 36.8^{0}C.

4.3.1 Pattern of onset dates of the rains in sokoto

The linear trend and trend line equation for the onset of the rainy season in the study area are shown in Fig. 4.1.

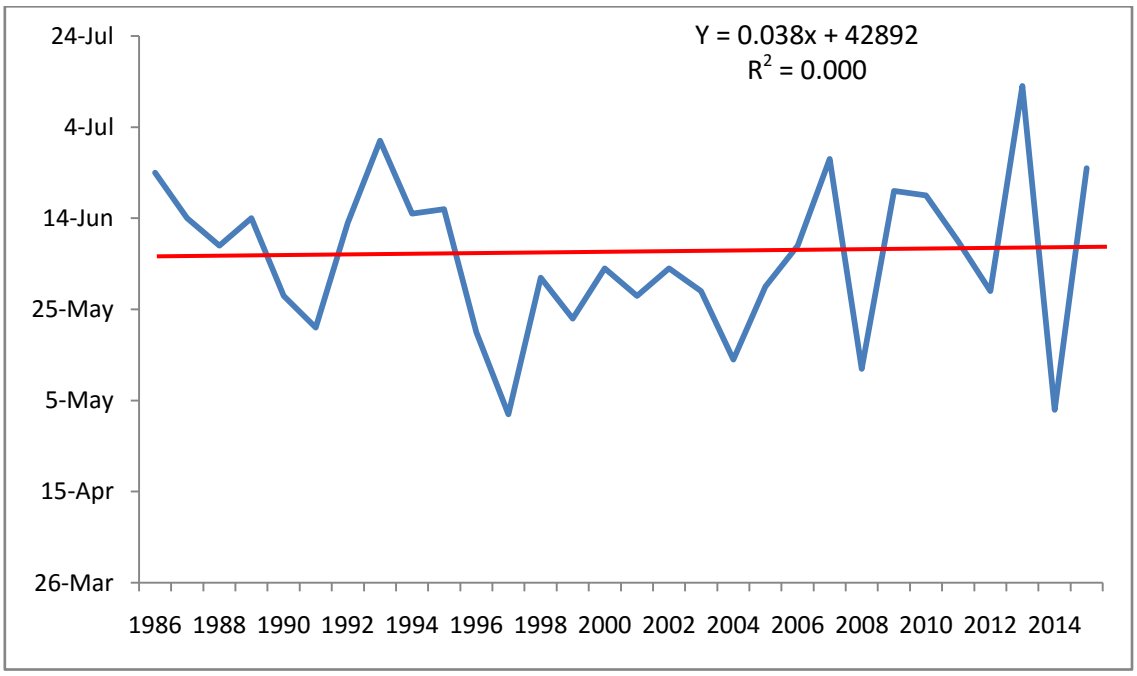

Fig. 4.1: Trend in Rainfall Onset Dates at Sokoto East Senatorial District (1986 – 2015)
Source: Author's Analysis (2016).

Fig. 4.1 clearly indicates decreasing trend in the onset dates (that is, the rains are now coming early as can be seen from the equation y = - 0.038x + 42892). This is not in consonance with the perception of the majority of the respondents who believed that the rains are getting established very late. The earliest onset date of rain in the study area within the 30 years of the study as shown in Table 4.6 is, 2nd May in 1997, while the least onset date within the 30 years of study is, 13 July in 2013. This implies that land preparation for agricultural activities can be carried out around the end of May while actual planting can commence from 5th of June which is the mean onset date of the study area within the study period. This is because rain may not be steady until 13th of July for the purpose of crop production. According to Ati (2002), in the Sudan savannah the start of the rains is seldom abrupt, but it is usually preceded by a succession of isolated showers of uncertain intensity with intermittent dry periods of varying duration. These may be false starts followed by prolonged dry spells whose duration may last for two or more weeks. This condition dries out the top soil and prevents the sprouting or emergence of crop plants, leading to poor germination necessitating repeated and or late planting which usually results in low crop yield or complete crops failure.

4.3.2 Pattern of rainy cessation dates at Sokoto east senatorial district

The trend in cessation dates also known as the end of the growing season for the study area are shown in Figure 4.2

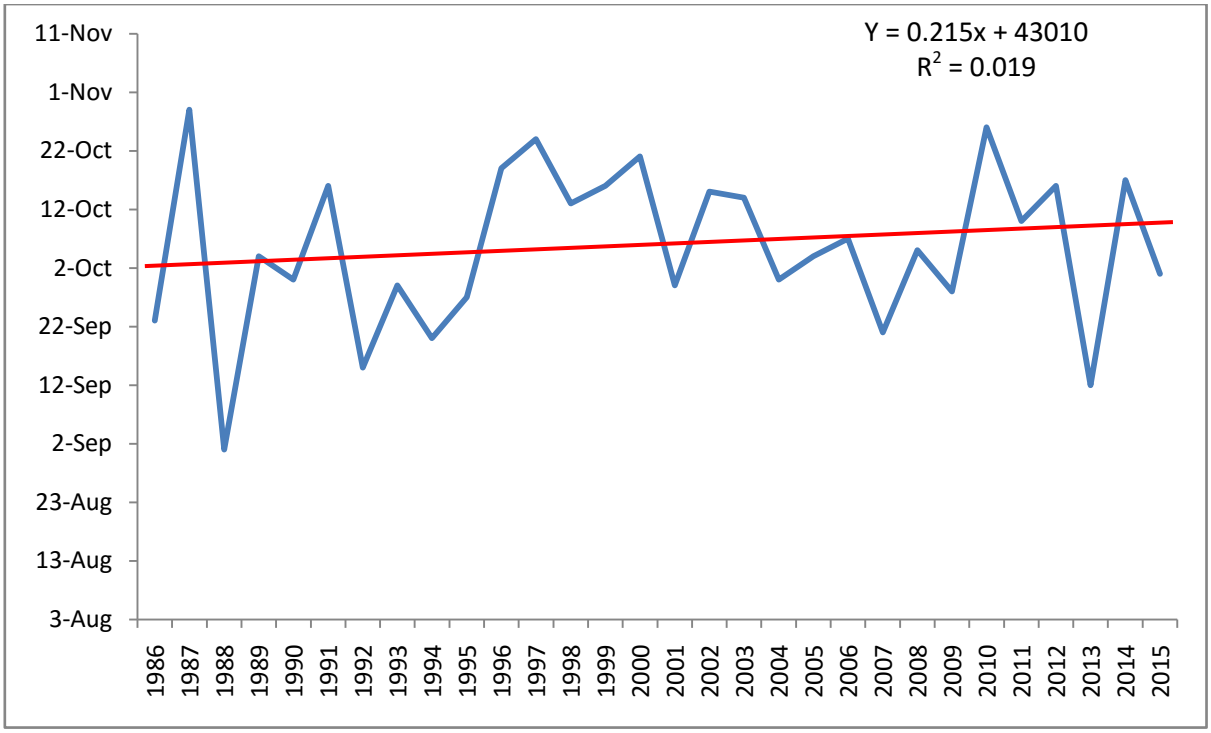

Fig. 4.2: Trend in Rainfall Cessation Dates at Sokoto East Senatorial District (1986 – 2015)

Source: Author's Analysis (2016).

The earliest cessation date in Sokoto East Senatorial District occurred on 1st September 1988, while the latest cessation date occurred 29th October 1987. The trend line for cessation is showing late cessation as can be seen from the equation y = 0.215x + 43010. This is not in line with the perception of majority of the respondents in the study area, who perceive that the rains are ceasing two early. The average cessation date of rain in the study area within the thirty years of study is 5th October as can be seen in Table 4.6. Cessation dates in the study area occurred between 1st September and 29 October. Early cessation and late cessation are anomalies and affect the production of most crops in the study area especially sorghum and cowpea.

4.3.3 Pattern of length of rainy season at Sokoto east senatorial district

The pattern and linear trend line equation for the length of rainy season is shown in figure 4.3.

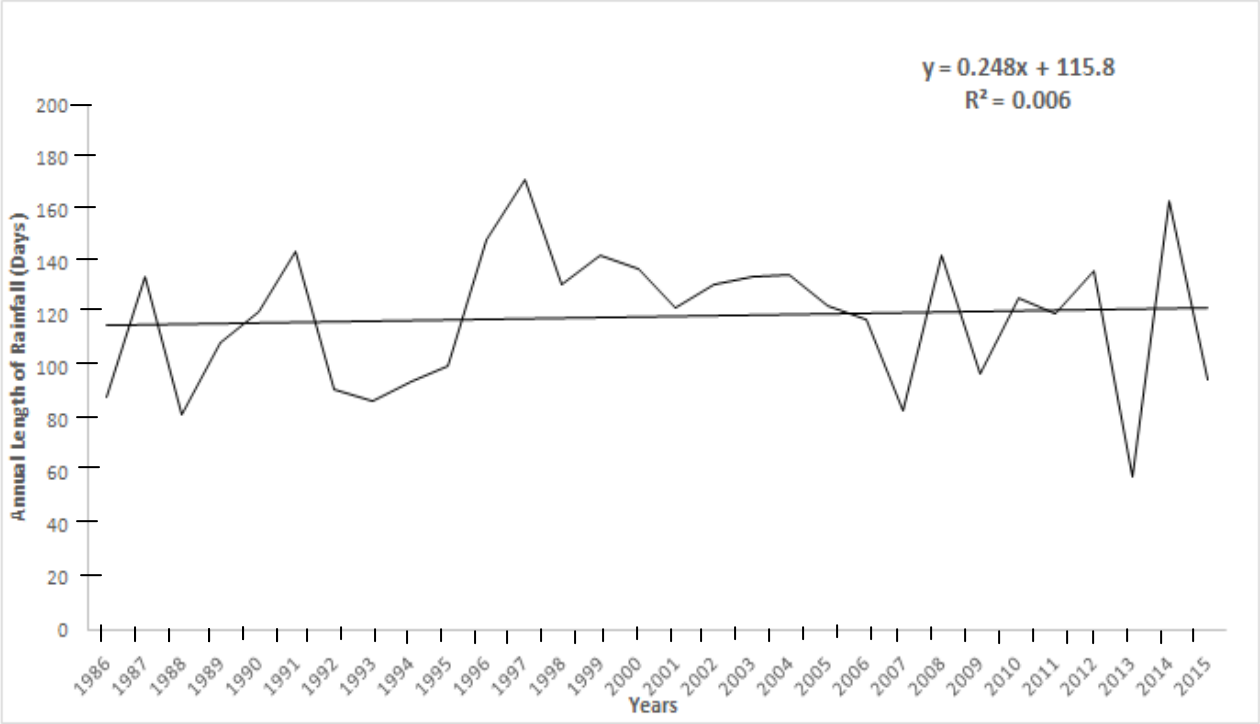

Fig. 4.3: Trend in Length of Rainy Season (Days) at Sokoto East Senatorial District (1986 – 2015)
Source: Author's Analysis (2016).

From Figure 4.3, it is observed that the trend line for the length of rainy season is increasing. The linear trend line equation for the length of rainy season is y = 0.2488 x + 11589, indicating that the length of the rainy season is on the increase in the study area. This result contradicts the perception of the majority of the farmers who opined that the length of rainy season is decreasing. The highest number of rainy days was recorded in 1997 (172) while the lowest were recorded in 1988 (83).

It is clear from figure 4.3 that the high annual rainfall witnessed in some years 2004 (992.4), 2010 (1146.7) does not matched with the high number of rainy days. The implication of this pattern is that rainfall may not be witnessed when desired for agricultural production (especially during the planting season). Apart from the fact that a well distributed rainfall, during the growing season is more agriculturally

advantageous, concentration of rainfall of high intensity such as was witnessed in October 2010 could result in flooding as its negative consequences.

4.3.4 Pattern of annual rainfall at Sokoto east senatorial district

Trend in total annual rainfall of the study area for the study period is presented in figure 4.4.

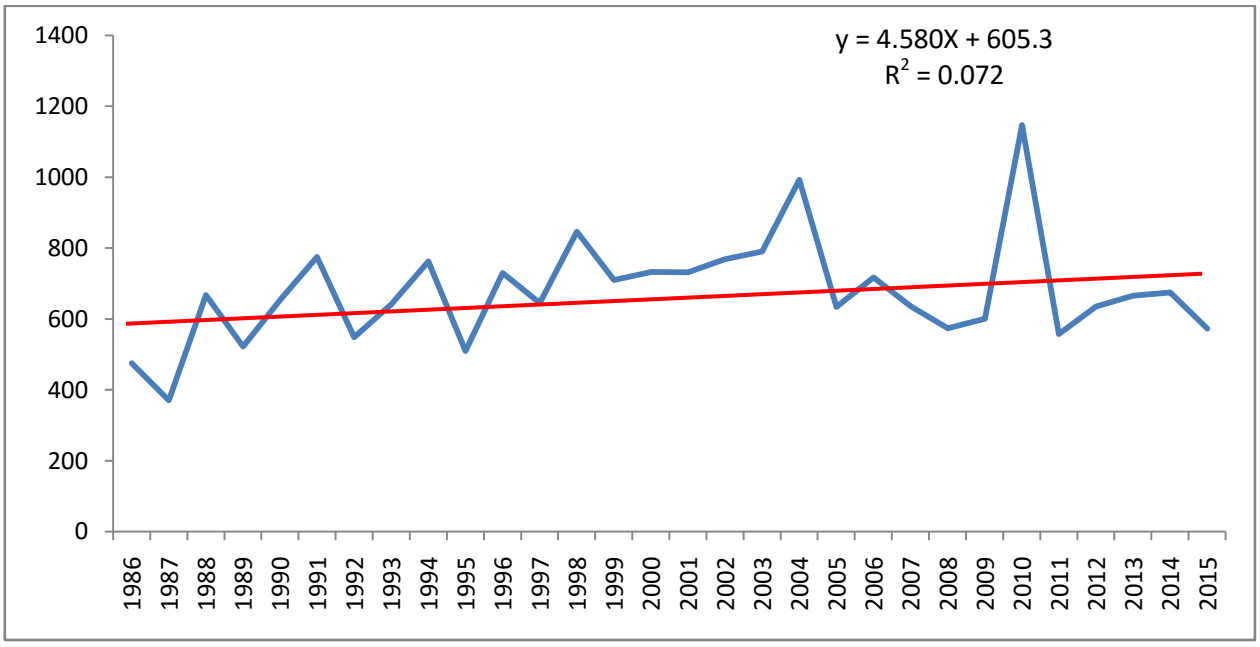

Fig. 4.4: Pattern of Annual Rainfall Trend in Sokoto East Senatorial District (1986 – 2015)
Source: Author's Analysis (2016).

The trend in Fig. 4.4 shows an increasing annual rainfall amount. The best fit trend line equation is y = 4.580 + 605.36. The positive linear trend line equation implies that annual rainfall is on the increase. The mean annual rainfall is (676.4mm) as can be seen in Table 4.6, the lowest rainfall was in 1987 (370.4mm), while the highest rainfall was recorded in 2010 (1146.7mm). This high positive rainfall deviation resulted to the devastating flood incidence which washed away farmlands and settlements. It is important to stress that decreasing rainfall trend in the absence of irrigation, pose a serious threat to agriculture and therefore increases the local farmers' agricultural

vulnerability to climate. The mean annual rainfall of 676.4mm is lower for most crops especially maize and some varieties of sorghum. This explains the reason why millet is the most cultivated crop in the study area as it falls within the annual mean rainfall of the study area. The maximum requirement for millet production is between 300mm to 600mm of rainfall per annum. The increasing trend in annual rainfall is at variance with the perception of the majority of the farmers who believed that rainfall amount is decreasing. This could be because the increase is more pronounced from 2010 upward.

4.3.5 Pattern of mean annual maximum temperature at Sokoto east senatorial district

The trend in mean annual maximum temperature of the study area shown in Figure 4.5 indicates a gradual increasing trend with an increase rate of 0.3546^{0}C. Temperature plays a significant role in agricultural and climate change adaptation strategy issues. In general, higher temperatures are associated with higher radiation, higher evapotranspiration and high plant water use.

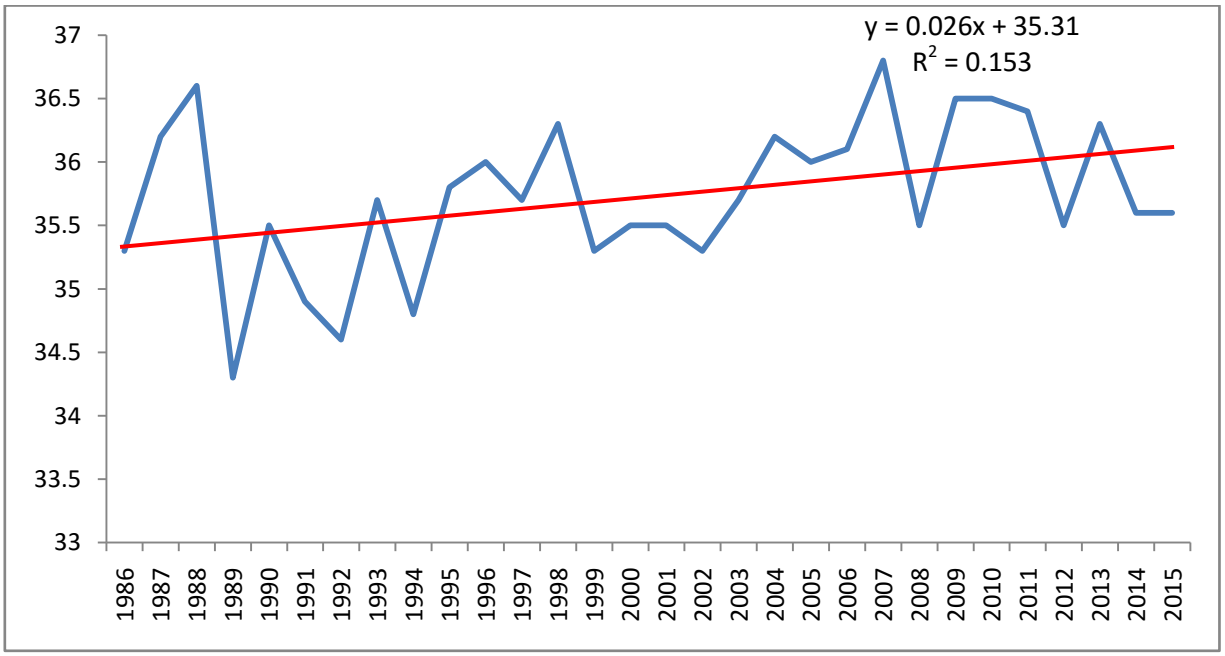

Fig. 4.5: Mean Annual Maximum Temperature in Sokoto East Senatorial District (1986 – 2015)
Source: Author's Analysis (2016).

According to Bannayan (2011) rising temperatures would diminish the yields of some crops, especially if night temperatures are increased, while CO_2 induced warming would result in almost equally large rise in minimum and maximum temperatures. Even a slight increase in surface air temperature will affect evaporation, atmospheric moisture and precipitation. Higher temperature particularly in arid conditions, entail a high evaporative demand. The highest maximum temperature within the 30 years of study is 36.8^0C in 2007 while the lowest maximum temperature was 34.3^0C in 1989. The increasing trend in temperature is in line with the farmers' perception that temperature is on the increase in the study area.

4.4 Farmers' Awareness of Climate Change

Awareness of climate change helps farmers plan their production activities and reduces risks and uncertainties associated with agricultural production. Awareness is having a knowledge or understanding of a subject, issue or situation. Farmers' awareness of climate change therefore becomes a critical tool in identifying potentially useful adoption strategies to mitigate the effect. Table 4.14 shows the farmers levels of awareness to climate change.

Table 4.7: Respondents Awareness of Climate Change

Awareness	Frequency	Percentage
Yes	373	97.2
No	11	2.8
Total	**384**	**100**

Source: Author's Analysis (2016).

The distribution as shown in Table 4.7 shows that majority of the respondents about (97%) are aware of climate change while only about 3% seem not to be aware of climate change.

4.4.1 Sources of information about climate change

There are many sources of information about climate change related issues available to the farmers in the study area. The information is shown on Fig. 4.9. Of these many sources, personal observation seems to be prominent according to the survey. Eighty-five percent of the respondents stated that personal observation is their main source of information. Forty-eight percent said electronic media, while 1% said extension agent were their source. About 0.70% of respondents mentioned printed media as their source of information respectively

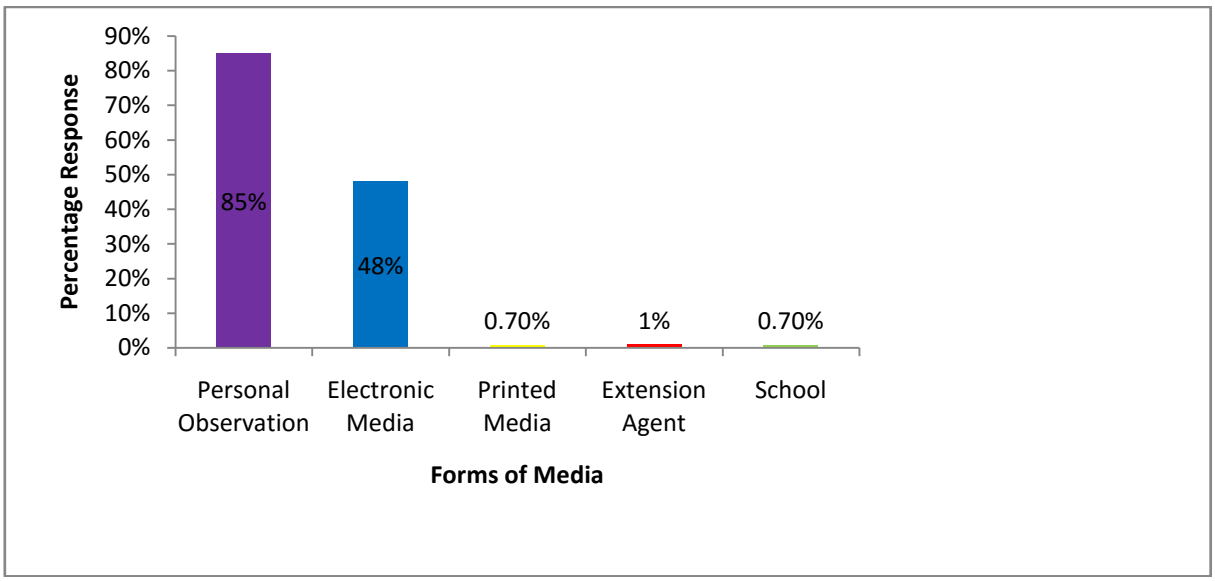

Fig. 4.6: Information on Climate Change
Author's Analysis (2016).

4.5 Perceived Effects, Crops cultivated and Animal Production in the Study Area

4.5.1 Types of farming practiced

Table 4.8 shows the various types of farming practiced in Sokoto East Senatorial District.

Table 4.8: Types of Farming Practiced

Types of Farming	Frequency	Percentage
Commercial	50	12.9
Subsistence	192	50.0
Both	142	37.1
Total	**384**	**100**

Source: Author's Analysis (2016).

The study showed that majority of the farmers in Sokoto east senatorial district are engaged in subsistence farming as can be seen in Table 4.8. Fifty percent of the respondents indicated that they practice farming in small scale and for the main purpose of providing food for their family, while 37.1% engaged in both subsistence and commercial farming. Only 12.9% of the sampled farmers are engaged in commercial farming. This result may not be unconnected with the low income status of the farmers as well as the risk involved in farming as a business due to climate change.

4.5.2 Major crops produced in the study area and reasons for producing them

The major crops produced by farmers in the study area were investigated and the findings presented in Table 4.9.

Table 4.9: Major Crops Cultivated in the Study Area

Major Crops	Frequency	Percentage
Millet	274	71.4
Sorghum	85	22.1
Cowpea	25	6.4
Total	**384**	**100**

Source: Author's Analysis (2016).

Table 4.9 shows that 71.4% of the respondents noted that millet is their most cultivated crops, 22.1% stated that sorghum is their major crops, while 6.4% ticked cowpea as their most cultivated crops. However, it is observed that most of the farmers practice

mixed cropping, by combining the above mentioned crops on a piece of land during every growing season as an adaptation strategy.

4.5.3 Reason for choosing millet as the most cultivated crop

On why the farmers preferred the cultivation of millet to other crops as shown on Table 4.9, their reasons are given in Fig. 4.6. The investigation showed that large number of farmers 35% stated that millet has short growing duration, 34.3% stated that it is because millet is drought resistant, while 30.7% stated that it is high yielding. It is clear that about 70% of the farmers believe that millet is adapted to climate change as it is both short duration as well as drought resistance. Hence the cultivation of millet is part of the coping strategies for climate change.

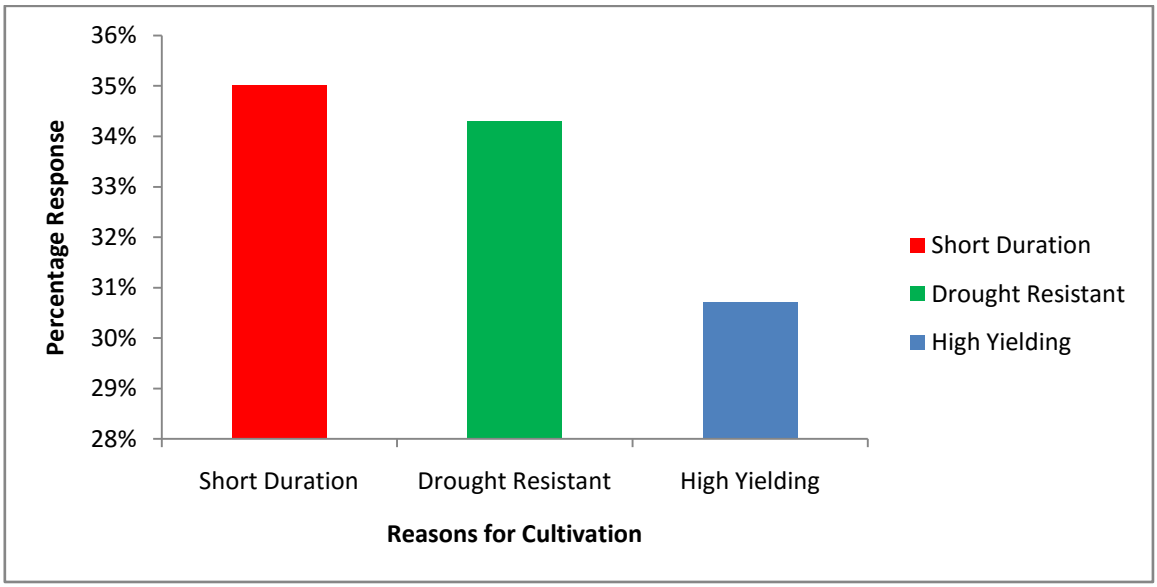

Fig. 4.7: Farmers Reasons for Cultivating Millet
Source: Author's Analysis (2016).

4.5.4 Observed changing pattern of annual harvest

Yield reduction in cultivated crops is one major impact of climate change according to (Nhemachena and Hassan, 2007). To this effect, farmers were asked whether their yield from the same piece of land is increasing or decreasing over the years and what could be the reason for that. Their response is shown in Table 4.10.

Table 4.10: Annual Harvest Increasing or Decreasing

Observed Pattern	Frequency	Percentage
Yield is increasing	184	47.9
Yield is decreasing	200	52.1
Total	**384**	**100**

Source: Author's Analysis (2016).

As can be seen in the Table 4.10, 47.9% of respondents stated that crop yielding over the years is increasing, while the majority 52.1% stated that the yield is decreasing. The famers' reason for either increasing or decreasing yield are presented in Figure. 4.8a and b. On the possible reasons for increasing, majority of the farmers 46.4% attributed the use of improved seed as the reason for increase yield, 38.60% attributed increase in yield to adaptation strategy (early and frequent weeding) while 12.10% said it is due to early rains.

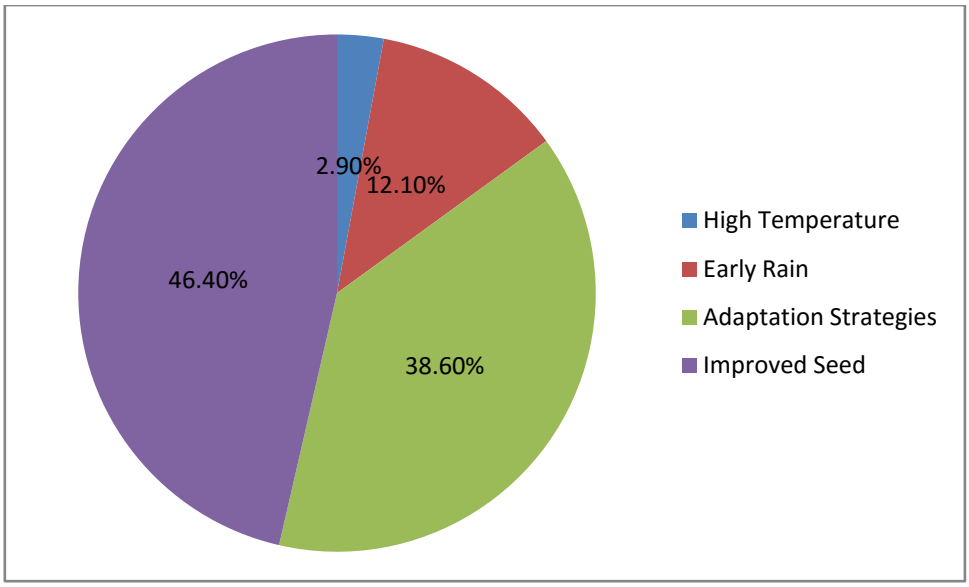

Fig. 4.8a: Reasons for Increasing Yield
Source: Author's Analysis (2016).

The study therefore revealed that over 80% of the farmers believe that use of improved seed and other adaptation strategies are responsible for increase in yield of annual harvest.

On the reasons why yield is decreasing, Figure 4.7b shows that majority of the farmers (52.9%) attributing it to insufficient amount of rainfall, 26.7% attributed it to late onset or arrival of rainfall while 20.4% believed that high temperature is the reason for decreasing yield.

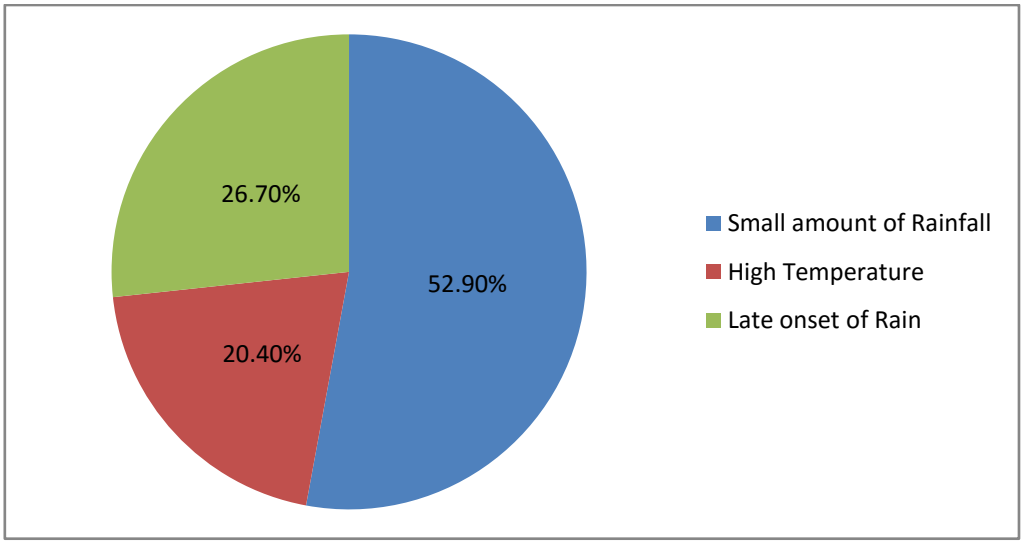

Fig. 4.8b: Reason for Decreasing Yield
Source: Author's Analysis (2016).

4.5.5 Animal production

4.5.6 Involvement of farmers in animal production

Level of involvement of farmers in the study area on animal production was investigated and the result is presented in Table 4.11.

Table 4.11: Involvement in Animal Production

Involvement	Frequency	Percentage
Yes	359	93.5
No	25	6.5
Total	**384**	**100**

Source: Author's Analysis (2016).

Majority of the farmers (93.5%) stated that they are involved in one form of animal production or the other, and only about 6.5% of the farmers are not involved in animal production. This reveals that majority of the farmers are involved in animal production possibly to augment their income especially when there is crop failure or low yield occasioned by climate change. Traditionally the Hausa/Fulani practice mixed farming taking the advantage of their animal dung for fertilizer.

4.5.7 Types of animals reared

Table 4.12 shows the types of animals reared in the study area.

Table 4.12: Types of Animals Reared in the Study Area

Type of Animal	Frequency	Percentage
Cow	156	40.7
Goat	137	35.7
Sheep	52	13.6
Donkey	38	10.0
Total	**384**	**100**

Source: Author's Analysis (2016).

Table 4.12, show that majority of farmers in the study area (40.7%) are involved in cow rearing, 35.7% in goat production, 13.6% rear sheep while 10.0% are involved in donkey rearing. These types of animals, especially cow and donkey play important role in agricultural activities in the study area. They are most valuable for land cultivation or preparing and transportation of farm produce to the homes or markets.

4.5.8 Reasons for animal production

The study investigated the reasons for rearing animals in the study area as can be seen in Table 4.13

Table 4.13: Reasons for Animal Rearing

Reasons for animal rearing	Frequency	Percentage
Commercial purpose	77	20.0
Domestic purpose	115	30.0
Both domestic and commercial purpose	192	50.0
Total	**384**	**100**

Source: Author's Analysis (2016).

Majority of the respondents (50%) indicated that they produce animal for both domestic and commercial purposes. Animals are used both for tillage operations as well as for transportation in the study area. And in the event of crop failure due to climate change, animals are sold in order to raise money for the running of the family. This could be the reason why majority of the farmers are rearing the types of animals in the study area and are producing for both domestic and commercial purposes. Very few of the farmers 20% are producing for commercial purposes while 30% are producing solely for domestic purposes.

4.5.10 Observed pattern of animal production and reasons for observed pattern

The study observed pattern of animal production and reasons for observed pattern are revealed in Table 4.14

Table 4.14: Animal producing more or less

Observed pattern	Frequency	Percentage
Producing more	126	32.8
Producing less	258	67.2
Total	**384**	**100**

Source: Author's Analysis (2016).

Table 4.14 reveals that a good number of farmers (67.2%) stated that the rate of animal production is decreasing, while about 32.8% stated their animal production is increasing.

4.5.10 Reasons for reduction or increase in animal production

The respondents were able to give reasons for the decreasing rate of animal production as shown in Figure 4.8. Thirty six percent stated that high temperature is the reason for decrease in animal production, 30% gave their reason to be water shortage, 20% stated that lack of adequate feed was responsible for the decrease in production while 13.6% believed that reduced grazing land due to desert encroachment in the study area is the reason for the noted decline.

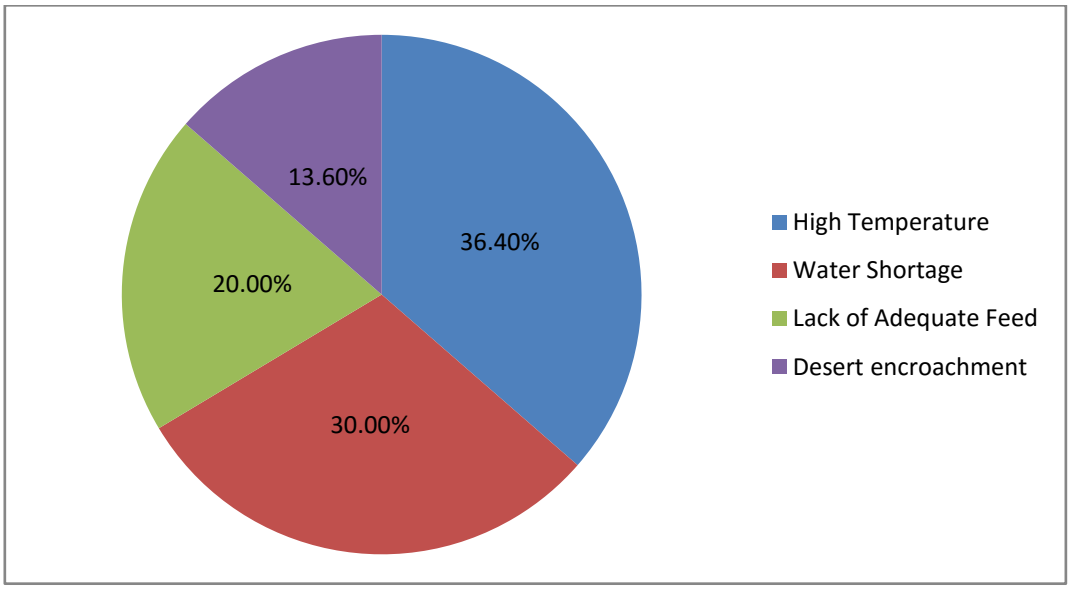

Fig. 4.9: Reasons for Decreasing Animal Production
Source: Author's Analysis (2016).

4.5.11 Perceived effect of climate change on agriculture

The effect of climate change on agricultural production varies from one region to another depending on the prevailing climate of the region, hence affect agricultural productivity differently. According to Obioha (2009), climate change resultant scenario like drought, erosion, flooding, heat wave, desert encroachment etc. occur in most semi arid area of Nigeria including the study area and affect farming activities negatively. The assessment of the effect of climate change on agriculture in the study area is presented in table 4.15.

Table 4.15 shows the response of the sampled farmers on whether climate has affected agriculture in the study area.

Table 4.15: Effect of Climate Change on Farming Activities

Response	Frequency	Percentage
Yes	362	94.3
No	22	5.7
Total	**384**	**100**

Source: Author's Analysis (2016).

On whether climate change has affected farming activities in the study area, overwhelming majority 94.3% said yes, while only 5.7% are not sure of the impact of climate change on farming activities.

4.5.12 Effect of low rainfall on farming activities

Rainfall amount in recent years has been fluctuating in the study area due to climate change. The response of respondents on how low rainfall affected their farm activities is presented in Table 4.16 The response shows that majority, about 95% of the respondents had their crop yield reduced, about 3% had reduced water for animals, while 2% had reduced grass or biomass. This therefore implies that, low rainfall brought about by climate change has affected agricultural activates in the study area.

Table 4.16: Effects of Low Rainfall on Farm Activities

Response	Frequency	Percentage
Reduced crop yield	364	95
Reduced water for animals	11	2.8
Reduced grass/biomass	8	2.2
Total	**384**	**100**

Source: Author's Analysis (2016).

4.5.13 Effect of extreme/high temperature on farm activities

High temperature resulting from climate change has affected agricultural production in the study area. The distribution of the respondent according to the effect of extreme/high temperature is presented in Table 4.17. The distribution shows that majority of the respondents about 89% stated that high temperature has brought about wilting of their crops, 7% had their farm produce spoilt, while about five percent had their livestock dead. It is evident from this result that high temperature brought about by ozone layer depletion (climate change) has affected agricultural activities in the study area. (Odjugo 2010).

Table 4.17: Effect of Extreme/High Temperature

Response	Frequency	Percentage
Wilting of crops	340	88.6
Spoilage of farm produce	27	7.1
Death of farm livestock	16	4.3
Total	**384**	**100**

Source: Author's Analysis (2016).

4.5.14 Farmers perception of climate change

The farmers' perception on the various indices of weather and climate were collected, collated and presented in Table 4.18.

Table 4.18: Perceived effect of Climate and Perceived Effects of Climate Change on Agriculture

Indices	A	D	SA	SD	U	Total
There have been increased frequency of dry spell within the rainy season	187 48.6%	148 38.6%	30 7.9%	11 2.9%	8 2.1%	384 (100%)
The environment in this village is changing	343 89.3%	11 2.9%	25 6.4%	3 0.7%	3 0.7%	384 (100%)
Rainfall onset is now coming late	258 67.1%	71 18.6%	27 7.1%	3 0.7%	25 6.4%	384 (100%)
Number of rainy days/months/year is increasing	58 15%	118 30.7%	91 5%	181 47.1%	8 2.1%	384 (100%)
Temperature around this village is rising	275 71.5%	77 20%	30 7.9%	3 0.7%	0 0.0%	380 (100%)
Rainfall amount compared to the past ten years plus is decreasing	151 39.3%	27 7.1%	192 50%	14 3.6%	0 0.0%	384 (100%)
The yearly rainfall is not supporting production as before	354 92.1%	14 3.6%	8 2.1%	0 0.0%	5 1.4%	384 (100%)
The changing climate has led to crop infestation by diseases pests	332 86.4%	8 2.1%	38 10%	3 0.7%	0 0.0%	384 (100%)
There has been increased incidence of flood during rainy season	101 26.4%	60 15.7%	96 25%	14 1.4%	113 29.3%	384 (100%)
There has been early cessation of rainy season	266 69.3%	44 11.4%	55 14.3%	5 1.4%	14 3.6%	384 (100%)

Where: A – Agreed; D – Disagreed; SA – Strongly Agreed; SD – Strongly Disagreed; U – Undecided
Source: Author's Analysis (2016).

Table 4.18 reveals that 49% of the farmers observed there have been increasing frequency of dry spells within the rainy seasons, 38% disagreed, while about 3% strongly disagreed. Eighty-nine percent observed that rainfall onset is changing, while 67% percent strongly disagreed that numbers of rainy days/month/years is increasing. This is most probably due to non-availability of recorded data to the respondents.

Thirty-one percent disagreed. Overwhelming majority 71% agreed that rainfall amount compared to the past ten years is decreasing, while only 7% percent disagreed.

Many respondents 86% agreed that changing climate has led to crop infestation by disease and pest, while only 10% disagreed. About 69% of the sampled farmers agreed that there has been early cessation of rainy season, while only 3% of the respondent agreed that yearly rainfall are not supporting crop production as before as against three to 4% that disagreed.

4.6 Farmer Adaptation Strategies to Climate Change

4.6.1 Possibility of adapting to climate change

The farmers were asked if it was possible to adapt to climate change. As can be seen in Table 4.19, the majority of the respondents believed that it is possible to adapt to climate change. Eighty percent of the sampled farmers believed it is possible to adapt to climate change while 20% think otherwise. According to Odjugo (2010), people's belief on issues has a way of spurring them into taking actions to justify their beliefs. The belief of the majority of the farmers on the possibility of adapting to climate change is a positive sign that if properly informed, the farmers will adopt relevant adaptation strategies to curb the negative effects of climate change.

Table 4.19: Possibility of farmers to Adapt to Climate Change

Possibility	**Frequency**	**Percentage**
Yes	307	80.0
No	77	20.0
Total	**384**	**100**

Source: Author's Analysis (2016).

4.6.2 Adaptation strategies adopted by farmers

The adaptation measures embarked upon by the farmers to minimize the effect of climate change in the study area is presented in Table 4.20. There is no doubt that adaptation strategies or measures can reduce the impact of climate change and increase crop yield: mixed cropping, mix farming, use of improved seed varieties, adopting irrigation/fadama farming, increase use of chemical fertilizer, early and constant weeding are major adaptation strategies to climate change adopted by farmers in the study area as can be seen in table 4.20..

Table 4.20: Major Adaptation Strategies to Climate Adopted by Farmers

Adaptation strategies	Frequency	Percentage
Increase use of chemical fertilizer	23	5.96
Mix cropping	142	36.90
Use of improved seed varieties	35	9.05
Changing the extent of land put into cultivation	2	0.48
Adoption irrigation/fadama farming	12	3.10
Early planting	5	1.43
Mixed farming	46	11.90
Late planting	6	1.67
Early weeding to reduce weed competition for water and nutrient	65	16.90
Use of early maturing varieties	19	5.00
Use of resistant varieties	17	4.51
Construction of dam within farm	12	3.10
Total	**384**	**100**

Source: Author's Analysis (2016).

Over 36% of the farmers practice mixed cropping, while about 17% practiced mix farming as adaptation strategy. Sixteen percent say they practice early and constant weeding to reduce weed and nutrient competition with the crop. Nine percent use improved seed variety, while 5% use early maturing varieties as adaptation strategy.

About 6% practice high dose of chemical fertilizer. Three percent practice irrigation/fadama farming. Three percent of the farmer practice construction of dams on the field while less than 2% practice early and late planting respectively. The study revealed that farmers in the study area have different adaptive measures to reduce the effect of climate change.

4.6.3 Adaptation strategies most adopted

Most adaptation strategies adopted by the farmers are strategies that are commonly used and have recorded successes over the years with regards to good yield. The response of farmers on what is their best adaptation strategies in the study area is shown in Table 4.21.

Table 4.21: Adaptation Strategies Most Adopted

Best Adaptation Strategies	**Frequency**	**Percentage**
Mixed farming	107	27.8
Mix cropping	195	50.7
Early and constant weeding to reduce weed competition for water and nutrient	22	5.7
Use of improved seed varieties	41	10.6
Changing the extent of land put into cultivation	3	0.7
Increase use of chemical fertilizer	11	2.9
Adaptation of irrigation and fadama farming	6	1.6
Total	**420**	**100**

Source: Author's Analysis (2016).

4.6.4 Adaptation strategy widely used

Apart from identifying most adaptation strategies adopted by farmers in the study area, the study went ahead to investigate strongest adaptation strategies adopted by farmers in the study area. By strongest adaptation strategies, I refer to those strategies that have been consistently used over the years by farmers and have consistently guaranteed yield for the farmers despite the effect of climate change thereby providing the most

cushioning effect against climate change. The result of the investigation is shown on table 4.22.

Majority of the farmers 57.9% stated that mixed cropping is the strongest adaptation strategies adopted while 42.1% of the farmers indicated that mixed farming is their strongest adaption strategies. The study therefore established that mixed cropping and mixed farming are the strongest adaptation strategies adopted by farmers in the study area and provide the most cushioning effect against climate change.

Table 4.22: Strongest Adaptation Strategies

Strongest Adaptation Strategies	Frequency	Percentage
Mixed cropping	222	57.9
Mixed farming	162	42.1
Total	**384**	**100**

Source: Author's Analysis (2016).

4.7 Perceived Factors Hindering Adaptation Techniques to Mitigate Climate Change

Adaptation to climate change in the study area is constrained by many factors. The hindrances are presented in Table 4.23. Prominent among them are; lack of adequate knowledge or information about climate and weather incidence via extension services, appropriate technologies, necessary inputs (seeds, fertilizers, pesticides) access to loan and credit facilities.

Table 4.23: Factors Hindering Adaptation

Limiting Factors on Adaptation Strategies	Frequency	Percentage
Lack of information on modern adoption technique	187	48.6
Lack of information on agro-meteorology	52	13.5
Lack of access to water for irrigation	50	12.9
Lack of credit/loan facilities	58	15.0
Lack of farm inputs	38	10
Total	**384**	**100**

Source: Author's Analysis (2016).

According to this studies as presented in Table 4.23, 48.6% of the farmers stated that lack of adequate information on modern technologies (adaption strategies) was the main factor hindering adaptation of modern technology. Over thirteen percent identified lack of information on agro-meteorology as another major hindrance to adaptation of modern strategies, 12.9% saw lack of access to water as a hindrance to adaptation strategies. Over 14% see lack of loan or credit facilities for farmers as a major hindrance to adaptation of modern technologies while 10% stated that lack of farm inputs are hindrances to adoption of modern adaptation strategies. This study reveal therefore that lack of adequate information both on modern adaptation method as well as on agrometeorological issues are major hindrances to the adoption of adaptation strategies in the study area.

4.7.1 Farmers suggestions to enhance the fight against climate change in the study area

Farmers were asked to make suggestions on how to enhance the fight against climate change in the study area. Their suggestions are given in Table 4.24.

Table 4.24: Farmers suggestions on enhancing fight against climate change

Farmers suggestions to enhance fight against climate change	Frequency	Percentage
Provision of irrigation facilities	148	38.6
Increase information on agroclimatology and modern adaptation strategies	132	34.3
Improved seed varieties and animal species	38	10
Provision of credit and loan facilities to farmers	36	9.3
Provision of farming facilities	30	7.8
Total	**384**	**100**

Source: Field Survey, October 2016.

Table 4.24 reveals that majority of the farmers 38.6% suggested the provision of both small and large scale irrigation facilities, 34.3% suggested increase information on agro-climatology and modern adaptation strategies, (e.g. water harvesting and storage strategies) 10% suggested improved seed varieties and animals species, 9.3% suggested provision of credit and loan facilities while 7.8% suggests provision of farming inputs to the farmers (e.g. fertilizers, implements, chemicals).

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter summarizes the research and made conclusion and recommendations to address the issues of climate change and its looming effects on agriculture and were given herein.

5.2 Summary of Major Findings

The problem of climate change as observed from the study is very obvious in the study area. These constraints or problems range from pronounced seasonality of rainfall (which confines cultivation to short periods of three to four months) to severe and recurrent drought (which disrupts the usual pattern of seasonal water availability). False onset of rains, late onset of the rains, increase dry spells within the rainy season, early cessation of the rains, less rainfall, too much rainfall, hail storms, high temperature and increase pest and disease infestation, are also major constraints. These constraints have led to reduced crop yield and animal productivity, shortage of water and biomas for animal, wilting of crops, diseases, erosion and desertification.

The study aimed at examining the adaptation strategies to climate change by farmers in the study area. This was achieved by a set of objectives which include to characterized the climate of the study area, assess the awareness and perception of farmers on climate change issues and examine the impact of climate change on agriculture as well as adaptation strategies adopted by farmers in the study area.

Temperature and rainfall data of the study area for a period of 30 years (1986 – 2015) was collected, from the Nigerian Meteorological Agency NIMET Sokoto, 384 closed

ended and open ended questionnaires were used to generate data to address the objectives. The rainfall and the temperature data were used to characterize the climate of the study area. The research used purposive sampling to administer questionnaire in the study area. The data were analyzed using a simple regression line graph analysis and descriptive statistics and presented in tables and charts. The results showed that rainfall onset in the study area is coming early and cessation is coming late within the period under study, thereby prolonging the duration of the rainy season. The results also showed that maximum temperature is increasing. Furthermore, the result indicated that millet is the most widely cultivated crop in the study area because it is better adapted to the climate. Donkeys, goats and cows are the most reared in the study area. Mixed cropping, mixed farming, early and constant weeding, uses of improved varieties are some of the adaptation strategies adopted by farmers in the study area.

5.3 Conclusion

Based on the findings of the research, the researcher concluded that rainfall is characterized by significant inter-annual variability. The annual rainfall amount in Sokoto East Senatorial District is on the increase. The mean annual rainfall is (676.4mm) and this favours the cultivation of such crops as millet and early maturing varieties of sorghum. There has also been decreasing and increasing pattern of both the onset and cessation of the rainfall in the study area. The study discovered that the onset of the rains is coming early while cessation is coming late. The study revealed that the length of the rainy season in Sokoto East Senatorial District even though increasing, is still too short for farming activities hence the reason for employing effective adaptation strategies. Conclusively, the pattern of rainfall in the study area is characterized by

inconsistencies and variations. Temperature shows a fluctuating trend with an increase slightly below 1 degree Celsius.

Going by the characteristics of rainfall and temperature of the study area, the research concluded that the onset dates, cessation dates, length of rainy season and the amount of annual rainfall is not consistent. The observed inconsistencies that characterize the climate of Sokoto East Senatorial District will have a serious implication on agricultural activities as the farmers would find it difficult to predict the rainfall and temperature characteristics of the areas, consequently affecting crop yield by affecting the cultivation processes (land clearing and preparation, planting, weeding, fertilizer application and even harvesting).

The study also concluded that millet is the most cultivated crop in the study area. The choice of millet as the farmers favorite crop is because it is better adapted to dry, infertile soils, high temperature, low and erratic precipitation and poor water-holding capacity soil than most other crops.

Furthermore, the study found that farmers' perceptions of climate variability are not in line with climatic data records of the study area with exception of increase temperature. Farmers in Sokoto east senatorial zone are able to recognize that temperature is on the increase.

The study further concluded that the inconsistencies in rainfall and temperatures have impacted agricultural activities negatively through reduced crop yield, reduced water for animal and reduced grass or biomass and wilting of crops as well as death of livestock.

Access to climate change information as revealed by the study is mainly through personal observation and electronic media. The activity of extension agents with regards to information disseminaton on climate change is very poor in the study area. And this accounts for the dearth of modern adaptation techniques in reducing the effect of climate change in the study area.

Although farmers are well aware of climate changes in the study area, the main adaptation strategies of farmers in Sokoto east senatorial district are (1) mix cropping, (2) mixed farming, (3) use of improved varieties, (4) early and constant weeding (to reduce weed competition for water and nutrient) (5) high use of organic and inorganic fertilizers among others.

The study also showed that inadequate knowledge and information on climate issues via extension services, lack of information on modern adaptation techniques, lack of credit and loan facilities, lack of access to water for irrigation are major hindrances to combating climate change in the study area.

5.4 Recommendations

Based on the findings of the research and the conclusions made in the study, the following recommendations are made:

1. Based on the characteristics of the rainfall in the study area, it is recommended that farmers are encourage to start land preparation and planting of crops between the 5th of June to early July when rainfall stability could be fully achieved.
2. More so, since the annual rainfall favours the cultivations of millet and rearing of cattle and donkeys, farmers in the study area should concentrate more on millet cultivation (instead of sorghum and maize) and rearing of these animals (instead of sheeps) so as to maximize crop yield and animal production and the federal

government should liaise with Universities and research institutions to initiate and fund specialized research on crops and animals that will take advantage of new environmental conditions created by climate change in semi-arid region like the study area. Findings of such research activities should be properly disseminated to the local farmers through the ADPs and Local Government Area Agric departments.

3. High yielding and early maturing improved varieties of millet as well as animals with high production potential should be used. Also, superior integrative stress resistance and wide adaptability should be made available to farmers by both the federal, state and local government so as to reduce incidences of climate variability.
4. Agro-meteorological extension services and other extension service should be enhanced by the state government through training and deploying of more extension agents to increase awareness of climate issues and introduction of modern technologies for mitigating climate change impacts in the study area.
5. Government at various levels (local, state and federal) should formulate and implement policies that will ensure that farmers in the study area have access to sustainable loan and credit facilities as this will increase the adaptive capacity of local farmers to climate change and enhance their ability to adopt new innovations and technologies.
6. In addition, access to water through the construction of support facilities for large scale water saving for irrigation, building water harvesting schemes, water storage ponds and improved irrigation system should be made available for farmers in the study area by the state and federal government.

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APPENDIX I

QUESTIONNAIRE

Department of Geography and
Environmental Management
Faculty of Physical Sciences
Ahmadu Bello University
Zaria.

Dear Respondents,

I am an M.Sc. student of the above named University undertaking a research on **"Assessment of Farmers Adaptation Strategies to Climate Change in Sokoto State, Nigeria."** Please help fill this questionnaire. All the information you provide will be treated with all confidentiality and none will be use for any other purpose than this research.

Samuel Ogbonnaya

Instruction: Please tick [√] where appropriate

Section A: Personal Biodata

1. Name of village_____
2. Sex: (a) Male [ ] (b) Female [ ]
3. Age: (a) 31 – 40 [ ] (b) 41 – 50 [ ] (c) 50 and above [ ]
   (d) 41 – 50 [ ] (e) 50 and above [ ]
4. Marital Status: (a) Married [ ] (b) Single [ ] (c) Widow [ ] (d) Divorced [ ]
5. Educational qualification: (a) Primary [ ] (b) Secondary [ ] (c) Tertiary [ ] (d) Koranic [ ] (e) None [ ]
6. How long have you been in this place: (a) 20 – 30yrs [ ] (b) 31 – 40yrs [ ] (c) 41 yrs and above

Section B: Farmers and Crop Production

7. What type of farming are you practicing? (a) Commercial [ ] (b) Subsistence [ ] (c) Mix farming [ ] (d) Both [ ]
8. What type of crops do you grow? (a) Millet [ ] (b) Sorghum [ ] (c) Cowpea [ ] (d) Others specify_____
9. What is your reason for cultivating your present crop(s)?
   (a) it is drought resistant [ ] (b) it is early maturing [ ] (c) it is high yielding [ ]
10. In your own opinion which is the most cultivated crop in your area?
    (a) Millet [ ] (b) Maize [ ] (c) Cowpea [ ] (d) Others specify_____

11. Is your annual harvest of the crops on the piece of land increasing or decreasing?
    (a) increasing [ ] (b) decreasing [ ] (c) the same every year [ ]
12. If increasing, what do you think could be responsible for the increase?
    (a) early rainfall [ ] (b) Adaptation strategies [ ] (c) high temperature [ ]
    (d) improved seed [ ] (e) Others specify_____
13. If decreasing, what do you think is responsible for the decrease?
    (a) Late rainfall [ ] (b) small amount of rainfall [ ] (c) low temperature [ ]
    (d) Others specify_____
14. Are you involved in animal production? (a) Yes [ ] (b) No [ ]
15. What types of animals do your rear? (a) Cow [ ] (b) Goat [ ] (c) Sheep [ ]
16. Are you producing for domestic or commercial purpose or both?_____
17. Are your animals producing more or less?_____
18. What do you think is the reason for the reduction or increase in your animal production_____

Section C: Farmers Awareness of Climate Change

19. Are you aware that the climate is changing? (a) Yes [ ] (b) No [ ]
20. What are your source of information about climate change?
    (a) Personal observation [ ] (b) through interacting with friends [ ]
    (c) Printed materials (e.g. newspapers, magazines) [ ] (d) Electronic media (e.g. radio, television etc) [ ] (e) from the school [ ] (f) from extension agent [ ]
    (g) All of the above [ ]

Section D: Effect of Climate Change on Agriculture in the Study Area

21. In your opinion do you think climate change have affected farming activities in your area?_____
22. How has low rainfall affected farming activities in your area?_____
23. How has high temperature affected farming activities in your area?_____

Use the option below to answer question 24 – 33

(a) A – Agreed
(b) D – Disagreed
(c) U – Undecided
(d) SA – Strongly agreed
(e) SD – Strongly disagreed

24. There have been long period of dry spell within rainy season_____
25. The environment in this village is changing_____

26. Rainfall onset is now coming late _____
27. Number of rainy days/months/years is increasing _____
28. The temperature around this village is rising higher_____
29. Rainfall amount compared to the past ten years plus is decreasing every year _____
30. The yearly rainfall are not supporting crop production as before _____
31. The changing climate has led to crop infestation by disease and pest _____
32. There have been increase incidences of flood during the rainy season _____
33. There has been early cessation of rainy season_____

Section E: Farmers Adaptive Strategies

34. From your experience in farming over the years, is it possible to adapt to climate change? (a) Yes [ ] (b) No [ ]
35. What are the strategies you have adapted to cope with the effect if climate change in your farming? (a) early planting of the seed [ ]
    (b) Late planting [ ] (c)early weeding to reduce weed competition for water and nutrient [ ] (e) use of early maturing varieties (f) Use of drought resistant [ ] (g) Construction of dam within the farm [ ]
    (h) Access to credit loan [ ] (i) Othes specify_____
36. From your farming experience, what are the best strategies you have adopted to climate change? (a) Crop rotation [ ] (b) Mix cropping [ ]
    (c) Use of improved seed varieties [ ] (d) Changing the extent of land put into crop production [ ] (e) adopting irrigation/fadama farming [ ] (f) increase use of chemical fertilizer [ ] (g) mulching with crop residue [ ] (h) access to loan facility (i) Other specify_____
37. What are the strongest adaptation strategies to climate change that you are using? (a) Irrigation [ ] (b) Mixed farming (c) use of improved crop variety [ ] (d) planting of early maturing crop [ ] (e) Intensive manure application [ ] (f) Mix cropping [ ] (g) Early and consistent weeding [ ]
38. In your own opinion, what are the perceived hindrances to adaptation of modern techniques of combating climate change? (a) Lack of improved seed [ ] (b) lack of access to water for irrigation [ ] (c) lack of adequate knowledge on adaptation methods [ ] (d) lack of proper information on weather incidence [ ] (e) there is no hindrances to adaptation [ ].
39. What do you recommend to be done that will enhance the fight against climate change in your environment? Comment freely._____