CLIMATE CHANGE AND LAND USE IMPACTS ON MIGRATION AND FOOD SECURITY IN NORTH CENTRAL REGION OF NIGERIA

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PhD/SPS/FT/2019/11129

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY (PhD) IN CLIMATE CHANGE AND HUMAN HABITAT.

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ABSTRACT

Challenges brought on by climate and land use changes have a negative impact on food security in a variety of ways. These changes have impacts on ecosystem products and services leading to migration of people, particularly rural residents. In order to evaluate the impacts of climate and land use changes in the selected States of the North Central Region of Nigeria (Niger, Kwara, and Benue), as well as their consequent impacts on migration and food security in these areas, this study used NASA Power Data, multispectral satellite remote sensing, net migration data, crop yields data, expert interviews, focus group discussions, and household survey (structured questionnaire) methods. The spatio-temporal changes in climate parameters (minimum, maximum, and average temperatures; and rainfall) between 1985 and 2020 were assessed using the Mann-Kendal test and non-parametric test. Landsat images were utilised to extract remote sensing data and images for 1990, 2000, 2013, and 2020. The link between the climate parameters, net migration and crop yields (maize, yam, cassava, rice, and groundnut) was investigated using regression analyses. The focus group discussion, expert interview, and questionnaire were all analysed using descriptive statistics. The results indicated an upward trend in the annual temperature of Niger ($p<0.0001$, $\alpha=0.05$, $Q=0.059$) and Benue ($p<0.0001$, $\alpha=0.05$, $Q=0.044$) and downward trend in the annual rainfall of Niger State ($p=0.006$, $\alpha=0.05$, $Q=-14.324$) and Benue State ($p=0.010$, $\alpha=0.05$, $Q=-11.661$) but no significant trend in both temperature ($p=0.099$, $\alpha=0.05$, $Q=0.012$) and rainfall ($p=0.902$, $\alpha=0.05$, $Q=-0.328$) of Kwara State. The results of Land Use and Land Cover (LULC) of the areas between1990-2020 show that the majority of the vegetation, agricultural land, and water body areas have been converted to built-up areas and barren land in Kwara and Benue States, whereas there has been a noticeable rise in agricultural land (45.29 per cent increase) and built-up areas (4.41per cent increase) in Niger State. Furthermore, in Niger State, there was a statistically significant negative relationship between maize yields and temperature ($p=0.0294$, $\alpha=0.05$, $t= -2.4469$, $R^2=0.417$) while there was a statistically insignificant relationship between temperature and other crops. There was a statistically insignificant relationship between average annual temperature and all the five food crops in Kwara State. Also, in Benue State, there was a statistically significant positive relationship between temperature and groundnut ($p=0.0119$, $\alpha=0.05$, $t= 2.924$, $R^2=0.310$) but statistically insignificant relationship between temperature and other crops. In addition, there was a statistically significant positive relationship between rainfall and maize yields ($p=0.00036$, $\alpha=0.05$, $t= 4.779$, $R^2=0.0217$) and cassava yields ($p=0.0112$, $\alpha=0.05$, $t= 2.951$, $R^2=0.218$) in Niger State and there was also a statistically significant positive relationship between rainfall and maize yields ($p=0.0405$, $\alpha=0.05$, $t= 2.274$, $R^2=0.0360$) and cassava yields ($p=0.0326$, $\alpha=0.05$, $t= 2.392$, $R^2=0.0472$) in Kwara State but a statistically insignificant relationship between rainfall and other crops in these two States whereas in Benue State, there was a statistically significant positive relationship between rainfall and maize yields ($p=0.000216$, $\alpha=0.05$, $t= 5.0674$, $R^2=0.4073$), cassava yields ($p<0.00001$, $\alpha=0.05$, $t= 24.5975$, $R^2=0.34016$) and rice yields ($p=0.000613$, $\alpha=0.05$, $t= 4.48553$, $R^2=0.1532$) but there was a statistically insignificant relationship between rainfall and other crops. These findings imply that climate change and land use change have caused the increase in rural-urban migration leading to the fluctuation in the yields of the five crops. Changing of farming methods, income diversification, supports from external bodies, and change of profession were all mentioned by respondents as sustainable adaptation strategies that help them to reduce the negative impacts of climate change, land use change, and migration. It is recommended that the relevant stakeholders

should provide adequate weather forecasts, climate smart technologies and an attractive environment to boost agricultural production and reduce rate of rural-urban migration.

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LIST OF ABBREVIATIONS AND ACRONYMS

ABU	Ahmadu Bello University
ADP	Agricultural Development Programme
AGW	Anthropogenic Global Warming
AL	Agricultural Land
BA	Built up Area
BL	Barren Land
CCA	Council of Canadian Academies
CO_2	Carbon dioxide
FAO	Food and Agriculture Organization
FGN	Federal Government of Nigeria
GIS	Geographic Information System
GPS	Global Positioning System
IBM	International Business Machines
IDMC	Internal Displacement Monitoring Centre
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IOM	International Organization for Migration
IPCC	Intergovernmental Panel on Climate Change
LGA	Local Government Area

LULC Land Use and Land Cover

NASA National Aeronautics and Space Administration

NAERLS National Agricultural Extension and Research Liaison Service

NBS National Bureau of Statistics

NetMig Net Migration

NDVI Normalized Difference Vegetation Index

NGOs Non-Governmental Organisation

NiMet Nigerian Meteorological Agency

NISER Nigerian Institute of Social and Economic Research.

NPC National Population Commission

NRC Norwegian Refugee Council

SDGs Sustainable Development Goals

UN United Nations

UNEP United Nations Environment Programme

USGS United States Geological Survey

UTM Universal Transverse Mercator

VG Vegetation

WB Water Body

WFP World Food Programme

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The current food crisis in Nigeria is unprecedented, which has caused a significant increase in food costs and the situation is getting worse every day due to the detrimental effects of climate change (Igbokwe-Ibeto, 2019). One of the evidences of negative effects of climate change on food security in Nigeria is low agricultural productivity causing many Nigerians to be hungry, malnourished, poor, starving and suffering from various health problems (Okoli and Ifeakor, 2014).

Flooding, drought, land degradation, risks to biodiversity, and issues with food and health security are just a few of the ways by which climate change endangers human society (Food and Agriculture Organisation (FAO) and United Nations International Children's Emergency Fund (UNICEF), 2017; Sanfo *et al.,* 2017). In poor nations where communities depend on agriculture as a source of livelihood, the effects of climate change are profound and have cascading effects on food security (Olutegbe and Fadairo, 2016, Okeleye and Olorunfemi, 2016). Climate change has an impact on rural migration as well as other socioeconomic factors of migration such as rural poverty and food insecurity. (FAO, 2017). Agriculture employment has a key role in how climate change affects rural-urban migration (Nawrotzki *et al*., 2015).

Nigeria is not an exception when it comes to the threat that climate change poses to food security and sustainable development in Africa (Intergovernmental Panel on Climate Change (IPCC), 2014; Mercandalli *et al.,* 2019). Due to their impoverished economic conditions, pervasive poverty, and little capacity for adaptation, Nigeria and other African nations are particularly vulnerable to the adverse effects of climate change (Abugu and

Onuba, 2015). Challenges brought on by climate change and worsened by land degradation through a variety of paths have a significant impact on food production systems. It affects ecosystem goods and services cumulatively, causing migration of people, particularly rural residents (Fonta *et al.,* 2011, Okeleye *et al.,* 2016). Existing food systems that are disrupted will have catastrophic impacts on food security, livelihoods, poverty, and its ripple effects on human security (De Wit and Stankiewicz 2006).

Changes in land use affect the environment on a local, regional, and international scale (Lambin and Geist, 2006). These large changes cause sediment loads, abnormalities in water cycles, and a spike in soil erosion in addition to local, regional, and global biodiversity loss. Local changes in land use and land cover have an impact on microclimatic resources, which directly affect local inhabitants' means of subsistence (Sultan, 2016). About 15% of all human greenhouse gas emissions are attributed to the livestock industry, and 10% are attributable to changes in land use, such as deforestation, which are caused by agriculture (FAO, 2017). Approximately one-fourth of the overall loss and damage brought on by climate change in developing nations can be attributed to the impact of climate-related disasters on the agricultural sectors. These effects raise the likelihood of food insecurity and boost global migration (FAO, 2016).

Land degradation leads to low and decrease in productivity of agricultural output which by extension aggravates poverty (Kirui, 2016). Long term undernourishment leads to stunted growth, slow mental development and increase in vulnerability to sickness (FAO, 2016). Presently, over 800 million people who are majorly smallholder farmers who depend on agriculture as the source of livelihood for themselves and their families sleep every night with empty stomach (Nair, 2019). Approximately 75% of the impoverished people in developing countries live in rural areas, despite the fact that urban slums have grown exponentially over the past 10 years (Nair, 2019). Climate, food security, and human security are all significantly impacted by soil protection and sustainable land use (Amundson, 2015). Despite this, land degradation is a widespread issue that affects both developed and developing nations. It is estimated to affect 1.5 billion people and a quarter of the world's land area, making it important to implement an appropriate land use policy (Lal *et al.*, 2012; Lal *et al.*, 2014; Le *et al.*, 2014).

Migration is considered as a dynamic and complicated global process (Froese and Schilling, 2019). About 26.4 million people are displaced globally each year due to natural hazards and climate-related causes (Internal Displacement Monitoring Centre (IDMC) and Norwegian Refugee Council (NRC), 2015). The current anticipated total number of international migrants, including those displaced by climate related natural hazards, is 40% greater than those in 2000. By 2050, this number is predicted to exceed 400 million (FAO, 2016).

Rural-urban migration patterns in Sub- Saharan Africa are multifaceted. People may be forced to migrate due to environmental, political, cultural, demographic or socio-economic factors. Most of the time, a combination of the aforementioned factors affects a person's decision to migrate (Sedoo *et al.*, 2019). Because there is a shortage of housing due to migration to urban areas, many urban people live in informal housing (Amrevurayire and Ojeh, 2016). Migration is seen as one of the strategies of adapting to climate change (International Organization for Migration (IOM), 2016). Study found out that regular, organized and safe migration can be a contributor to development of agriculture, food security, livelihoods of rural dwellers and economic growth (IOM, 2017). Social protection systems and decent employment via skills, knowledge, transferring remittances and technology can also be created through the help of migrants (FAO, 2017).

The significance of this study has been demonstrated by case studies in other parts of the world. For example, studies showed China which is one of the countries that is mostly affected by natural disasters worldwide because of its huge climate fluctuations, large territory and complex geographical environment, has experienced intense and frequent natural disasters that greatly affected food production in recent years (Cheng *et al*., 2014; Zhang *et al*., 2014; Hong *et al*., 2015; Guo *et al*., 2016, Guo *et al*., 2019). Out of these natural disasters, drought and floods are the commonest and most serious ones accounting for more than 50 percent of the total grain lost in the last four decades (Guo *et al*., 2019). The increase in intensive agricultural practices in China has caused a serious land degradation in the country and this is one of the reasons why China has been struggling with the challenge of feeding Chinese huge population which constitutes of about 22% of the world population (Norse and Ju 2015; Yu and Wu 2018). Urbanization and the rapid economic growth in the country are also challenges to rural society and food security of China (Yu and Wu 2018). Also, existing evidences showed that fluctuations in temperature and precipitation increase internal migration in China making it to host the world’s largest population of internal migrants and this represents the largest migration event in the history of human race (Liang *et al.*, 2014, Zhao *et al*., 2016, Gray *et al*., 2020).

Furthermore, Burkina Faso, which is one of the world's least developed nations is susceptible to the harmful effects of climate change which is characterized by land degradation, prolonged drought, flooding, water scarcity and deforestation because many of the Burkinabe depend on climate sensitive means of livelihood, have limited access to adequate social services and live in abject poverty (Crawford *et al*., 2016). Land degradation in Burkina Faso is worsened by factors like poor resource management, reduced rainfall and population pressure (Nebie and West, 2019). An increasing population in addition to high internal rural migration rates and 30 years of desiccation have led to intense land-use and land-cover change (LULCC) in the country with consequent impacts on food security of Burkina Faso (Nebie and West 2019). Furthermore, the major drivers of environmental related migration in Southwestern Burkina Faso include reduction in rainfall amount, insecurity in land tenure system and soil degradation (Sanfo *et al.,* 2017).

Dry and rainy seasons are experienced in Nigeria. Excessive heat negatively affects vegetation and crops while excessive rainfall results in extensive flooding which can induce migration (Amanchukwu *et al.,* 2015). The patterns of migration include rural-urban, rural-rural, urban-rural and urban-urban (Eze, 2016). Rural-urban inequality in terms of wealth and higher quality of life that are in urban regions is the cause of individuals moving from rural to urban areas in quest of better opportunities (Alarima, 2018).

The vulnerability analysis indicated that northern States of Nigeria with higher levels of rurality have higher levels of vulnerability than the southern counterparts (Madu *et al.,* 2016). The degree of vulnerability is as a result of the predominance of climate-sensitive agricultural practices (Madu *et al.,* 2016). Agriculture which is a dominating sector that promotes degradation, and unsustainable land management and changes in land use are the direct causes of degradation (Olsson *et al.,* 2019).

1.2 Statement of the Research Problem

Nigeria and indeed Northern Nigeria which is known for blossoming agricultural productivity before is now heavily affected by climate change and land degradation in the form of prevalent drought and flood (Dahiru and Tanko, 2018). Also, most of the crops are less productive due to the over dependence on rainfed agricultural practices and high poverty level of the residents (Dahiru and Tanko, 2018).

The degradation of agricultural assets exacerbated by climate change is causing production to fall and sharply limiting options for rural residents to make a living (IPCC, 2014). The current land use system does not favour farmers because there is unavailability of land for those who are interested in farming. In order to achieve food security in Nigeria, it is necessary to reform the country's current *Land Use Act* (Kehinde *et al.*, 2021). This will make it possible for both adult males and females to have access to land for farming.

Rural-urban migration is influenced by both poverty and food insecurity (International Organization for Migration (IOM), 2016). Potential paths from climate change to migration include increases in the frequency and severity of weather and climate-induced risks, including rapid and slow-onset events (FAO, 2017). Extreme meteorological events which are sudden-onset events tend to have immediate impact and direct linkages between climate change and migration (FAO, 2017). Rural populations are often displaced as a result of damage done to their assets and/or production because of natural disasters attributed to these sudden-onset events (IPCC, 2014).

It is being argued that the overall implications of climate change in Sub-Saharan Africa have not been thoroughly grasped despite several discussions on the relationship between migration and climate change in Africa (Serdeczny *et al*., 2017). Researchers, especially those in charge of policy creation and implementation during the past 20 years, are paying more and more attention to the effects of climate change on migration (Yusuf, 2019). Understanding the connection between population growth and climate change depends in large part on migration (Stephenson *et al*., 2010).

Low agricultural yield, poverty, low access to quality education and healthcare are some of the main determinants of rural migration. (IOM, 2016). While some scholars described migration as a climate change adaptation measure (Davis *et al*., 2018), it is also seen as the failure to mitigation or adaptation (Mayer, 2011). In North Central Nigeria, majority of the farming households have between one and four members that migrate every year as a result of climate related disasters thereby reducing their ability to be food secured (Ngutsav *et al*., 2021).

1.3 Justification of the Study

Most of the previous studies on changes in LULC in North Central Nigeria used remote sensing to evaluate the dynamics of changes in LULC, but explanations on the opinions of the local people on the drivers of changes in LULC were not included (Ali *et al.*, 2021; Zubairu *et al*., 2019 and Yakubu *et al*., 2018). This study will fill the gap.

Also, many studies on climate change and land use change have been conducted, the majority of these studies have not thoroughly examined the relationship between land use-migration-food productions in the North Central Region of Nigeria. Uncertainty in climate has a significant impact on the region's agriculture, economy, and overall country (Okeleye *et al*., 2016). This study aims to start addressing this nexus and to encourage more investigation that could shed light on how climate change will affect food security in the future. The results of this study may provide the States involved and the Federal Government of Nigeria with information that can potentially improve the manner food insecurity is addressed in assumed climatically low-risk and high-risk environments.

The findings of this study may influence decision-makers in the participating States and the Federal Government of Nigeria to create policies that are related to the Sustainable Development Goals (SDGs), such as those that address climate action, land use, internal migration, food production, and food security.

It may also motivate the conduct of a similar study that will cover the entire nation because this research would be conducted in selected communities in North Central Region of Nigeria. Such a nationwide study will improve the performance of stakeholders in the various Ministries, Agencies and Organizations that deal with migration, food security, land use and climate change issues. For example, Food and Agriculture Organization (FAO), Federal and States Ministries of Agriculture and Rural

Development, Federal and States Ministries of Environment, Federal and States Ministries of Works and Housing and Federal and States Ministries of Humanitarian Affairs and Disaster Management.

Furthermore, this study will contribute to the scientific literature of the public from a transdisciplinary and interdisciplinary perspective of reasoning. Specifically, the general public will find this study useful in revising and extending their knowledge on complex relationships that exist among climate change, land use change, migration and food security.

1.4 Aim and Objectives

The aim of this study is to analyze the climate and land use change and migration nexus and the consequent impacts on food crop production in North Central Region of Nigeria. The specific objectives are to:

i. Examine the trends in temperature and rainfall patterns in North Central Region of Nigeria (1985-2020);

ii. Assess the spatio-temporal dynamics of land use within the period of 1990-2020;

iii. Evaluate the resultant impacts of climate change and land use on migration as it affects food production and food security; and

iv. Identify sustainable adaptation strategies to minimize the impacts of climate, and land use changes and migration monitoring at different levels.

1.4.1 Research questions

1. What are the trends in temperature and rainfall patterns in the North Central Region of Nigeria (1985-2020)?
2. Which land use has had the most negative impact on food security within the period of 1990-2020?
3. How do the resultant impacts of climate change and land use on migration affect food production?
4. What are the sustainable adaptation strategies to minimize the impacts of climate, and land use changes and migration monitoring at different levels?

1.4.2 Research hypotheses

The following hypotheses are formulated for this study:

Null hypothesis (H_0): There is no statistically significant change in air temperature and rainfall of North Central Region of Nigeria.

Alternative hypothesis (H_a): There is statistically significant change in air temperature and rainfall of North Central Region of Nigeria.

1.5 Description of the Study Area

1.5.1 Location

The study was carried out in the North Central Region of Nigeria with Longitude 4000’-11000’ East of the Greenwich Meridian and Latitude 7000’-11030’ North of the equator (Figure 1.1). It begins in the west and circles the point where the rivers Niger and Benue converge. Approximately 32% of the country's total geographical area or 296, 898 km^2 lies within the region (National Bureau of Statistics (NBS), 2008). Six States and Abuja, the Federal Capital Territory, are located in the region. These States are Benue, Kogi, Kwara, Nasarawa, Niger, and Plateau. The region is situated in the sub-humid region of central Nigeria and is bordered to the north by Bauchi, Kaduna, Zamfara, and Kebbi States, the south by Cross-River, Ebonyi, Edo, Ekiti, Enugu, Ondo, Osun, and Oyo States, the east by Taraba State and the Republic of Cameroon, and the west by the Republic of Benin (National Population Commission (NPC), 2006). The region is situated in the sub-humid region of central Nigeria and is bordered to the north by Bauchi, Kaduna, Zamfara, and Kebbi States, the south by Cross-River, Ebonyi, Edo, Ekiti, Enugu, Ondo, Osun, and Oyo States, the east by Taraba State and the Republic of Cameroon, and the west by the Republic of Benin (National Population Commission (NPC), 2006).

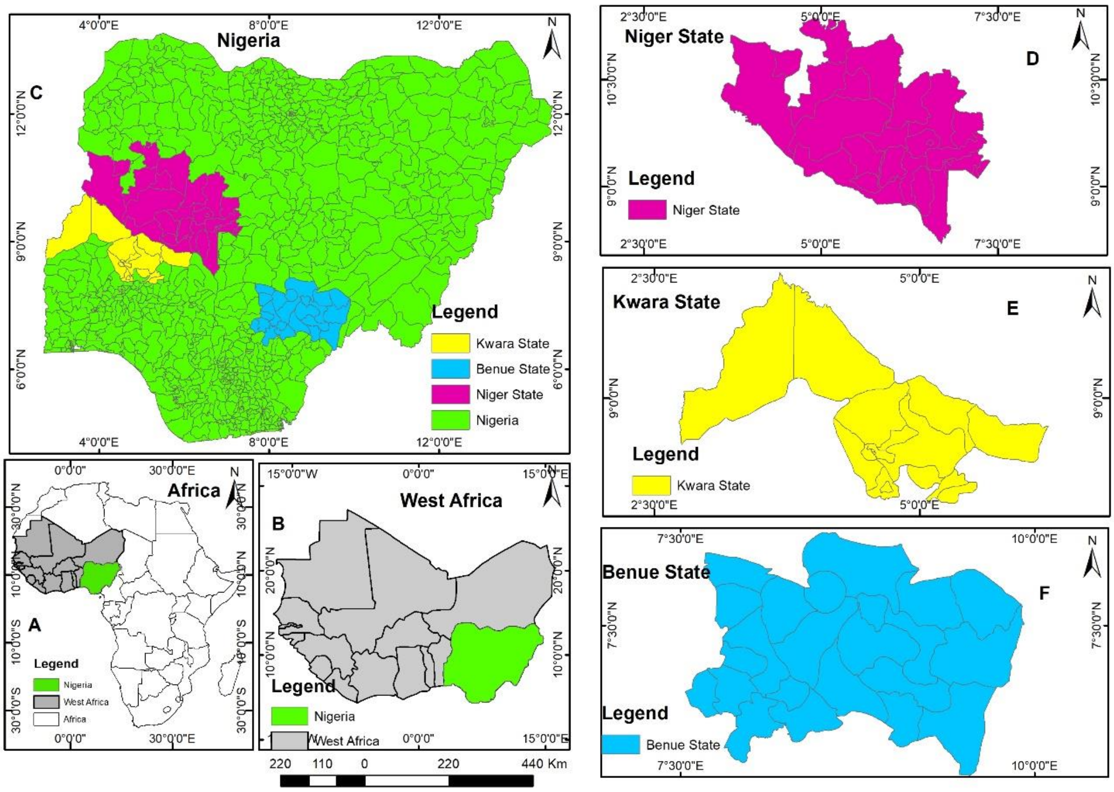


Figure 1. 1 Map of the Study Area

Source: Author’s fieldwork (2023)

1.5.2 Climate

The region has a tropical continental climate that has wet and dry seasons. Because rainfed agriculture is mostly performed in the area, crop planting is primarily done during the rainy season (Olanrewaju and Fayemi, 2015). The average annual rainfall is between 1200mm and 1500mm, while the average air temperature is between 22.55°C and 33.54°C. Except for the harmattan season, which starts in November and lasts until February, the air is generally warm throughout the year (Ugbem, 2019). The weather is dry and cold during this time of year, and there are also hazy skies and moving dust particles. The Guinea savanna gets between 1000mm and 1500mm of rain per year, which falls over a period of 6 to 8 months. Additionally, the Sudan savanna receives an average annual rainfall of 600mm to 1000mm. The region has a dry season that lasts for roughly 4-6 months. The area is vulnerable to the harmful effects of climate change. (UNDP, 2020).

1.5.3 Vegetation/drainage/soil

The vegetation of North Central Nigeria crosses the three savannah belts of Guinea, Sudan, and the Sahel. The vegetation consists of open woods with tall grasses of 1 to 3 metres high and trees around 15 metres high, typically with short boles and large leaves. The vegetation is sparse, resembling more the Guinea savanna. The typical vegetation is primarily made up of stunted tree species and short grasses that are between one and two metres tall. The Sahel savanna experiences dry seasons that last more than 8 months and annual rainfall of less than 600 mm (Ugbem 2019, Olanrewaju and Fayemi 2015). The predominant vegetation is made up of grasses, an open thorn shrub savanna with a few scattered trees, and long, sparse grasses that range in height from 4 to 9 metres, the majority of which are thorny (Federal Government of Nigeria (FGN), 2018).

Furthermore, the region is drained by River Niger and River Benue and their tributaries. Also, the areas which are close to the river levees have clayey soils while areas which are far from the river levees positions have variable and sandy soils (Ande *et al.*, 2016).

1.5.4 Population and economic characteristics of the study area

The population of Nigeria's North Central Region was predicted to be 29,252,408 as of 2016, with roughly 77 percent of people living in rural areas (United Nations Development Programme (UNDP), 2020). After the North West and South West, it is the third most populous region in Nigeria. The Nupe, Igala, Gbagyi, Idoma, Gwandara, Yoruba, Eggon, Tiv, and Berom tribes are the most prevalent. The region has a large amount of land that can be used for farming different kinds of crops such as yam, cassava, millet, cowpea, Irish potato, rice, and for raising animals including chickens, cattle, sheep, and goats. The area is Nigeria's primary agricultural producer (Ugbem, 2019, National Bureau of Statistics (NBS), 2008 and National Population Commission (NPC) 2006).

1. 6 Scope and Limitations

1.6.1 Scope

(a) Temporal scope: The period of temporal range of climate change data is 1985-2020; a period of 36 years. This was selected to know the trends of change in climate variables (air temperature and rainfall). Also, a temporal range of 1990-2020; a period of 30 years for satellite imageries. This was selected to ensure clear satellite imageries were used to assess the spatio-temporal dynamics of land use. Satellite images of 2013 were used instead of 2010 because of Landsat scan line error that occurred between May 2003 and February 2013. Crops yields of maize, yam, cassava, rice and groundnut for 2005-2020 were used and net migration data of 2005-2020 were used.

(b) Spatial scope: Niger, Kwara and Benue States in North Central Region of Nigeria are purposively selected out of the six states and FCT that make up the North Central Region of Nigeria. They are selected because they are the three largest States (land mass) in the Region and these three States produce Nigeria's major staple food crops in abundance (Okeleye *et al*., 2023).

(c) Content scope: The climate variables used focused on air temperature and rainfall because they are the mostly used climate variables in determining the trends of climate change. Also, the study on migration focuses on rural-urban migration because rural agriculture is mostly practised in Nigeria. This study did not cover migrants in Internally Displaced Persons (IDP) camps in the study area.

1.6.2 Limitations

The field data were collected during the COVID-19 period when limited close interaction with the respondents was encouraged. Also, due to the diversity of North Central Region of Nigeria, consideration of the three States as the representation of the whole Region was considered as another limitation of this study.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual Framework

2.1.1 Concept of climate change

Climate change can be defined as the statistically significant change in the mean of the climate and /or the variability of its properties over a long period of time typically decades or longer (IPCC 2007). According to Elisha *et al*. (2017); Ebele and Emodi, (2016); and Olaniyi *et al.* (2013), the evidences of changing climate in Nigeria include variation in rainfall pattern, increase in temperature, flooding and sea level rise; drought and desertification; loss of biodiversity, land degradation among others. Also, Akande *et al.* (2017) projected a significant increase in temperature in all the agro-ecological zones of Nigeria and it is predicted that because of climate change, there will be an increase in temperature of 0.4^0C to 1°C over the time period of 2020-2050, and an increase of up to 3.2°C by 2050.

There is gradual drying up and disappearance of Lake Chad and other lakes (Dioha and Emodi, 2018); Elisha *et al.,* 2017). Furthermore, Akande *et al.,* (2017) and Amanchukwu *et al.,* (2015) argued that Nigeria has been experiencing climate extremes in recent years and according to Federal Government of Nigeria, (2013), flooding is the commonest and recurring disaster experienced in Nigeria.

Out of the six geopolitical zones in Nigeria, the North Central Region of Nigeria has the lowest sensitivity to climate change impacts. This likely has something to do with relatively stable seasonal rainfall pattern in the Region and the presence of a large distribution of lakes which allow for year round irrigation farming (Haider, 2019). However, Ideki and Weli, (2019) observed a decreasing trend in rainfall in many States of the North Central Region such as Benue, FCT Abuja, Plateau, Benue and Nasarawa which is due to climatic shift towards aridity, with decreasing rainfall that negatively affects water resources, agricultural output and economic performance.

2.1.2 Concept of land degradation

Land degradation can be seen as the decline in the natural quality of any component of soil in an ecosystem. Particle size, bulk density, pH and permeability of the soil are used to determine the level of land degradation of an area (Ewetola *et al.,* 2015). According to Maconachie (2016) both the environment and the society in its 'close-settled zone' are extensively impacted by Kano's 'ecological footprint' more than ever before. Despite the fact that creative and ingenious strategies for coping in increasingly difficult situations is usually adopted by peri-urban land managers. Also, sustainability of a once apparently resilient system might start to break down as a result of recent increases in competition for resource use between local actors. Greater percentage of the soil in Ogbomosho area of Oyo State is degraded and some signs of serious degradation are noticed in fallowed plots that are expected to be better (Ewetola *et al*., 2015). Linda *et al.* (2015) who worked on suitability of land for the production of maize in Egbeda local government area of Oyo state through the use of GIS techniques and found out that great number of the nutrients in the soils falls within the low and medium values which will require application of fertilizer to increase its rate of fertility and that only good soil conservation practices will be needed to conserve soil nutrients in the study area. Similarly, according to Ideki and Weli (2019), larger part of the soil in the North Central Region of Nigeria is degraded as a result of flooding.

2.1.3 Concept of migration

Migration can be seen as the temporary or permanent movement of people from one geographical location to another (Amrevurayire and Ojeh, 2016). There are many forms of migration (IOM, 2016). Migrants may move within their countries of birth; this type of migration is known as internal migration or move across borders to other countries either to live or work; this is known as international migration (IOM, 2016). Their movements to the destination regions or countries can be complex and involve numerous steps. The movement of the migrants may be voluntary or forceful as a result of threat to their safety or livelihoods. (World Food Programme (WFP), 2017). The reasons why people migrate vary and it depends on the situation that led to such decision. The commonest form of migration in Nigeria is from rural to urban areas (Amrevurayire and Ojeh, 2016).

Globally, the nexus between migration and development has always been a subject under vigorous academic debate (Oginni and Abdoulaye, 2019). The major driver of Nigeria's rapid urbanization has always been rural-urban migration. The Rural "push" factors have been encouraging rural-urban migration include decrease in agricultural incomes as a result of overvalued foreign exchange rate and perpetual conflict in north and north central regions of the country (World Bank, 2016).

Oginni and Abdoulaye (2019) found out that rural-urban migration grossly affects agricultural activities in the rural area. The youth who are supposed to be agents of agricultural development are leaving rural areas for the urban areas due to limited jobs opportunities, high level of poverty and insufficient availability of social and infrastructural amenities.

2.1.4 Concept of food security

Food security as defined by World Food Security and the World Food Summit Plan of Action is a condition when "…all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life" (FAO, 1996). The availability, accessibility, and utilisation of food are the three key requirements that must be met for food security to exist (Snitter and Berry, 2019).

To attain food security, the three aforementioned components must be timely stable (Snitter and Berry, 2019). According to Council of Canadian Academics (CCA) (2014), "both the inability to secure an adequate diet today and the risk of being unable to do so in the future" are included in the definition of "food insecurity," demonstrating the significance of the long-term stability of food supply, accessibility, and utilisation. When one or more of these fundamental requirements is not supplied, food insecurity results. Figure 2.1 shows the graphical summary of the conceptual framework.

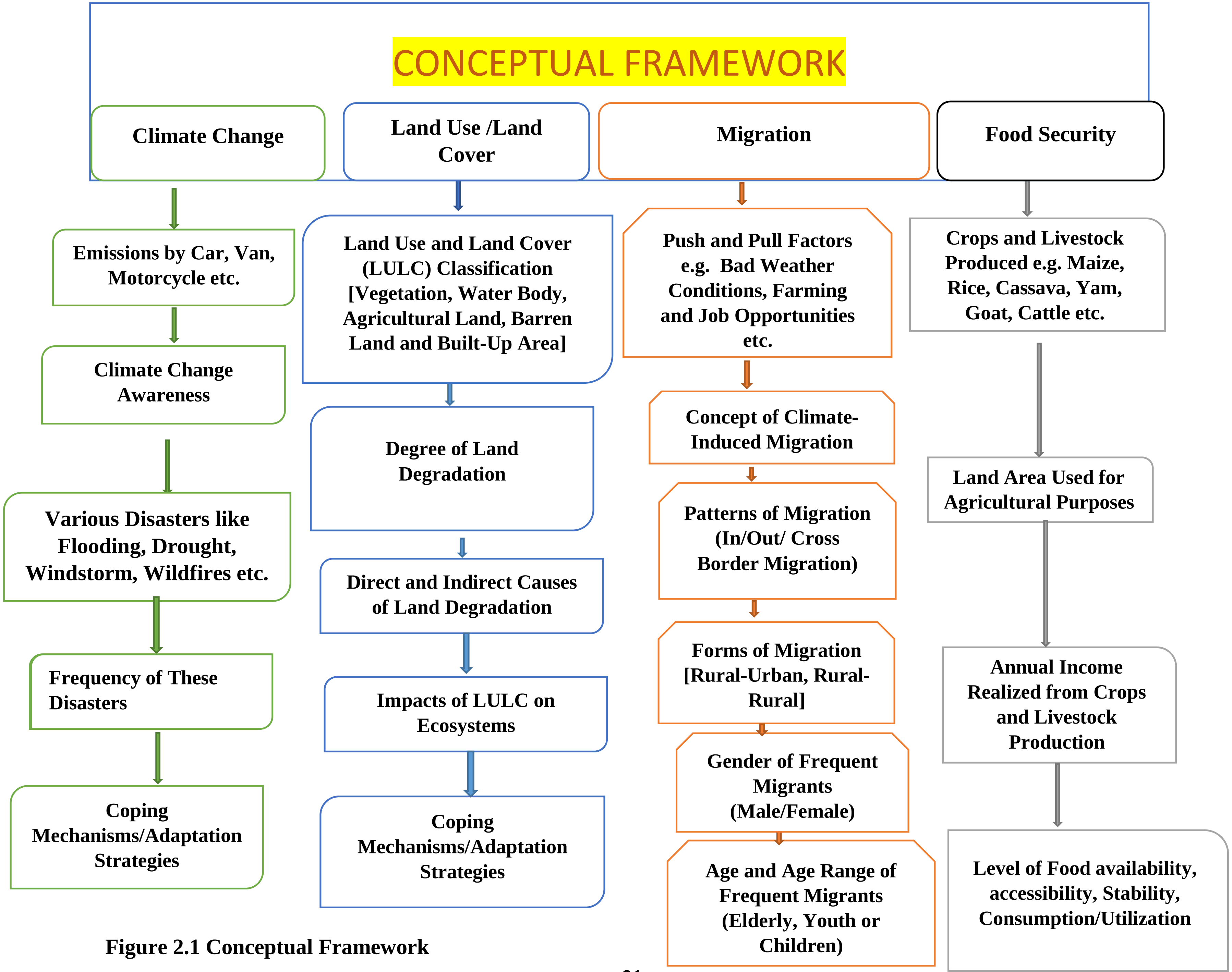


Figure 2.1 Conceptual Framework

Source: Author’s fieldwork (2023)

2.2 Theoretical Framework

2.2.1 Climate change theories

The review of the climate change theories is premised on the seven theories of climate change by Bast (2010) although three that are mostly relevant to this study would be reviewed.

2.2.1.1 Anthropogenic global warming (AGW) theory

According to Bast (2010), this is the first theory of climate change. This theory explains that greenhouse gases emissions like carbon dioxide, nitrous oxide and methane by human beings have caused the astronomical rise in average global temperature leading to a mechanism known as greenhouse effect and that is why this theory is termed "anthropogenic global warming" or simply put "AGW."

According to him, due to the transparent nature of the atmosphere of the Earth, some of the energy from the sun that travels through the space are absorbed while the remaining are reflected back in the form of heat energy into the atmosphere. This theory further explains that water vapour majorly contributes to greenhouse effect and it causes about 36%-90% of the greenhouse effect and this is followed by carbon dioxide which is responsible for about 1%-26%, followed by methane (4%-9%) and ozone (3%-7%). The theory stated human activities such as cutting down of trees of trees, burning wood, burning fossil fuels, burning forests in the past century had caused increase in the carbon dioxide concentration by approximately 50% in the atmosphere.

Furthermore, this theory believes that emissions of carbon dioxide mostly by human beings are responsible for catastrophic disasters like droughts, floods, extinctions of species, famines, severe weather, the spread of various diseases among others.

2.2.1.2 Cloud formation and albedo theory

This theory states that the formation changes, cloud, and albedo that arise in the negative feedbacks cancel out almost all of the warming impacts of increased levels of CO_2. This idea, in contrast to the AGW theory, primarily relied on observational data made public by a group of researchers, as opposed to computer models. In the past, NASA researchers found that variations in cloud cover in the tropics acted as a natural thermoregulator to keep sea surface temperature (SST) between 28°C and 30°C. According to their analysis, as SST rises, the moist static energy required for clouds to reach the upper troposphere is charged into the air at the base of the clouds. At this point, the cloud cover reduces the amount of solar radiation obtained at the sea's surface, and cool and dry downdrafts encourage ocean surface cooling (Spencer *et al.*, 2007).

This "thermostat-like control, tends to ventilate the tropical ocean efficiently and help contain the SST between 28°-30°C. This phenomenon is also expected to prevent SSTs from rising any higher in response to enhanced CO_2-induced radiative forcing. In the early 2000, some renowned meteorologists examined upper-level cloudiness data and SST data and discovered a strong indirect relationship between upper-level cloud area and the mean SST of cloudy regions of the eastern part of the western Pacific. The area of cirrus cloud coverage decreased about 22 percent for each 1°C increase in SST. The cloudy-moist region serves as an infrared adaptive iris that opens up and closes down the regions free of upper-level clouds, which more effectively permit infrared cooling, in such a manner as to resist changes in tropical surface temperature." According to estimates, this negative feedback is so sensitive that it has the potential to completely negate all positive feedbacks in the existing climate models (Lindzen and Choi, 2010).

However, this theory has been criticized by some scientists from the fact the tropic clouds' negative feedback suggests that the models overestimate climate sensitivity.

2.2.1.3 Planetary motion theory

According to Bast (2010), this hypothesis contends that the majority or all of the warming in the latter part of the twentieth century was caused by the magnetic and natural gravitational oscillations of the solar system, which are driven by the movement of the planet through space. Due to the modification of the oscillations of solar variations and/or extraterrestrial activities that affect the Earth, this resulted in climate change. The theory explains further that the orbit of the Earth that revolves over the sun assumes the nature of eclipse and not a circle. “perihelion” is termed to be the nearest region of the planet to the sun while “aphelion” is the farthermost region to the sun. The theory mentioned that in January, the winter in the northern hemisphere is slightly milder because of the occurrence of perihelion.

Furthermore, the tug of other planets, particularly Saturn and Jupiter on Earth, causes variations in the "eccentricity" or shape of the Earth's ellipse on cycles of 100,000 and 400,000 years. Due to this, Earth's orbit changes from one that is short and broad and brings it closer to the sun to one that is long and flat and moves it away from the sun and back towards it. Additionally, Earth revolves on an axis that goes through a 41,000-year cycle of "tilting" lower and then higher. Less "tilt" means that summers are cooler and winters are milder, whereas more "tilt" means that the northern hemisphere is warming in the summer and getting colder in the winter. According to the theory, the convergence of these cycles causes the cooling and warming phases that are known from historical evidence as the Ice Ages and Interglacials, helped by the favourable climate feedbacks such water vapour.

However, Scafetta (2010) saw this model as being straight forward and model that explains most of the warming of that takes place in twentieth century. He noted that the dissimilarity between climate forecast of this model and that of IPCC is that IPCC forecasts catastrophic warming while this model forecasts cooling for the next two decades

2.2.2 Land use theories

The review of land use theories is based on the middle-range theories of land system change presented by Meyfroidt *et al.* (2018)

2.2.2.1 Land-use expansion and intensification theory

This theory argues that intensity and extent of changes of land use are required because of the increase in global demands on land placed by human societies for the nature protection, provision of ecosystem services and production of essential goods. This theory describes the occurrence of land use expansion as the conversion of unconverted areas to anthropogenic or man-made land cover (Baumann *et al.*, 2017). Also, land use intensification is seen as the activities that increase the productivity of land by increasing input or output or changing the ecosystem features like the homogenization of tree species in intensive forestry.

The supporters of this theory believe that intensification can lead to the production of many unpleasant social and environmental impacts like impoverishment of smallholders as a result of increase in capital costs (Kremen, 2015; Gossner *et al*., 2016; Erb *et al*., 2016). According to the proponents of this theory, intensity and extent of land use changes can be mapped out in a two-dimensional space by ranking the actors and places based on their integration's degree in markets and their dependence on labour and capital inputs.

Apart from the land productivity explanation and its changes, the change in the efficiency of other factors can also be predicted using this theory.

2.2.2.2 Smallholder subsistence land use theory

This theory explains the attitudes of subsistence peasant or smallholders farming and reliance on labour as major input. This theory assumes that smallholders go after a adequate strategy towards maximizing productivity of labour productivity and avoiding the labour plodding.

This theory further explained that there are availability of technologies needed by the farmers for intensification and explanation on why these technologies are adopted is one of the assumptions of the theory. The theory emphasizes that intensification is preferred to expansion only when there is scarcity of land due to the fact that in the systems that are not mechanized, there is assumption that gains in the marginal productivity are declining meaning land productivity is increased while labour productivity is decreased by intensification. However, in this theory, there is no clear discussion on either intensification or expansion is preferred in meeting the needs of the increasing consumption.

2.2.2.3 (Neo) classical economic land rent theory

This theory is of the assumption that the usage of the land is for the activity that produces the greatest expected value therefore formalizing the processes of intensification and expansion by constructing the land's underlying rent, or value. According to the theory, rent has something to do with land's biophysical characteristics such as the availability of water, and the quality of the soil quality. In this theory, proximity to the central market determines land rent because this affects the costs of transportation of bulky and perishable farm produce. This is the reason why production of crops with expensive transport costs and expensive value costs takes place close to the central market. Additionally, production decreases with farther distance to market within each land use type. Land rent presents itself through the highest amount that any intending land user would be ready to pay for using that land-a term called “bid rent”. The extent and intensity in the use of land change as the bid rent changes and this is determined by a lot of factors like new technologies, road construction, climate change and conditions of market. These changes increase the frontier of the land use specifically by expanding and increasing the profitability of the land use (Angelsen, 2010). Land use influenced by conditions of market in which land could be rented or bought and in which produced goods on land are sold in local central market is the original description of this theory.

There is a general relaxation of these assumptions when contemporary contexts are studied. During colonial era, local land users always reacted to distant markets leading too intensive land uses that are located distant from the target market, where there are no or insufficient labour, land, or product markets. Theories of "shadow rents" or "shadow prices"—the value that households place on slight changes in these variables—are frequently applied in these situations. This theory has been extensively utilised to explain changes in agriculture, urbanisation, and deforestation. (Walker, 2004; Angelsen, 2007). Although this theory explains large patterns of land use but fails to elucidate local level specificity (that is, parcel) of land-use change resulting from the decision making of an individual.

2.2.3 Migration theory

2.2.3.1 Push and pull theory

This theory was presented by Everett Spurgeon Lee in 1965. According to the theory, migration is generally described as a change in residence either on permanent or semi-permanent basis. According to the theory, every act of migration requires an origin, a destination and obstacles that can intervene irrespective of the distance and difficulty faced in such movement. According to him, the reasons why people migrate are functions of push and pull factors. These are the two forces that either attract people to move to a new location or compel them to leave old residences. It could be environmental, cultural, economic or political.

Push factors are conditions that can compel people to leave their places of residence. Examples of push factors especially in rural areas and among farmers are unfavourable weather condition, poor soil profitability, deforestation, climate change, insecurity, disasters, hunger, land/soil degradation, land insecurity, demographic pressure among others. On the other side, pull factors are the factors that draw people to a certain location. They are the exact opposite of push factors. Better educational possibilities, better weather, better career prospects, better farming activities, and other things are examples of pull forces among farmers and in rural areas. Although this hypothesis inspired research of the different elements affecting migration, it neglected to take into account the traits of migrants, their assimilation at their destinations, or their motivations for migrating.

All the theories discussed above are very germane to this study because they offer intuition into the dynamics and nature of climate change, land use change, migration and food security in Nigeria. In this regard, it should be noted that the migration has been caused by the eagerness of the groups that are mostly affected to advance and protect the interests of their food security in the face of incessant dwindling ecological space, scarcity of resource, increase in population, crisis in livelihood, competition in resource. Considering North-Central, the situation has been exacerbated by the climate change-induced migration of farmers (Adogi, 2014).

2.2.4 Food security theory

The review of Food Security is based on World Food Programme (WFP) of FAO (1996). FAO (1996) categorized food security into four components viz: food availability, food accessibility, food stability and food utilization/consumption

2.2.4.1 Food availability theory

Food availability as described by FAO (1996) is when the appropriate food quality with adequate quantities are being supplied either via local production or imports (including food aid) are available. Food production which is an important aspect of the food availability includes subsistence and commercial agriculture, livestock production, fisheries, aquaculture, hunting among others. This is the beginning of the food system which provides essential raw materials for processing and food system. Any decline in the productivity of food production will ultimately have effects on food security (Snitter and Berry, 2019).

The conditions of climate like temperature and rainfall patterns have direct influence on food production like modulation of irrigation and water management techniques (McMichael *et al.,* 2017). Also, nutritional quality of food is affected by climate related factors effects on biodiversity, fresh water, soil degradation, fisheries and so on (UNEP, 2018). Globally, increase in global warming will significantly affect food production (Fanzo *et al.,* 2018). Although climate change may offer numerous chances for food production in Nigeria, such as an extension of the growing season and an increase in the time when animals can graze outdoors, an extreme drought may severely hamper food production in the North Central Region, which is Nigeria's primary agricultural region (Okeleye *et al.,* 2023).

2.2.4.2 Food accessibility theory

Food accessibility is when people have access to resources required for getting appropriate nutritious diet as food (FAO, 1996). Food distribution is the link between availability and accessibility components of food security (Snitter and Berry, 2019). Climate change can hinder network of distribution of food. Climate change affects virtually all modes of transportation in Nigeria which undermine food security especially in rural areas of the country due to their low ability to produce or store food products locally.

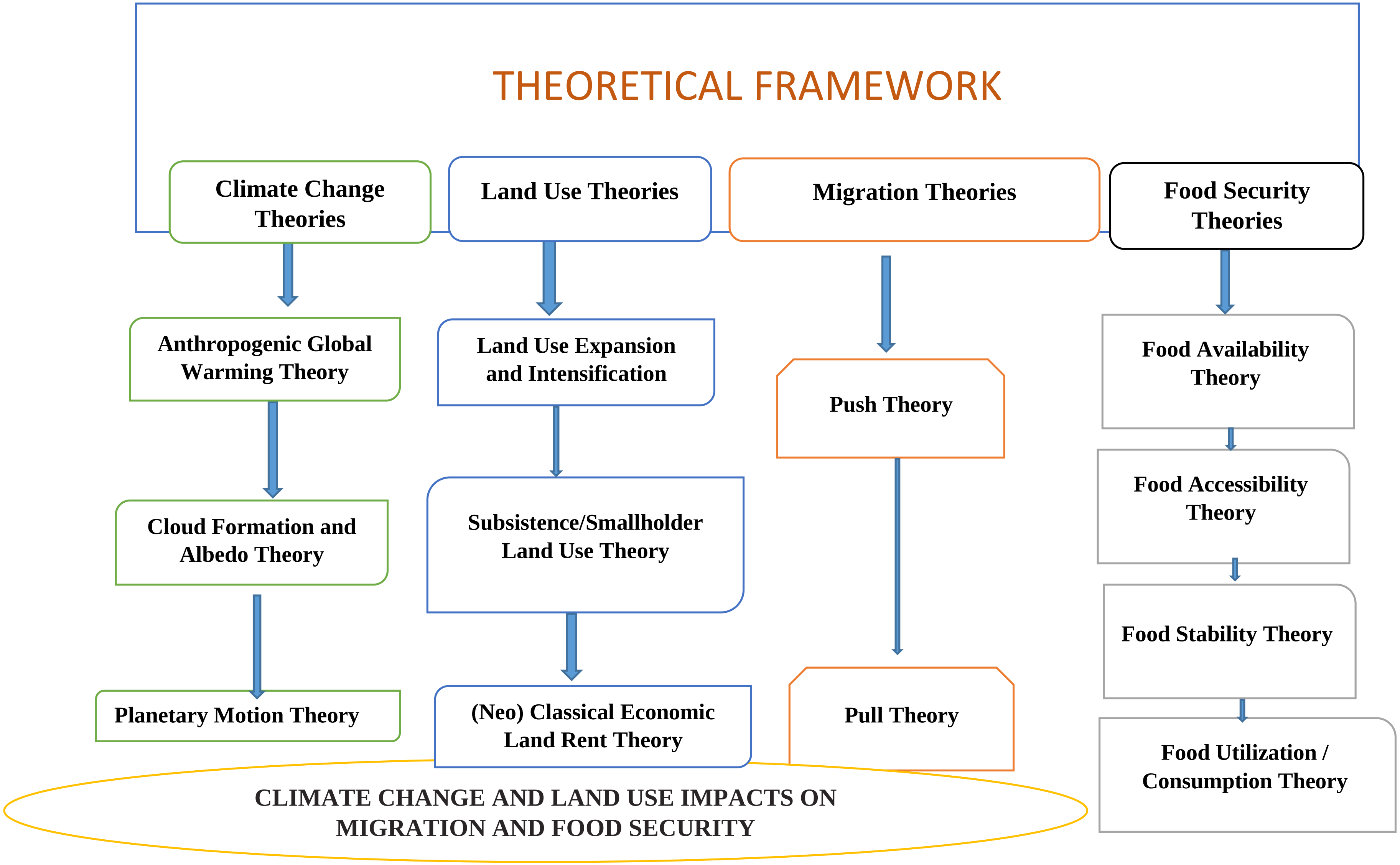
2.2.4.3 Food stability theory

FAO (1996) defined food stability as a situation in which an individual, household or population have access to enough food every time. Food processing which is an essential part of food stability is the conversion of raw food materials into food products that are consumed directly by people or used in the preparation of meals (Snitter and Berry, 2019). This aspect of food system which include preparing, washing and sanitizing safe food for the consumption of human has a direct link to human health (Snitter and Berry, 2019). Despite the fact that there haven't been many studies on the direct effects of climate change on the production of food in Nigeria and the North Central Region of the country, there are some indications that this is the case (Campbell *et al.,* 2014; Ziska *et al.,* 2016; Fanzo *et al.,* 2018).

2.2.4.4 Food utilization/ consumption theory

Food utilization/ consumption as explained by FAO (1996) is when an individual is able to consume food in form of clean water, adequate diet, health care and sanitation in order to reach a condition of well-being that meet all the physiological needs of that person. According to Biehl *et al.* (2017), this food is consumed must be safe, prepared in culturally acceptable way and must not lose its appropriate adequate nutritional value so as to achieve food security (Snitter and Berry 2019). Climate change affects diet diversity and composition (Springmann *et al.*, 2016). In North Central Nigeria, traditional meals which contribute to healthy diets are mostly consumed and this can be jeopardized with the negative impacts of climate change.

In summary, adequate functioning of food system is an integral part of food security (food availability, food accessibility and food utilization) and all these dimensions are interrelated. Disruption in any of these dimensions of food security in North Central Region of Nigeria will make food security in Nigeria unattainable. Figure 2.2 shows the graphical summary of the theoretical framework.



Adapted and Modified from Bast (2010), Meyfroidt (2018), Lee (1966) and FAO (1996)

Figure 2.2 Theoretical Framework

2.3 Review of Related Studies

2.3.1 Climate change and food security

A situation in which every human being, at every time, has social, economic, and social access to food that is sufficient, nourishing, and safe to meet their dietary needs and food preferences needed for their healthy and active lives is referred to as having food security (FAO, 1996). Food insecurity frequently contributes to poverty and hinders the ability of families, communities, and nations to flourish and succeed over the long run. A report by FAO (2004) stressed that agricultural practice is a key to achieving food security in many countries of the world. The report further explains that agricultural practice contributes to poverty reduction by reducing prices of food, improving employment creation, increasing farm income and improving wages.

Despite the presence of crude oil, agriculture, which serves as the primary means of subsistence for the majority of Nigerians, is the foundation of the country's economy (FAO, 2019). Through the analysis of different food security policies implemented in Nigeria, Matemilola and Elegbede (2017) conducted a study on the challenges of food security in Nigeria. They discovered that some of the factors working against food security in Nigeria include insufficient production, gender inequality, ineffective policies, and corruption, conflicts and civil unrest, climate change and natural disasters, low technology for processing and storage. Inability to develop a strong, enduring, and integrated policy to facilitate good available resources to end the conflict-climate change-food insecurity nexus is one of the major challenges Nigeria, especially the North-Eastern region of the country, faces. Despite the extensive review of the present food security situation in Nigeria by the authors, empirical data were not used to validate their claims.

Agriculture should be made to be a popular and a business that is climate-resilient and traceable to agro-based to drive economic, reduce poverty, employment generation, and achieve food security of the country. Additionally, farmers and pastoralists in the area must be able to quickly adjust to climate change if the North-Eastern region of Nigeria is to have food security (Fudjumdjum *et al.,* 2019). The three most important factors that determine how crop farmers in states in Nigeria adapt to the negative effects of climate change are farm size, people's perceptions of the climate and its effects, and barriers to adaptation and agricultural extension agents should intensify raising awareness of these issues (Olutegbe and Fadairo, 2016).

Furthermore, climate change is regarded as one of the environmental issues of this generation that poses a threat to both human existence and the environment because it poses a serious threat to food security and agricultural productivity in many countries in sub-Saharan Africa, including Nigeria (Okoli and Ifeakor, 2014). Globally, the World Bank estimates that 793 million people are malnourished and 702 million people live in extreme poverty (Skullerud, 2018). Despite the fact that more than half of the population depends on agriculture, the Federal Ministry of Agriculture of Nigeria reports that in 2018, an estimated 65% of Nigeria's population experiences food insecurity. This is because 90% of the agricultural produce are from subsistence farming, hindered by climate changes emanating from flood, drought, pest and disease manifestation and unfavourable temperature resulting in Nigeria having more than 13 million people that are suffering from malnutrition and hunger (FAO, 2016). The rural areas in Nigeria have become susceptible to malnutrition, low quality food, erratic food supplies, very expensive food cost, and even a complete absence of food, which is particularly prevalent in northern Nigeria where the majority of the 14 million farmers are small-scale subsistence farmers (Saheed and Isa, 2017).

2.3.2 Relationship between climate change and migration

Environmental migrants are persons who are compelled or willingly choose to vacate their homes as a result of unexpected or continuous changes in the environment, which negatively impact the living conditions of the persons displaced within their country or outside their country (IOM, 2014). It should be noted that persons that are compelled to move outside their country because of natural hazards and sudden environmental and climatic events are not considered refugees but environmental migrants. Migration added to the evolution of the societies we live in today which has become part of history we share.

The causes and results of migration are complicated and multifaceted. Some people quit their homes because of conflict or penury while some move under peace conditions, development and political stability. According to the report of the Human Development, more than 10 percent of the population of the world's population had internal migration and the United Nations Environment Programme (UNEP) said that there will be about 50 million environmental migrants in Africa by 2060 (Afifi, 2011).

Despite trends in urbanization rural-rural migration is frequent in many developing countries because it is less expensive and it requires lesser investment in new skills. In developing countries such as Nigeria, migration is a potent mode of climate change adaptation. Rural households migrate in Nigeria so as to diversify the sources of income of the family across sectors, and regular income during the unpredictable circumstances related to climate shocks and climate variability (Okeleye *et al*. 2023). Although some of these studies used empirical data to show the relationship between climate change and migration in Nigeria and North Central Region of Nigeria but the potential future impacts of this relationship are missing in some of these studies.

2.3.3 Effects of land use change on food security

Branca *et al*. (2013) reviewed related studies on food security and sustainable land management. The findings indicated that there will be increase in yields when sustainable land management is adopted. Also the effects of yields can vary, but they are typically negative for live fences, terraces, improved fallows, and minimal tillage. It was shown that the use of cover crops, organic fertiliser, mulch, and water harvesting invariably increased yield. Furthermore, rainfall distribution is a key factor in determining the effects of sustainable land management on yields, and it has been discovered that locations with variable and low rainfall produce better yields.

In addition, according to Nigeria's Federal Ministry of Environment in 2010, the potential greatest environment problem in northern Nigeria is desertification. It has be having negative impacts on the production of crop and livestock and it is known as a cause of migration in northern Nigeria (IDMC and NRC, 2015). Nigeria is losing between 2,000 square kilometres and 3,500 square kilometres every year as a result of desertification (Mohammed, 2015, Werz and Conley, 2012). Most of these reports are reviews of the current situation of the effects of land use on migration on the national scale which did not include the opinions of the local people on the causes of land use change and its impacts on migration.

2.3.4 The links between migration and food security

Exploration of the relationships that exist between migration and food security involves a deeply rooted understanding of drivers of migration and various interactions that take place with each other. Food insecurity and outmigration may disrupt existing social cohesion in local communities. In Nigeria, there are evidences that food insecurity is a crucial driver of internal migration. Similar study has been discovered in Nigeria in which rural households involve in internal migration to cope with both ex ante and ex post agricultural risk instigated by that are related to the environment (Okeleye *et al.*, 2023).

According to FAO (2019), a household that is poor and that is not food secured has a 51 percent higher probability of chasing an internal migrant. This is because international migration comes with much costs, households that are poor and that are not food secured poor have a significantly lower probability of about 77 percent of accepting an international migrant in comparison with households that are rich and food secured. Food insecurity as a result of Natural hazards such as floods and droughts may lead to displacement and migration especially in developing countries which lack adequate measures of preventing and coping with the possible impacts that such occurrences might have on the population. Although this report is robust but it is on the global scale. Hence, there is a need to look at the link between migration and food security in Nigeria especially in North Central Region of Nigeria using empirical data.

2.4 Examples from Other Region

2.4.1 Climate change, land use change, migration and food security nexus: case studies of China and Burkina Faso

Some of the most urgent issues resonating in global sustainability discourses include climate change, land use change, migration, population shifts, and their interactions (Stapleton *et al*., 2017). Due to their scarce resources, developing nations are unable to cope with and adapt to these issues, which exacerbates them (Thomas *et al*., 2019). According to Mpandeli *et al* (2020), the main causes of migration in Africa as a whole include the rising risk of reduced precipitation, the frequency and intensity of cyclones along the Atlantic coast, ongoing desertification, environmental degradation, the depletion of fisheries, and sea level rise, among other factors. As a result of the regional nature of the issues, they suggested regional approaches and strategies to transform migration into an adaptation strategy. This can be done by using transformative approaches or qualitative system dynamics modelling to comprehend the intricately intertwined drivers of climate change, land degradation, migration, and food security (De Haas 2011).

Specifically because of its profound effects on food production systems, climate change is one of the key issues affecting food security in the nation. Grain growth seasons are shortened as a result of rising temperatures and drought (FAO, 2016). There could be significant losses of up to 8% in the yields of three important crops (corn, rice and wheat) by 2030 as a result of climate change related seasonal drought (International Food Policy Research Institute (IFPRI), 2018). Furthermore, economic growth and rapid urbanization have huge effects on agricultural practices of the country (Bao and Wu, 2002, Yu and Wu, 2018). Urbanization causes land conversion and migration with consequent challenges like loss or abandonment of arable land and abandonment of villages (Yu and

Wu, 2018). This has made many peasants to become landless (Yu and Wu, 2018). Many of the peasants have moved from villages to urban areas, which aids rapid urbanization process (Zhang and Song, 2013). Although rural-urban migration contributes greatly to urban population, it leads to significant labour loss in agricultural sector and this contributes to increase in the opportunity cost of labour-intensive farming and change in production patterns and behaviours (Jiang *et al.*, 2013).

Furthermore, there are evidences of climate change throughout Burkina Faso (IPCC 2014). For example, the southwestern and eastern parts of the country which usually have more favourable weather are now greatly hit by drought and high temperature. As a result of the location of the country, its climate is susceptible to seasonal and annual variation. Also, climate change is affecting this country in form of water shortage, erratic rainfall pattern and low agricultural yields. According to a report published by UNDP in 2020, the rainfall is expected to drop by 10 percent and the temperature is expected to increase by 1.4-1.6^{0}C by 2030 and this can increase the risk of bushfires and forest fires. Additionally, poor resource management and declined rainfall coupled with increasing population, high internal rural migration and desiccation of over 30 years have worsened land degradation in all the regions of Burkina Faso (Nebie and West, 2019). According to UNDP (2020), migration to the south has been a preferred livelihood strategy to overcome food insecurity in the northern region of the country.

2.5 The Overview and Key Issues of the Study

Climate change and land use change have become major concerns for the international community (Piguet *et al.,* 2011). Their impacts on migration and food security are increasingly gaining the attention of researchers and policy makers. Still, knowledge of these fields remain fragmented and limited (Piguet *et al.,* 2011). The full understanding of migration dynamics in terms of the environment, the economy, and politics is necessary given the controversy between natural and social scientists and the importance placed on environmental factors in migration dynamics that is based on both intellectual traditions and hard facts (IOM, 2016).

In addition, land degradation and migration are closely interconnected processes in many countries of the world and the relationship between them is very complex. It includes social, political, economic, environmental and demographic processes that are in operation from micro (local) to macro (global) scales (Metternicht, 2017).

Also, the field of study of climate change is highly political which means that statements and research that have to do climate change-migration nexus are hard to differentiate from politicized on climate change on its own (IPCC, 2007). Furthermore, despite the growing use of environmental migrants for the past two decades, there is still low in-depth studies on the subject (Piguet *et al*., 2011).

CHAPTER THREE

3.0 MATERIALS AND METHODS

This chapter deals with methods that the researcher used in carrying out this research. The chapter gives explanations to the materials description, methods description, method of data collection, method of data analyses and method of data presentation.

3.1 Description of Materials

The main instruments used for the collection of data were satellite images, questionnaires, Geographic Positioning System (GPS) and GIS tools. The summary of the means of data collection is indicated in Figure 3.1

3.1.1 Climate data

Climatic data of daily (minimum temperature, maximum temperature and rainfall) were obtained from NASA Power Data. NASA Power Data have been found to be useful for generating weather data sets in a situation where ground weather stations data are not available (Rodrigues and Braga, 2021). These three climatic parameters were chosen because of their influence in agricultural production. The duration chosen for both temperature and rainfall analyses was 36 years (1985-2020) for all three States (Niger, Kwara and Benue).

3.1.2 GIS and remote sensing

Portable Global Positioning System (GPS) was used to take all the coordinates needed and Landsat 5 TM, Landsat 7 TM+ and Landsat 8 remote sensing images covering 1990-2020 were employed for the study.

3.1.3 Migration data

Net migration data by United Nations for Nigeria for the period of 2005-2020 were downloaded from the World Bank's website (http://data.worldbank.org). These data were accessed on 29th November, 2022.

3.1.4 Crop yield data

Crops yields and estimated cultivated landmass data of maize, yam, cassava, rice and groundnut for 2005-2020 were extracted from National Reports on Wet Season Agricultural Performance published by the Nigeria's National Agricultural Extension and Research Liaison Services (NAERLS), Ahmadu Bello University, Zaria, Kaduna State. These crops were selected because they are being produced in abundance in North Central Region of Nigeria.

3.1.5 Sample survey

Primary data to validate results of the analyses of the GIS and satellite imageries were collected using expert interview, focused group discussions and questionnaires. Portable Global Positioning System (GPS) was used to take all the coordinates needed. River channels, and utility infrastructure, were examined and matched with all the images. Ground truthing exercises in the form of a collection of geographical coordinates via the use of Global Positioning Receiver (GARMIN GPS) and direct observation through transect walk were used to collect primary data on LULC. The coordinates that served as the reference system were used to represent the locations of the satellite imageries in the GIS analysis. This was done in order to establish the actual state of the vegetation and land use, which was then used as a benchmark to ensure and confirm the accuracy of the interpretation of the satellite images and to ascertain the dynamics of migration in the research region.

3.1.6 Secondary data

Satellite images were used to gather secondary data on LULC, including yield and land mass statistics for crops from 2005 to 2020. While crop yield statistics were utilised to determine the trajectory of food production and the state of food security, satellite imageries were employed for geographical analysis of LULC changes. The Landsat 5 TM, Landsat 7 TM+, and Landsat 8 remote sensing pictures from 1990-2020 were used to analyse LULC. Satellite images from 1990 were retrieved through the Portable Global Positioning System (GPS). For the three sampled States, Landsat 7 TM+ satellite pictures from 1990 and 2000 and Landsat 8 satellite images from 2013 and 2019 were downloaded for the three sampled States (Niger, Kwara, and Benue), all from the United States Geological Survey (USGS) website (earthexplorer.usgs.gov, accessed online on 17th January, 2022). Digital topographic maps produced in 1990, 2000, 2013, and 2020 were georeferenced to a common UTM coordinate system and used as base maps to geo-reference the Landsat images acquired in these years. Many ground control points, like intersections of roads and agricultural plots, river channels, and utility infrastructure were examined and matched with all the images. For the crop yield data, the National Agriculture Reports published by the National Agricultural Extension and Research Liaison Services (NAERLS), Ahmadu Bello University (ABU), Zaria, Kaduna State, Nigeria served as the source of documented information on the five crops' yields (yam, cassava, rice, maize, and groundnut) for the years 2005 to 2020.

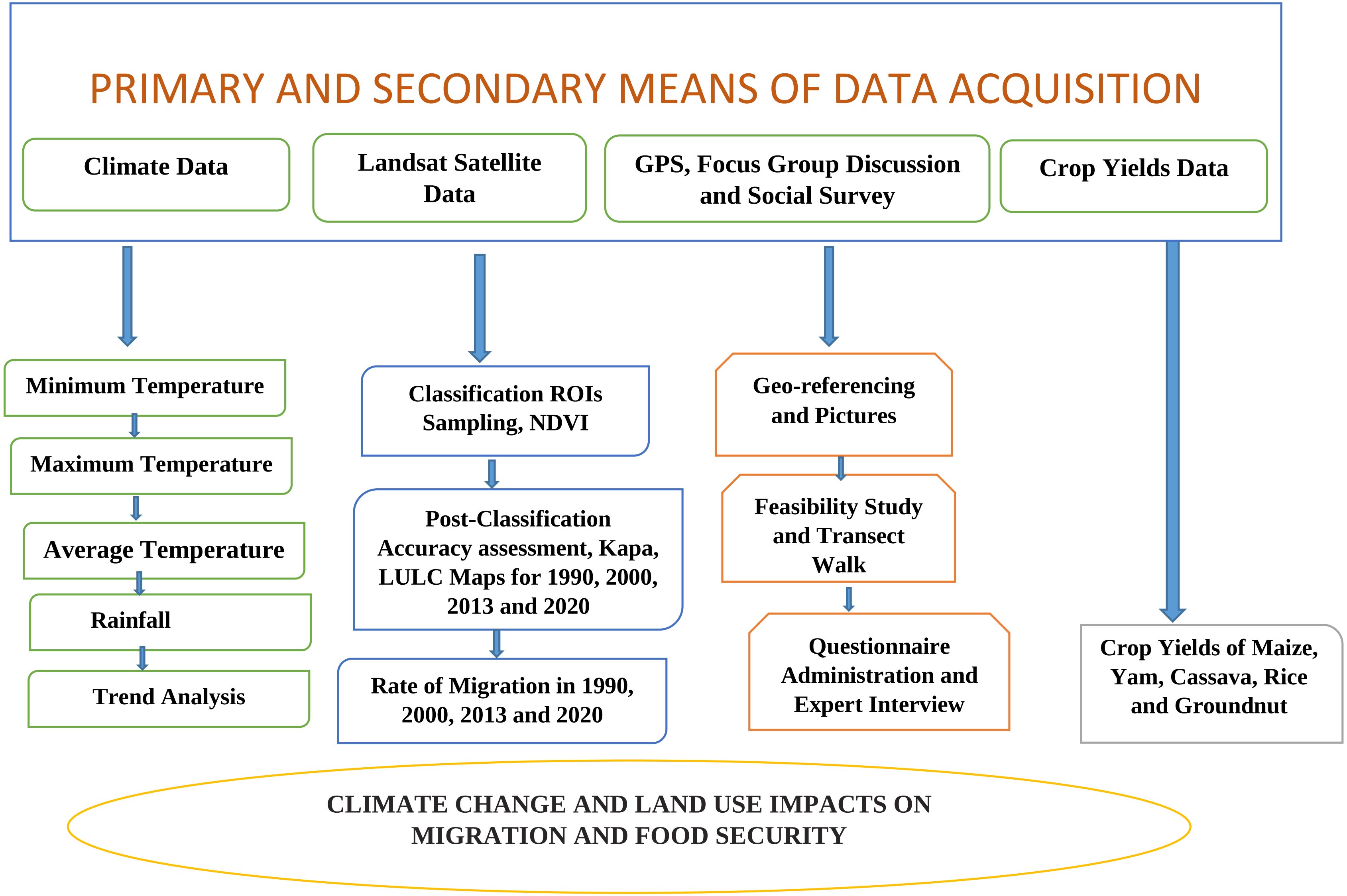


Figure 3. 1 Methodology Flowchart

Source: Author's fieldwork (2023)

3.2 Description of Methods

The research design refers to the steps involved in the research process. This research adopted the case study strategy. This allowed the use of both qualitative and quantitative methods.

3.2.1 Method of data collection

Both primary and secondary data were used for this study. The primary data involved the use of a semi structured questionnaire, expert interviews, focus group discussions, stakeholder's meetings and reconnaissance. All these activities took place between June 2021 and December 2021. A sample size of 600 respondents was chosen using a multi-stage random selection method. Due to the respondents' limited accessibility and availability, this sample size was chosen. Three States from north-central Nigeria were purposefully chosen for the initial stage because they have the highest land masses in the area. Thus, Niger, Kwara, and Benue states were chosen. Secondly, two agricultural zones from each of the six states that were chosen for the study were sampled. These two agricultural zones are the ones that are most impacted by migration and changes in land use. Thirdly, each agricultural zone produced two local government areas, for a total of twelve local government areas. In the fourth step, a total of twenty-four farming villages were created by randomly selecting two from each local government area. Finally, 25 farmers were chosen at random from each farming community, for a total of 600 farmers in the sample (200 respondents from each State). Table 3.1 lists the communities that were selected.

The information was gathered using a well-structured interview schedule that was written in English but was frequently translated into Hausa or Yoruba (the languages that the respondents understood and spoke) during the interview. Joint interviews have occasionally been utilised to obtain feedback from as many respondents as possible while sparing them from interview weariness.

In addition, the experts interviewed included the officials of Ministry of Agriculture, Agricultural Development Project (ADP) and International Fund for Agricultural Development (IFAD) in Niger, Kwara and Benue States. The participants included in the stakeholders' meetings held in the three States were traditional rulers, community leaders and farmers' leaders (Plates 3.1-3.2). They were selected based on their familiarity with the study area. Each of the States were represented by ten (10) members making a total of 30 members in the three States. During the Focus Group Discussion (FGD) held at each of the ADP zones, attendees included representatives of men, women and youth farmers (Plate 3.3). Ten (10) participants were drawn from each ADP zones making a total of 60 representatives across the three States and they were selected because they represented groups that are mostly affected by the negative impacts of land use change on migration and food security.

Plate 3.1: Researcher with some farmer leaders after a stakeholders' meeting

Source: Author's fieldwork (2023)

Plate 3.2: Researcher with some community leaders after a stakeholders' meeting

Source: Author's fieldwork (2023)

Plate 3.3: Researcher with some farmers after a Focus Group Discussion (FGD)

Source: Author’s fieldwork (2023)

Table 3. 1 List of the Selected Communities in the Study Area

NIGER STATE							
NIGER ADP ZONE 1				**NIGER ADP ZONE 2**			
Katcha LGA		**Bida LGA**		**Bosso LGA**		**Suleja LGA**	
Badeggi Community	Shaba-Woshi Community	Batavovogi Community	Debarako Community	Shata Shiqmar Community	Lokoto Community	Chaza Community	Rafinseyi Community
KWARA STATE							
KWARA ADP ZONE C				**KWARA ADP ZONE D**			
Asa LGA		**Moro LGA**		**Oke-Ero LGA**		**Irepodun LGA**	
Alapa Community	Ballah Community	Olooru Community	Shao Community	Imode Community	Ayedun Community	Araromi-Ipo Community	Okeya-Ipo Community
BENUE STATE							
BENUE ADP ZONE B OR NORTHERN ZONE				**BENUE ADP ZONE C OR CENTRAL ZONE**			
Makurdi LGA		**Gwer East LGA**		**Obi LGA**		**Otukpo LGA**	
Tse-Ayihe Community	Agan Communities	Ikapayongo Community	Taraku Community	Ijegwu Community	Okpokwu-Ito Community	Otobi Community	Asa-Otukpo Community

ADP: Agricultural Development Project
LGA: Local Government Area
Source: Author’s fieldwork (2023)

3.3 Method of Data Analyses

3.3.1 Examining the trends in temperature and rainfall patterns in North Central Region of Nigeria (1950-2019)

The Mann-Kendal test was applied to the meteorological data in order to identify temperature and rainfall trends. Furthermore, Excel xlstat software was used to determine the descriptive statistics of the climatological data.

3.3.2 Assessment of the spatio-temporal dynamics of land use within the period of 1980-2019

A composite band image comprising bands relevant to the analysis of land-use changes was made using ARC GIS 10.1. The Landsat 5 TM, 7 TM+, and 8 databases' bands 4, 3, and 2 correspond to near-infrared, red, and green colours, respectively. This results in a single layer multiband image that is appropriate for studies of vegetation cover and land use. Additionally, the vector shape files that were developed and the raster image (Landsat imageries) were given precise spatial references using the geographic coordinate systems from the World Geodetic System. After that, the photos were taken out for analysis. Maximum likelihood classification was used to classify the processed satellite images into the five LULC (Land Use and Land Cover) categories that are displayed in Table 3.2. Any scale over 0.5 to 1 indicates an accurate assessment, whereas scales below 0.5 were regarded to be inaccurate. The results were evaluated for accuracy using a scale range of -0.1 to 1.

Table 3. 2 Classification of Land Use and Land Cover

LULC CLASSES	DESCRIPTION
Vegetation	Grasslands, trees, shrubs, gardens, palms, orchids, forests and herbs.
Waterbody	Rivers, streams, ponds, wetlands, reservoirs, swamps and marshy areas.
Barren Land	Empty lands without grasslands, shrubs or trees.
Agricultural Land	Cropland, orchards, pasture, nurseries, groves, horticultural land, confined feeding operations lands, ornamental lands, groves and livestock pens.
Built up Area	Commercial, industrial and residential areas, transportation infrastructure and village settlement.

Source: Author's fieldwork (2023)

3.3.3 Evaluation of the resultant impacts of climate change and land use on migration as it affects food production

Additionally, images from Landsat 5 TM, Landsat 7 TM+, and Landsat 8 (1990-2020) were gathered for the study in order to identify the trends in land use changes and migration. These satellite data over a 30-year period will provide a useful examination of change detection in the local land use and land cover. Data was extracted for a descriptive quantitative study after satellite image datasets were analysed using remote sensing and GIS techniques. Regression analysis was used to examine crop yield data along with climatological data (air temperature and rainfall).

3.3.4 Identification of sustainable adaptation strategies to minimize the impacts of climate change and land use changes and migration monitoring at different levels

Both descriptive and inferential statistics were used to analyse the potential present and future land use and migration dynamics, as well as the socio-economic characteristics of the residents, in order to identify sustainable adaptation strategies to minimise the effects of climate and land use changes and migration monitoring at different levels. Using the SPSS and Excel software, the survey data was first checked for its statistical distribution. Specific statistical tests were applied and cross-tabulated after comparing the means of various variables with regard to distinct groups of households to see whether there are any statistically significant links between various variables.

3.4 Method of Data Presentation

The findings of the GIS and remote sensing image analyses were shown as maps, and the survey-method data were subjected to the appropriate statistical analyses. Descriptive and inferential statistics were used to the quantitative data gathered using the structured questionnaires and interview schedule. Inferential statistics used included crosstabulations while the descriptive analysis used included percentages, means, bar charts, pie charts, and frequency counts.

3.5 Statistical Treatment

3.5.1 Accuracy assessment

The technique of quantifying an estimated remote sensing dataset is called accuracy assessment (Abbas and Jaber, 2020). It can be characterised as the degree of similarity between created maps and reference maps, and it is one of the crucial last steps in the classification of an image (Amini *et al.*, 2022). Most often, the degree of accuracy is assessed using the kappa coefficient and overall classified accuracy. Kappa coefficient is used to determine the proportion of improvement by the classifier classes that are purely assigned randomly (Njoku and Tenenbaum, 2022; Pal and Zial, 2016) while the producer and user accuracies are used to determine the proportion of the map that is correctly classified from the point of views of producer and user respectively (Njoku and Tenenbaum, 2022). The Kappa coefficient ranges between -1 and 1. According to Monserud and Leemans (1992) and Amini *et al*. (2022), a value of 0 indicates that there is no degree of agreement while a value close to 1 shows an excellent degree of agreement and a negative value indicates a very poor degree of agreement (Amini *et al*., 2022).

$$\text{Accuracy}=\frac{Tp+Tn}{Tp+Tn+Fp+Fn} \tag{3.1}$$

Where Tp, Tn, Fp and Fn are number of true positive, true negative, false positive and false negative respectively.

$$\text{Pa}=\sum_{i=1}^{c} pii \tag{3.2}$$

Pa is the simplest and mostly used level of agreement

$$\text{Pb}=\sum_{i=1}^{c} pi.\,pi \tag{3.3}$$

$$K=\frac{Pa-Pb}{1-Pb} \quad (3.4)$$

Where Pa, Pb and K are relatively observed agreement, probability that agreement due to chance and Kappa coefficient respectively.

3.5.2 Annual Percentage Change and Annual Rate of Change

$$Mc = A2 - A1 \quad (3.5)$$

$$Ac=\frac{Mc}{\sum LULC} \times 100 \quad (3.6)$$

A negative value indicates a decrease while a positive value indicates an increase

$$Ar = Ac \div \frac{100}{Y2-Y1} \quad (3.7)$$

Where Mc, Ac, Ar and LULC are values of magnitude of change, annual percentage change, annual rate of change and Land Use and Land Cover classes respectively while Where Ac, is the annual percentage change, A1 is the extent of initial area of each of the LULC classes at initial year (Y1) and A2 is the extent of the final area of each of the LULC classes at final year (Y2).

3.5.3 Impacts of LULC on migration

Univariate regression analysis was used to show the impacts of changes in LULC on migration in Niger, Kwara and Benue States. Statistical Package for Social Sciences (SPSS)-IBM SPSS Statistics 25 version was used for the statistical analysis.

$$\Delta NetMig = constant + (\beta \times \Delta VG) + (\gamma \times \Delta WB) + (\mu \times \Delta AL) + (\lambda \times \Delta BL) + (\phi \times \Delta BA) \quad (3.8)$$

Where ΔNetMig is the observed change in Net Migration due to changes in vegetation (VG), water body (WB), agricultural land (AL), barren land (BL) and built-up area (BA).

Similarly, β, γ, μ, λ, and ϕ are coefficients of vegetation, water body, agricultural land, barren land and built-up area respectively. Furthermore, ΔVG, ΔWB, ΔAL, ΔBL and ΔBA are observed changes in vegetation, water body, agricultural land, barren land and built-up area respectively. Significance level (alpha) of 0.05 was used.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Presentation and Analysis of Results

4.1.1 Examining the trends in temperature and rainfall patterns in the study area

4.1.1.1 Trends analysis of temperature and rainfall patterns in Niger, Kwara and Benue States

(a) Trends analysis of temperature and rainfall patterns in Niger State

Figures 4.1-4.4 show the graphs of minimum temperature, maximum temperature, average temperature and annual rainfall for Niger State. From the Mann-Kendall result of Niger State, it was found out that the values of Sen's slope for minimum temperature, maximum temperature and average temperature were 0.047°C, 0.066°C and 0.059°C respectively (Table 4.1). These positive values indicate an upwardly and increasing trend over time. The result also shows that there is a significant increase in the trend at a 5% level of significance since the computed p-value (<0.0001) is less than the significant level, alpha (0.05) (Table 4.1). So, the null hypothesis can be rejected. The significant increase in the mean annual temperature over 36 years in Niger State is an indication of climate change in the State and this is in tandem with the outcomes of many studies that indicated increase in global and Nigeria average temperatures (Hansen *et al*. 2010, Lindsey and Dahlman, 2020, Ojekunle *et al.*, 2014).

Regarding the rainfall of the State, there is a significant downward trend and decreasing trend over the period of time as indicated in the negative value of Sen's slope (- 14.324) and computed p-value being less than alpha (0.05) which means the null hypothesis can be rejected. It can also be inferred from the result of this study that the annual minimum temperature, annual maximum temperature and annual average temperature increases by 0.047°C, 0.066°C and 0.059°C per year respectively while the annual rainfall decreases by 14.324mm per year. This is similar to the findings of Ojekunle *et al*. (2014) that there is an increase in temperature and decrease in rainfall in many parts of Nigeria. If the decrease in rainfall persists, there will be incessant drought and decline in water availability for agricultural production in the State. The increase in temperature in the State will lead to increase in evaporation and also affects crop water supply-demand gap the crop's increased water needs worsen the water supply-demand imbalance.

Table 4. 1 Trend Analysis of Air Temperature and Rainfall for Niger, Kwara and Benue States

State	Test	Min Temp	Max Temp	Average Temp	Rainfall
Niger	P-value (two-tailed)	<0.0001	<0.0001	<0.0001	0.006
	Mann-Kendall stat (S)	330	296	324	-204
	Kendali's tau	0.524	0.470	0.514	-0.324
	Alpha	0.05	0.05	0.05	0.05
	Sen's slope Q	0.047	0.066	0.059	-14.324
	Var (s)	5390	5390	5390	5390
	Trend	**Increasing**	**Increasing**	**Increasing**	**Decreasing**
Kwara	P-value (two-tailed)	0.002	0.817	0.099	0.902
	Mann-Kendall stat (S)	234	18	122	-10
	Kendali's tau	0.371	0.029	0.194	-0.016
	Alpha	0.05	0.05	0.05	0.05
	Sen's slope Q	0.020	0.04	0.012	-0.328
	Var (s)	5390	5390	5390	5390
	Trend	**Increasing**	**Insignificant**	**Insignificant**	**Insignificant**

Benue	P-value (two-tailed)	<0.0001	<0.0001	<0.0001	0.010
	Mann-Kendall stat (S)	329	302	340	-190
	Kendali's tau	0.523	0.479	0.540	-0.302
	Alpha	0.05	0.05	0.05	0.05
	Sen's slope Q	0.036	0.052	0.044	-11.661
	Var (s)	5390	5390	5390	5390
	Trend	**Increasing**	**Increasing**	**Increasing**	**Decreasing**

Source: Author's fieldwork (2023)

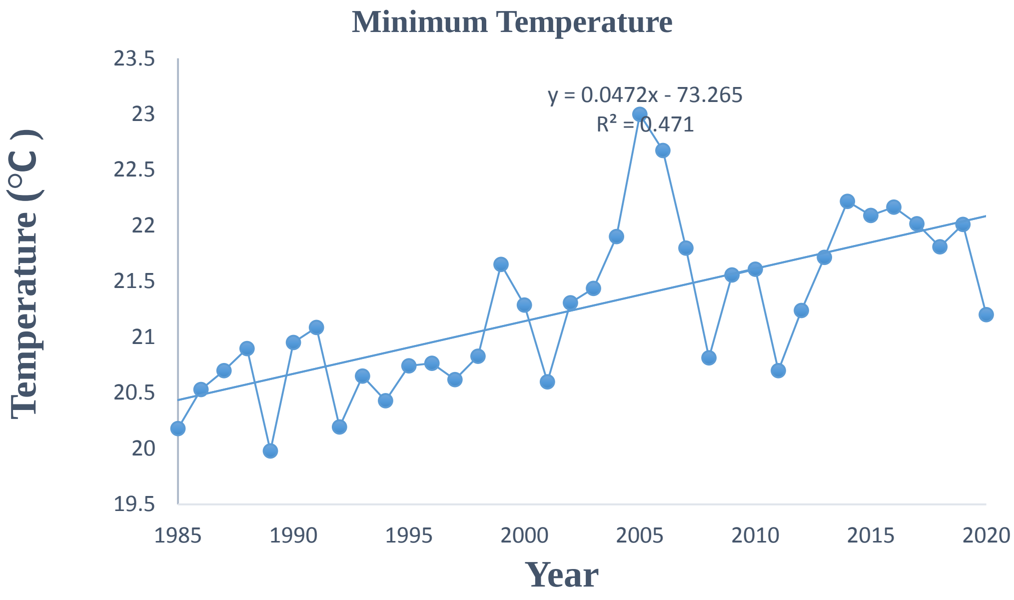


Figure 4. 1 Plot of minimum temperature from 1985 to 2020 for Niger State

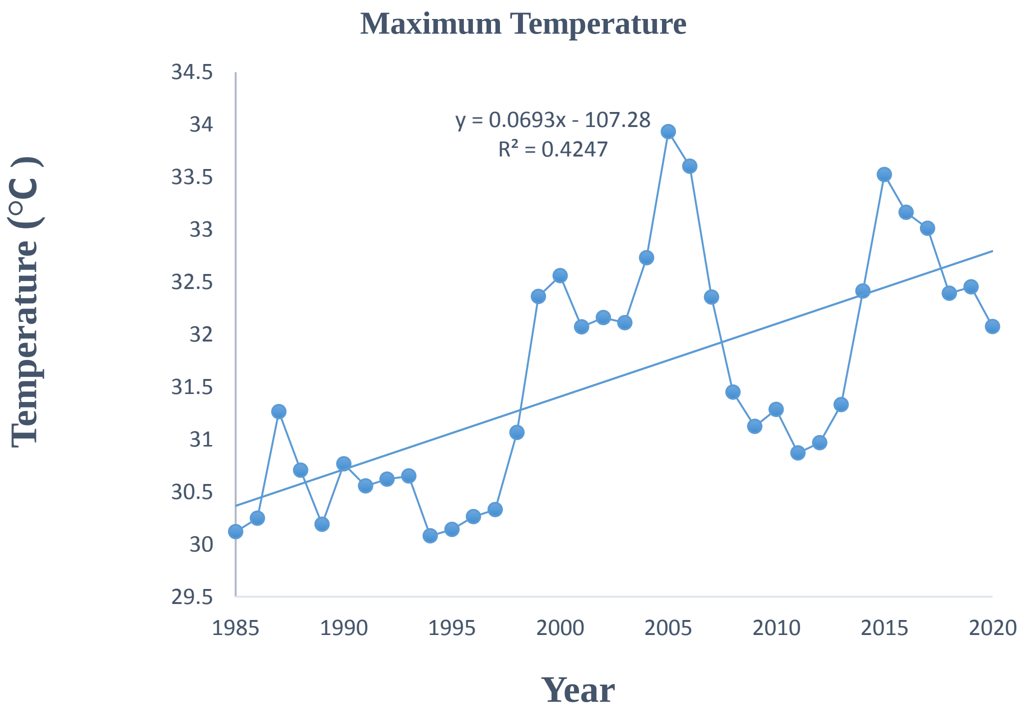


Figure 4. 2 Plot of maximum temperature from 1985 to 2020 for Niger State

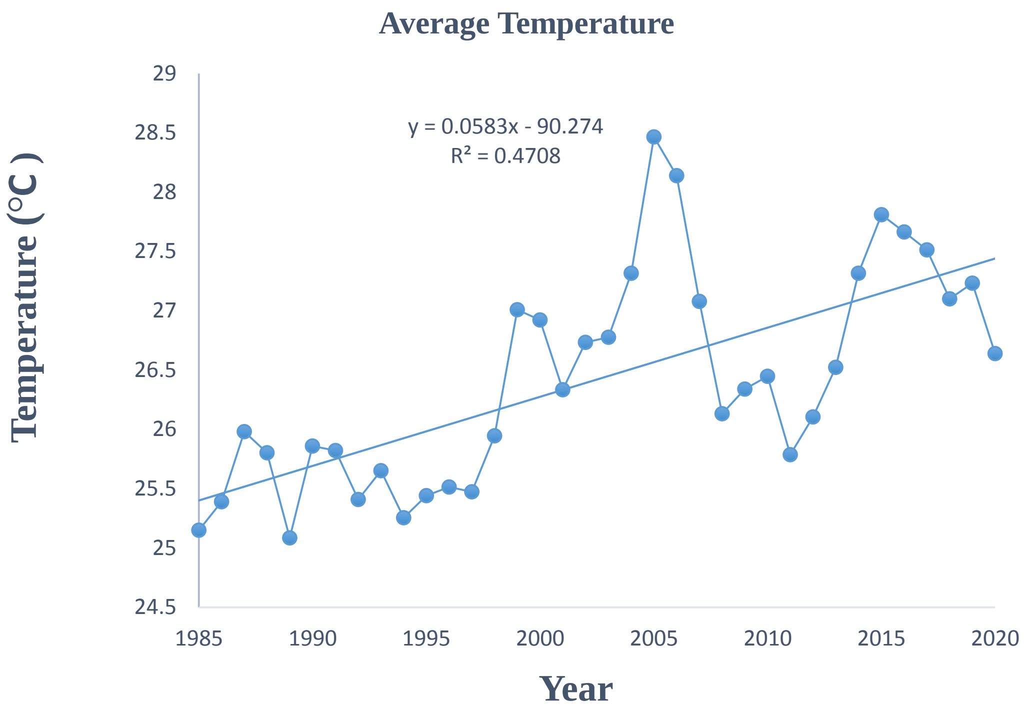


Figure 4. 3 Plot of average temperature from 1985 to 2020 for Niger State

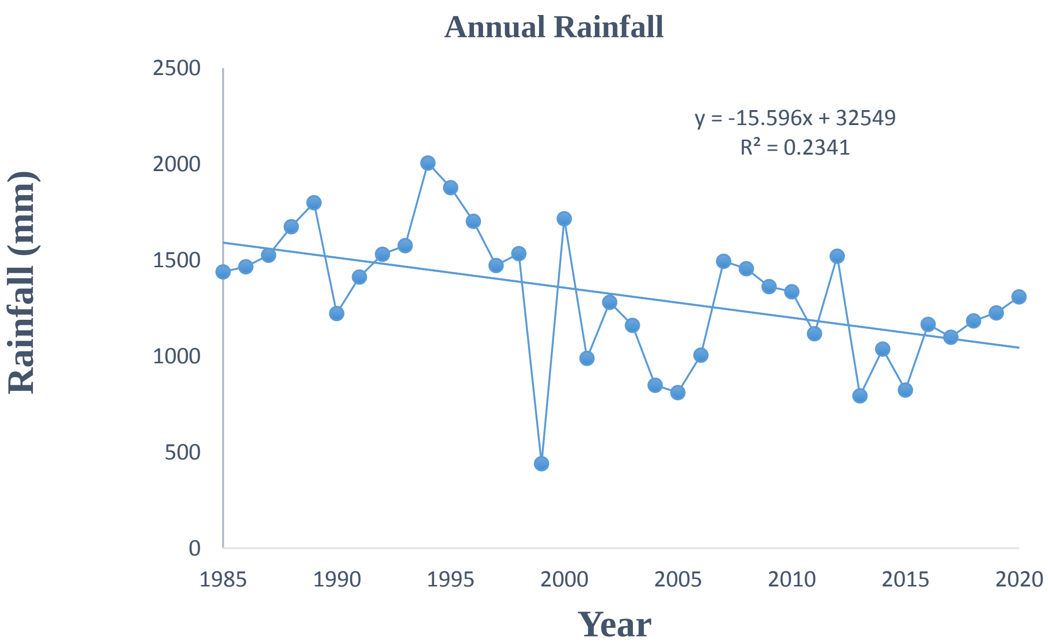


Figure 4. 4 Plot of annual rainfall from 1985 to 2020 for Niger State

(b) Trends analysis of temperature and rainfall patterns in Kwara State

Figures 4.5-4.8 depict the graphs of minimum temperature, maximum temperature, average temperature and annual rainfall for Kwara State. In Kwara State, as depicted by Figures 4.5-4.8, there is significant upward and increasing trend in minimum temperature as indicated by computed p-value of 0.002 which is less than the alpha of 0.005 and positive value of Sen's slope (0.02). This means the null hypothesis can be rejected and alternative hypothesis can be accepted. Conversely, there is a positive insignificant trend in maximum and average temperatures because of respective computed p-values of 0.817 and 0.099 which are greater than alpha of 0.05. This means null hypothesis can be accepted and alternative hypothesis can be rejected. This is in partial conformity with the findings of Adedapo (2020) that there is statistically significant difference in minimum and maximum temperature in Kwara State between 1978 and 2017

In addition, there is a negative insignificant trend rainfall pattern in Kwara State with computed p-value of 0.902 and Sen's slope of -0.328 as indicated in Table 4.2 Since the computed p-value is greater than alpha value, the null hypothesis can be accepted while alternative hypothesis can be rejected. It is also observed from Table 4.1 that the annual minimum temperature, annual maximum temperature and annual average temperature increases by 0.02°C, 0.04°C and 0.012°C per year respectively while the annual rainfall decreases with an insignificant value of -0.328mm per year.

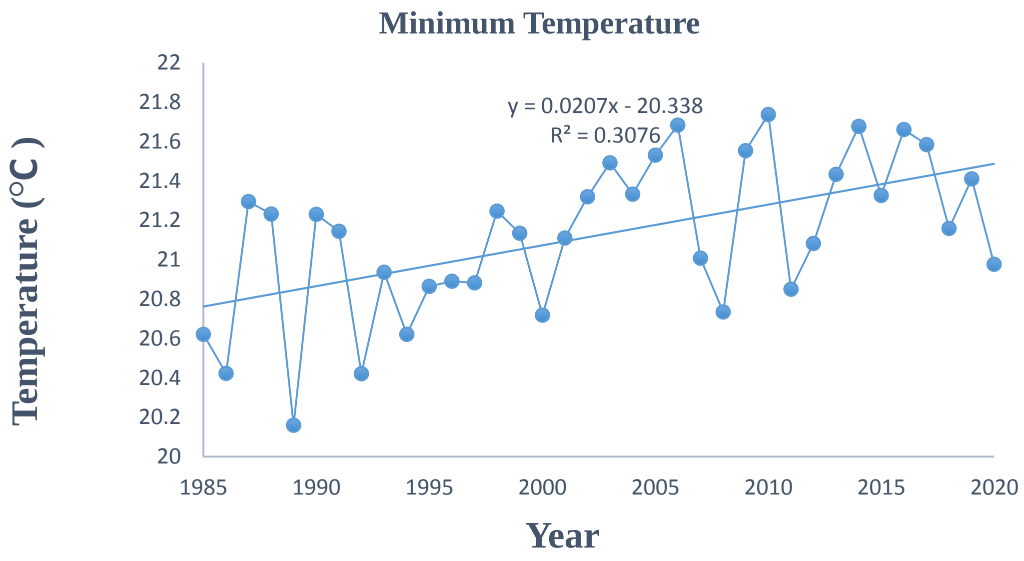


Figure 4. 5 Plot of minimum temperature from 1985 to 2020 for Kwara State

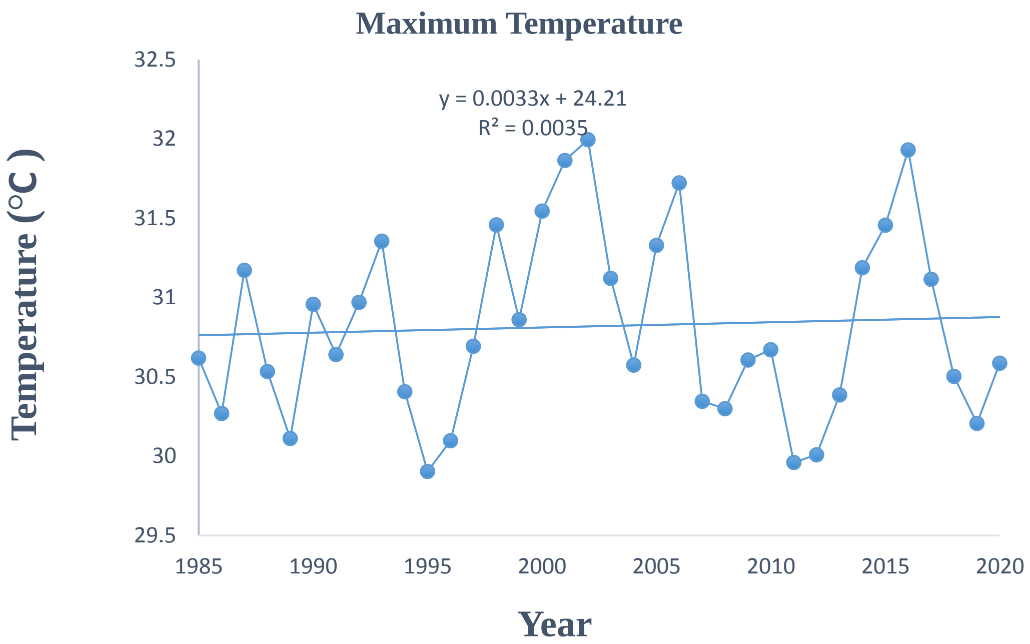


Figure 4. 6 Plot of maximum temperature from 1985 to 2020 for Kwara State

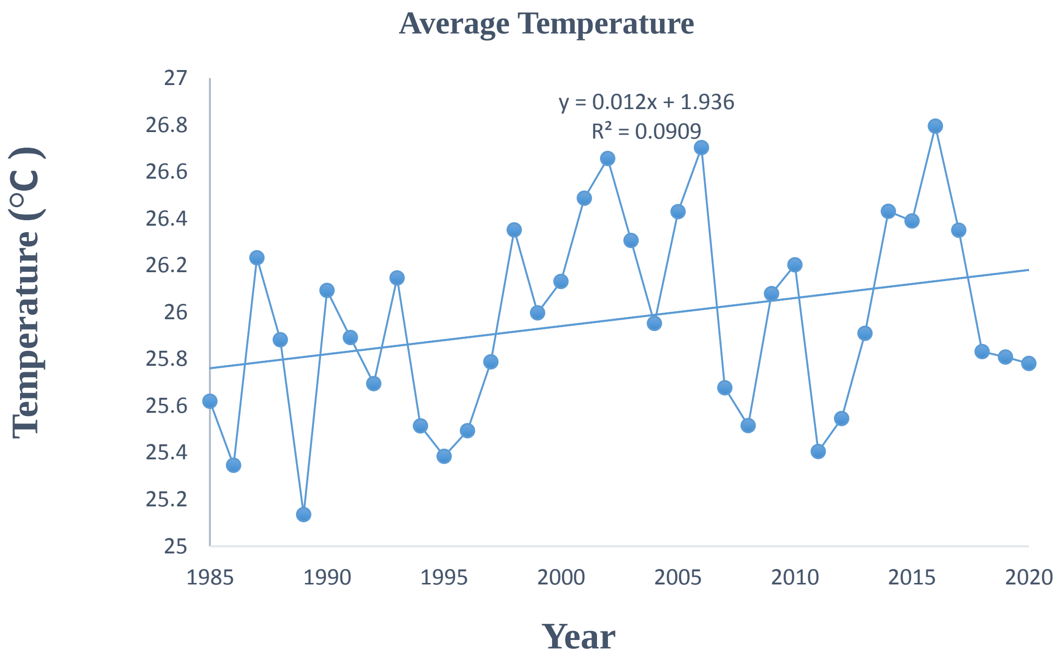


Figure 4. 7 Plot of average temperature from 1985 to 2020 for Kwara State

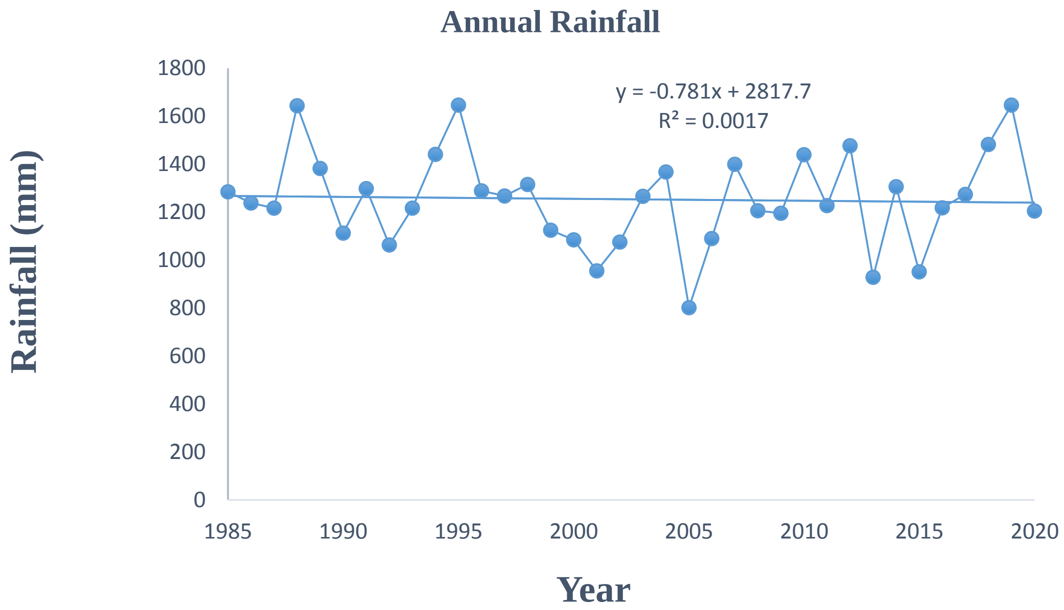


Figure 4. 8 Plot of annual rainfall from 1985 to 2020 for Kwara State

(c) Trends Analysis of temperature and rainfall patterns in Benue State

Figures 4.9-4.12 describe the graphs of minimum temperature, maximum temperature, average temperature and annual rainfall for Benue State. A significant positive increasing trend is observed in minimum temperature, maximum temperature, average temperature of Benue State with respective Sen's slope values of 0.036, 0.052 and 0.044 respectively and p-value that is less than 0.0001 as indicated in Figures 4.9-4.11 and Table 4.1. This result suggests that the null hypothesis can be rejected. However, Figures 4.12 and Table 4.1 show a significant downward and decreasing trend in the rainfall pattern over period of 36 years due to negative value of Sen's slope (-11.661) and computed p-value (0.010) that is greater than alpha value (0.05). Consequently, the null hypothesis states can be rejected. This is contrary to the findings of Aho *et al.* (2019) that there was a negative decreasing statistically insignificant trend in the annual rainfall of some parts of Benue State between 1955 and 2015. Also, from Table 4.1, the annual minimum temperature, annual maximum temperature and annual average temperature increases by 0.036°C, 0.052°C and 0.044°C per year respectively whereas the annual rainfall decreases by 11.661mm per year.

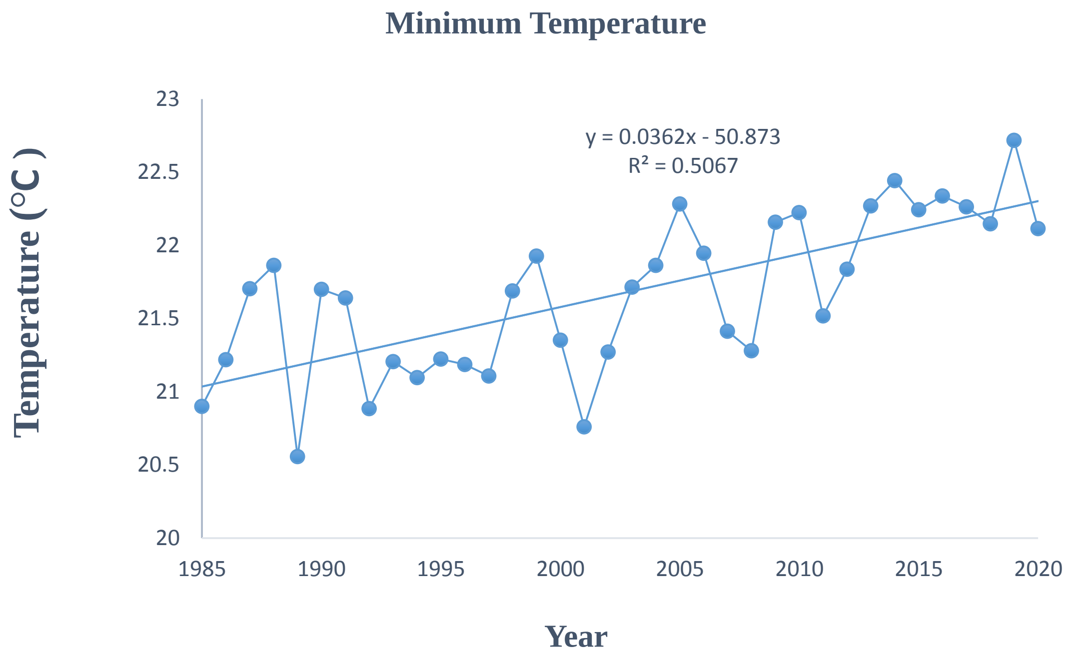


Figure 4. 9 Plot of minimum temperature from 1985 to 2020 for Benue State

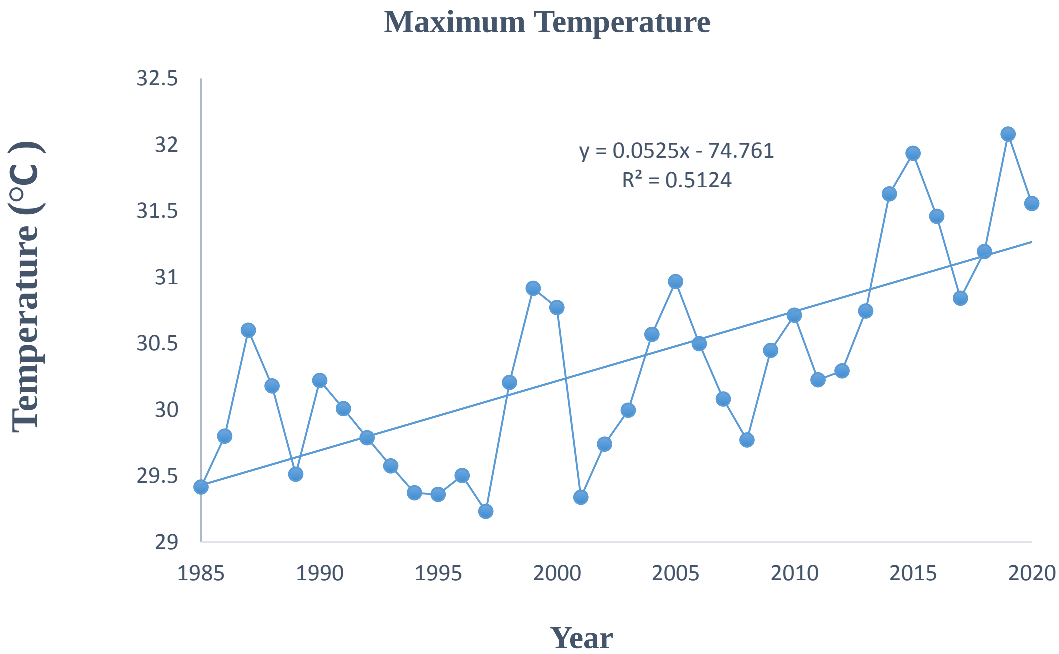


Figure 4. 10 Plot of maximum temperature from 1985 to 2020 for Benue State

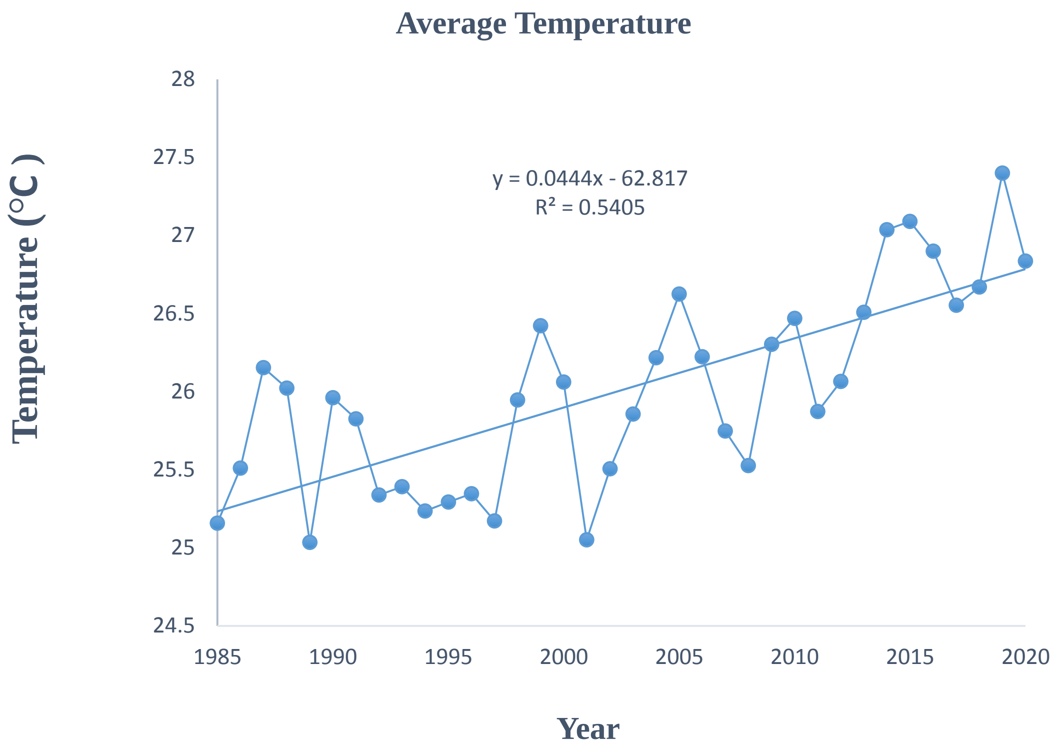


Figure 4. 11 Plot of average temperature from 1985 to 2020 for Benue State

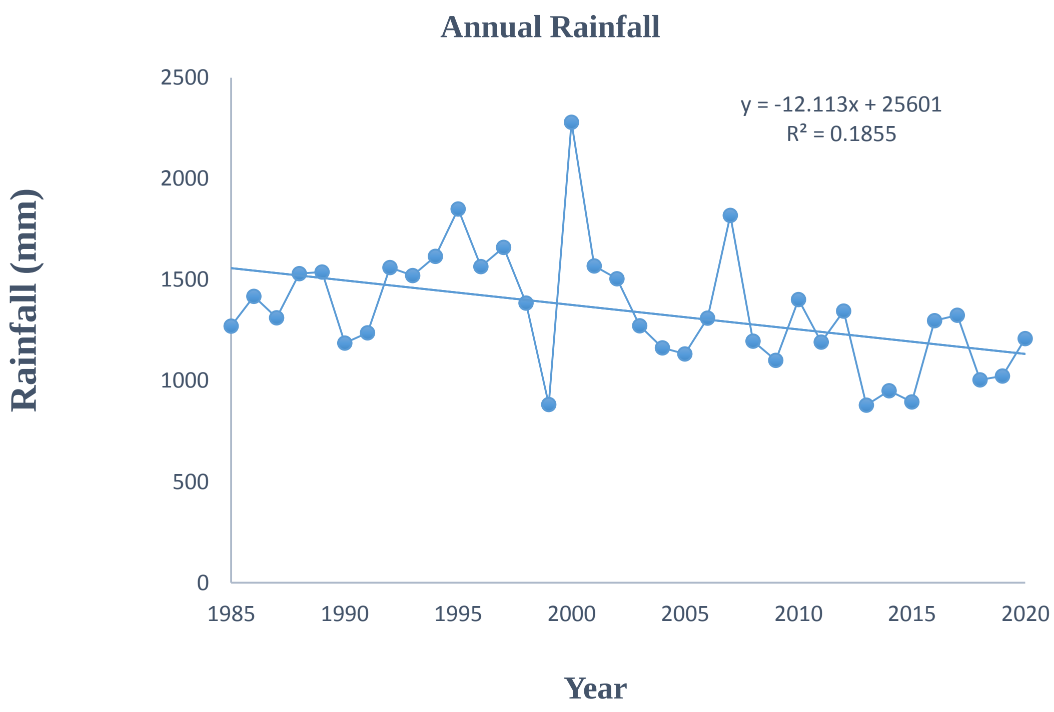


Figure 4. 12 Plot of annual rainfall from 1985 to 2020 for Benue State

4.1.1.2 Descriptive statistics of air temperature and rainfall in Niger, Kwara and Benue States

Table 4.2 shows the descriptive statistics of air temperature and rainfall in Niger, Kwara and Benue States over a period of 36 years (1985-2020). For Niger State, the average annual minimum temperature ranges from 19.98°C to 23.00°C while average annual maximum temperature ranges from 30.08°C to 33.93°C whereas the average annual average temperature ranges from 25.09°C to 28.47°C. Furthermore, the average annual rainfall ranges from 440.480mm to 2005.04mm. Their respective mean annual values are 21.26°C, 31.58°C, 26.42°C and 1317.21mm for minimum temperature, maximum temperature, average temperature and rainfall. According to method of classifying the degree of rainfall variability used for a study by Getachew (2018), rainfall variability is high when Coefficient of Variation (CV) is greater than 30 per cent, moderate when CV is less than 30 per cent and less variable when CV is less than 20 per cent. Based on this, it can be concluded that Niger State has a moderate degree of rainfall variability with CV of 25.78 per cent. Coefficient of Variation (CV) affects how much water is available to crops in the soil, which determines agricultural productivity. For most of the farmers in Niger State who only depend on rainfall, information on annual rainfall is crucial to overcoming their social and economic challenges.

In Kwara State, the average annual minimum temperature ranges from 20.16°C to 21.74°C and average annual maximum temperature ranges from 29.90°C to 32.00°C whereas the average annual average temperature ranges from 25.14°C to 26.80°C and average annual rainfall ranges from 802.15mm to 1253.69mm. Average annual minimum temperature has a mean of 21.26°C while average annual maximum temperature has a mean of 31.582°C whereas average annual average temperature has a mean of 26.42°C and average annual rainfall has a mean of 1317.210mm. Kwara State with a CV of 15.71

per cent has a low rainfall variability. These results are similar to the findings of Ayanshola et al. (2018) that the minimum annual average temperature in Kwara State between 1997-2015 Was 21°C while the maximum annual average was 33.3°C.

Regarding Benue State, the average annual minimum temperature varies from 20.56°C to 22.72°C with a mean of 21.699°C and standard deviation of 0.54°C while the average annual maximum temperature ranges from 29.23°C to 32.078°C with a mean of 30.348°C and standard deviation of 0.773°C whereas average annual average temperature falls within 25.03°C to 27.40°C with a mean of 26.01°C and standard deviation of 0.64°C and average annual rainfall varies between 878.95mm to 2280.25mm with a mean of 1344.67mm and standard deviation of 296.31mm. Benue State with a CV of 22.04 per cent has a moderate degree of rainfall variability. This is similar to the findings of Abugu *et al.* (2020) which indicated that the mean annual minimum temperature, maximum temperature and rainfall for Benue State are respectively 21.43°C, 32.73°C and 1358.88mm.

Table 4.2 Descriptive Statistics of Air Temperature and Rainfall

States	Parameters	Years	Tmin	Tmax	Mean	Var	SD	(CV) (%)
Niger	Tmin (°C)	36	19.98	23.00	21.26	0.53	0.73	3.41
	Tmax (°C)	36	30.08	33.93	31.58	1.26	1.12	3.55
	Average Temp. (°C)	36	25.09	28.47	26.42	0.80	0.90	3.39
	Rainfall (mm)	36	440.48	2005.04	1317	115355	340	25.78
Kwara	Tmin (°C)	36	20.16	21.74	21.13	0.15	0.39	1.86
	Tmax (°C)	36	29.90	32.00	30.82	0.35	0.59	1.91
	Average Temp. (°C)	36	25.14	26.80	25.97	0.18	0.42	1.61
	Rainfall (mm)	36	802.15	1646.04	1254	38784	197	15.71
Benue	Tmin. (°C)	36	20.56	22.72	21.67	0.29	0.54	2.47
	Tmax (°C)	36	29.23	32.08	30.35	0.60	0.77	2.55
	Average Temp. (°C)	36	25.034	27.40	26.01	0.40	0.64	2.44
	Rainfall (mm)	36	878.95	2280.25	1345	87780	296	22.04

Tmin-Minimum Temperature, Tmax-Maximum Temperature, Var-Variance, SD-Standard Deviation, CV-Coefficient of Variation

Source: Author's fieldwork (2023)

4.1.2 Assessment of the spatio-temporal dynamics of land use in the study area

4.1.2.1 Accuracy assessment of LULC classification

To ensure the reliability of the results of LULC, efforts were made to determine its accuracy assessment using Equations (3.1)–(3.4). Global Positioning System was used to do the ground truthing. This was done to obtain the ground reference data for the different years from 1990 to 2020. The results presented in Tables 4.3 and 4.4 indicate that LULC classification of the three states has a great significant alignment with ground observation of the various land cover classes.

Table 4. 3 LULC Accuracy Assessment (Overall Classified Accuracy and Overall Statistic Kappa) for Niger, Kwara and Benue States for the years 1990, 2000, 2013 and 2020.

	Producer's Accuracy (%)					User's Accuracy (%)				
LULC	**VG**	**WB**	**AL**	**BL**	**BA**	**VG**	**WB**	**AL**	**BL**	**BA**
1990	100.00	66.00	80.00	100.00	98.00	92.59	76.74	74.07	100.00	100.00
2000	100.00	66.00	80.00	100.00	98.00	92.59	76.74	74.07	100.00	100.00
2013	100.00	66.00	80.00	100.00	98.00	92.59	76.74	74.07	100.00	100.00
2020	100.00	66.00	80.00	100.00	98.00	92.59	76.74	74.07	100.00	100.00

Source: Author's fieldwork (2023)

Table 4. 4 LULC Accuracy Assessment (Producer's Accuracy and User's Accuracy) for Niger, Kwara and Benue States for the years 1990, 2000, 2013 and 2020

	NIGER STATE		KWARA STATE		BENUE STATE	
YEAR	**Overall Classified Accuracy**	**Overall Statistic Kappa**	**Overall Classified Accuracy**	**Overall Statistic Kappa**	**Overall Classified Accuracy**	**Overall Statistic Kappa**
1990	80%	0.75	80%	0.75	98%	0.975
2000	81%	0.7625	76%	0.7	76%	0.7
2013	61%	0.5125	80%	0.75	95%	0.9375
2020	62%	0.525	78%	0.725	94%	0.925
AVERAGE	**71%**	**0.6375**	**78.5%**	**0.73125**	**90.75%**	**0.884375**

Source: Author's fieldwork (2023)

4.1.2.2 Description of the LULC of the study area

(a) Description of the LULC of the Niger State

Changes in land use are a direct indication of ecological migration (Zhang and Song, 2013). Data in Table 4.5 and Figures 4.13-4.16 show the Land Use and Land Cover (LULC) Change of Niger State between 1990 and 2020. As indicated by Figure 4.13, vegetation with a land mass of 28604 km^2 (40.40 per cent) was predominant in Niger State in 1990 and this can be found in every domain of the map especially in the northern and southern part of the map followed by agricultural land (19361 km^2) and barren land (1936 km^2) in approximately equal proportion (27.27 per cent). Most of the agricultural land areas are located at the central part of Niger State and close to riverine areas. Barren land are also found mostly at the centre of the State. Also, built up areas cover 2465 km^2 (3.03 per cent) majorly on the southern part of the State and some small patches on the northern part. This indicates that as at 1990, there were settlement in Niger State. Finally, water body covers 1169 km^2 (2.20 per cent) which flows from the edges of the northern part of the State to the edges of the central part of the State. The total land area of Niger State is approximately 71121km^2. This result follows the outcome of the studies of some authors like Yakubu *et al.* (2018) and Zubairu *et al*. (2019) that most parts of Niger State were predominantly occupied by vegetation, barren land and agricultural land in around 1990.

Furthermore, within the space of ten (10) years as depicted by Figure 4.14, most portions of the barren land have turned to vegetation mostly in the northern and central parts of the State and this makes the barren land to decrease rapidly from 19521km^2 (27.27 per cent) to 6685km^2 (9.09 per cent) while increasing the vegetation from 28604km^2 (40.40 per cent) to 41720km^2 (59.60 per cent). This change can be attributed to change in weather at this period. Other classes have little changes. This result is in conformity with the findings of Zubairu *et al.* (2019) that there was conversion of barren lands to vegetation and built-up areas between 1990 and 2001 in some parts of Niger State like Minna and its environs.

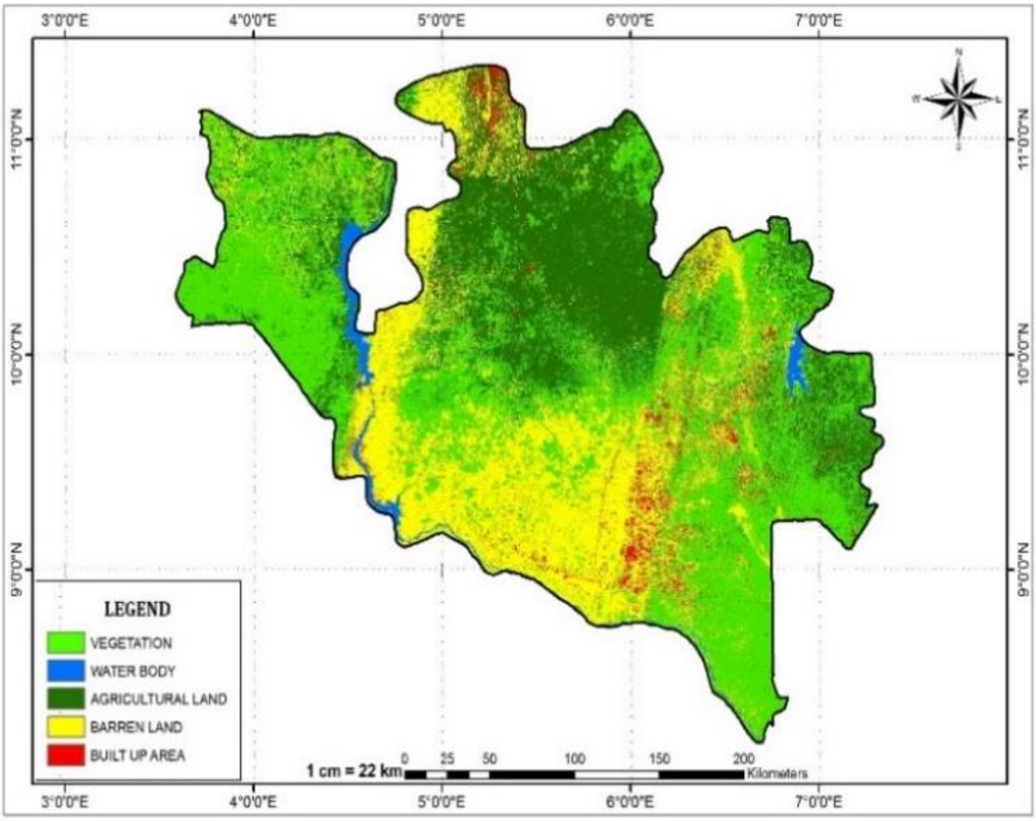
There was astronomical decrease in vegetation from 41720km^2 (40.40 per cent) in 2000 to 9513km^2 (13.00 per cent) in 2013 which can be seen in every part of Niger State as depicted by Figure 4.15, and this led to rapid increase in areas occupied by farmland from 18564km^2 (26.26 per cent) in 2000 to 47618km^2 (67.00 per cent) in 2013. This rapid conversion of vegetation to agricultural land can be due to increase in deforestation necessitated by increase in demand for food. There was a slight increase in other classes like water body from 1031km^2 (1.01 per cent) to 1268km^2 (2.00 per cent), barren land from 6685km^2 (9.09 per cent) to 9287km^2 (13.00 per cent) and built up area from 3121km^2 (4.04 per cent) to 3435km^2 (5.00 per cent). The slight increase in built up areas can be attributed to gradual influx of people from rural areas to urban centres as can be seen on the map. This result is similar to the findings of Ejaro and Abdullahi (2013) in Suleja Area of Niger State, that there was increase in the proportion of land covered by farmland, barren land and built-up area in 2012 and that there was a drastic decrease in vegetation cover in the same year. They attributed the decrease in vegetation cover to influx of people to Suleja due to its close proximity to Abuja which is the Federal Capital Territory (FCT) of Nigeria.

Additionally, Figure 4.16 indicates that the barren land has decreased drastically from 9287km^2 (13.00 per cent) to 2293km^2 (3.00 per cent) over seven (7) years. Most of the portions of the barren land especially in the riverine areas and cities have turned to agricultural land from 47618km^2 (67.00 per cent) to 50312km^2 (71.00 per cent) and built up areas from 3435km^2 (5.00 per cent) to 5481km^2 (8.00 per cent). These changes can be attributed to increase in population hence needs for increase in food supply and settlement. There was a slight increase in vegetation during this period from 9513km^2 (13.00 per cent) to 1161 km^2 (16.00 per cent) especially in the northern part of the State. This might be as a result of change in weather. There was no significant change in the water body which covers 1268km^2 (2.00 per cent) in 2013 and 1373km^2 (2.00 per cent) in 2020 of the landmass. Most of the conversion of other LULC classes to farmland and vegetation occured in the rural areas and along the riverine areas of the State while their conversion to built-up areas occurred in the cities and this is in agreement with the outcome of the study of Salami *et al*. (2020) which indicated that there was a continuous conversion of vegetation to farmland and built-up areas in Garatu Urban Corridor of Minna, Niger State between 2000 and 2019. They attributed these changes to unprecedented urban growth as a result of rural-urban migration and urbanization. However, this result is contrary to one of the findings of the same authors which indicated increase in barren land during this period of time.

Table 4. 5 Classified LULC 1990-2020 for Niger State

CLASS	1990		2000		2013		2020	
	Area (km^2)	**(%)**	**Area (km^2)**	**(%)**	**Area (km^2)**	**(%)**	**Area (km^2)**	**(%)**
VEGETATION	28604	40.40	41720	59.60	9513	13.00	11661	16.00
WATER BODY	1169	2.02	1031	1.01	1268	2.00	1373	2.00
AGRICULTURAL LAND	19361	27.27	18564	26.26	47618	67.00	50312	71.00
BARREN LAND	19521	27.27	6685	9.09	9287	13.00	2293	3.00
BUILT UP AREA	2465	3.03	3121	4.04	3435	5.00	5481	8.00
TOTAL	**71121**	**100.0**	**71121**	**100.0**	**71121**	**100.0**	**71121**	**100.0**

Source: Author’s fieldwork (2023)



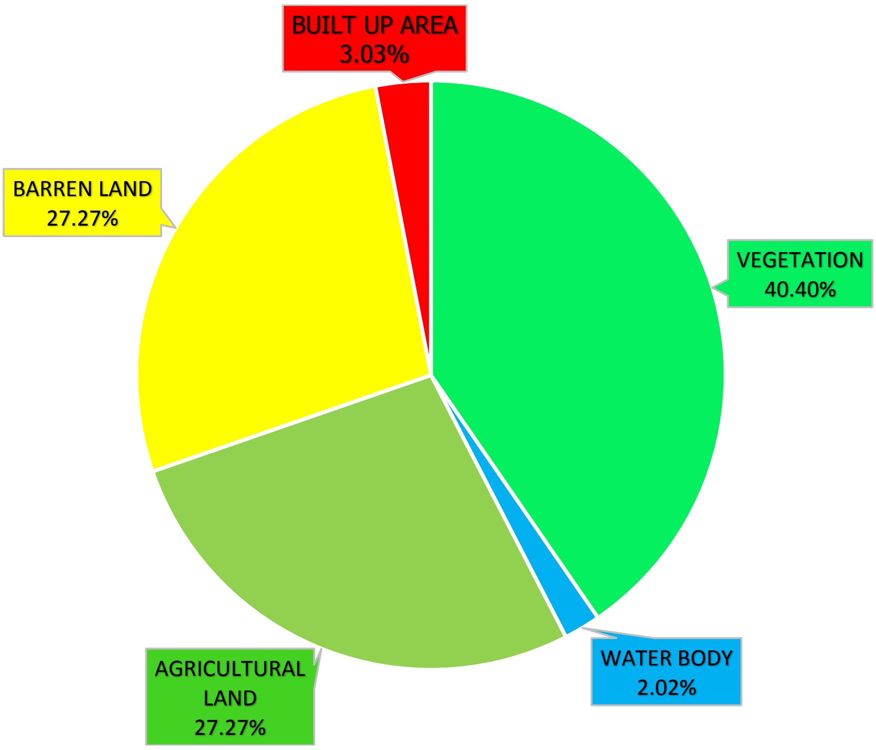


Figure 4. 13 Classified LULC 1990 for Niger State

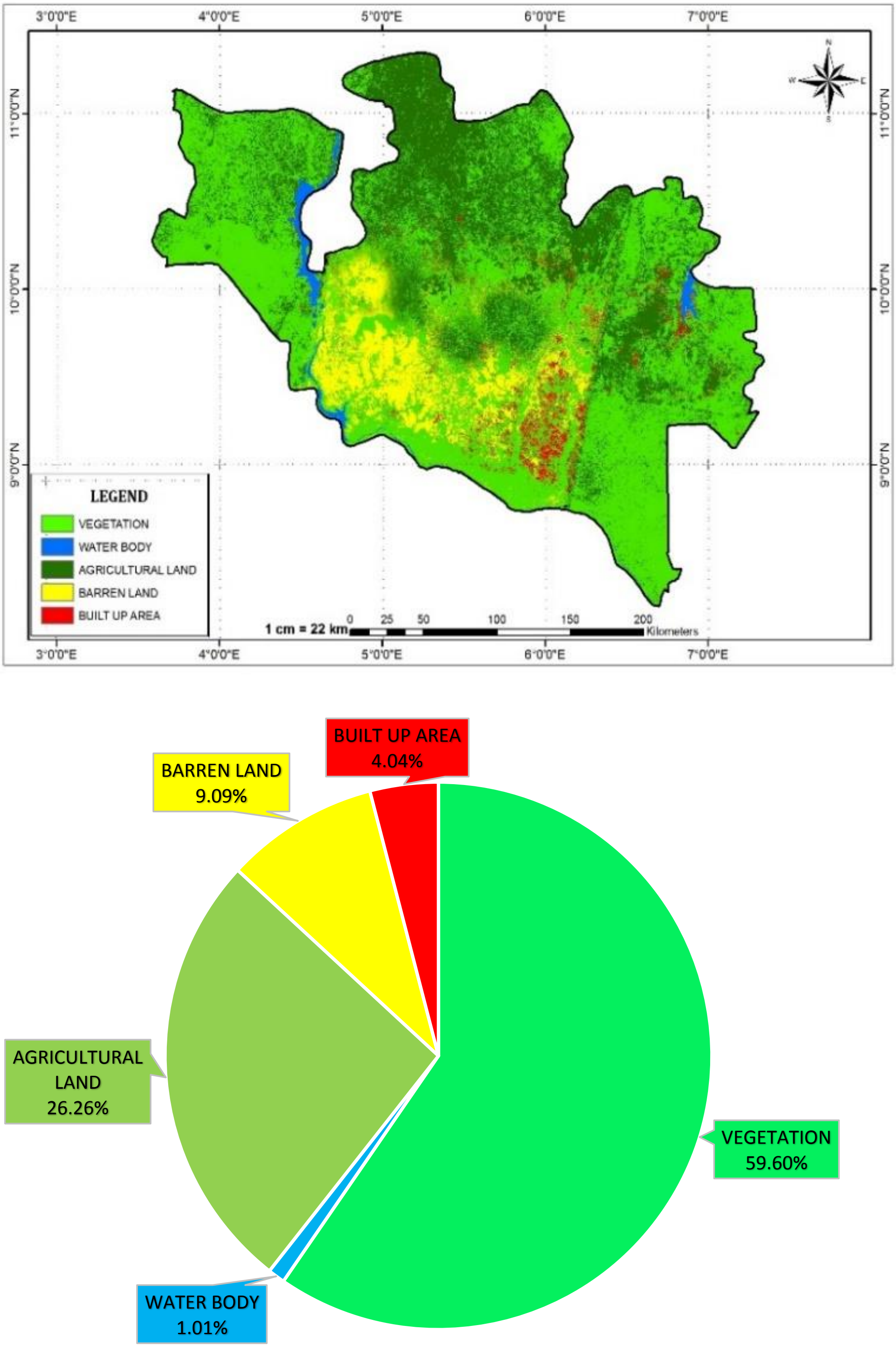
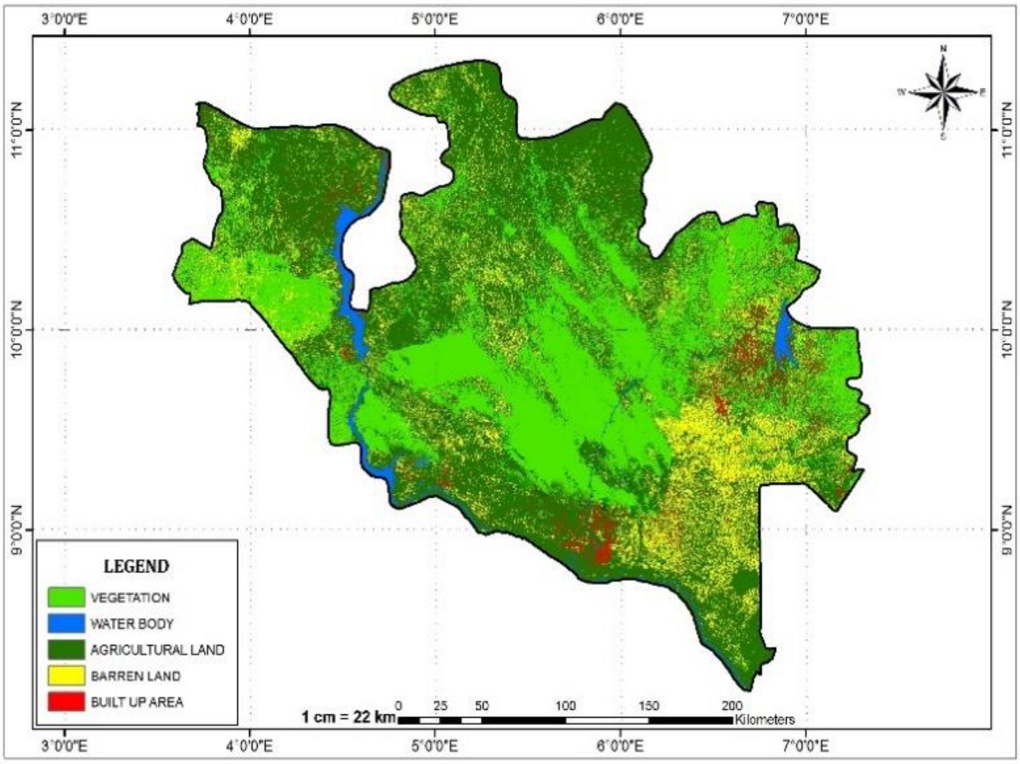


Figure 4. 14 Classified LULC 2000 for Niger State



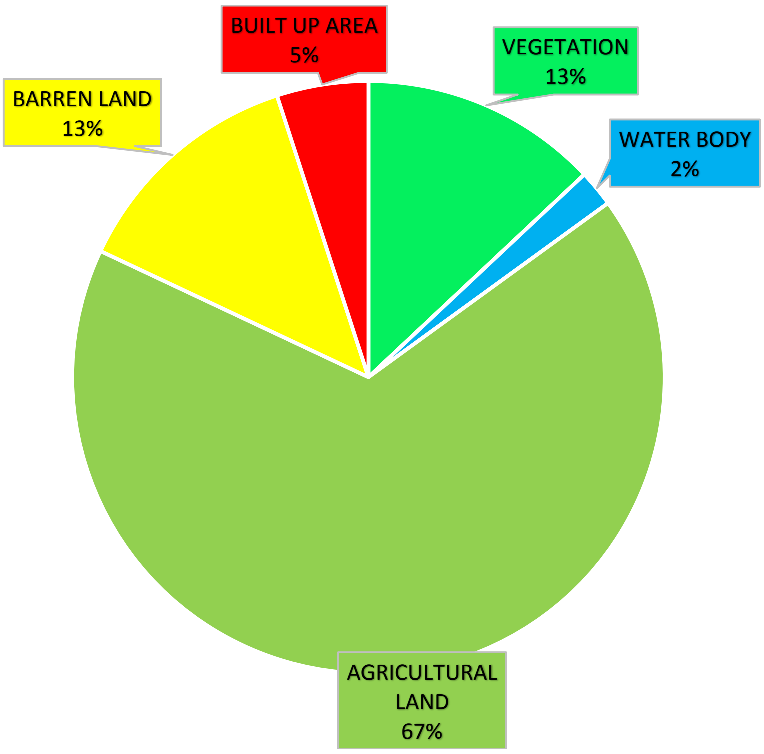
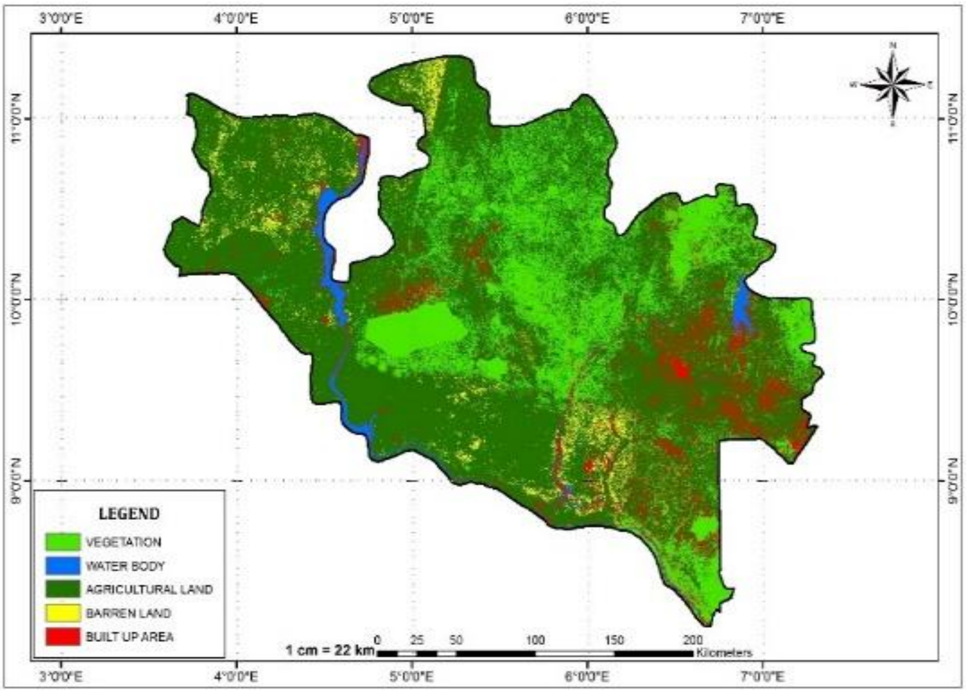


Figure 4. 15 Classified LULC 2013 for Niger State



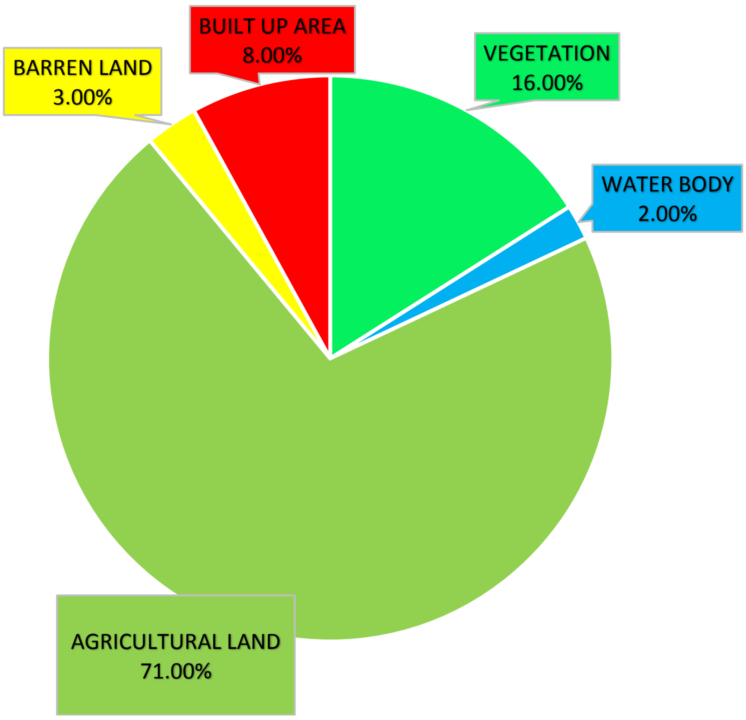


Figure 4. 16 Classified LULC 2020 for Niger State

(b) Description of the LULC of Kwara State

Data in Table 4.6 and Figures 4.17-4.20 show the Land Use and Land Cover (LULC) Change of Kwara State between 1990 and 2020. Figure 4.17 shows the Land Use and Land Cover (LULC) analysis of Kwara State for 1990 and it indicates that agricultural land was the dominant land cover feature which covered 19671km^2 (55.54 per cent) of the entire area. This can be seen in every part of the area especially in the northern part of the State. This indicates that Kwara State has been an agrarian State from the time immemorial. Barren land occupied 9977km^2 (28.17 per cent) of the landmass and this is observed at both extreme ends of the State. It can be inferred that there was a little development in the State as at that time. Vegetation cover occupies 5623km^2 (15.88 per cent) and this is located in every part of the State. The land cover consists of 91km^2 (0.26 per cent) of built up area noticeable towards the end of the centre of the State. This shows that there were few settlements and low development in the State as at the year 1990. Lastly, the State is occupied by 57km^2 (0.16 per cent) of water body which is insignificant to see. The total land mass of Kwara State is approximately 35420km^2.

As portrayed by Figure 4.18, the agricultural land has drastically reduced over the period of ten (10) years from 19671km^2 (55.54 per cent) in 1990 to 11597 km^2 (32.74 per cent) in 2000 and this is mostly observed at the upper part of the State. This change might be attributed to the abandonment of agricultural land leading to its huge conversion to vegetation causing the increase in the portion of land occupied by vegetation from 5623km^2 (15.88 per cent) in 1990 to 14872km^2 (41.99 per cent) in 2000 and this is noticed mostly in the upper part of the State. There was a gradual decrease in barren land from 9977km^2 (28.17 per cent) to 8540km^2 (24.11 per cent) which is noticed towards the southern part of the State. This gradual change is as a result of early stage of urbanisation and rural-urban migration in the State which caused an increase in the built up areas from

91km^2 (0.26 per cent) to 361km^2 (1.02 per cent). There was insignificant decrease in water body from 57km^2 (0.16 per cent) to 51km^2 (0.14 per cent). This is similar to the findings of Olaleye *et al.* (2012) which indicated that vegetation and barren land were two of the most predominant LULC classes in many parts of Kwara State in the year 2000.

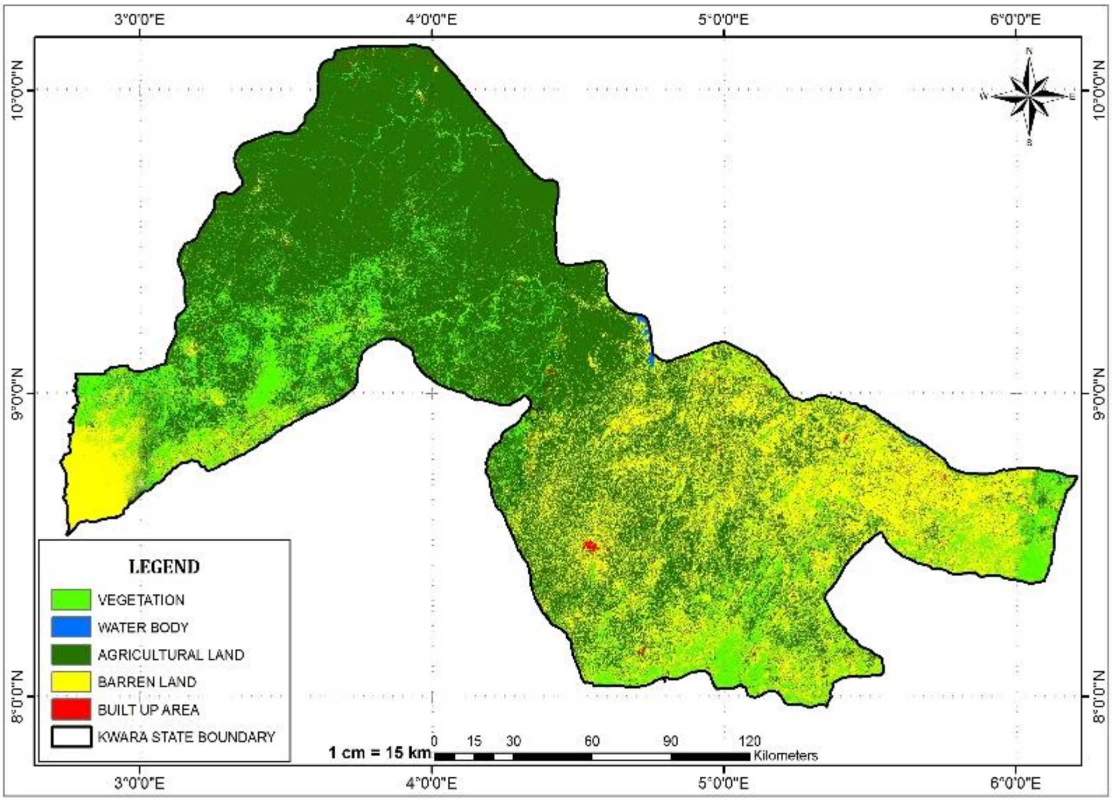
Thirteen (13) years after, as illustrated by Figure 4.19, there was a decrease in vegetation from 14872km^2 (41.99 per cent) to 12586km^2 (35.53 per cent) and this is predominantly observed at the upper part of the State. Also, there was a decrease in barren land from 8540km^2 (24.11 per cent) to 6837km^2 (19.30 per cent) observed at the lower part of the State. The reduction in vegetation and barren land can be attributed to increase in population and increase in the demand for land for food cultivation and that could have caused increase in agricultural land from 11597km^2 (32.74 per cent) to 15365km^2 (43.38 per cent) and increase in built up areas from 361km^2 (1.02 per cent) in 2000 to 568km^2 (1.60 per cent) in 2013. There was also a slight increase in water body from 51km^2 (0.14 per cent) to 64km^2 (0.18 per cent). This study is in agreement with the findings of Njoku and Tenenbaum (2022), which indicated that agricultural land and vegetation (green/sparse vegetation) were predominant in some parts of Kwara State like Ilorin in 2013.

There was a continuous decrease in vegetation from 12586km^2 (35.53 per cent) to 10123km^2 (28.58 per cent) observed especially at the southern part of the State in 2020 as delineated in by Figure 4.20. This reduction can be attributed to continuous deforestation and encroachment of people into the forest areas of the State. Agricultural land also decreased from 15365km^2 (43.38 per cent) to 13579km^2 (38.34 per cent). This can be traced to conversion of some agricultural land to other land use such as built up areas which expanded from 568km^2 (1.60 per cent) to 1266km^2 (3.57 per cent) especially towards the central and southern parts of the State. There was also a sudden increase in barren land from 6837km^2 (19.30 per cent) to 10399km^2 (29.36 per cent) over the seven years majorly at the southern part of the State. The sudden increase in barren land and decrease in agricultural land in 2020 might be as a result of the continuous usage of agrochemicals like pesticides, insecticides, herbicides and pesticides by the farmers in most parts of the State which could have made the farmers to migrate from these areas and leave most of the agricultural land portions barren. Finally, there was a slight decrease in water body from 64km^2 (0.18 per cent) to 54km^2 (0.15 per cent). This slight decrease might be resulted from over dependence on water resources due to rapid increase in population.

Table 4. 6 Classified LULC 1990-2020 for Kwara State

CLASS	1990		2000		2013		2020	
	Area (km^2)	**(%)**	**Area (km^2)**	**(%)**	**Area (km^2)**	**(%)**	**Area (km^2)**	**(%)**
VEGETATION	5623	15.88	14872	41.99	12586	35.53	10123	28.58
WATER BODY	57	0.16	51	0.14	64	0.18	54	0.15
AGRICULTURAL LAND	19671	55.54	11597	32.74	15365	43.38	13579	38.34
BARREN LAND	9977	28.17	8540	24.11	6837	19.30	10399	29.36
BUILT UP AREA	91	0.26	361	1.02	568	1.60	1266	3.57
TOTAL	**35420**	**100.0**	**35420**	**100.0**	**35420**	**100.0**	**35420**	**100.0**

Source: Author’s fieldwork (2021)



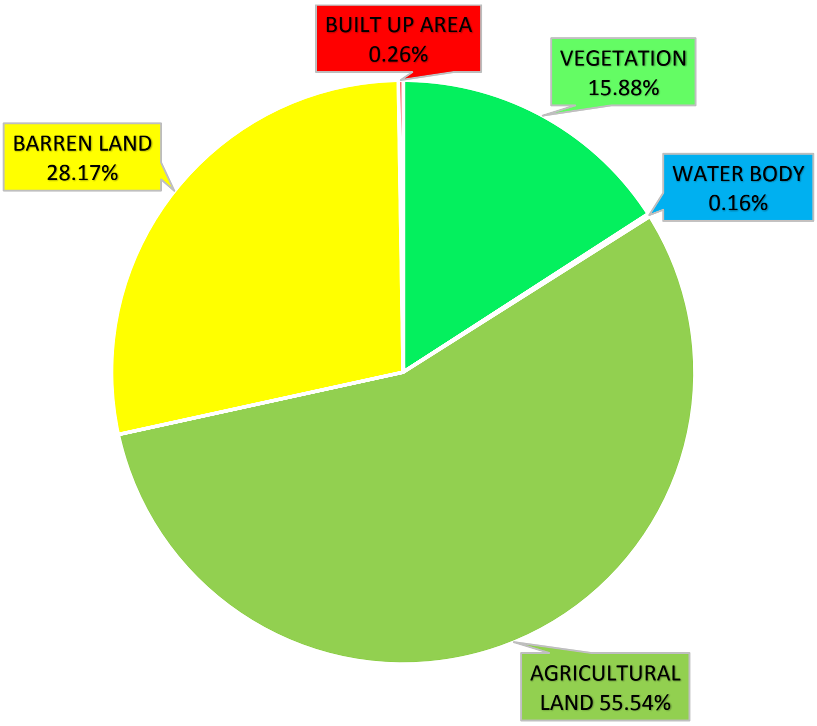


Figure 4. 17 Classified LULC 1990 for Kwara State

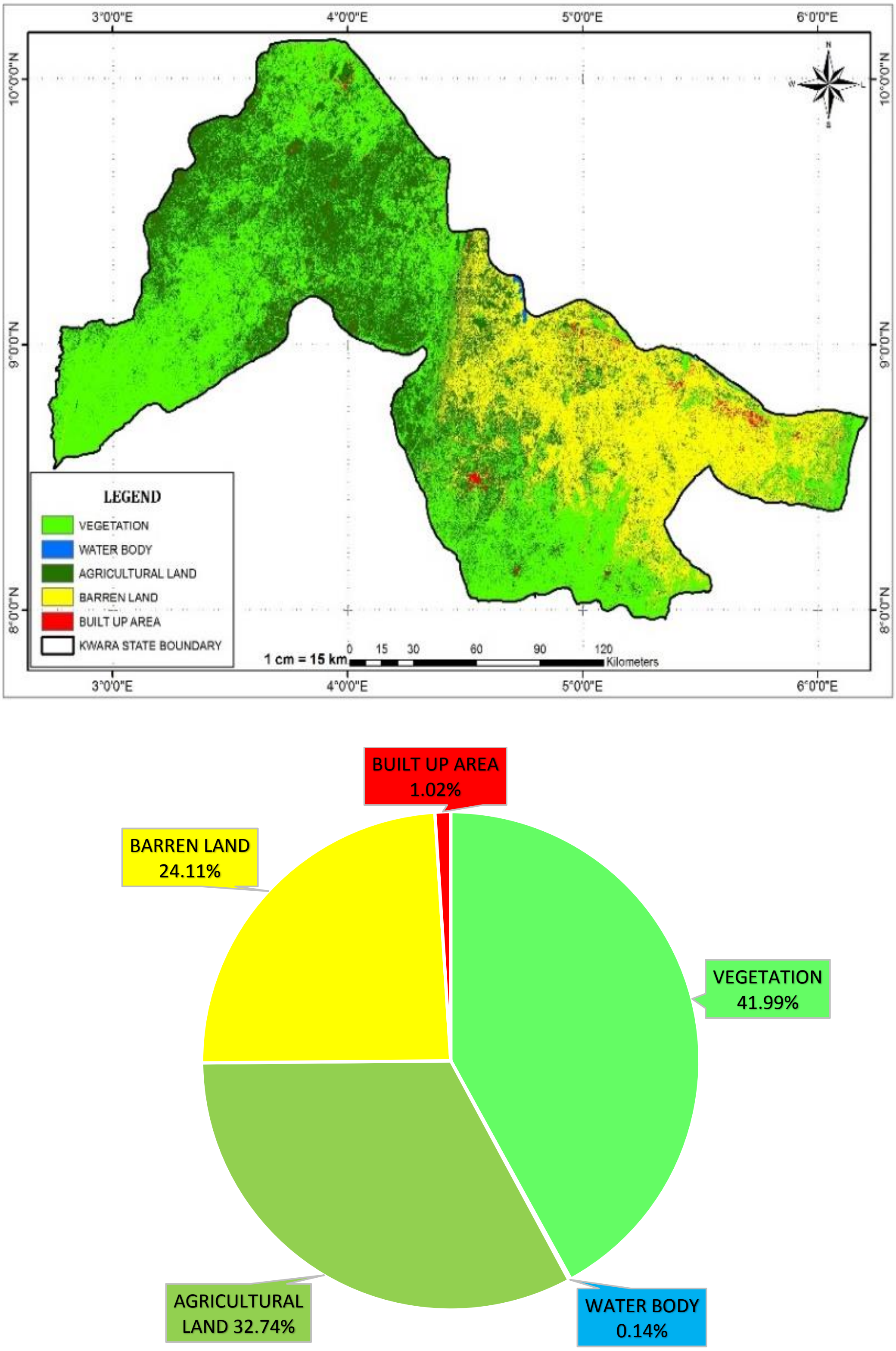
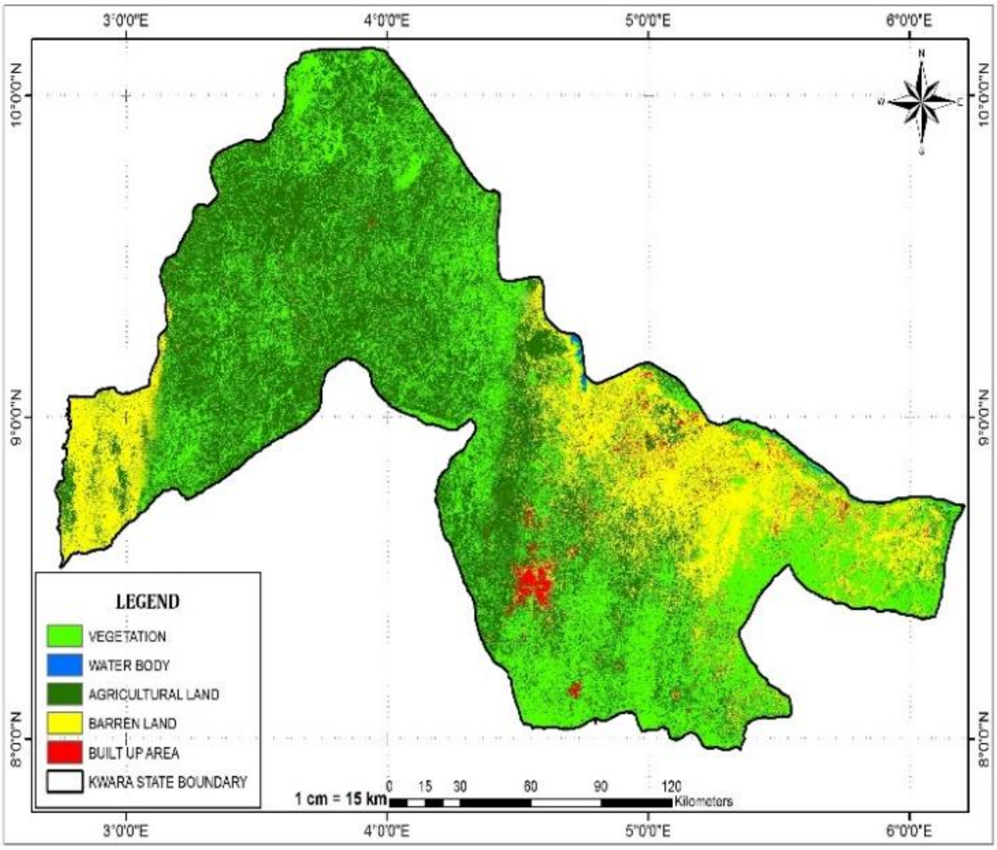


Figure 4. 18 Classified LULC 2000 for Kwara State



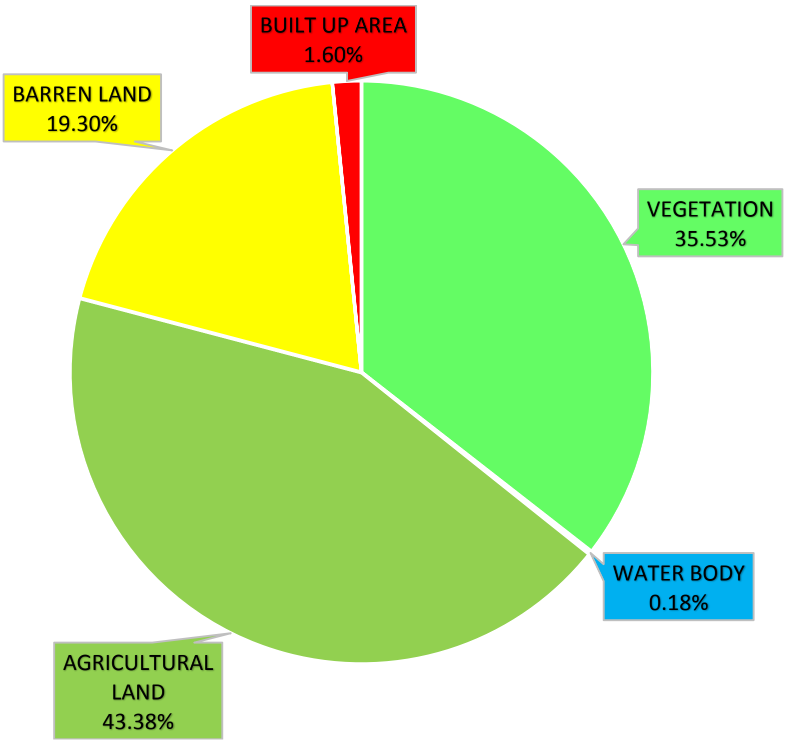
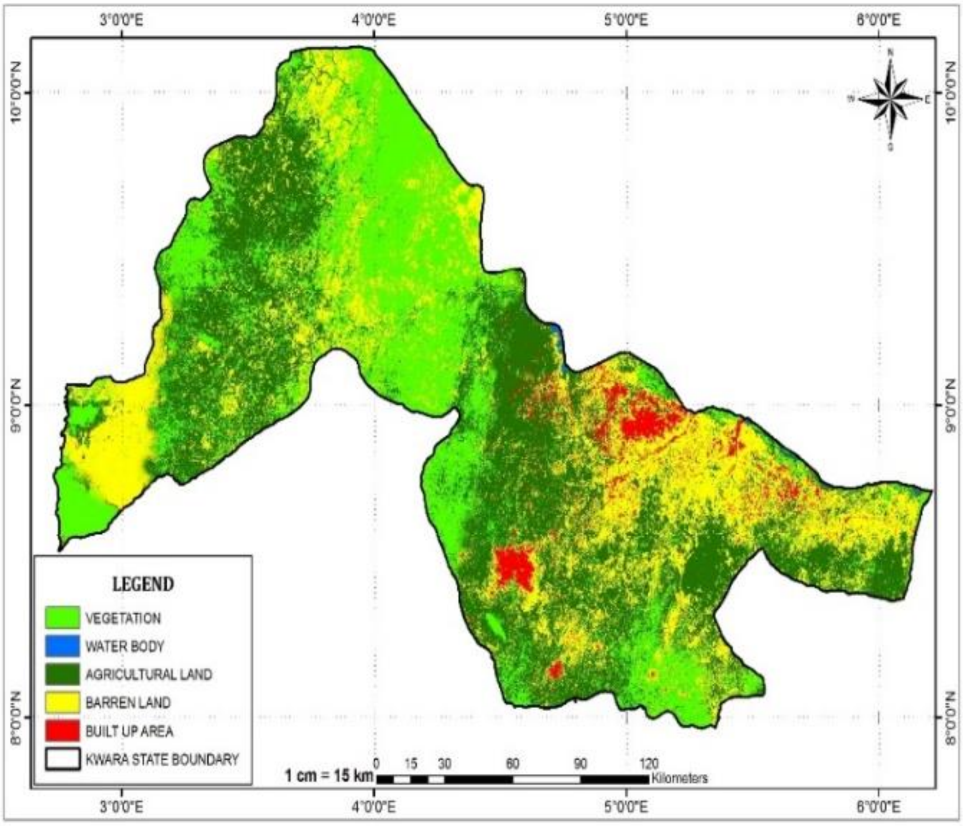


Figure 4. 19 Classified LULC 2013 for Kwara State



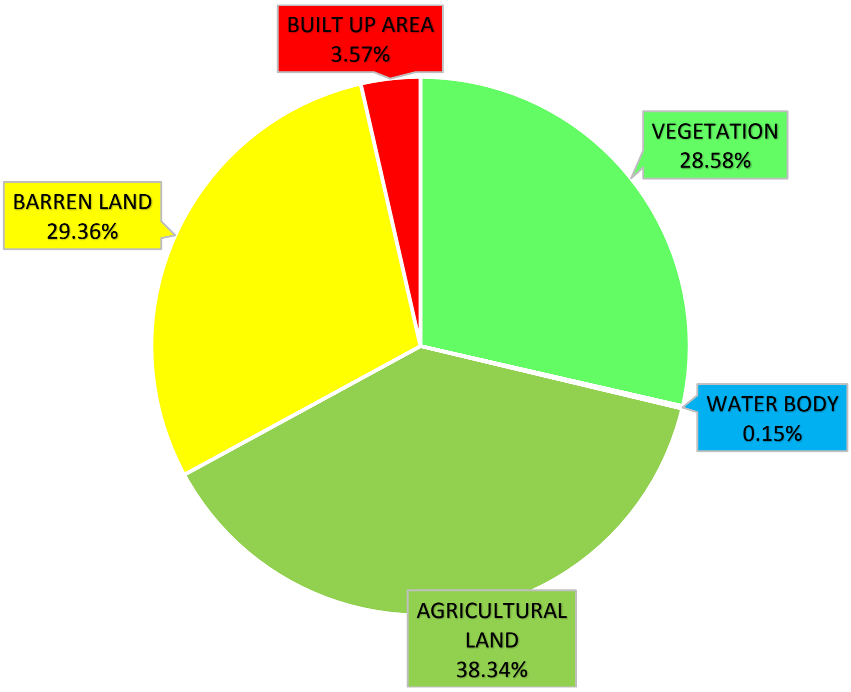


Figure 4. 20 Classified LULC 2020 for Kwara State

(c) Description of the LULC of Benue State

Data in Table 4.7 and Figures 4.21-4.24 depict the Land Use and Land Cover (LULC) Change of Benue State between 1990 and 2020. As indicated in Figure 4.21, the land cover was mostly dominated by agricultural land with a land mass of 18818km^2 (60.11 per cent) and this is observable majorly on the northern part of the State and at the extreme end of the southern part. This can be attributed to the agrarian nature of the northern part of the State over some decades ago. Vegetation with 7849km^2 (25.07 per cent) observed mostly at the central part of the State was also dominant. This shows that there was little encroachment into the forest as at 1990. Barren land was 4160km^2 (13.29 per cent) mostly located at the central and southern parts of the State. This results shows that there was little reliance on the ecosystem services back then. The built up areas occupied land mass of 465 km^2 (1.49 per cent) and they were located at the extreme ends of the northern parts of the State. This might be as a result of low population and dominant rural nature of the State. The land mass occupied by water was 16km^2 (0.05 per cent) and its flow is not noticeable on the map. The total land mass of Benue State is 31308km^2. This confirms the findings of Ali *et al.* (2021) which indicated that as at 1990, Benue State was predominantly agrarian with a vast agricultural land followed by vegetation (forest) while other classes like built-up areas, water body and barren land were of insignificant quantity.

In the year 2000, as illustrated by Figure 4.22, there was a huge increase in agricultural land from 18818km^2 (60.11 per cent) in 1990 to 22399km^2 (71.54 per cent) in 2000. This rapid change could be seen in every part of the State and this change can be attributed to conversion of vegetation to agricultural land to meet more food demand of the State. There was a drastic reduction in vegetation from 7849km^2 (25.07 per cent) in 1990 to 2919km^2 (9.32 per cent) in 2000 and this is noticeable in every part of the State. Most of the vegetation land mass were converted to other land use like agricultural land, built up areas and barren land. This conversion might be as a result of increase in population necessitated by increase in demand for food, settlement and developmental facilities like roads and other basic amenities. Barren land especially at the central part of the State increased from 4160km^2 (13.29 per cent) in 1990 to 5111km^2 (16.33 per cent) in 2000. This change might be as a result of change in weather. Also, there was an increase in built up areas from 465km^2 (1.49 per cent) to 734km^2 (2.35 per cent). This can be as a result of influx of people towards the urban centres due to increase in population hence need for settlement and other basic amenities. Finally, water body changed from 16km^2 (0.05 per cent) in 1990 to 145km^2 (0.46 per cent) in 2000. This result is similar to the outcome of the study of Tyubee and Anyadike (2015) that between 1991 and 2006, there was a drastic conversion of many other LULC classes like vegetation, waterbody and farmland to built-up areas in Makurdi, the Benue State capital. They indicated the need and demand for physical infrastructure as a result of increase in socioeconomic activities and population as some of the reasons for this conversion.

There was a huge decrease in agricultural land from 22399 km^2 (71.54 per cent) to 12922km^2 (41.27 per cent) over the period of thirteen (13) years as it can be observed in every part of the State. Agricultural land is converted to other land use thereby leading to increase in other land use like vegetation from 2919 km^2 (9.32 per cent) to 4569km^2 (14.59 per cent), barren land from 5111km^2 (16.33 per cent) to 8801km^2 (28.11 per cent), water body from 145km^2 (0.46 per cent) to 171km^2 (0.55 per cent) and built up area from 734km^2 (2.35 per cent) to 8801km^2 (28.11 per cent) as depicted by Figure 4.23. This conversion is traceable to increase in population which necessitated the conversion of most of the agricultural land to built up areas to solve the problem of shelter. It can also be inferred that as a result of continuous application of agrochemicals like pesticides, herbicides, fungicides, insecticides among others, most of the agricultural land became barren and while some portions were abandoned for some time, change in weather made some of them to be converted to vegetation.

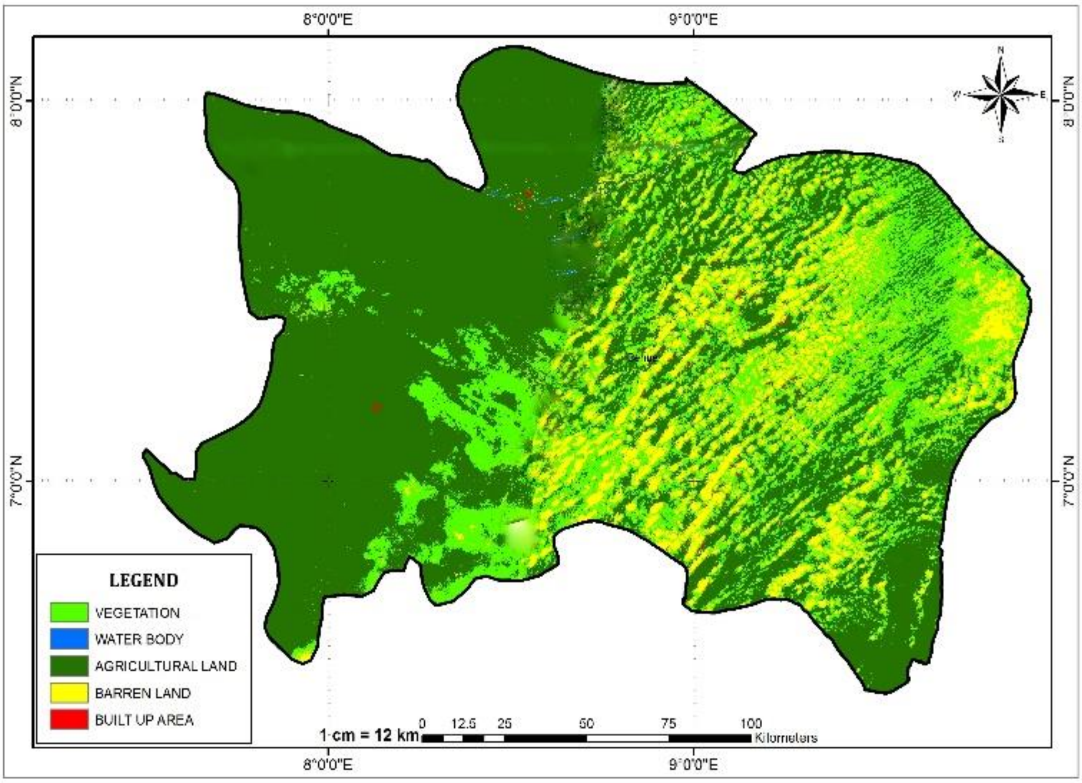
Also, as described by Figure 4.24, there was a continuous decrease in agricultural land from 12922km^2 (41.27 per cent) in 2013 to 10559km^2 (33.73 per cent) in 2020. This is mostly observed at the northern part of the State. Also, there was continuous increase in the built up areas from 4846km^2 (15.48 per cent) in 2013 to 8408km^2 (26.86 per cent) in 2020. Increase in built up areas could be as a result of continuous conversion of agricultural land into built areas because of influx of people into the urban centres. Also, there was a slight decrease in vegetation from 4569km^2 (14.59 per cent) in 2013 to 4025km^2 (12.86 per cent) in 2020. This is observable towards the border of Benue State to other States of Nigeria and this might be influenced by the influx of people towards border towns. Barren land decreased from 8801 km^2 (28.11 per cent) to 8122 km^2 (25.94 per cent) and this is observed mostly at the centre of the map and this can also be attributed to need for more space for development. Finally, there was a slight increase in water body from 171km^2 (0.55 per cent) in 2013 to 192km^2 (0.61 per cent) in 2020. The slight increase in the water body might be as a result of incessant increase in the rate of flooding in Benue State especially Makurdi, the State capital which is prone to flood disaster always resulting in the migration of people to the nearby location (Isma'il and Kersha 2018).

This study is contrary to the assertion that there was an increase in agricultural land and barren land between 2010 and 2020 as started by Ali *et al.* (2021) while it agreed that there was a reduction in vegetation and increase in waterbody and built-up areas between 2010 and 2020 as indicated by the same authors.

Table 4. 7 Classified LULC 1990-2020 for Benue State

CLASS	1990		2000		2013		2020	
	Area (km^2)	(%)	Area (km^2)	(%)	Area (km^2)	(%)	Area (km^2)	(%)
VEGETATION	7849	25.07	2919	9.32	4569	14.59	4025	12.86
WATER BODY	16	0.05	145	0.46	171	0.55	192	0.61
AGRICULTURAL LAND	18818	60.11	22399	71.54	12922	41.27	10559	33.73
BARREN LAND	4160	13.29	5111	16.33	8801	28.11	8122	25.94
BUILT UP AREA	465	1.49	734	2.35	4846	15.48	8408	26.86
TOTAL	**31308**	**100.0**	**31308**	**100.0**	**31308**	**100.0**	**31308**	**100.0**

Source: Author's fieldwork (2023)



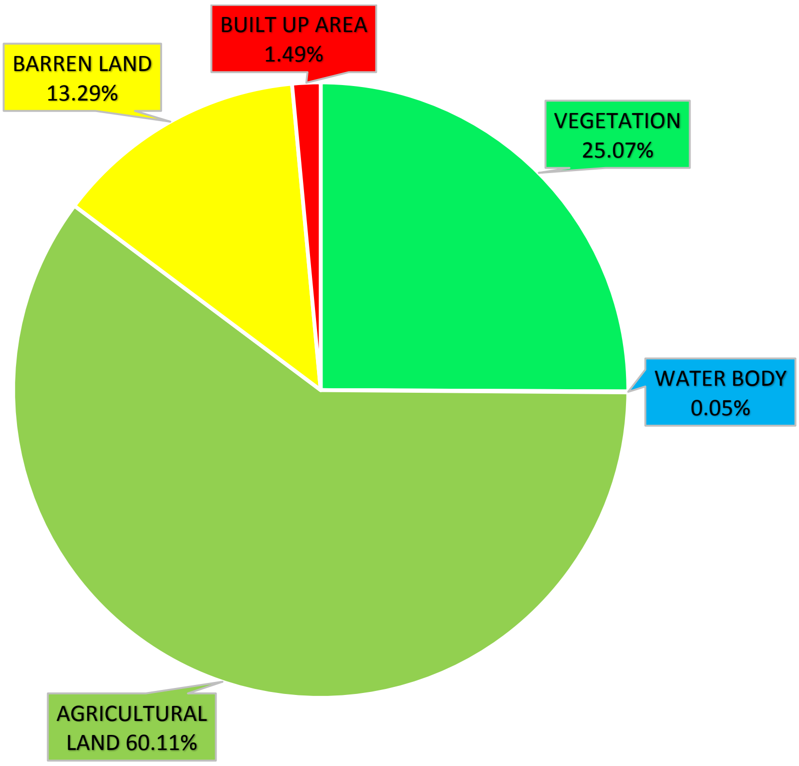


Figure 4. 21 Classified LULC 1990 for Benue State

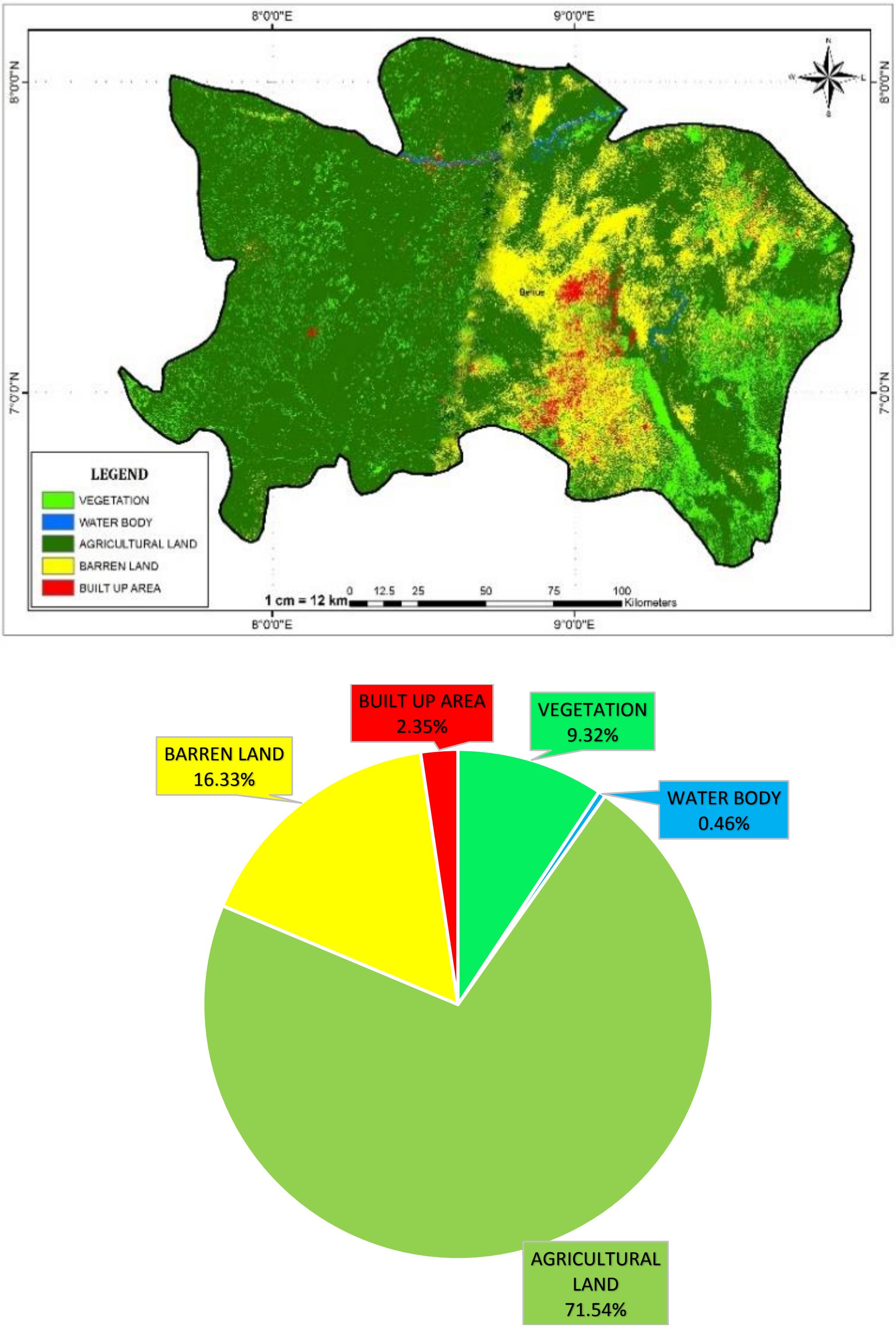
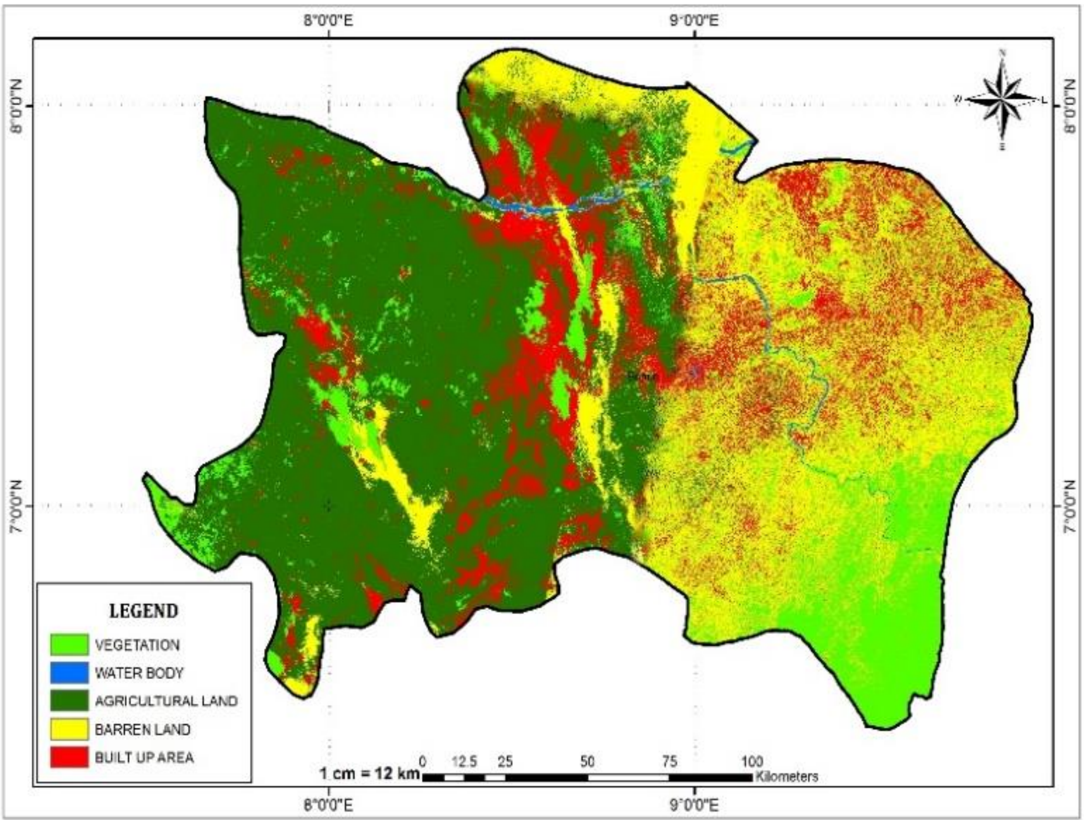


Figure 4. 22 Classified LULC 2000 for Benue State



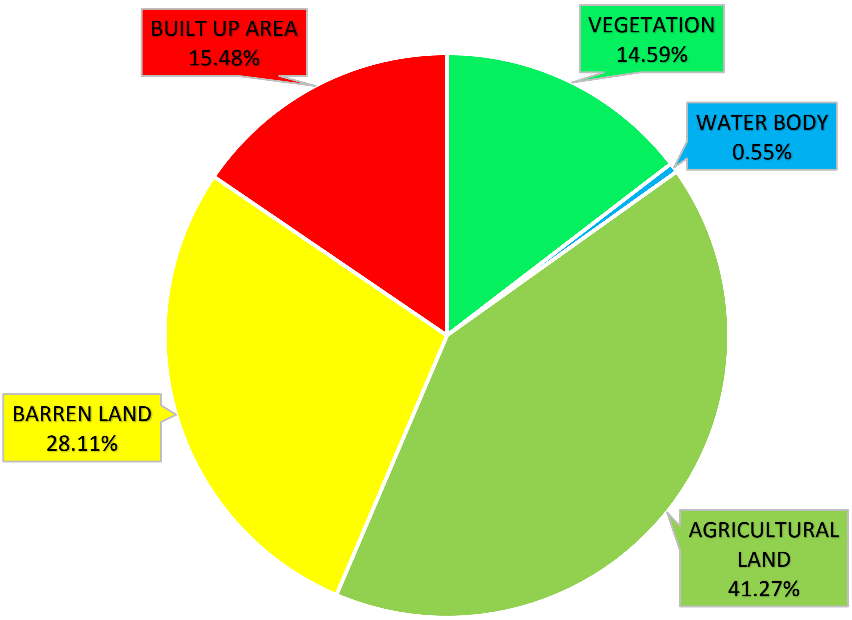
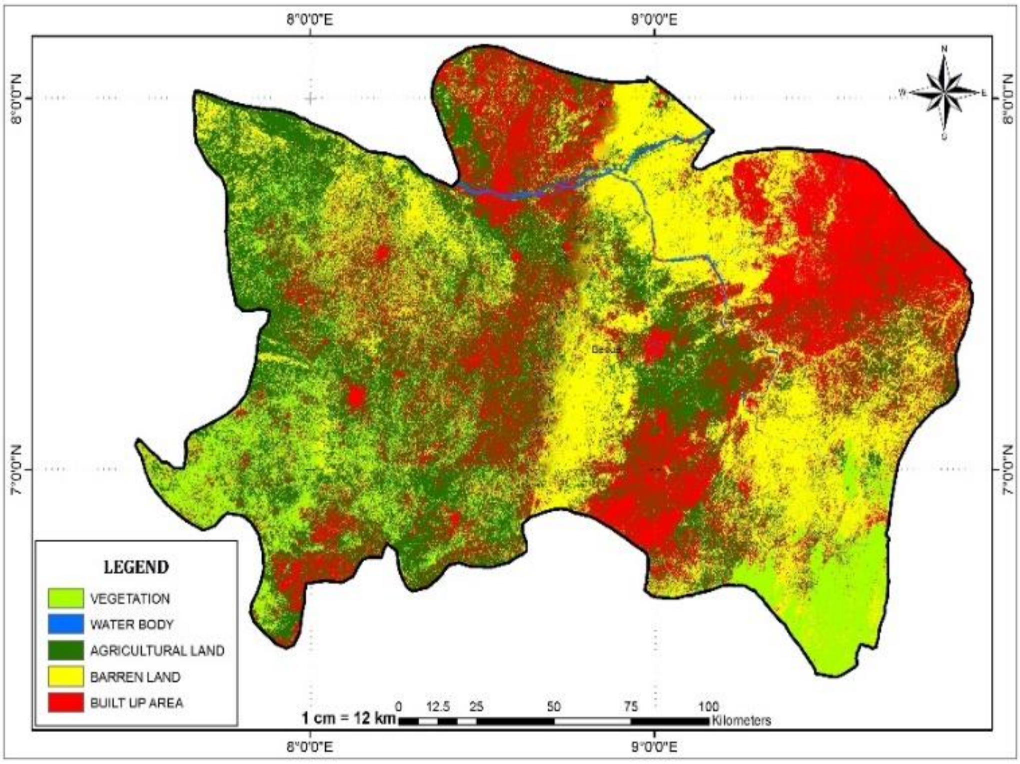


Figure 4. 23 Classified LULC 2013 for Benue State



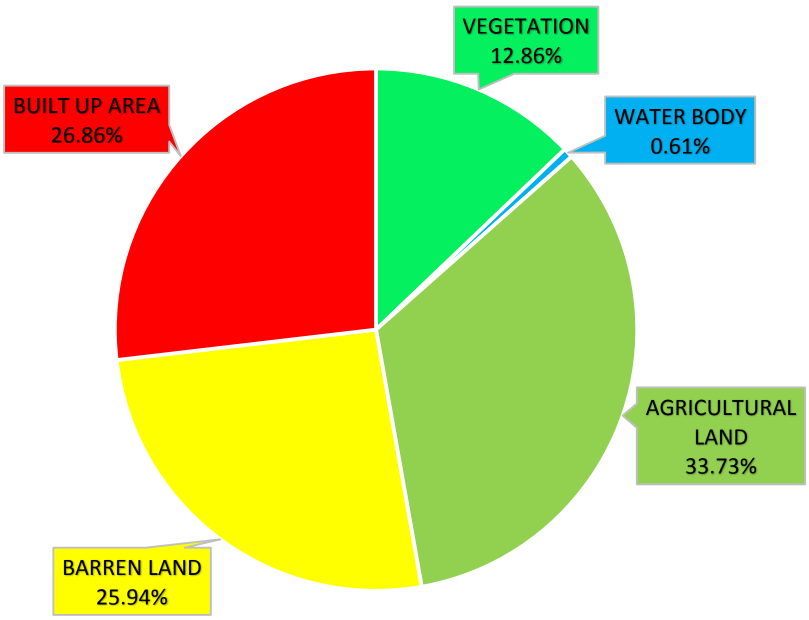


Figure 4. 24 Classified LULC 2020 for Benue State

4.1.2.3 Percentage change and annual rate of change in LULC of the study area over a period of 30 years and its implications on food security

Tables 4.8, 4.9 and 4.10 respectively show the percentage change in LULC for Niger, Kwara and Benue States between 1990 and 2020. The percentage change in LULC for the three States between 1990 and 2020 indicates that there was a decrease in vegetation in Niger (24.79 per cent) and Benue (15.83 per cent) States at the annual rate of 7.44 per cent and 4.75 per cent respectively. This drastic reduction in vegetation in these States might be as a result of deforestation while 36.91 per cent increase in vegetation witnessed in Kwara State at the annual rate of 11.07 per cent could be as a result of change in weather conditions. Regarding the water body in the three States, Kwara State experienced slight decrease (0.02 per cent) in the volume of their water body at the annual rate of 0.09 per cent which can be attributed to encroachment of the populace into the water bodies for development as a consequence of increase in population. Furthermore, investigation shows that surface water in Kwara State has been reducing because of expansion of agricultural land and intensification of agricultural practices like irrigation and construction of buildings in the riverine areas of the State. The decrease in water body can be a threat to food security in the State because of the farmers in the State practice rain fed agriculture. Conversely, there was a slight increase in the volume of water body in Niger (0.30 per cent) and Benue (0.73 per cent) States at the annual rate of 0.09 per cent and 0.22 per cent respectively and this can be as result of flooding which made many people to relocate from riverine areas to inlands.

Furthermore, there was a huge increase of 45.29 per cent in agricultural land with annual rate of 13.59 per cent in Niger State. The increase in the agricultural land in this state might be predominantly as a result of encroachment into vegetation, barren land and water body which might lead to land degradation and loss of ecosystem services. However, this increase is expected to improve the food production in Niger State and ensure food security in this State and Nigeria as whole. In contrary, there was a decrease of 49.97 per cent and 34.18 per cent in agricultural land at the annual rate of 14.99 per cent and 10.25 per cent for Kwara and Benue States respectively. The continuous decrease in the agricultural land is as a result of its conversion to built up areas necessitated by increase in population and this will have negative implications on the food security of these two States and the nation as a whole considering these high percentages decrease.

There was a decrease in barren land by 25.21 per cent at the annual rate of 7.56 per cent in Niger State which might be as a result of its conversion to agricultural land in order to enhance food production in the State. Conversely, there was an increase in barren land in Kwara (3.46 per cent) and Benue (16.40 per cent) States at the annual rate of 4.92 per cent and 1.04 per cent respectively. The increase in barren land in these two States might be as a result of change in weather and continuous use of agrochemicals such as pesticides, insecticides, herbicides among others leading to abandonment of barren land by farmers while migrating to other locations with viable soil for food production. The increase in barren land might also be traceable to uncontrollable deforestation leading to land degradation in these two States as witnessed by the author during physical observation visits to these States. Additionally, there was an astronomical increase of 4.41 per cent 9.64 per cent and 32.87 per cent at the annual rate of 1.32 per cent, 2.89 per cent and 9.86 per cent for Niger, Kwara and Benue States respectively in the built up areas. The increase in the built up areas in these three States especially in the cities can be attributed to the migration of people from the rural areas to cities thereby necessitating the need to meet the housing shortage and other basic amenities and infrastructure like transportation networks, roads, communication networks and so on of the urban areas.

Table 4. 8 Percentage Change and Annual Rate of Change in Niger State for 1990-2020

CLASS	1990 Extent (Km^2)	2020 Extent (Km^2)	Magnitude of Change (Km^2)	Percentage Change (%)	Annual Rate of Change (%)
VEGETATION	28604	11661	-16943	24.79 **Decrease**	7.44
WATER BODY	1169	1373	204	0.30 **Increase**	0.09
AGRICULTURAL LAND	19361	50312	30951	45.29 **Increase**	13.59
BARREN LAND	19521	2293	-17228	25.21 **Decrease**	7.56
BUILT UP AREA	2465	5481	3016	4.41 **Increase**	1.32
TOTAL	**71121**	**71121**	**68342**	**100**	

Source: Author

Table 4. 9 Percentage Change and Annual Rate of Change in Kwara State for 1990-2020

CLASS	1990 Extent (Km^2)	2020 Extent (Km^2)	Magnitude of Change (Km^2)	Percentage Change (%)	Annual Rate of Change (%)
VEGETATION	5623	10123	4500	36.91 **Increase**	11.07
WATER BODY	57	54	-3	0.02 **Decrease**	0.007
AGRICULTURAL LAND	19671	13579	-6092	49.97 **Decrease**	14.99
BARREN LAND	9977	10399	422	3.46 **Increase**	1.04
BUILT UP AREA	91	1266	1175	9.64 **Increase**	2.89
TOTAL	**35420**	**35420**	**12192**	**100**	

Source: Author's fieldwork (2023)

Table 4. 10 Percentage Change and Annual Rate of Change in Benue State for 1990-2020

CLASS	1990 Extent (Km^2)	2020 Extent (Km^2)	Magnitude of Change (Km^2)	Percentage Change (%)	Annual Rate of Change (%)
VEGETATION	7849	4025	-3824	15.83 **Decrease**	4.75
WATER BODY	16	192	176	0.73 **Increase**	0.22
AGRICULTURAL LAND	18818	10559	-8259	34.18 **Decrease**	10.25
BARREN LAND	4160	8122	3962	16.40 **Increase**	4.92
BUILT UP AREA	465	8408	7943	32.87 **Increase**	9.86
TOTAL	**31308**	**31308**	**24164**	**100**	

Source: Author’s fieldwork (2023)

4.1.3 Evaluation of the resultant impacts climate change and land use on migration as it affects food production

4.1.3.1 Relationship between climate parameters (temperature and rainfall) and yearly crop yield

Figures 4.25-4.30 show the relationship that exists between climate parameters (temperature and rainfall) and yearly crop yields of maize, yam, cassava, rice and groundnut between 2005 and 2020. In Niger State as depicted in Figure 4.25, Niger State witnessed various degrees of fluctuations in temperature. The temperature was highest in 2019. There was a huge impact of temperature on the yields of some crops. For instance, as the temperature increased from around 26.70°C in 2006 to about 28°C in 2019, there was a decrease in the yields of cassava from about 5000 metric tons (mt) to about 1500 metric tons (mt). However, increase in temperature favoured the yields of yam in Niger State. The change in temperature had little impacts on the yields of other crops like rice, groundnut and maize. Furthermore, Figure 4.26 shows that Niger State recorded the highest rainfall amount of about 1550mm in 2013. There were also fluctuations in the rainfall pattern of the State. However, the State recorded increase in rainfall amount over the last four years (2017-2020). The fluctuations in rainfall have different impacts on the crop yield of the State. As the rainfall increased, there was increase in the yields of yam and cassava. There was also increase in the yields of maize and rice while fluctuations in rainfall pattern had little impacts on the yields of groundnut.

Similarly, the peak of temperature in Kwara State as depicted in Figure 4.27, was in 2017 with approximately 26.8°C although there were fluctuations in the temperature pattern, the temperature tends to be decreasing in the last three years and this has led to decrease in the yields of some crops like yam and cassava. On the contrary, the decrease in temperature in the last 3 years led to increase in the yields of some crops like groundnut and maize while it had little or no impacts on the yields of rice. Furthermore, Kwara State recorded highest rainfall of about 1700mm in the year 2019. Over the last 16 years, the pattern of rainfall Kwara State has been fluctuating and this has been having negative impacts on the yields of various crops in the State. There was a sharp increase in the amount of rainfall between 2015 and 2019 which later reduced drastically in 2020. Increase in the amount of rainfall in Kwara State caused an increase in the yields of cassava, yam and groundnut in the State while it has little effects on the yields of rice and maize (Figure 4.28).

Figure 4.29 depicts the impacts of temperature on the yields of maize, yam, cassava, rice and groundnut in Benue State. There was a sharp fall in the temperature pattern of Benue State between 2005 and 2008. The temperature rose astronomically between 2011 and 2014 and started to decline till 2020. These fluctuations had huge impacts on the yields of all the five crops. For instance, there was increase in the yields of cassava between 2005 and 2019 with a decline in temperature in this period of years. Contrarily, as the temperature decreased between 2016 and 2020, the yields of cassava also decreased. Also, decrease in temperature led to increase in other crops like yam, maize, rice and groundnut in Benue State.

Additionally, Benue State recorded highest rainfall amount of about 1850mm in 2007 and lowest of about 500mm in the year 2013. In the last 16 years, there has been fluctuations in the pattern of rainfall in Benue State. The increase in rainfall led to increase in the yields of all the crops although in different proportion (Figure 4.30).

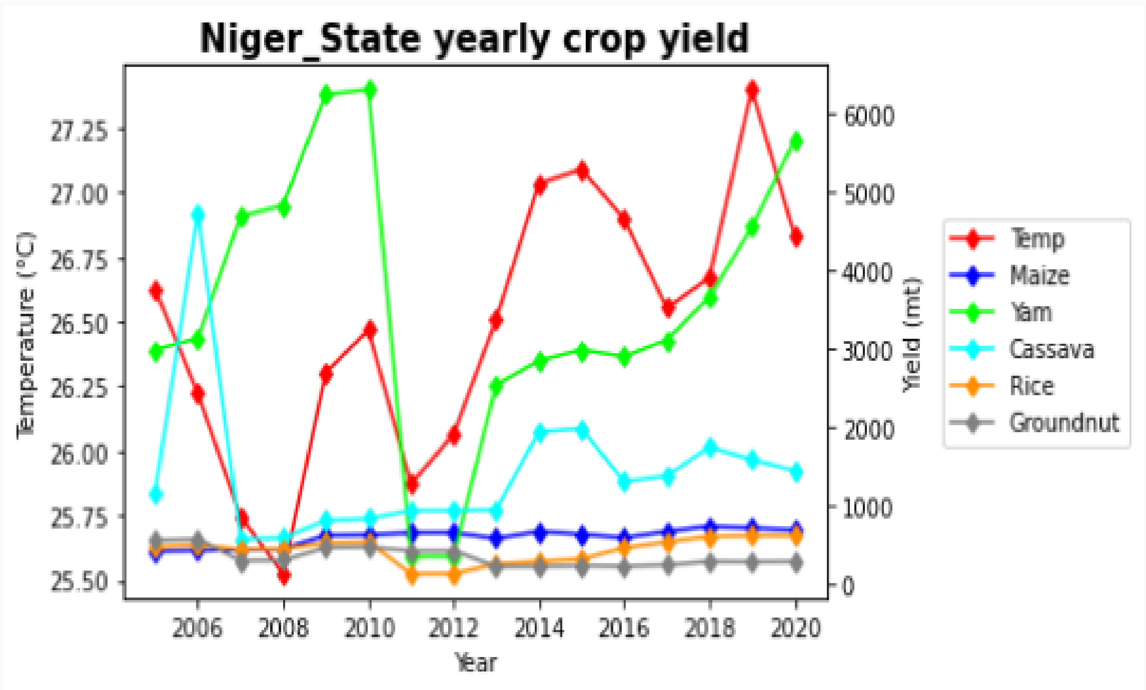


Figure 4. 25 Temperature and Yearly Crop Yield in Niger State

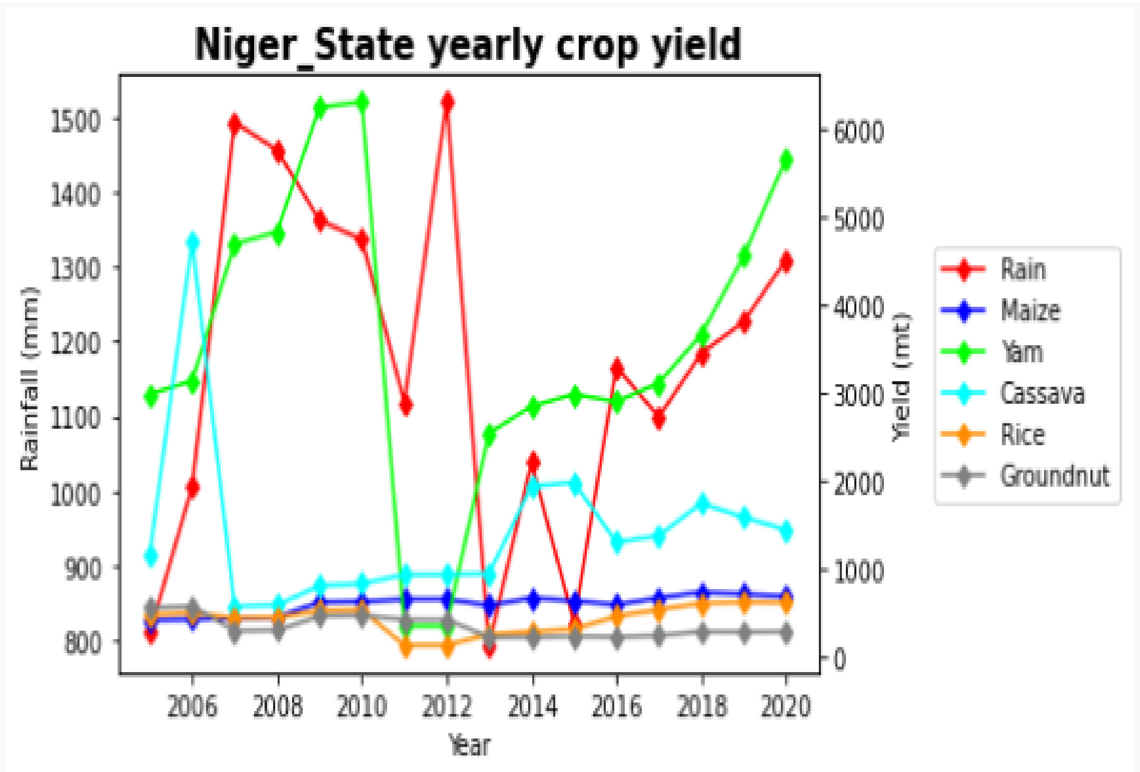


Figure 4. 26 Rainfall and Yearly Crop Yield in Niger State

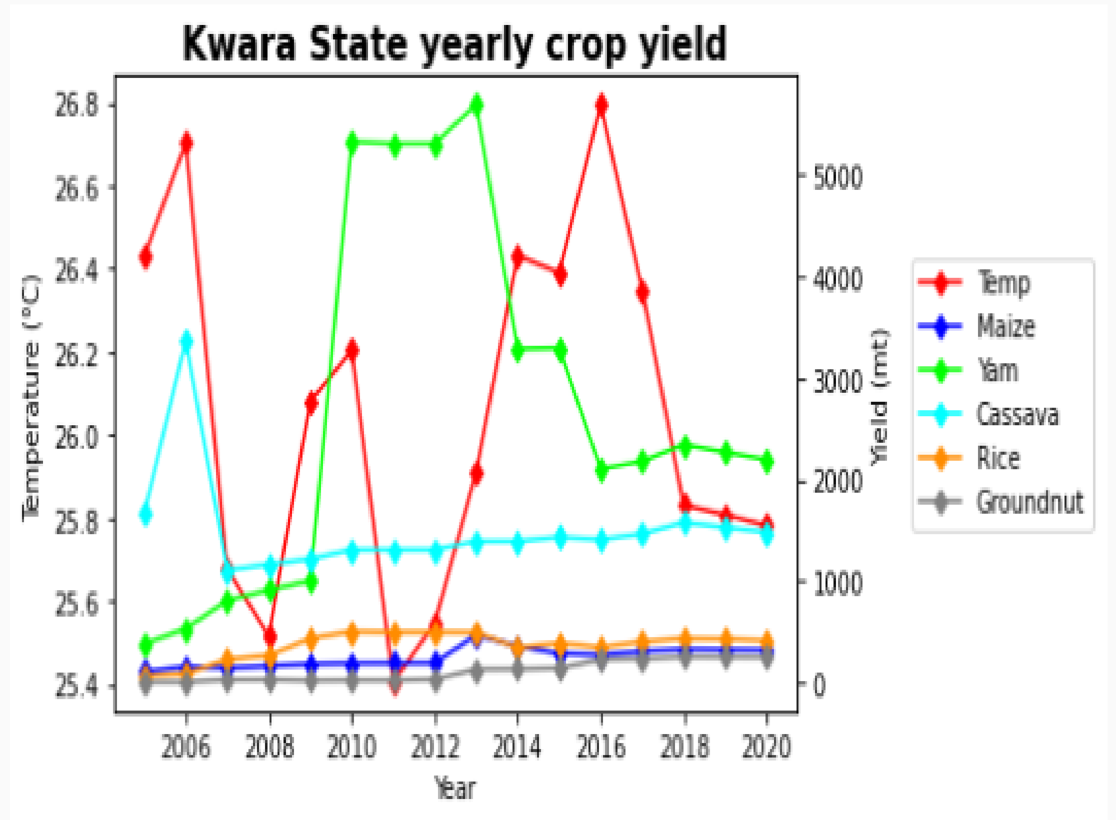


Figure 4.27 Temperature and Yearly Crop Yield in Kwara State

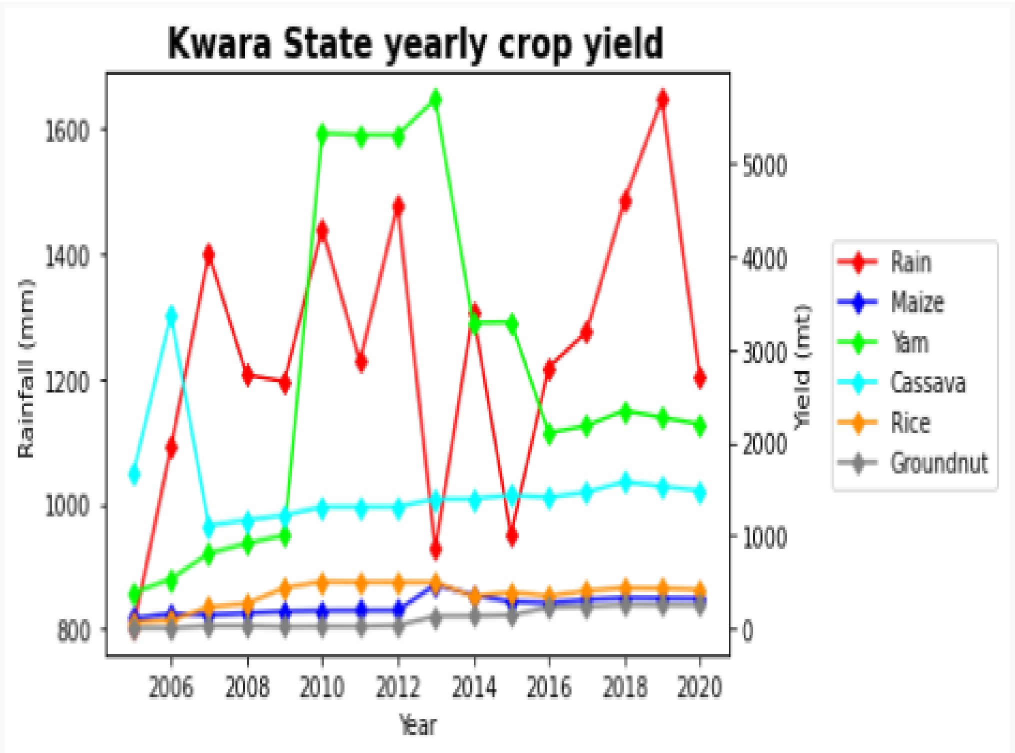


Figure 4. 28 Rainfall and Yearly Crop Yield in Kwara State

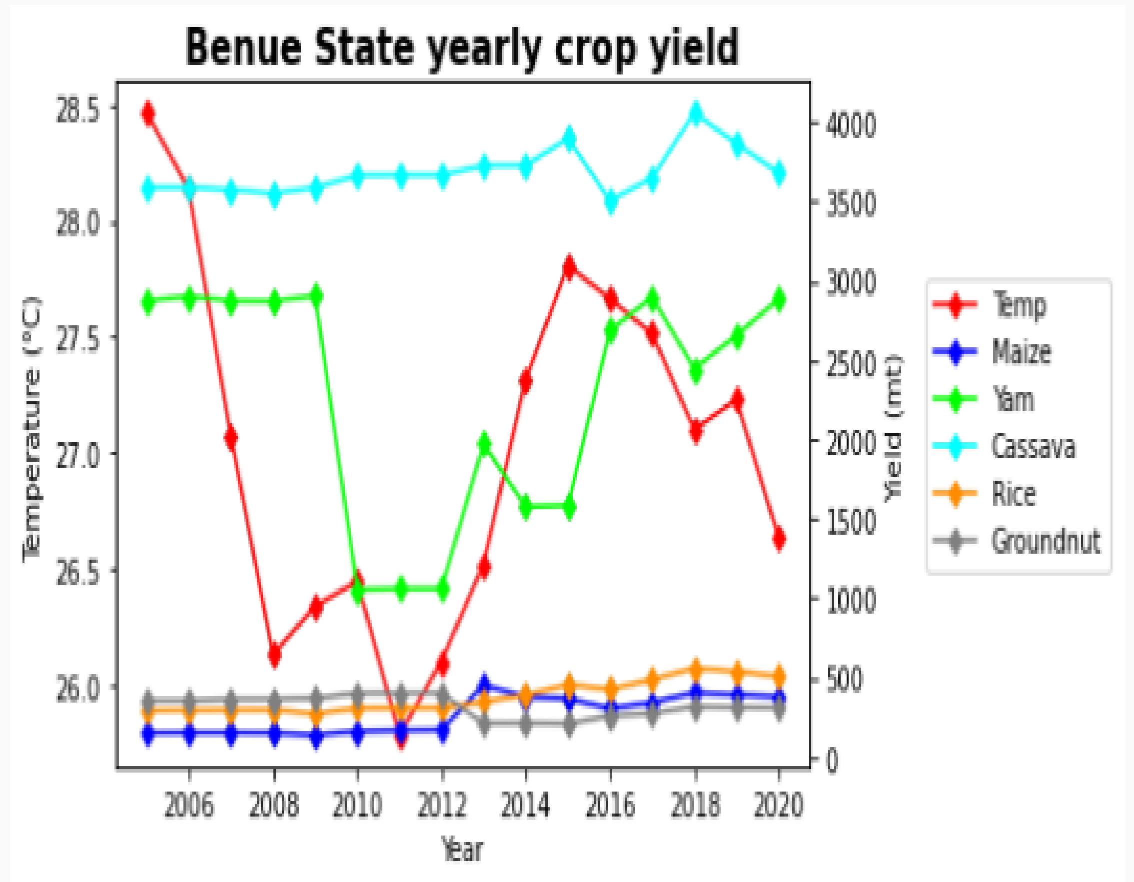


Figure 4. 29 Temperature and Yearly Crop Yield in Benue State

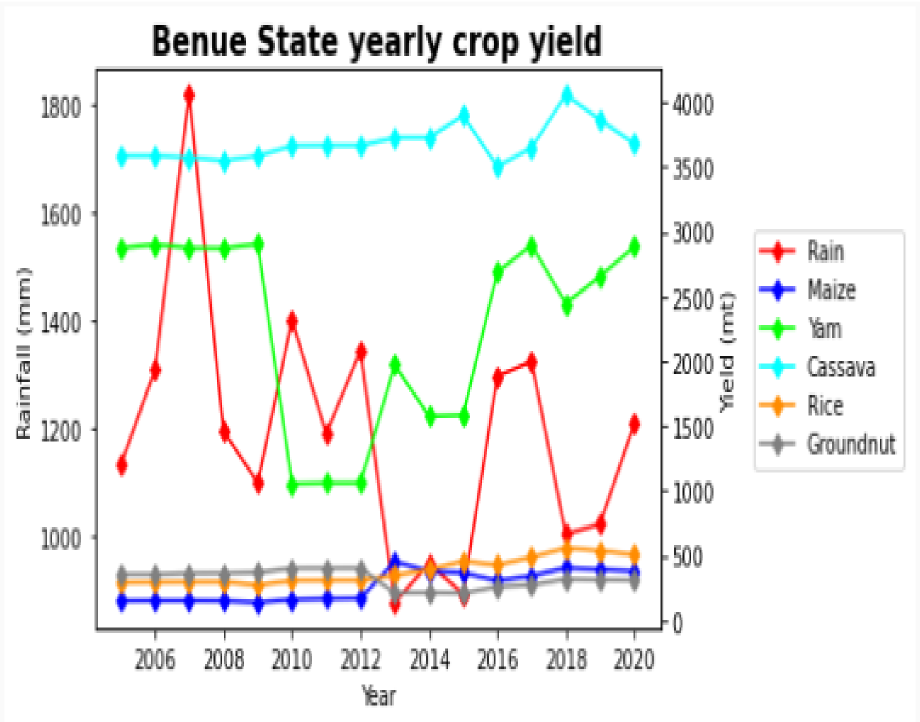


Figure 4. 30 Rainfall and Yearly Crop Yield in Benue State

4.1.3.2 Impacts of climate change on food production in the study area

Climatic parameters play a vital role in the yields of many food crops in many parts of Nigeria. These parameters have variable trends and patterns which lead to variations in the yields of these food crops (Adamgbe and Ujoh, 2012).

(a) Relationship between crops yields and temperature

Table 4.11 gives the result of the regression analysis between crop yields of maize, yam, cassava, rice and groundnut and temperature in Niger, Kwara and Benue States from 2005-2020. The results show that the regression value (R^2) for maize in Niger State was 0.4167 while the t-statistic value, p-value and alpha values were -2.4469, 0.0294 and 0.05 respectively. The results indicate that there is a moderate negative statistically significant relationship between maize yields and temperature in Niger State. Therefore, increase in temperature will lead to decrease in crop yields. This result seems to agree with the findings of Ajetomobi (2016) that exposure of maize to high heat rate has negative influence on its yields. Also, there is a weak negative insignificant influence of temperature on the yields of yam, cassava and rice with the respective R^2 values of 0.1058, 0.06758 and 0.3075. This implies increase in temperature will cause insignificant decrease in their yields. This is in agreement with the outcome of the study by Agba *et al*. (2017) that temperature has insignificant influence on crop production in Nigeria. On the contrary, there is a weak positive insignificant relationship between temperature and groundnut yields (R^2=0.1989) which means that a marginal increase in temperature will have an insignificant increase in the yield of the crop. This is similar to the findings of Sule *et al.* (2020) that there is no meaningful contribution of temperature to the variation in groundnut yields. Additionally, the linear regression analysis of Table 4.11 reveals that the model is only able to explain variations in the yields of various crops ranging from 0.4167 (41.67 per cent) for maize, 0.1058 (10.58 per cent) for yam, 0.06758 (6.758 per cent) for cassava, 0.3075 (30.75 per cent) for rice and 0.19890 (19.89 per cent) for groundnut. This implies that 58.8 per cent, 89.42 per cent, 93.242 per cent, 69.25 per cent and 80.11 per cent for maize, yam, cassava, rice and groundnut yields respectively are explained by other influential factors like the use of fertilizers, good crop seeds, the use of agro-technological equipment, effective crop management among others.

In Kwara State, there was a weak negative insignificant relationship between temperature and the yields of maize, cassava and groundnut with respective R^2 values of 0.02278, 0.2373 and 0.1571. This implies that increase in temperature will result to insignificant decrease in yields of these crops whereas there was a weak positive insignificant influence of temperature on the yields of yam (R^2=0.05782) and rice (R^2=0.13854) which indicates that increase in temperature will lead to insignificant increase in the yields of yam and rice in Kwara State. These results agree with the findings of Mijinyawa and Akpenpuu (2015), that increase in temperature will lead to increase in rice and decrease in maize. The results also indicate that the crop yields in Kwara State are majorly influenced by other similar factors like the case of Niger State.

There was a weak and a negative insignificant relationship between temperature and crop yields of maize (R^2=0.1274), yam (R^2=0.1470) and rice (R^2=0.1769) in Benue State. This indicates that increase in temperature will only have insignificant decrease in their yields. This partially agrees with the findings of Adamgbe & Ujoh (2012) that increase in temperature will lead to significant increase in the yields of maize and rice in Benue State. Also, there was a weak and positive statistically insignificant relationship between temperature and cassava yields (R^2=0.02548) in Benue State meaning that increase in temperature will lead to insignificant increase in cassava yields. On the contrary, there was a weak but statistically significant relationship between temperature and groundnut yields (R^2=0.30985) in the State.

This implies that increase in temperature will result in significant increase in the groundnut yields. In addition, the model also indicates greater percentage of other similar factors as in the case of Niger and Kwara States influence the yields of the five crops under consideration

Table 4. 11 Regression Analysis of Crop Yields and Average Annual Temperature for Niger, Kwara and Benue States

State	Test	Maize	Yam	Cassava	Rice	Groundnut
Niger	R-square	0.416699	0.105757	0.067583	0.307474	0.198948
	Significance F	0.009346	0.707548	0.349414	0.264931	0.09562
	Regression coefficient	-2525.45028	-5937.33	-11684.5	-2080.68	2810.735496
	t-statistic	-2.4469	-0.23843	-0.8631	-0.96292	2.043816
	P-value	0.029383	0.815263	0.403728	0.353157	0.061782
	Alpha	0.05	0.05	0.05	0.05	0.05
	Remarks	**Significant**	**Insignificant**	**Insignificant**	**Insignificant**	**Insignificant**
Kwara	R-square	0.022778	0.057822	0.237259	0.138538	0.157064
	Significance F	0.591334	0.387983	0.065545	0.17188	0.16066
	Regression coefficient	-585.505	28701.48	-14043.4	2989.456	-2404.14
	t-statistic	-0.37946	0.990963	-1.8167	1.662088	-1.41838
	P-value	0.710473	0.339791	0.092382	0.120405	0.181523
	Alpha	0.05	0.05	0.05	0.05	0.05
	Remarks	**Insignificant**	**Insignificant**	**Insignificant**	**Insignificant**	**Insignificant**

Benue	R-square	0.127419	0.14698	0.025484	0.176928	0.309846
	Significance F	0.191521	0.158363	0.569828	0.118472	0.031146
	Regression coefficient	-1361.42	-8956.69	2786.693	-1241.38	1822.225
	t-statistic	-1.14684	-1.19823	1.795888	-1.27489	2.923898
	P-value	0.272117	0.252218	0.095779	0.224663	0.011851
	Alpha	0.05	0.05	0.05	0.05	0.05
	Remarks	**Insignificant**	**Insignificant**	**Insignificant**	**Insignificant**	**Significant**

Source: Author’s fieldwork (2023)

(b) Relationship between crop yields and rainfall

Table 4.12 indicates the results of the regression analysis between rainfall and crop yields of maize, yam, cassava, rice and groundnut in Niger, Kwara and Benue States from 2005-2020. The results show that there was a positive relationship between rainfall and all the crops in all the three States although some were significant while some were insignificant. In Niger State, there was a weak statistically significant positive relationship between the yields of maize (R^2=0.021701, t=4.779 and p=0.00036) and cassava (R^2=0.2183, t=2.951, p=0.01124). This implies that increase in rainfall will lead to increase in the yields of maize and cassava. On the contrary, there was a weak statistically insignificant relationship between rainfall and yields of yam (R^2=0.1059, t=0.1778 and p=0.8616), rice (R^2=0.0395, t=1.0793 and p=0.30) and groundnut (R^2=0.199, t=1.035275 and p=0.06178). This means an increase in the quantity of rainfall will lead to an insignificant increase in the yields of yam, rice and groundnut in Niger State. These findings agree with the findings of Sule *et al*. (2020) that maize yields depend on rainfall but disagrees with the same findings that groundnut yields are dependent on rainfall in Niger State.

Kwara State also follows the same pattern of significance like Niger State. Yields of maize (R^2=0.0360, t=2.274 and p=0.0405) and cassava (R^2=0.047218, t=2.3919 and p=0.03258) showed a weak statistically significant relationship with rainfall. This indicates that increase in rainfall will lead to increase in their yields. This is contrary to the findings of Oriola and Oyeniyi (2017) that rainfall has no impacts on the yields of maize and cassava in Kwara State. The yields of yam (R^2=0.000483, t=0.9535 and p=0.3577), rice (R^2=0.03784, t=1.1783 and p=0.2598) and groundnut (R^2=0.00736, t=0.395 and p=0.70) indicated a weak statistically insignificant relationship with rainfall. This means there will be insignificant effects of increase in rainfall on their yields in Kwara State. This is not in agreement with the predicted model by Mijinyawa and

Akpenpuun (2015) that increase in rainfall will cause the decrease in the yields of rice in Kwara State.

A moderate statistically significant positive relationship existed between maize yields (R^2=0.40728, t=5.0674 and p=0.000216) and rainfall in Benue State. Similarly, there was a weak statistically significant positive relationship between rainfall and yields of cassava (R^2=0.3402, t=24.59748 and p<0.000001) and rice (R^2=0.15316, t=4.48553 and p=0.000613) in the State. This indicates that increase in rainfall will cause a significant increase in the yields of maize, cassava and rice in Benue State. There was a weak statistically insignificant positive relationship between rainfall and the yields of yam (R^2=0.03284, t=1.483 and p=0.1619) and groundnut (R^2=0.3391, t=1.4322 and p=0.1757) indicating that increase in rainfall will have insignificant impacts on the yields of yam and groundnut in Benue State. These findings seem to partially agree with the findings of Patrick *et al.* (2019) that there is a relationship between crop yields and amount of rainfall in Benue State.

Table 4. 12 Regression Analysis of Food Crops and Annual Rainfall for Niger, Kwara and Benue States

State	Test	Maize	Yam	Cassava	Rice	Groundnut
Niger	R-square	0.021701	0.105896	0.218328	0.039461	0.198948
	Significance F	0.600341	0.236589	0.079067	0.477866	0.09562
	Regression coefficient	696.2194998	458.9965	3987.723	261.8344	2810.735496
	t-statistic	4.778645	0.177835	2.951467	1.079341	1.035275
	P-value	0.00036039	0.861594	0.01124	0.300055	0.061782
	Alpha	0.05	0.05	0.05	0.05	0.05
	Remarks	**Significant**	**Insignificant**	**Significant**	**Insignificant**	**Insignificant**
Kwara	R-square	0.036034	0.000483	0.047218	0.03784	0.00736
	Significance F	0.498013	0.938002	0.436602	0.487235	0.77058
	Regression coefficient	378.471	3088.718	2244.071	243.2187	74.47113
	t-statistic	2.274284	0.953476	2.391908	1.178311	0.394968
	P-value	0.040546	0.357742	0.032575	0.259792	0.699797
	Alpha	0.05	0.05	0.05	0.05	0.05
	Remarks	**Significant**	**Insignificant**	**Significant**	**Insignificant**	**Insignificant**

Benue	R-square	0.407281	0.03284	0.340163	0.153158	0.339094
	Significance F	0.010462	0.518052	0.022479	0.14916	0.022743
	Regression coefficient	649.8109	1546.965	4116.353	580.6521	114.483
	t-statistic	5.067436	1.482908	24.59748	4.48553	1.432242
	P-value	0.000216	0.161932	<0.000001	0.000613	0.175679
	Alpha	0.05	0.05	0.05	0.05	0.05
	Remarks	**Significant**	**Insignificant**	**Significant**	**Significant**	**Insignificant**

Source: Author's fieldwork (2023)

4.1.3.3 Impacts of land use change on migration as it affects food production in the study area

(a) Impacts of LULC on migration

To evaluate the influence of changes in LULC on migration, Univariate regression analysis was conducted using Equation (3.8). The results presented in Table 4.13 showed that changes in vegetation, water body, and agricultural land have little or no influence on the rate at which people migrate in and out of these three States. On the contrary, conversion of other LULC classes to barren land and built-up areas negatively influenced migration of people in and out of the three States except in Benue State in which changes in built-up areas have little or no influence on their rate of migration. The results also indicated that 63.7 per cent, 54.7 per cent, and 63.2 per cent of net migration in Niger State, Kwara State, and Benue State, respectively, was influenced by the changes in all five classes of LULC. These results showed that changes in vegetation, water body, and agricultural land had little or no impacts on the rate of migration in the three States, whereas a rapid increase in barren land and built-up areas had caused a significant migration of people from the three States and if this remains uncontrolled, it will have a serious impact on the food availability in the region and country as a whole.

Table 4. 13 Univariate Regression Analyses Showing the Influence of Changes in LULC on Migration in Niger, Kwara and Benue States

State			VG	WB	AL	BL	BA	R^2
Niger	NetMig	p-value	0.117	0.108	0.110	0.004	0.002	0.64
		Coeff.	-150.622	9425.086	-247.240	-24.57	-76.485	
Kwara	NetMig	p-value	0.289	0.764	0.371	0.005	0.002	0.55
		Coeff.	6.107	2249.173	-27.764	33.074	-146.09	
Benue	NetMig	p-value	0.119	0.112	0.111	0.014	0.953	0.63
		Coeff.	2012.620	133980.98	728.388	-23.60	-0.178	

Coeff.=Coefficient, NetMig=Net Migration, VG=Vegetation, WB=Waterbody, AL=Agricultural Land, BL=Barren Land, BA=Built-up Area.

Source: Author's fieldwork (2023)

(b) Effects of LULC on food crop production

To evaluate the resultant impacts of LULC change on crop production, estimated cultivated land area and crop yields data of maize, rice, groundnut, cassava and yam for the three States obtained from National Agricultural Extension and Research Liaison Services (NAERLS), Zaria-Nigeria were analyzed and efforts were also made to calculate the yield per land area cultivated (Figures 4.31-4.33), there has been fluctuations in the area of land apportioned for cultivation of the crops in Niger State except for cassava, which has been increasing over the last 15 years. These fluctuations in the estimated cultivated land area led to myriad changes in the yields of all the five crops in the State. Despite the appreciable increase in the estimated cultivated land area for all five crops over the last 15 years in Kwara State, there have been fluctuations in the quantities of the yields produced during these years.

Similarly, there has been a continuous increase in the estimated land area for the cultivation of all the crops in Benue State except for rice and groundnut, which decreased in 2015 and yam, which declined in 2020. This continuous increase over the 15 years translated to a drastic increase in yields of all the crops except yam. Regarding crop yield per cultivated land area, there was a drastic and continuous decrease in yam and rice in all three States, while others showed various degrees of fluctuations. The increase in estimated cultivated land areas from available land mass in Kwara and Benue States, the reduction in agricultural land of these two States between 1990 and 2020, could be attributed to farmers shifting their attention to these five common staple crops in the areas thereby expanding the cultivated land areas of these five crops from the available land mass.

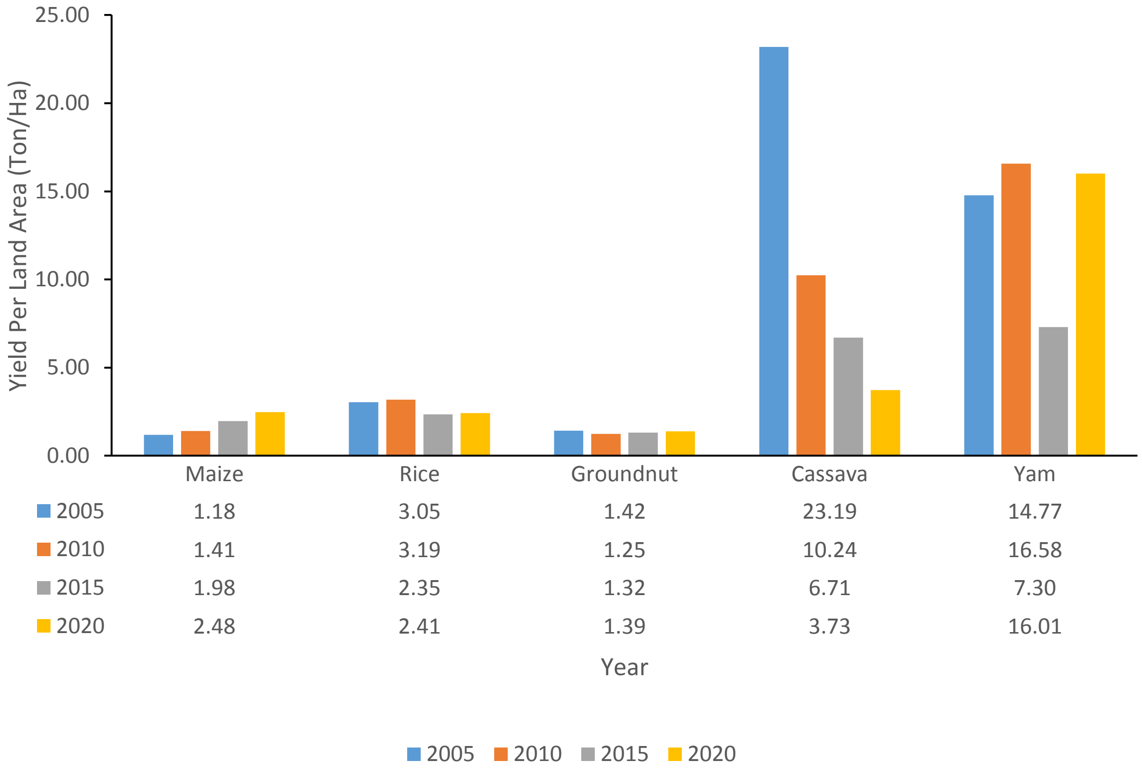


Figure 4. 31 Estimated Yield per Land Area for Niger State

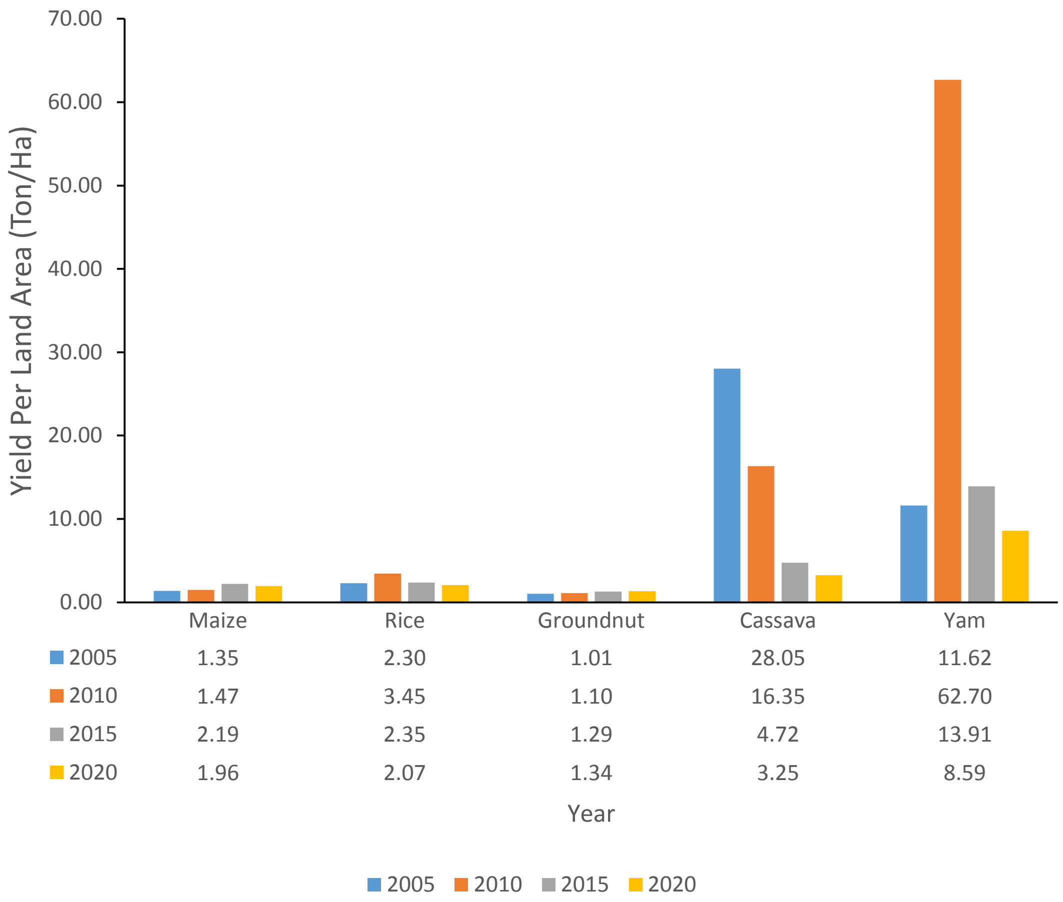


Figure 4. 32 Estimated Yield per Cultivated Land Area for Kwara State

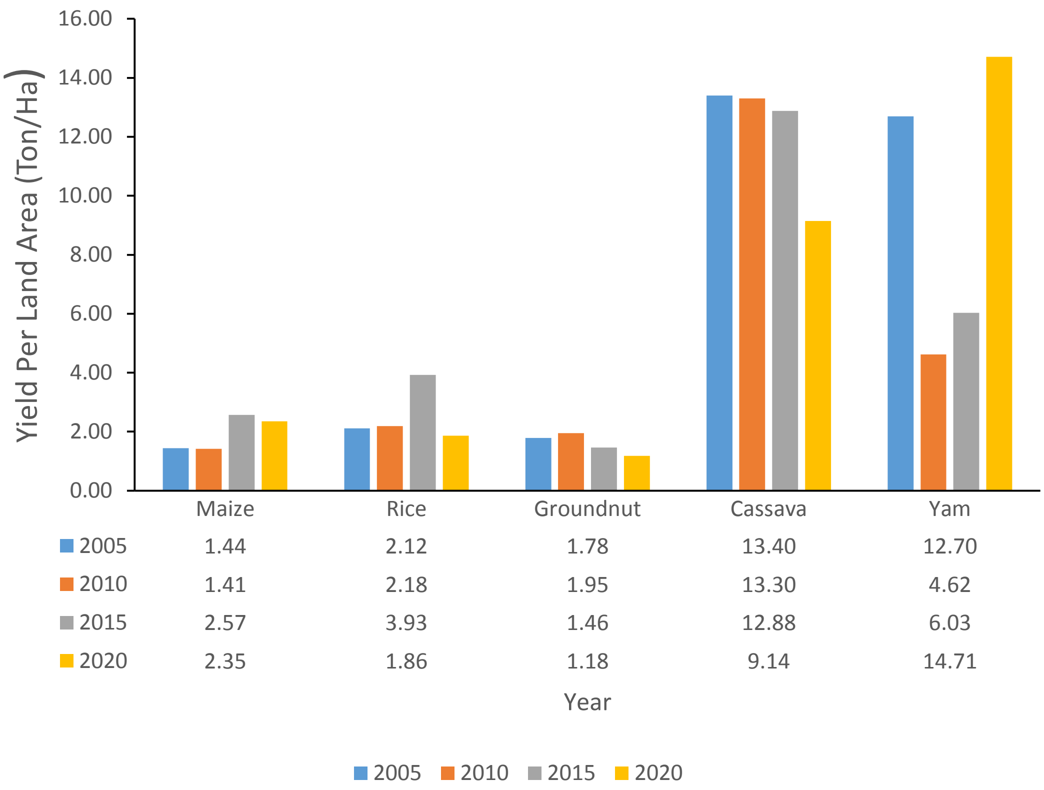


Figure 4. 33 Estimated Yield per Land Area for Benue State

(c) Effects of migration and changes in LULC on crop production

The results of multivariate regression analysis for maize, rice, groundnut, cassava, and yam for Niger, Kwara, and Benue States are presented in Table 4.14. The results showed that the model was able to explain the variations in the yields of food crops ranging from 95.5 per cent (0.955) for rice in Benue State to only 29.7 per cent (0.297) in the case of cassava in Niger State. The regression analysis showed a lot of significant relationships, while only few, mostly with cassava, are insignificant.

The coefficients can be used to assess the impacts of changes in net migration and LULC on food crop yields. The sign of the coefficients indicated the direction of the change in food crop yields with respect to net migration and LULC. Changes in maize yields are largely explained by changes in net migration and LULC, as these variables accounted for 87.1 per cent, 70.7 per cent, and 92.0 per cent changes in maize yields in Niger, Kwara and Benue States, respectively. Furthermore, 74.1 per cent, 76.2 per cent, and 95.5 per cent variations in the yields of rice in Niger, Kwara, and Benue States, respectively, are explained by changes in net migration and LULC.

Similarly, groundnut yields in Niger, Kwara, and Benue States with respective R-squared values of 0.942, 0.936, and 0.898 are majorly influenced by the changes in net migration and LULC. Cassava yields showed a weak relationship in all three States. Only 29.7 per cent, 40.9 per cent, and 36.8 per cent in cassava yields variations in Niger, Kwara, and Benue States, respectively, are controlled by changes in net migration and LULC, while changes in net migration and LULC have high impacts on the yields of yam in Niger, Kwara, and Benue States with respective R-squared values of 0.522, 0.698, and 0.752. Furthermore, net migration was a major variable that influenced the yields of groundnut and yam in Niger State. Maize yields in Niger and Benue States and yam in Benue State are influenced by changes in all the classes of LULC. Other classes of LULC had varied degrees of impact on the yields of the five food crops across the three States. These results showed that net migration and changes in LULC have a great impact on the yields of the five food crops in all the three States.

Table 4. 14 Multivariate Regression Analyses Showing the Influence of Net Migration and LULC on Crop Yields of Niger, Kwara and Benue States

State	Crop		NetMig	VG	WB	AL	BL	BA	R^2
Niger	Maize	p-value	0.402	0.017	0.018	0.017	0.013	0.004	0.871
		Coeff.	0.001	0.791	-48.123	1.286	0.094	0.344	
	Rice	p-value	0.166	0.314	0.245	0.281	0.004	0.020	0.741
		Coeff.	-0.003	-0.64	46.104	-1.122	-0.20	-0.45	
	Groundnut	p-value	0.000	0.001	0.000	0.000	0.052	0.022	0.942
		Coeff.	0.003	1.446	-88.427	2.322	-0.91	-0.33	
	Cassava	p-value	0.192	0.628	0.623	0.629	0.575	0.461	0.297
		Coeff.	0.025	-3.11	192.91	-5.003	0.317	1.248	
	Yam	p-value	0.024	0.322	0.283	0.301	0.010	0.015	0.522
		Coeff.	-0.070	-9.54	635.35	-16.14	-2.61	-7.18	
Kwara	Maize	p-value	0.341	0.026	0.826	0.350	0.004	0.001	0.707
		Coeff.	0.001	-0.05	-6.045	0.110	-0.17	0.826	
	Rice	p-value	0.069	0.614	0.624	0.308	0.049	0.048	0.762
		Coeff.	-0.003	-0.01	-17.084	0.152	-0.14	0.566	
	Groundnut	p-value	0.328	0.000	0.121	0.161	0.045	0.000	0.936
		Coeff.	0.001	-0.09	21.167	-0.079	-0.055	0.549	
	Cassava	p-value	0.065	0.563	0.873	0.885	0.883	0.732	0.409
		Coeff.	0.016	-0.09	32.706	-0.124	-0054	0.520	
	Yam	p-value	0.615	0.622	0.314	0.058	0.003	0.008	0.698

		Coeff.	0.010	0.203	-536.89	4.521	-3.63	12.78	
Benue	Maize	p-value	0.651	0.001	0.001	0.001	0.044	0.007	0.920
		Coeff.	0.000	15.66	1023.2	5.504	0.093	0.038	
	Rice	p-value	0.969	0.018	0.015	0.017	0.399	0.000	0.955
		Coeff.	<0.0001	5.983	403.90	2.141	-0.17	0.057	
	Groundnut	p-value	0.971	0.000	0.000	0.000	0.058	0.521	0.898
		Coeff.	<0.0001	-15.6	-1013.0	-5.479	-0.08	-0.01	
	Cassava	p-value	0.774	0.686	0.686	0.692	0.503	0.153	0.368
		Coeff.	0.001	4.825	316.19	1.676	0.058	0.036	
	Yam	p-value	0.105	0.018	0.016	0.016	0.005	0.013	0.752
		Coeff.	-0.014	104.8	7051.7	38.088	-1.20	0.290	

Coeff.=Coefficient, NetMig=Net Migration, VG=Vegetation, WB=Waterbody, AL=Agricultural Land, BL=Barren Land, BA=Built-up Area.

Source: Author’s fieldwork (2023)

4.1.4 Identification of sustainable adaptation strategies to minimize the impacts of climate change and land use changes and migration monitoring at different levels

To validate the results of the analysis of climate change and LULC and their influence on migration and food security, efforts were made to analyze the outcome of the field survey (household questionnaire, focus group discussions, and expert interviews),

4.1.4.1 Demographic characteristics of the respondents

This segment presents the descriptive statistics of socio-economic characteristics of the respondents

(a) Names of the communities of the respondents

Data in Table 4.15 and Table 4.16 reveal that the respondents for the study were drawn from three (3) States in the North Central Geo Political Zone of the Federal Republic of Nigeria. From all the three States, four Local Governments each were visited for the purpose of data collections. From Niger State: Bida Local Government, Katcha Local Government, Bosso Local Government and Suleja Local Governments were selected. Badaggi and Shaba-Woshi from Katcha Local Government, Batavovogi and Debarako from Bida Local Government Shata-Shiqmar and Lokoto from Bosso Local Government, and Chaza and Rafinseyi from Suleja Local Government. 25 respondents were interviewed in each community making a total of 200 respondents in Niger State.

Also, from Kwara State: Alapa and Ballah from Asa Local Government, Olooru and Shao from Moro Local Government, Imode and Aiyedun from Oke-Ero Local Government, and Araromi and Okeya-Ipo from Irepodun Local Government with all the communities having 25 respondents each making a total of 200 respondents in Kwara State. The third State is Benue State: Tse and Agan from Makurdi Local Government, Ikapayongo and Taraku from Gwer-East Local Government, Otobi-Okpa and Asa-Otukpo from Otukpo

Local Government, Okpokwu-Ito and Ijegwu-Ito from Obi Local Government with all the communities having 25 respondents each and making a total of 200 respondents in Benue State. In all, 600 respondents were interviewed in the three States.

Table 4. 15 Frequency Distribution of Names of respondents' Communities

SN	Names of Communities	Frequency	Percentage (%)
1	Badeggi (Katcha)	25	4.2
2.	Shaba-Woshi (Katcha)	25	4.2
3.	Batavovogi (Bida)	25	4.2
4	Debarako (Bida)	25	4.2
5	Shata-Shiqmar (Bosso)	25	4.2
6	Lokoto (Bosso)	25	4.2
7	Chaza (Suleja)	25	4.2
8	Rafinseyi (Suleja)	25	4.2
9	Alapa (Asa)	25	4.2
10	Ballah (Asa)	25	4.2
11	Olooru (Moro)	25	4.2
12	Shao (Moro)	25	4.2

Source: Author's fieldwork (2023)

Table 4. 16 Frequency Distribution of Names of respondents' Communities (Cont.)

SN	Names of Communities	Frequency	Percentage (%)
13	Imode (Oke-Ero)	25	4.2
14	Aiyedun (Oke-Ero)	25	4.2
15	Araromi (Irepodun)	25	4.2
16	Okeya-Ipo (Irepodun)	25	4.2
17	Tse-Ayihe (Makurdi)	25	4.2
18	Agan (Makurdi)	25	4.2
19	Ikapayongo (Gwer East)	25	4.2
20	Taraku (Gwer-East)	25	4.2
21	Ijegwu-Ito (Obi)	25	4.2
22	Okpokwu-Ito (Obi)	25	4.2
23	Otobi-Okpa (Otukpo)	25	4.2
24	Asa-Otukpo (Otukpo)	25	4.2
	Total	600	100.0

Source: Author's fieldwork (2023)

(b) Gender, marital status and ethnicities of the respondents

Table 4.17 reveals that 88.9 per cent of the respondents are male while only 11.2 per cent are female. This implies that majority of the respondents are male. This is in agreement with the general notion that Nigerian farmers are mostly male (Okeleye *et al*. 2016). Also, 89.8 per cent of the respondents are married, 9.2 per cent of the respondents are single while the remaining 1.0 per cent of the respondents are widow/widower. This implies that majority of the respondents are married.

In addition, Table 4.17 reveals that 25.3 per cent of the respondents are between the ages of 30-39years, 22.4 per cent are between the ages 50-59years, 16.5 per cent are between the ages of 20-29 years while the remaining 31.4 per cent are those from 50years and above. This implies that majority of the respondents fall within the youthful and working class ages and this can facilitate the agricultural practices in the study area as physical strength is needed for the cultivation of crops and rearing of livestock.

Furthermore, Table 4.17 indicates that 31.9 per cent of the respondents are Yoruba, 17.7 per cent of the respondents are Nupe, 17.0 per cent are Tiv, 8.8 per cent are Idoma, 8.3 per cent are Igede, 6.0 per cent are Gbagyi, 3.8 per cent are Hausa, 2.3 per cent are Gwagi, 1.3 per cent are Fulani, 1.0 per cent are Igbo, 0.8 per cent of the respondents are Igala, 0.7 per cent are Gwari, while the remaining 0.2 per cent of the respondents are Bassa. This shows that North Central Region is diverse in culture. Yorubas are mostly found in Kwara. Nupes, Tivs and Gbagyis are mostly found in Niger State while Idomas and Igedes are mostly found in Benue State (Okeleye *et al.* 2023).

Table 4. 17 Gender, Marital Status, Age and Ethnicities of the Respondents

Variable	Percentage
Gender	
Male	88.9
Female	11.2
Marital Status	
Single	9.2
Married	89.8
Widow/widower	1.0
Age	
20-29	16.5
30-39	25.3
40-49	26.0
50 and above	31.4
Ethnicity	
Yoruba	31.9
Nupe	17.7
Tiv	17.0
Idoma	8.8
Igede	8.3
Gbagyi	6.0
Hausa	3.8
Gwagi	2.3
Fulani	1.3
Igbo	1.0
Igala	0.8
Gwari	0.7
Bassa	0.2

Source: Author’s fieldwork (2023)

(c) Household characteristics and the level of education of the respondents

Table 4.18 reveals that 22.7 per cent of the respondents are from household size between 1-5 members, 40.9 per cent of the respondents are from house hood size between 6-10 members, 36.4 per cent of the respondents are from house hood size of 11 members and above, while the remaining. Members of this relatively high household size can be sources of labour in their respective families' farms.

The Table also reveals that 75.4 per cent of the respondents are head of the family, 13.1 per cent of the respondents are children in the family, while the remaining 11.5 per cent of the respondents are wives in the family. This implies that majority of the respondents are heads of their families.

Regarding the level of education of the respondents, 38.6 per cent of the respondents have secondary level of education, 22.7 per cent of the respondents have primary level of education, 20.5 per cent of the respondents have no formal education, 13.9 per cent of the respondents have NCE/OND level of education, 4.4 per cent of the respondents have BSc/HND level of education, while the remaining 1.5 per cent of the respondents did not indicate their level of education. This implies that majority of the respondents have moderate level of education and this can increase the rate at which they adapt to the negative impacts of climate and land use changes on their food security.

Table 4.18 also indicates that 26.1 per cent of the respondents have more than four (4) women in their household, 23.5 per cent of the respondents have two (2) women in their household, 22.0 per cent of the respondents have three (3) women in their household, 16.9 per cent of the respondents have four (4) women in their household while the remaining

11.5 per cent of the respondents have one (1) woman in their household. This implies that respondents with more than four (4) women in their household participated more in the study. This means majority of the respondents practised polygamy. The women in the household can engage in the processing of the agricultural produce and this will increase the income of their families and improve the food security of the study area.

Also, Table 4.18 shows that 22.6 per cent of the respondents have two (2) children in their household, 22.1% of the respondents have three (3) children in their household, 17.0 per cent of the respondents have four (4) children in their household, 16.2% of the respondents have above five (5) children in their household, 14.8 per cent of the respondents have five (5) children in their household, while the remaining 7.3 per cent of the respondents have one (1) child in their household. This implies that majority of the respondents have at least two (2) children.

Table 4. 18 Household Characteristics and the Level of Education of the Respondents

Variable	Percentage
Household size	
1-5	22.7
6-10	40.9
>10	36.4
Household position	
Head	75.4
Wife	11.5
Child	13.1
Level of education	
HND/BSc.	4.4
NCE/OND	13.9
Secondary	38.6
Primary	22.7
No formal education	20.5
Number of women in the household	
1	16.9
2	23.5
3	22.0
4	16.9
>4	26.1
Number of children in the household	
1	7.3
2	22.6
3	22.1
4	17
5	14.8
>5	16.2

Source: Author's fieldwork (2023)

(d) Land ownership and agricultural practices

Table 4.19 reveals that 48.4% of the respondents have 1 elderly person in their household, 42.5 per cent of the respondents have 2 elderly persons in their household, 6.1 per cent of the respondents have 3 elderly persons in their household, 2.5 per cent of the respondents have 4 elderly persons in their household, while the remaining 0.5 per cent of the respondents have 5 elderly persons in their household. This implies that majority of the households in the study have at least 2 elderly persons irrespective of the gender. Furthermore, Table 4.19 shows that 56.8 per cent of the respondents owned 1-5 acres of land, 32.7 per cent owned 6-10 acres, 8.9 per cent owned 11-15 acres and 1.5 per cent owned 16 acres and more. This result indicates that most of the respondents have 1-5 acres of land and this can determine the extent of land available for their agricultural production.

Concerning the sources of land ownership, Table 4.19 shows that most of the respondents (60 per cent) inherited their pieces of land while 24.9 per cent of them rented or leased their lands and 19.7 per cent of them purchased their acres of land. Table 4.19 shows that respondents are mostly (56.8 per cent) arable farmers while 38.8 per cent practice mixed cultivation and 3.8 per cent of them engage in the rearing of livestock. This results implies that cultivation of crops and rearing of livestock are practised in the study area. However, majority of the respondents (57.1 per cent) do not have drainage on their farmland while 42.9 per cent of them do (Table 4.19). Presence of drainage reduces the risk of flooding on their farms.

Table 4. 19 Land Ownership and Agricultural Practices

Variable	Percentage
Number of the elderly persons in the household	
1	48.4
2	42.5
3	6.1
4	2.5
>4	0.5
Acres of land owned	
1-5	56.8
6-10	32.7
11-15	8.9
>15	1.5
Sources of land ownership	
Inherited	60.0
Rented/Leased	24.9
Purchased	19.7
Types of primary production	
Crop only	56.8
Livestock only	3.8
Mixed	38.8
Availability of drainage on the farm	
Yes	57.1
No	42.9

Source: Author’s fieldwork (2023)

4.1.4.2 The opinions of the respondents on climate change and its signals

According to Table 4.20, majority of the respondents (73.9 per cent) believed that weather is changing while 26.1 per cent of them were of the opinion that weather is not changing. Most of the respondents attributed this changing weather to human activities like pollution, degradation among others while only 1.5 per cent attributed it to non-human activities.

As touching the respondents' awareness of climate change, Figure 33 shows that majority of them (92.7 per cent) are aware of climate change while only 7.3 per cent are not aware of climate change. Most of the respondents (52.1 per cent) got the awareness from radio, 32.7 per cent from television, 4.7 per cent through extension workers and 3.1 per cent from friends and families (Figure 34)**.**

Also, Table 4.20 shows that flooding is the major disaster (84 per cent) recognized in the study area while 15.5 per cent of the respondents saw drought as the major disaster in study area and 0.5 per cent regarded windstorm as the common climate change hazards in the study area. By implications, the general perception and dispositions of the respondents is that flooding is the common natural disaster in the study area. However, majority of the respondents witnessed these disasters occasionally while 31.6 per cent of them experienced them often and 6.7 per cent experienced these disasters only once

Table 4. 20 The Opinions of the Respondents on Climate Change and its Signals

Variable	Percentage
Perception on the change in weather pattern	
Yes	73.9
No	26.1
Reasons for the change in weather pattern	
Human activities	98.5
Non-human activities	1.5
Climate change awareness	92.7
Yes	7.3
No	
Sources of climate change awareness	
Radio	52.1
Television	32.7
Newspaper	7.7
Extension workers	3.1
Friends and families	4.7
Common disasters in the area	
Flooding	84
Drought	15.5
Windstorm	0.5
Frequency of the disaster	
Often	31.6
Occasionally	62.3
Only once	6.7

Source: Author’s fieldwork (2023)

4.1.4.3 Land use change/land degradation

(a) Land use and land cover in the study area

The opinion of the respondents on land use and land cover is reflected in Figure 4.34. According to the respondents, greater portions of the land in the study area are used for crop production (85.1 per cent), 9.2 per cent are for housing and garden, 4.6 per cent are for rearing of livestock while 1 per cent is forest. By implications, the general perception and dispositions of the respondents is that the most importance of land use based on the economic values is agriculture.

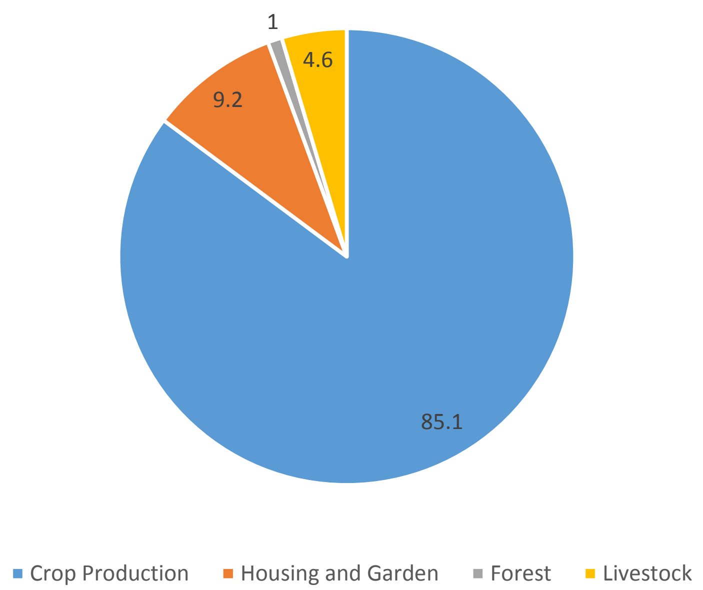


Figure 4. 34 Land Use and Land Cover in the Study Area

(b) History of vegetal cover and land degradation

Table 4.21 shows the vegetation composition/structure when the respondents first settled in the study area. Majority of them (66.7 per cent) said their communities were occupied by wild grassland. 26.4 per cent of them said their communities were wild forest, 4.9 per cent indicated their areas were predominantly water bodies while 1.4 per cent said it was same as today. Regarding the major types of land degradation, majority of the respondents (81.4 per cent) perceived soil erosion by water as the most prominent type. 9.4 per cent of them stated that there has been no degradation in their communities, 7.1 per cent of them said soil erosion by wind or chemical deterioration is the major type of land degradation in their communities.

Based on the assessment of the respondents as shown in Table 4.22, the study area is currently moderately degraded (72.6 per cent), 14.8 per cent of them said their communities are lightly degraded, 11.8 per cent of them were of the opinion that their communities are strongly degraded while 1.7 per cent said their lands are extremely degraded. However, in the last 10 years, majority of the respondents (34.5 per cent) said they are experiencing slowly increasing degradation, 33.4 per cent said they are experiencing moderate degradation, 18 per cent said their land is increasingly degrading, 13.4 per cent were of the opinion that their land is rapidly increasing while 0.7 per cent said there is no change in degradation. High rate of degradation can reduce their agricultural output.

Table 4. 21 History of Vegetal Cover and Land Degradation

Variable	Percentage
Vegetation composition when first settled	
Wild grassland	66.7
Wild forest	26.4
Water body	4.9
Same as today	1.4
Major types of land degradation	
Soil erosion by water	81.4
Soil erosion by wind/chemical deterioration	7.1
Others	2
No degradation	9.4
Current degree of land degradation	
Extreme	1.7
Strong	11.8
Moderate	72.6
Light	14.8
Rate of land degradation in the last 10 years	
Rapidly increasing degradation	13.4
Slowly increasing degradation	34.5
Increasing degradation	18.0
Moderate degradation	33.4
No change in degradation	0.7

Source: Author's fieldwork (2023)

(c) Coping mechanisms/ adaptation strategies

Regarding coping mechanisms/Adaptation to land degradation, according to Figure 4.35, majority (47.5 per cent) of the respondents stated that they migrate to another place temporarily whenever land is degraded, 41.5 per cent pointed that they look for alternative source of livelihood whenever land is degraded, 9.0 per cent said that they migrate to another place permanently whenever land is degraded, while the remaining 0.5 per cent said engage in other things. By implications, the general perception and dispositions of the respondents are that they migrate to another place temporarily and look for alternative source of livelihood whenever land is degraded.

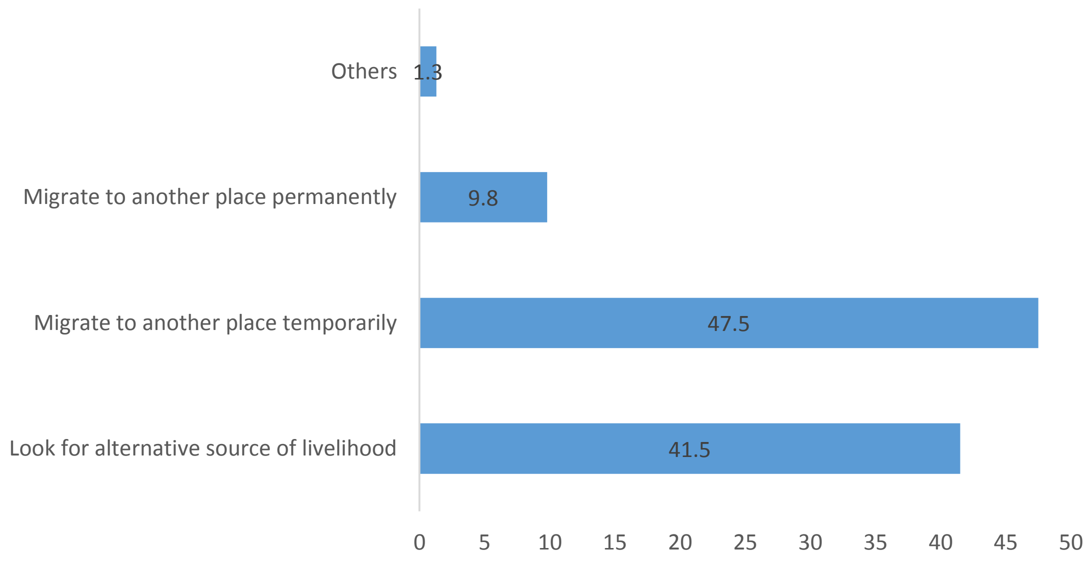


Figure 4. 35 Coping Mechanisms/Adaptation to Degradation

4.1.4.4 Migration

(a) Respondents' place of birth

Figure 4.36 shows the place of birth of respondents in the study Area. Majority of the respondents (69.4 per cent) said they were born in their current location while others (30.6 per cent) said they were born in another location. This implies that most of the respondents will be custodians of the culture and traditions of their respective communities. For the respondents who were born in the study Area, 66.5 per cent of them said they were born in the neighbouring town while 33.5% of them said they were born in another State (Figure 4.37).

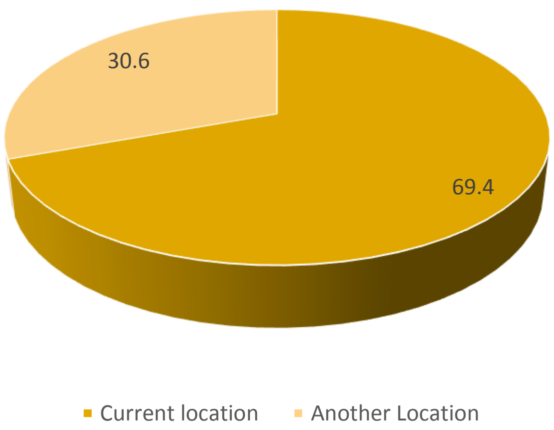


Figure 4. 36 Place of Birth

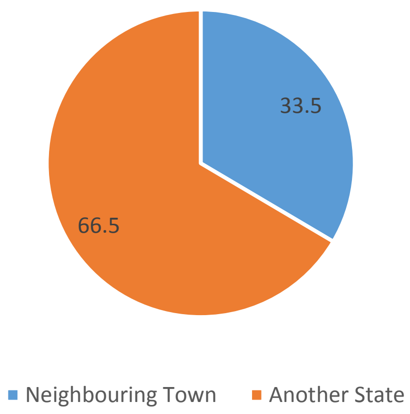


Figure 4. 37 Place of Birth for Respondents Not Born in the Study

(b) Respondents' reasons for migrating to the current location

Figure 4.38 indicates reasons why the respondents migrate to their current locations. Majority of the respondents (55.9 per cent) stated that they migrated in search of better farming activities, 33.9 per cent said that they migrated in search of better job opportunities, 9.3 per cent indicated that they migrated in search of better weather condition, while the remaining 0.5 per cent said that they migrated because of schooling. By implications, majority of the respondents who were not born in their current location migrated in search of better farming and job opportunities. According to the respondents, changes in LULC exacerbated by environmental and socio-economic factors are responsible for the migration of people in the study areas. The environmental factors that determine the rate of migration are majorly the state of the fertility of the soil and the rate of land/soil degradation in the area. Furthermore, availability of land, demographic pressure and hunger, and land insecurity are the major socio-economic factors that influence the rate of migration in the study area.

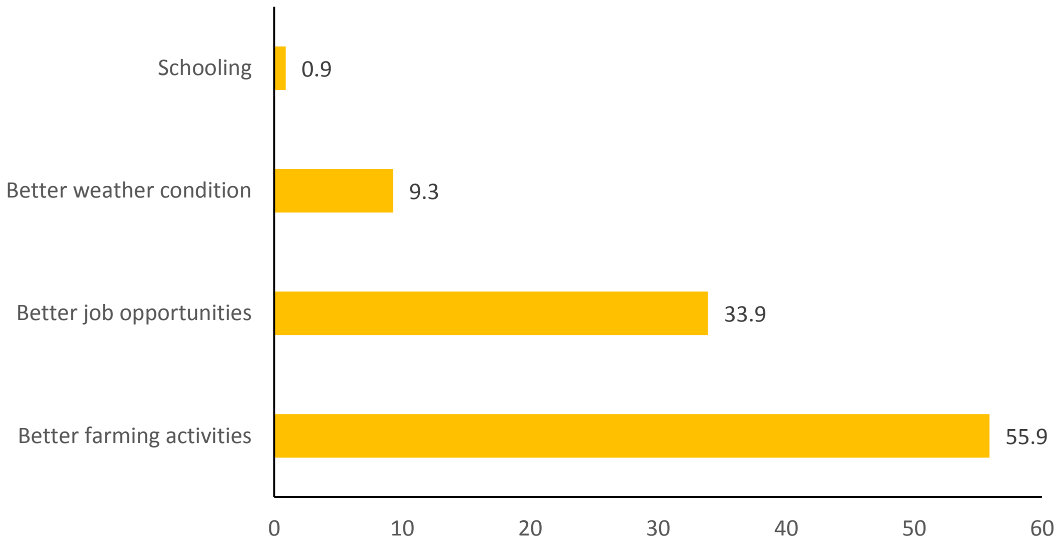


Figure 4. 38 Reasons for Migrating to the Current Location

(c) Factors responsible for pattern of migration

As presented in Table 4.22. In the three States, outmigration is the commonest pattern of migration. There were at least three family members on average of each of the respondents that migrated in the last five years. The majority of these migrants, who were male and young, went to the neighbouring states.

Table 4.22 Factors Responsible for Pattern of Migration

Variable	Percentage
Pattern of Migration	
In-migration	14.9
Out-migration	81.4
Cross border migration	3.7
Number of migrated family members in the last five (5) years	
1-5	73.9
6-10	18.7
Above 10	7.5
Destinations of migrated family members	
Neighbouring town	55.3
Another state	44.7
Frequently migrating gender	
Male	80.7
Female	19.3
Age categories of migrants	
Elderly	6.0
Youth	89.4
Children	4.6

Source: Author’s fieldwork (2023)

(d) Factors affecting the frequency of migration

Table 4.23 shows that the pattern of migration happens in every rainy season. Most of the participants during the stakeholders' meetings and expert interview attributed migration of young men to nearby States during the raining season to destruction of farmlands as a result of flooding, especially in farmlands situated near the river sides, hence, some of the young farmers usually migrate to the areas that are not prone to flooding to continue with their farming activities, while most of them migrate to the cities to look for greener pasture. According to them, some of these migrants do not always come back to their former locations.

Table 4.23 Factors Affecting the Frequency of Migration

Variable	
Frequency of migration of family members	**Percentage**
Every month	11.3
Every year	15.4
Every raining season	40.4
Every drying season	2.8
Once in a while	30.1
Environmental factors determining migration	
Soil fertility	46.5
Land/soil degradation	29.7
Deforestation	9.7
Poor soil profitability	10.4
Unfavourable weather condition	3.7
Socio-economic factors influencing migration	
Land availability	43.6
Demographic pressure	31.2
Hunger	15.4
Land insecurity	9.8

Source: Author's fieldwork (2023)

4.1.4.5 Food security

(a) Crops and livestock grown by the respondents

Figure 4.39 showcases the major crops grown and livestock reared by the respondents in the study area. When grouped together, rice and maize with 26 per cent and 23.7 per cent respectively are mostly cultivated in the study area. Other crops are cassava, yam, beans, groundnut and sorghum with respective percentages of 10.5, 7.3, 6.3, 4.2 and 4.2 other crops in little quantity are millet, cash crops, soybeans, potatoes, tomatoes, tobacco, cowpea, wheat, pepper and other crops. Some of the respondents also rear fishes, livestock like goat, sheep, cattle among others.

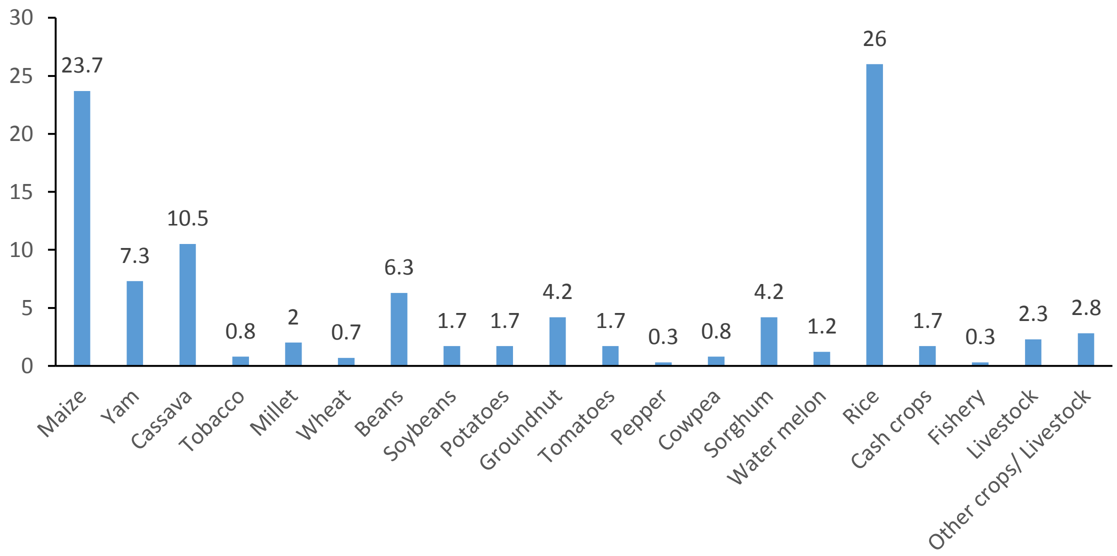


Figure 4. 39 Crops and Livestock Grown by the Respondents

(b) Area of land devoted to agriculture

Figure 4.40 indicates the area of land used by the respondents for the production of crop and/or livestock. More than two-third (69 per cent) of the respondents said they used 1 hectare, more than one-fifth (20.3 per cent) said they used less than 1 hectare for the cultivation of crops and/or rearing livestock while the remaining 10.7 per cent indicated they used more than 1 hectare. It can be implied that majority of the respondents have at least one hectare of land for agricultural production.

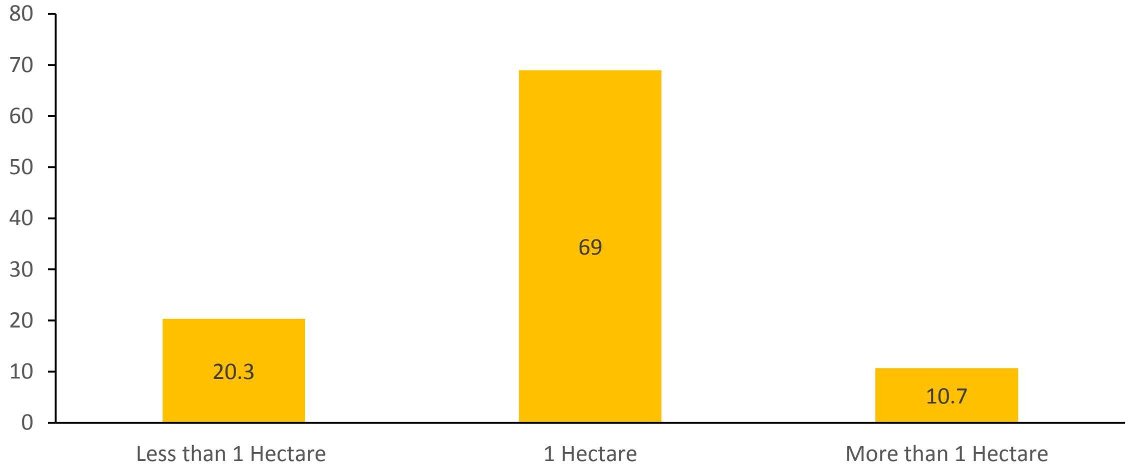


Figure 4. 40 Area of Land Devoted to Agriculture

(c) Average annual income from agricultural production

As touching annual income from agricultural production, as indicated in Figure 4.41, majority of the respondents (61.5 per cent) realized ₦500,000 to ₦990,000 which is approximately equivalent to $1,170-$2,320 per year. About 23 per cent of the respondents said they realized less than ₦500,000 ($1,170) per year while 15.9 per cent of them earned more than ₦1,000,000 ($2,350) per year. It should be noted that these amounts do not include the equivalent prices of the agricultural produce consumed by the respondents and their families.

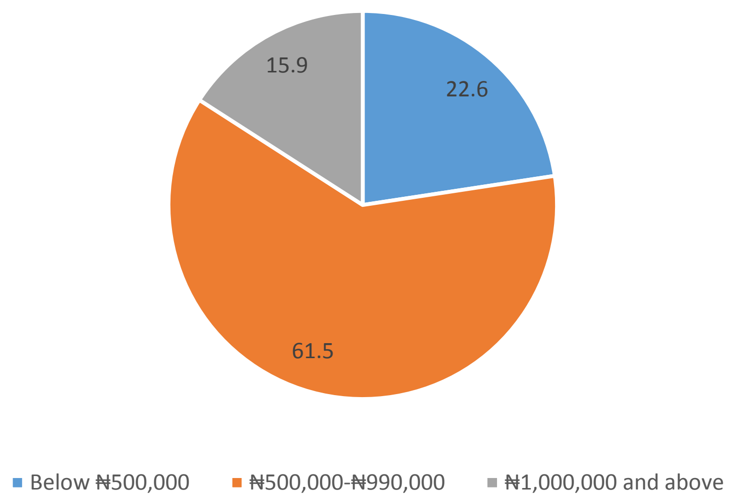


Figure 4. 41 Average Annual Income from Agricultural Production

(d) Respondents' perceptions on rainfall and air temperature patterns in the last twenty (20) Years

Figure 4.42 depicts the perception of the respondents on the rainfall pattern in the last 20 years. More than half of the respondents (50.3 per cent) said there has been decrease in rainfall pattern in the last 20 years. 37.3 per cent of them said the rainfall in their areas has been fluctuating in the last 20 years while the remaining 12.4 per cent were of the opinion that there has been increase in the rainfall pattern over the last 20 years. The opinion of the majority is in conformity with the outcomes of the analyses of the climatological parameters of this study which state that there was a significant decreasing trend in the average annual rainfall of Niger and Benue States between 1985 and 2020.

Regarding the perception of the respondents on the pattern of air temperature over the last 20 years, majority of the respondents (43.7 per cent) were of the opinion that the air temperature has been fluctuating in the last 20 years, 36.6 per cent perceived a decline in temperature while the remaining 19.7 per cent of them said the temperature has been increasing (Figure 4.43). This is contrary to the outcomes of the analyses of the climatological variables of this study which indicate that there is an upward increasing trend in the average air temperature of Niger and Benue States.

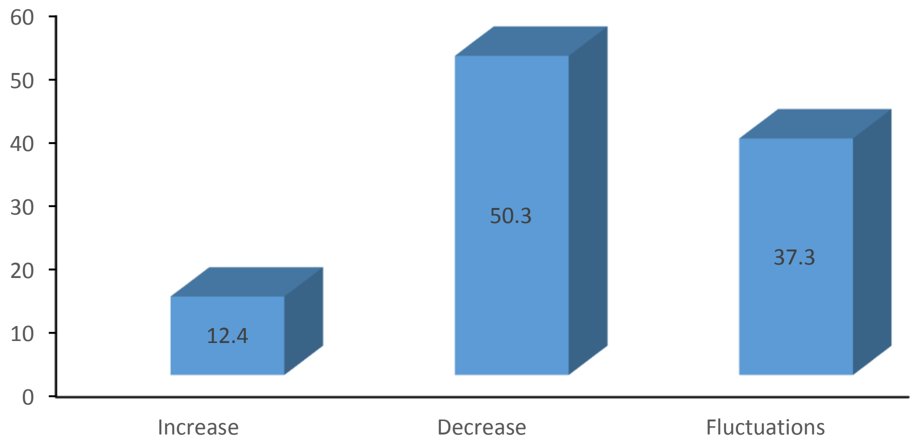


Figure 4. 42 Perception on Rainfall Pattern in the Last 20 Years

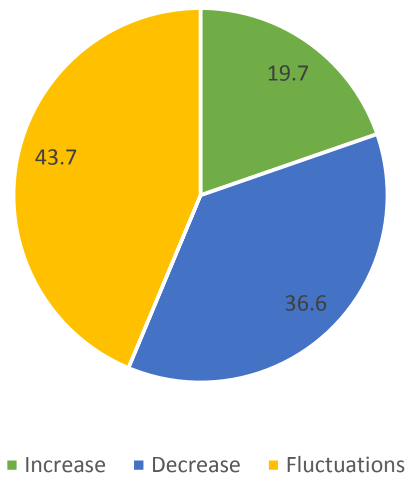


Figure 4. 43 Perception on Air Temperature Pattern in the Last 20 Years

(e) Climatic variables and crop production as perceived by respondents

Figure 4.44 showcases the effects of rainfall pattern on crop production in the last 20 years. Majority of the respondents (69 per cent) said rainfall pattern in the last 20 years has led to decrease in their crop production, 20.3 per cent of them said the rainfall pattern in the last 20 years has caused an increase in their crop production while the remaining 10.7 per cent of them said the changing rainfall pattern in the last 20 years has no effect in the production of their crops.

As depicted in Figure 4.45, majority of the respondents (61.5 per cent) said that pattern in air temperature in the last 20 years has caused a decrease in their crop production and 22.6 per cent of the respondents said air temperature pattern in the last 20 years has led to the increase in their crop production while the remaining 15.9 per cent of them were of the opinion that air temperature pattern in the last 20 years has no impacts on their crop production. By implications, the general perception and dispositions of the respondents is that the rainfall pattern in the last 20 years has brought a decline to crop production. Similarly, air temperature in the last 20 years has reduced crop production.

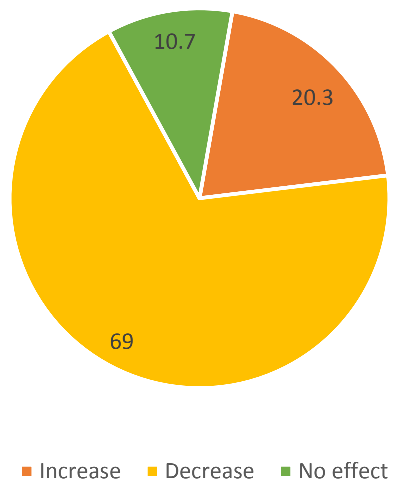


Figure 4. 44 Climatic Variables and Crop Production as perceived by Respondents

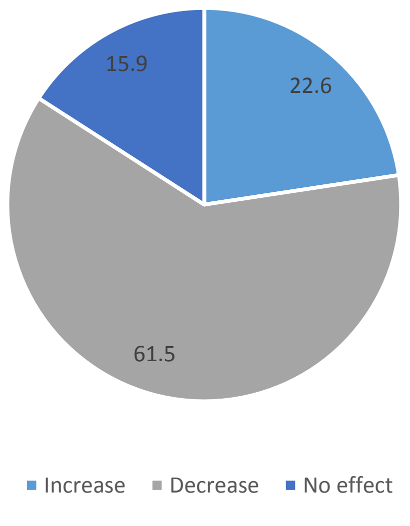


Figure 4. 45 Effects of Air Temperature Pattern on Crop Production in the Last 20 Years

(f) Opinions of respondents on crops mostly affected by changes in the pattern of rainfall and air temperature

Figure 4.46 shows crops that are mostly affected by climate parameters (rainfall and air temperature). Based on ranking, rice (44.2 per cent) is mostly affected followed by maize (17.9 per cent), yam (17 per cent), beans (6.1 per cent sorghum (55.5 per cent) and cassava. Those that are less affected include cowpea (2.5 per cent), groundnut (1.9 per cent), tomatoes (0.8 per cent) and pepper (0.4 per cent). This implies that rice, maize and yam are the three crops that are majorly affected by climate change in the study area.

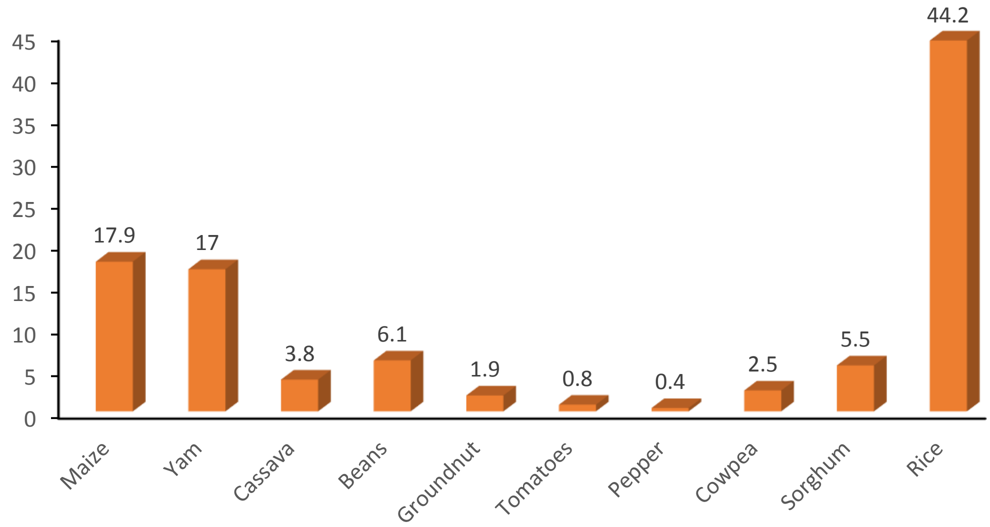


Figure 4. 46 Opinions of Respondents on Crops Mostly Affected by Changes in the Pattern of Rainfall and Air Temperature

(g) Respondents' Perceptions on the Food Availability in the Last Twenty (20) Years

Figure 4.47 shows the perception of the respondents on the food availability in the last 20 years. Majority of the respondents (95 per cent) said that the food availability in the study area has drastically reduced and 2.6 per cent said the food availability has increased while the minority (2.4 per cent) said there is no change in the food availability in the last 20 years.

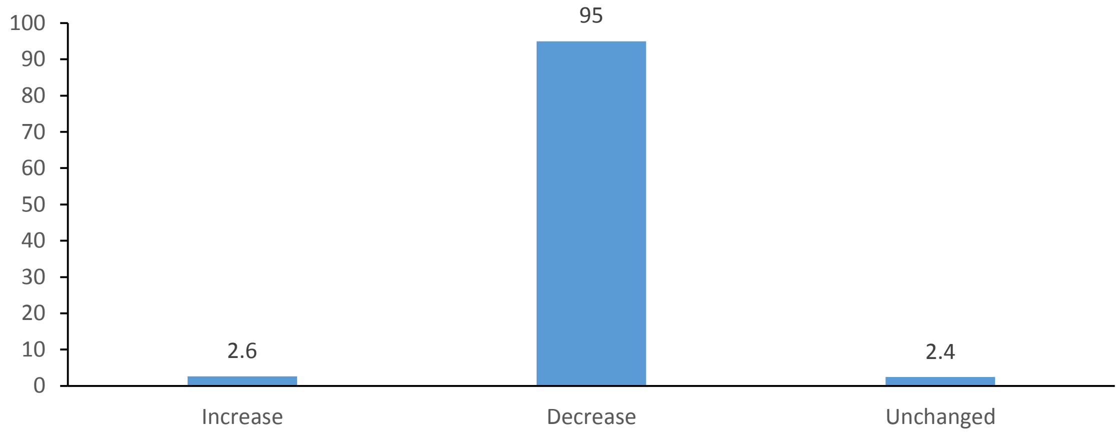


Figure 4. 47 Perception on Food Availability in the Last 20 Years

(h) ***Respondents' Perceptions on the Reasons for the Changes in the Food Availability in the Last Twenty (20) Years***

Concerning the respondents' reasons for the changes in the food availability in the last 20 years, majority of them (27.9%) attributed it to the decrease in crop production, 26.6 per cent said it was due to increase in food price. Also, 17.9 per cent of them said were of the opinion that the change in food availability was due to decrease in food price, 14 per cent said it was due to increase in their income, 6.4 per cent opined that it was because of increase in crop production, 5.1 per cent attributed it to decrease in their income, 1.3 per cent said it was because of the decrease in dairy products while the remaining 0.7 per cent attributed the change in food availability in the last 20 years to increase in other household burden (Figure 4.48).

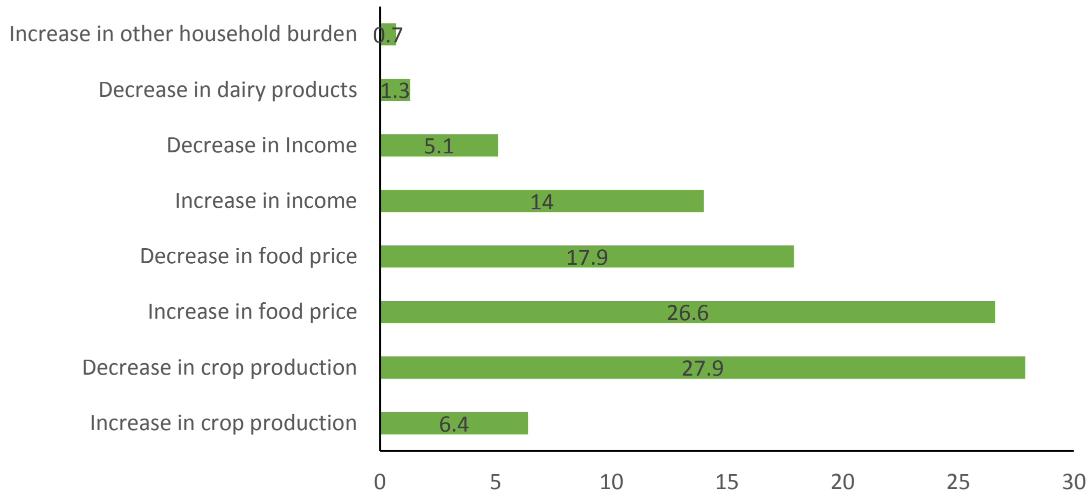


Figure 4. 48 Reasons for Changes in the Food Availability in the Last 20 Years

(i) ***Respondents' Perceptions on the Food Accessibility and Food Stability in the Last Twenty (20) Years***

Figure 4.49 pinpoints the perception of the respondents on the food accessibility in the last 20 years. Nearly three-quarter (74.3 per cent) of the respondents said that their access to food decreased in the last 20 years, 16.6 per cent of them said there was no change in their accessibility to food while the remaining 9.1 per cent were of the opinion that there has been an increase in their food accessibility in the last 20 years. As touching the food stability of the respondents in the last 20 years as showcased in Figure 4.50, more than three-quarter (76.2 per cent) of the respondents said their food stability level has deteriorated in the last 20 years, 13.3 per cent of the respondents said there has been no change in the level of their food stability while the remaining 10.5 per cent of them were of the opinion that the level of their food stability has improved. This implies the food accessibility and stability of most of the respondents have drastically reduced.

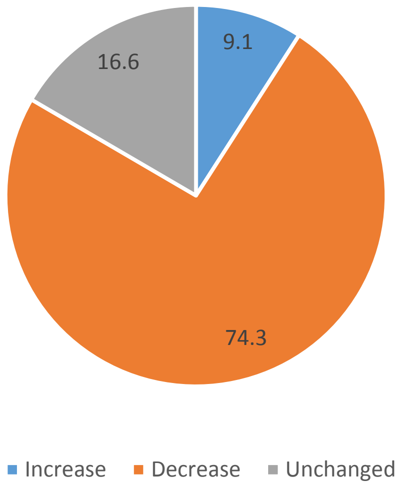


Figure 4. 49 Perception on Food Accessibility in the Last 20 Years

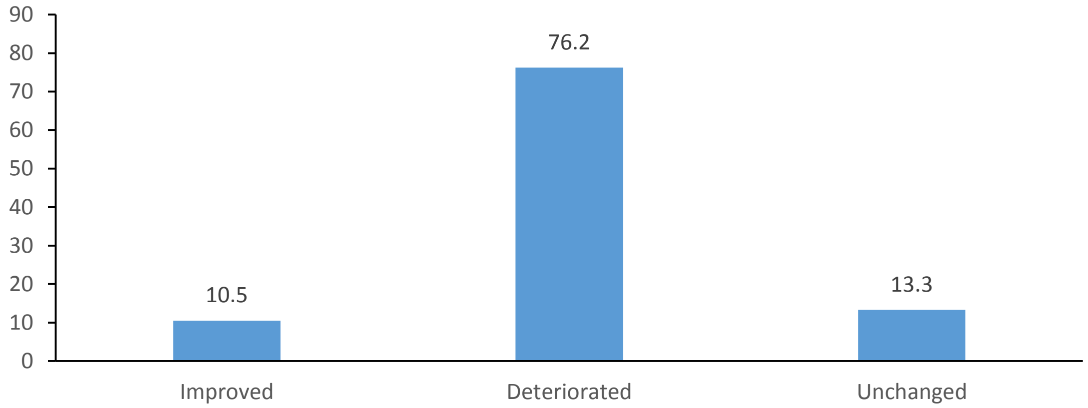


Figure 4. 50 Perception on Food Stability Level in the Last 20 Years

(j) Respondents' Perceptions on the Pattern of Food Utilization/Consumption in the Last Twenty (20) Years

Figure 4.51 depicts the perception of the respondents on their pattern of food consumption/utilization. Majority of the respondents (64.2 per cent) said their food consumption level has deteriorated, 18.7 per cent of them said there has not been any change in their level of food utilization in the last 20 years while 17.1 per cent of the respondents opined that their food consumption/utilization level has improved. By implications, the general perception and dispositions of the respondents is that food consumption/utilization pattern has deteriorated.

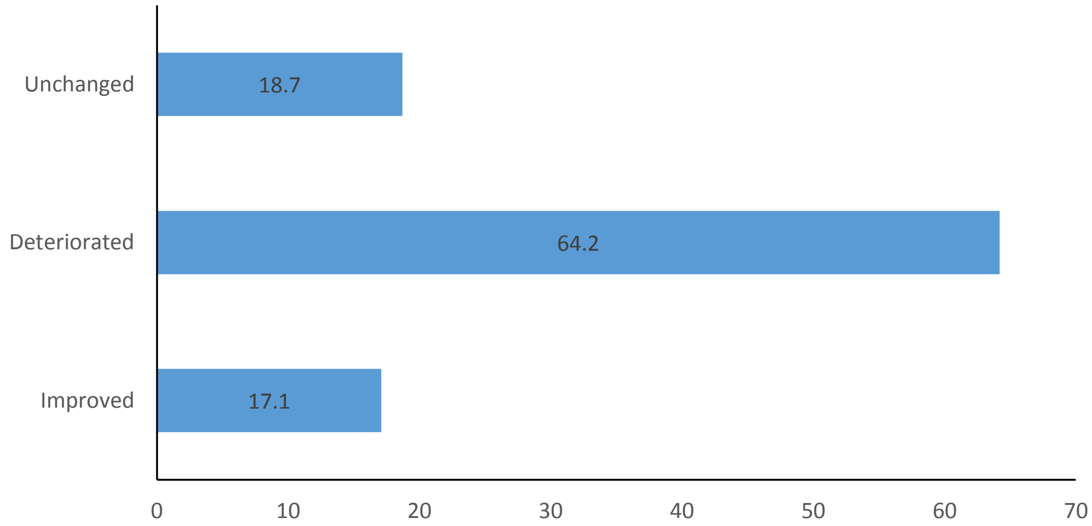


Figure 4. 51 Perception on the Pattern of Food Consumption/Utilization in the Last 20 Years

(k) Reasons for Changes in the Components of Food Security as Perceived by Respondents.

Figure 4.52 showcases the reasons for the changes in the components of the food security (food accessibility, stability and consumption/pattern) of the respondents. Based on percentage, majority of the respondents (27.8 per cent) said that the reasons for the changes in their food accessibility, stability and consumption/utilization is little or no awareness, 21.2 per cent stated that the reasons for the changes in their food accessibility, stability and consumption/utilization is unlimited accessibility to market, 19.0 per cent mentioned that the reasons for the changes in their food accessibility, stability and consumption/utilization is unfavourable weather condition, 11.1 per cent opined that the reasons for the changes in their food accessibility, stability and consumption/utilization is limited accessibility to market.

Also, 8.4 per cent were of the opinion that the reasons for the changes in their food accessibility, stability and consumption/utilization is unlimited awareness, 6.7 per cent said that the reasons for the changes in their food accessibility, stability and consumption/utilization is good road, 3.4 per cent stated that the reasons for the changes in their food accessibility, stability and consumption/utilization is bad road while the remaining 2.7 per cent established that the reasons for the changes in their food accessibility, stability and consumption/utilization is land degradation. By implications, the general perceptions and dispositions of the respondents is that little or no awareness, unlimited accessibility to market and unfavourable weather condition are the reasons for the changes in the food accessibility, stability and consumption/utilization of the respondents.

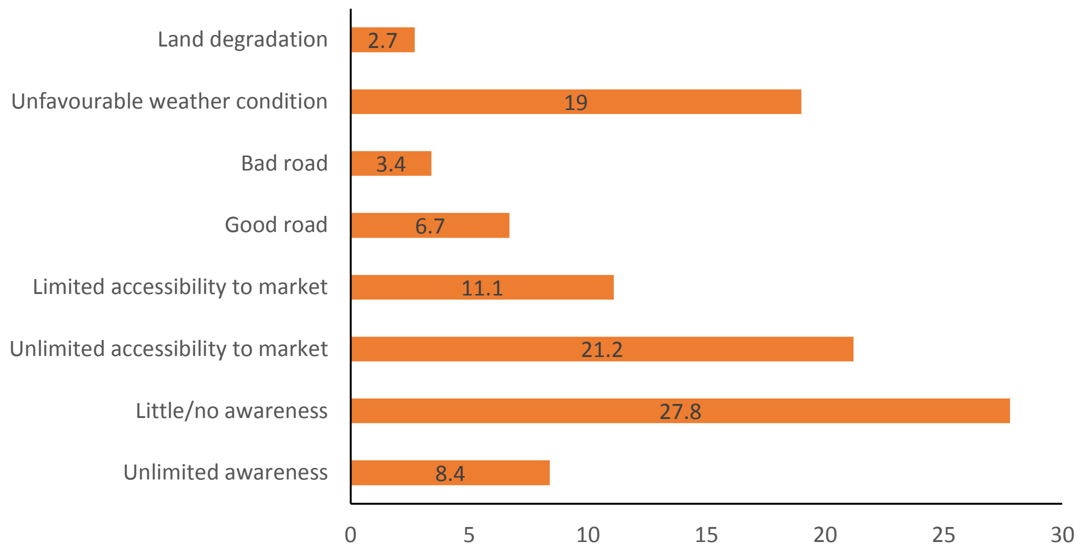


Figure 4. 52 Reasons for Changes in the Components of Food Security as Perceived by Respondents

(l) Respondents' Adaptation to the Negative Impacts of Climate Change and Land Use on Migration and Food Security

Figure 4.53 shows how the respondents adapt to negative impacts of climate change and land use change on migration and food security. Close to half (47.4 per cent) of the respondents adapt by changing their farming methods, 32.2 per cent said that income diversification has helped them adapt to negative impacts of climate change and land use change affecting their food security, 10.1 per cent stated that supports from external bodies has helped them to adapt to negative impacts of climate change and land use change affecting their food security, 5.0 per cent said that change of profession is a means by which they adapt to negative impacts of climate change and land use change affecting their food security, 3.9 per cent perceived migration to another place temporarily has helped them adapt to negative impacts of climate change and land use change affecting their food security, while the remaining 1.3 per cent saw migration to another place permanently as a way of adapting to negative impacts of climate change and land use change affecting their food security. This implies that the general perceptions and dispositions of the respondents is that changes in farming methods and income diversification have helped them adapt to negative impacts of climate change and land use change affecting their food security.

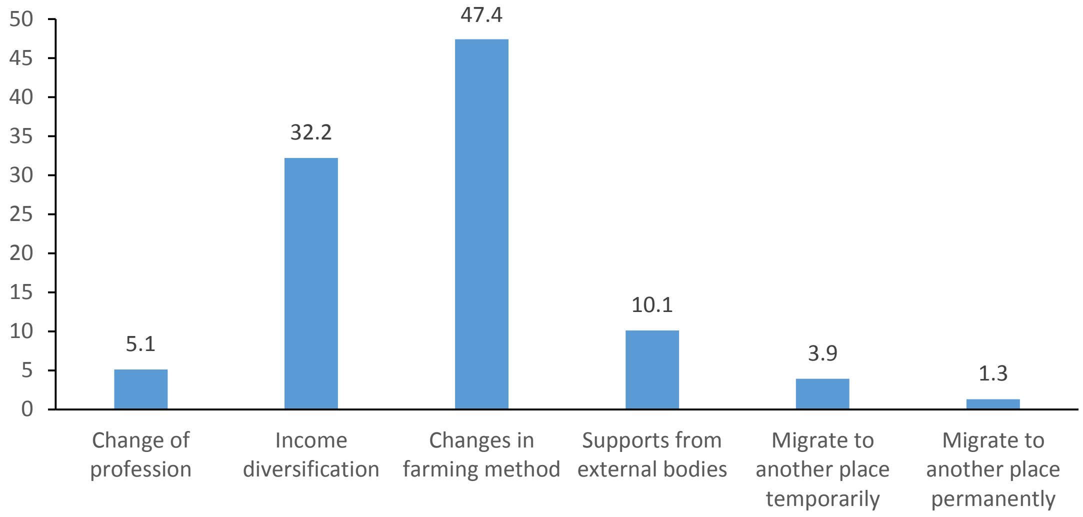


Figure 4. 53 Adaptation to the Negative Impacts of Climate Change and Land Use on Migration and Food Security

4.2 Discussion of Results

Results presented in section 4.1.1 indicate that the North Central Region of Nigeria experienced a considerable rise in temperature and a decline in rainfall between 1985 and 2020. Comparatively, the results show that Niger State seems to be the warmest out of all the three States because it has the highest increase in annual minimum, annual maximum and annual average temperatures and it also has the highest decrease in rainfall over the last 36 years. Benue State follows Niger State in terms of warming while Kwara State seems to be the coolest when compared with other two States because of its insignificant change in temperature and rainfall patterns in the last 36 years. Extreme weather events including flooding, fires, and torrential rainstorms are projected to become more common and more intense as global temperatures rise (IPCC, 2014 and Wilberforce, 2007). Due to the rise in the temperatures of these three States, extreme rainfall and ensuing severe flooding will likely have detrimental consequences on agriculture in all these three States, including soil nutrient leaching, topsoil erosion and flooding of previously arid soils. This may have consequential effects on food security and increase the rate of rural-urban migration.

Peasant farmers in Nigeria, notably in the North Central Region States like Niger, Kwara and Benue, deal with the effects of climate change every year. Rainfall that used to begin as early as March now begins in June and ends in September rather than October and this signifies the effects of climate variability in these three States. The results in Figures 4.4, 4.8 and 4.12 demonstrate that there is simply not enough time to cultivate crops because the rainy seasons have shrunk and reduced at a rate of -15.6 mm/year, -0.78 mm/year and -12.1 mm/year for Niger, Kwara and Benue States respectively. This implies a disaster for most of the farmers, where the vast majority of them depend on rainfall for their farming activities. The fact is that people's capacity to raise livestock, cultivate crops, and have access to drinkable water has all been negatively impacted by climate change.

The analysed results presented in Section 4.1.2 showed that the changes in LULC during the past 30years are a reflection of the influence of regional and national policies as well as human impacts on the study area, which have led to an increase in built-up areas and a decrease in vegetation. Food security and the availability of ecosystem products and services such as fertile land are both impacted by the bulk of agricultural land being converted to built-up areas. Infrastructure expansion and growing built-up areas result in the loss of agricultural land. In order to address the issues of forest degradation and deforestation, the expansion of urban or built-up areas, the loss of agricultural land, and water bodies in the study area, environmentalists, decision-makers, and other stakeholders urgently need to intervene.

Presently, Niger State has a comparative advantage over Kwara and Benue States in terms of available land for agricultural production, and if this opportunity is effectively utilized by relevant government agencies, it will boost the food security of the State. The growing amount of barren land in the Kwara and Benue States seems to indicate that afforestation and reforestation efforts to restore the vegetation are not progressing as quickly as they should. This is similar to the current situation in Malawi as reported by Munthali (2020). Furthermore, it can be asserted that Niger State would be food secured considering a high increase in agricultural land and a little increase in built-up areas in the last 30 years provided concerted effort is made to ensure continuous increase in agricultural land while at the same time reduce the pressure on the city’s infrastructure by discouraging rural-urban migration. However, in the case of Kwara and Benue States with a high decrease in agricultural land and continuous astronomical increase in built-up areas over the last

30 years, if it is business as usual, then the food security of the region and the entire country is under a serious threat.

According to FAO (1996), food security is measured by four components: food availability, food accessibility, food stability, and food utilization/consumption. The analysis of the crop yield and estimated cultivated land area indicated that there were fluctuations in the area of land used and this led to fluctuations in the quantities of the yields of these five crops. This study discovered that the fluctuations in the available land for agricultural production were as a result of changes in land use across different locations in the study area, as presented in the various LULC maps.

Regarding the impacts of changes in LULC on migration, this study found out that changes in vegetation, water body, and agricultural land had little or no impacts on the rate of migration in the three States, whereas a rapid increase in barren land and built-up areas had caused a significant migration of people from the three States and if this remains uncontrolled, it will have a serious impact on the food availability in the region and country as a whole.

Additionally, it was found out that there was a significant impact of the combination of net migration and changes in LULC on the yields of five major food crops in the three States, as changes in the yields of these food crops are majorly determined by this combination. Furthermore, most of the participants during the Focus Group Discussion corroborated this assertion by stating that there has been a drastic reduction in all the indicated components of food security because most of the young farmers are migrating out of these locations to look for greener pastures.

Furthermore, the results of the LULC and field survey indicated that outmigration is very common in all the three States. It can be inferred that as changes in LULC lead to the massive migration of people in the study areas, migration also impacts LULC, such as the conversion of agricultural land into barren land, especially in Kwara and Benue States. This is directly related to the impacts of outmigrated members who left agricultural land uncultivated and this is similar to the current situation of Bhanu Municipality of Tanahun district of Nepal, as reported by Bhandari *et al.* (2022). This conversion is mostly witnessed along the border towns. According to the majority of the respondents of household survey, at least an average of three members of each household outmigrated in the last five years, most of whom are young men who left their communities for neighbouring States because of poor soil fertility, degraded soil, limited land availability, demographic pressure, hunger, and land insecurity. They stated changes in farming method, income diversification, supports from external bodies and change of profession as some of the sustainable adaptation strategies to minimize the impacts of climate change, and land use changes and migration monitoring at different levels.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From the time immemoral, people living in the rural areas have seen migration to urban areas as means of adapting to climate change and land use and and this has a lot of negative effects on food security. It is on this basis that this study aims at analysing the effects of climate and land use change on migration and its consequent impacts on food security in the selected States (Niger, Kwara and Benue) in North Central Region of Nigeria. This study used mixed method of research approach involving quantitative and qualitative data collection.

The study revealed that there was an upward and statistically significant increase in the trend at a 5 per cent level of significance in minimum, maximum and average temperatures of Niger State and Benue States between 1985-2020 while there was an upward and statistically significant increasing trend in minimum temperature and statistically insignificant trends in maximum and average temperatures in Kwara State. The trend analysis also showed that there was a downward and statistically significant decreasing trend in the annual rainfall of Niger and Benue States while there was statistically insignificant trends in the annual rainfall of Kwara State.

The results of the Land Use and Land Cover (LULC) of Niger State between 1990-2020 showed that most of the vegetation, barren land and water areas in the State have been converted to agricultural land and built-up areas possibly because of increase in population which necessitates increase in food supply and settlement while LULC of Kwara and Benue States between 1990-2020 show that most of the vegetation, agricultural land and water bodies in the two states have been converted to built-up areas and Barren land which might be due to the continuous usage of agrochemicals like pesticides, insecticides, herbicides and pesticides by the farmers in most parts of the State and this makes the farmers to migrate from these areas while leaving most of the land portions barren.

Furthermore, findings from the study established that between 2005-2020, there was a statistically significant negative relationship between maize yields and temperature in Niger State while there was statistically insignificant relationship between temperature and other crops in Niger State, there was statistically insignificant relationship between average annual temperature and all the five food crops in Kwara State. Also, there was a statistically significant positive relationship between temperature and groundnut but statistically insignificant relationship between temperature and other crops in Benue State. In addition, there was a statistically significant positive relationship between maize and cassava yields and rainfall in Niger and Kwara States while there was a statistically significant positive relationship between maize, cassava and ricee yields and rainfall and statistically insignificant relationship between rainfall and yam and groundnut in Benue State.

The respondents identified changing of farming methods, income diversification, supports from external bodies, change of profession, migration to another place either temporarily or permanently as sustainable adaptation strategies in which they minimize the impacts of climate change and land use changes and migration.

5.2 Recommendations

Based on the findings from this study, the following are highly recommended.

5.2.1 Recommendations related to policy improvement

Federal and States Ministry of Agriculture should provide improved technology and seeds (drought resistant, flood resistant etc.) for the farmers in the study area to improve their crops productivity. Also, to lower the rate of rural-urban migration in the study areas, Federal and States Ministries of Housing, Humanitarian Affairs and Disaster Management and the key stakeholders should create an enabling environment and infrastructure for the rural residents. Federal and States Ministries of Agriculture, Rural Development, Land Resources, Environment, Works, Housing and relevant agencies should convert the vast barren lands in the study area to profitable agricultural and housing use so as to boost food security and reduce housing deficit in the study area.

Furthermore, decision makers in the three States and the Federal Government of Nigeria should create policies that are related to the Sustainable Development Goals (SDGs), such as those that address climate action, land use, internal migration, food production and food security. The results of this study can be used by policymakers and researchers to assess the current state of climate change and LULC and their potential future impacts on migration and food security in Nigeria.

5.2.2 Recommendations related to performance improvement

In order to lessen the vulnerability of the farmers in the study area to the adverse effects of weather changes, constant, timely weather information should be made available to them by relevant Agencies like Nigerian Meteorological Agency (NiMet). Furthermore, to assure an increase in food production, Ministry of Agriculture in these three States should make climate smart technologies available to the farmers in the research area. Also, relevant Ministries, NGOs, Agencies and organisations like FAO should provide agricultural insurance for the farmers and encourage them to enroll for it so as safeguard against total loss in case of crop yield failure or disaster like flooding.

5.2.3 Suggestions for further research

This study suggests a further research on the cause of the increasing trends in temperature and decreasing trends in rainfall in these three States because studies on this subject matter are currently limited. In order to motivate the stakeholders and authorities to take the required actions to promote sustainable development in the region, future estimations of LULC changes and how these changes in addition to already felt impacts of climate change affect migration and food security of these three States and the entire region for the years 2020–2050 should be done.

Also, this study recommends further research on development of scenarios for predicting the present and the future impacts of climate and land use changes on migration and food production in North Central Region of Nigeria. Due to the diversity of North Central Region of Nigeria and Nigeria as a nation, this study suggests similar study that will cover all the States in the Region and Nigeria as a nation. Such a nationwide study will improve the performance of stakeholders in the various Ministries, Agencies and Organizations that deal with migration, food security, land use and climate change issues.

5.3 Contributions to the Body of Knowledge

Based on the results of this study, there was 0.058°C rise in average annual temperature and 15.60mm decrease in annual rainfall of Niger State between 1985 and 2020. Also, there was 0.044°C increase in average annual temperature and 12.11mm decline in annual rainfall of Benue State within the same period of time while there was insignificant rise of 0.012°C in average annual temperature and insignificant decrease of 0.78mm of annual rainfall of Kwara State in these periods. Fluctuations in climate parameters have been having varied degrees of negative impacts on the yields of maize, groundnut, rice, cassava and yam in Niger, Kwara and Benue States.

Furthermore, between 1990 and 2020, there are a lot of changes in LULC in all the three States. Notably, in Niger State, barren land decreased annually by 7.56 per cent and vegetation decreased annually by 7.44 per cent while agricultural land, built-up area and water body increased annually by 13.59 per cent, 1.32 per cent and 0.09 per cent respectively. However, in Kwara State, agricultural land and water body decreased annually by 14.99 per cent and 0.007 per cent respectively while vegetation, built-up area and barren land increased annually by 11.07 per cent, 2.89 percent and 1.04 per cent respectively. Also, in Benue State, agricultural land and vegetation decreased annually by 10.25 per cent and 4.75 per cent respectively while built-up area, barren land and water body increased at the annual rate of 9.86 per cent, 4.92 per cent and 0.22 per cent respectively.

In Niger State, there was a statistically significant negative relationship between maize yields and temperature ($p=0.0294$, $\alpha=0.05$, $t= -2.4469$, $R^2=0.417$) while there was statistically insignificant relationship between temperature and other crops in Niger State. There was statistically insignificant relationship between average annual temperature and all the five food crops in Kwara State. Also, in Benue State, there was a statistically significant positive relationship between temperature and groundnut (p=0.0119, α=0.05, t= 2.924, R^2=0.310) but statistically insignificant relationship between temperature and other crops. In addition, there was a statistically significant positive relationship between rainfall and maize yields (p=0.00036, α=0.05, t= 4.779, R^2=0.0217) and cassava yields (p=0.0112, α=0.05, t= 2.951, R^2=0.218) in Niger State and there was also a statistically significant positive relationship between rainfall and maize yields (p=0.0405, α=0.05, t= 2.274, R^2=0.0360) and cassava yields (p=0.0326, α=0.05, t= 2.392, R^2=0.0472) in Kwara State but statistically insignificant relationship between rainfall and other crops in these two States whereas in Benue State, there was a statistically significant positive relationship between rainfall and maize yields (p=0.000216, α=0.05, t= 5.0674, R^2=0.4073), cassava yields (p<0.00001, α=0.05, t= 24.5975, R^2=0.34016) and rice yields (p=0.000613, α=0.05, t= 4.48553, R^2=0.1532) but there was statistically insignificant relationship between rainfall and yam and groundnut in Benue State

Average of three (3) family members who are mostly young farmers in North Central Region of Nigeria migrate to the neighbouring States in the last five (5) years as a result of the changes in land use and land cover (LULC). Migration also impacts LULC, such as the conversion of agricultural land into barren land, especially in Kwara and Benue States, and this is directly related to the impacts of out-migrated members who left agricultural land uncultivated. There was a continuous drastic reduction in food production as a result of changes in the land use and migration in recent years.

In order to comprehend the LULC changes that occurred in Niger, Kwara and Benue States between 1990 and 2020, this study provides information on the transformation of LULC in these States. Academics, environmentalists, Ministries of Agriculture and Land Resources, and other stakeholders will be able to use the information as vital planning tools for the sustainable management of natural resources in these States and North Central Region of Nigeria. The general public will find this study useful in revising and extending their knowledge on complex relationships that exist among climate change, land use change, migration and food security.

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APPENDICES

APPENDIX A: Questionnaire

CLIMATE CHANGE AND LAND USE IMPACTS ON MIGRATION AND FOOD SECURITY IN NORTH CENTRAL REGION OF NIGERIA.

Household Questionnaire

INTRODUCTION

Dear Respondent,

The study aims at analyzing the climate-land use change and migration nexus and the consequent impacts on food crop production in North Central Region of Nigeria. The data provided is for academic purpose as part of the requirement for the award of PhD in Climate Change and Human Habitat, Federal University of Technology, Minna, Niger State, Nigeria. The information provided would be treated with high sense of confidentiality.

Name of Community: ....

LGA: ……………………………………………………….……….

Variable	Question	Response	Code
A1	Gender	Male Female	1 2
A2	How old are you? *In years*		
A3	What is your ethnic group?		
A4	What is your marital status?	Single Married Divorced/Separate Widow/Widower	1 2 3 4
A5	House position of the respondent	Head Wife Child	1 2 3
A6	Household size		
A7	Highest level of education attained	No formal education Primary Secondary NCE/OND HND/ BSc PGD/MSc Above MSc	1 2 3 4 5 6 7
A8	What is the number of women in your household?	1 2 3	1 2 3

		4 5 Above 5	4 5 6
A9	What is the number of children under 15 in your household?	1 2 3 4 5 Above 5	1 2 3 4 5 6
A10	What is the number of persons above 60 (elderly) in your household?	1 2 3 4 5 Above 5	1 2 3 4 5 6
B1	How many acres of land do you own?		
B2	What is/are sources of your farmland ownership (tick as many as applicable)	Purchased Rented/leased Inherited	1 2 3
B3	What is the primary production type of your farmland?	Arable Livestock (meat, dairy) Mixed Agroforestry/Orchards	1 2 3 4
B4	Do you have drainage system on your farm?	Yes No	1 2
B5	Do you own or regularly drive a car/van?	Yes No	1 2
B6	If yes, roughly how many kilometres do you drive per year?		
B7	Do you think that the pattern of weather is generally changing?	Yes No	1 2
B8	If yes, why do you think this might be?		
B9	Have you heard of “climate change” before?	Yes No	1 2
B10	If yes, what do you know about it?	Climate change is just a natural fluctuation in earth’s temperatures Climate change is a consequence of modern life Recent floods and drought in this area are due to climate change Climate change is something that frightens people The evidence for climate change is unreliable Others (please specify)	1 2 3 4 5 6

B11	Where did you hear about climate change? Please tick as many as you feel apply	Radio Television Newspaper Friends and family Extension workers Others (please specify)	1 2 3 4 5 6
B12	How important is the issue of climate change to you personally?	Very important Important Not important	1 2 3
B13	Why is it important to you?	Increased risks/higher uncertainties Economic losses/Higher costs Others (please specify)	1 2 3
B14	What do you think are the causes of climate change?		
B15	Do you think climate change is something that is affecting or is going to affect you, personally?	Yes No	1 2
B16	Do you think something can be done to tackle climate change?	Yes No	1 2
B17	If yes, what do you think can be done to tackle climate change?		
B18	Who do you think should have the main responsibility for tackling climate change?	International organisations (e.g. the UN) Federal government State government Local government Private organisations Environmental organisations Individuals Others (please specify)	1 2 3 4 5 6 7 8
B19	Have you ever taken, or do you regularly take any action out of concern for climate change?	Yes No	1 2
B20	If yes, what did you do/ are you doing?		
B21	Which of the following natural disasters are common in this area?	Flooding Drought Windstorm Wildfires Others (Please specify)	1 2 3 4 5
B22	How frequent do you experience these disasters?	Often Occasionally Only once	1 2 3
B23	Have you experienced flooding in the last five years?	Yes No	1 2

B24	If yes, how frequent?	Every raining season Occasionally Only once	1 2 3
B25	Have you experienced drought in the last five years?	Yes No	1 2
B26	If yes, how frequent?	Every drying season Occasionally Only once	1 2 3
B27	What do you do whenever you experience change in weather pattern?	Look for alternative source of livelihood Migrate to another place temporarily Migrate to another place permanently Others (please specify)	1 2 3 4
C1	Do you have plans to clear your extended agricultural land portion in future?	Yes No	1 2
C2	What are the reasons for clearing vegetation in this area?	To create more agricultural lands To give room for more industrial development To create more spaces for settlement Others (please specify)	1 2 3 4
C3	Which of the following land use alternatives are the most important to you based on the economic values?	Agriculture Garden Forest Livestock Agroforestry	1 2 3 4 5
C4	How was the vegetation composition/structure when you first settled here?	Wild Forest Wild Grassland Same as today	1 2 3
C5	What are the major types of land degradation in your area?	No degradation Soil erosion by water Soil erosion by wind Soil chemical deterioration Water degradation Others (please specify)	1 2 3 4 5 6
C6	State the current degree of land degradation for the types identified	Light Moderate Strong Extreme	1 2 3 4
C7	What is the rate of land degradation in the last 10 years?	Rapidly increasing Moderate degradation Increasing degradation Slowly increasing degradation No change in degradation Slowly decreasing degradation Moderately decreasing degradation Rapidly decreasing degradation	1 2 3 4 5 6 7

			8
C8	What are the direct causes of land degradation in your area?	Improper soil management Improper crop and rangeland management Deforestation Over-exploitation of vegetation for domestic use Over grazing Industrial activities and mining Urbanisation and infrastructure development Cash cropping External investors Land grabbing Waste discharges Natural causes (flooding, drought etc) Others (please specify)	1 2 3 4 5 6 7 8 9 10 11 12 13
C9	What are the indirect causes of land degradation in your area?	Population pressure Consumption pattern and individual demand Land tenure system Poverty Labour availability Inputs and Infrastructure Limited awareness Conflict and war Governance, institutions and politics Others (please specify	1 2 3 4 5 6 7 8 9 10
C10	What are the impacts of the identified types of land degradation on ecosystem services?	Reduction in productive services (quantity and quality of water, land, animal etc.) Reduction in ecological services (water availability, soil cover, organic matter status etc.) Socio-cultural services / human well-being and indicators (education and knowledge, net income, health, conflict transformation etc.)	1 2 3
C11	What do you do whenever your land is degraded	Look for alternative source of livelihood Migrate to another place temporarily Migrate to another place permanently Others (please specify)	1 2 3 4
D1	Were you born here?	Yes No	1 2

D2	If no, where were you born?		
D3	Why did you migrate to this place?	Better farming activities Better job opportunities Better weather condition Schooling Others(please specify)	1 2 3 4 5
D4	What are the environmental factors that determine your migration to this place?	Soil fertility Land/soil degradation Deforestation Poor soil profitability Unfavourable weather condition Others (please specify)	1 2 3 4 5 6
D5	What are the socioeconomic factors that determine your migration to this place?	Land Availability Demographic pressure Land insecurity Others (please specify)	1 2 3 4
D6	Did any members of your family migrate in the last five years?	Yes No	1 2
D7	If yes, to where?		
D8	Why did they migrate?	Unstable weather condition Land degradation Land use change Schooling Natural disaster	1 2 3 4 5
D9	Have they ever had problems because of migration?	Yes No	1 2
D10	What is your perception on climatic migration phenomenon?		
D11	Do you think people should migrate due to unfavourable weather condition?	Yes No	1 2
D12	If yes, why?		
D13	If you had the chance, would you stop migration or would you encourage it?	I would encourage it I would stop it I won't do anything	1 2 3
D14	Would you return to your former residence once the problems which took you here is solved	Yes No	1 2
D15	Which gender migrate the most in this area?	Male Female	1 2
D16	What is the reason for your choice of option in D15 above		

D17	What pattern of migration is common in this area?	In-migration Out-migration Cross border migration			1 2 3
D18	Which of these groups migrate in or out of this area the most?	Elderly Youth Children			1 2 3
D19	What is the age range of migrants leaving or arriving in this area?	Below 10 years 10-20 years 21-30 years 31-40 years 41-50 years 51-60 years 61-70 years Above 70 years			1 2 3 4 5 6 7 8
E1	Please, indicate crops and livestock you are rearing including land area and annual income.	Crop/Livestock	Land area/ number of livestock reared	Annual income (₦)	1 2 3 4 5 6 7 8 9 10 11 12 13
		Maize Yam Cassava Tobacco Millet Vegetable Beans Soybeans Melon Water melon Cash crops Livestock Other crops/ Livestock			
E2	What is your perception in changes in rainfall pattern in the last 20 years?	Increase Decrease Fluctuations			1 2 3
E3	What is your perception in changes in air temperature	Increase Decrease Fluctuations			1 2 3
E4	What have been the effects of rainfall pattern on your crop production in the last 20 years?	Increase Decrease No effect			1 2 3

E5	What have been the effect of air temperature on your crop production in the last 20 years?	Increase Decrease No effect	1 2 3
E6	If you choose increase for any of questions E4 and E5, rank the reasons behind the changes	Irrigation facilities Use of fertilizers Introduction of new seeds Use of agricultural machines Others (please specify)	1 2 3 4 5
E7	If you choose decrease for any of questions E4 and E5, rank the reasons behind the changes	Climate change Land degradation Land use change Lack of manpower Less priority to agriculture Others (please specify)	1 2 3 4 5 6
E8	Which of your crops are affected by rainfall pattern and air temperature?		
E9	What can you say about food availability in the last 20 years?	Increased Decreased No change	1 2 3
E10	What are the reasons for changes in food availability?	Increase in crop production Decrease in crop production Increase in food price Decrease in food price Increase in income Decrease in Income Increase in dairy products Decrease in dairy products Increase in other household burden Decrease in other household burden Others (please specify)	1 2 3 4 5 6 7 8 9 10 11
E11	What can you say about the changes in your food accessibility?	Increased Decreased No change	1 2 3
E12	What can you say about your food consumption pattern?	Improved Deteriorated Unchanged	1 2 3
E13	What are reasons for the changes in your food accessibility and consumption?	Unlimited awareness Little/no awareness Unlimited accessibility to market Limited access to market Good road Bad road	1 2 3 4 5 6
E14	How do you adapt to negative impacts of climate change and land use change?	Change of profession Income diversification Changes in farming methods	1 2 3

		Supports from external bodies	4