CLIMATE CHANGE EFFECTS ON MAIZE PRODUCTIVITY IN SOUTHWESTERN NIGERIA

by

SEUN BOLUWATIFE AJALA

Submitted in accordance with the requirements

.

for the degree of

DOCTOR OF PHILOSOPHY

in the Subject

AGRICULTURE

at the

UNIVERSITY OF SOUTH AFRICA

SUPERVISOR: DR C. CHAGWIZA

DEDICATION

This work is dedicated to the Lord Almighty, the giver of knowledge

DECLARATION

Name: **SEUN BOLUWATIFE AJALA**

Student number: **57634270**

Degree: **DOCTOR OF PHILOSOPHY**

"CLIMATE CHANGE EFFECTS ON MAIZE PRODUCTIVITY IN SOUTHWESTERN NIGERIA"

I declare that the above thesis is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I further declare that I submitted the thesis to originality checking software and that it falls within the accepted requirements for originality.

I further declare that I have not previously submitted this work, or part of it, for examination at Unisa for another qualification or at any other higher education institution.

SIGNATURE

14 October 2022

DATE

ACKNOWLEDGEMENTS

I am grateful to God for guiding me to this point in my academic career. This project would not be completed without Him. Dr Claire Chagwiza, my supervisor, deserves special recognition for her unwavering support, encouragement, and efforts throughout this project. I applaud her unwavering guidance from the moment our paths crossed until now. Words are inadequate to express my gratitude, but I pray for God's blessing on you and your family. Professor Michael A. Antwi, you are not only my supervisor but also a father to me. I would not be here today if it were not for your counsel and fatherly support during my master's degree under your supervision. Thank you very much, sir.

I owe UNISA's Funding Directorate my gratitude for providing funding for this study. The funding paid for both the expense of participating in research activities as well as the yearly tuition.

Mr. Simeon Kola Ajala and Deaconess Bola Lydia Ajala, my loving parents, have my profound gratitude for their constant love, efforts, prayers, financial, and spiritual support for me; in Jesus' name, you will reap the benefits of your work in due season. I appreciate my siblings, Oluwadamilare and Oluwafemi Ajala, for their constant love, prayers, encouragement, and care. Christianah Bidemi Ajala, my "inestimable treasure," has been tremendously supportive through her love, prayers, care, and guidance. In Jesus' name, may the good Lord make us live together to attain our life goals. Furthermore, I owe my thanks to my children, Ethan Ifedayo Seun-Ajala and Nathan Ifeoluwa Seun-Ajala, who missed my presence and fatherly care during the period I was away from home conducting research. In the name of Jesus, I pray that you continue to be a blessing to your family and generation.

Dr. Lawrence Olusola Oparinde, Department of Agricultural and Resource Economics, Federal University of Technology, Akure, has been a constant source of inspiration, as well as his brotherly role and support, providing me with a shoulder to depend on as the journey became more tough. My sincere prayer is that God would hear all your unspoken requests. It gives me great pleasure to thank my spiritual father, Pastor (Dr) M.J Erhiorin, the pastor in charge of the zone at the Redeemed Christian Church of God, Orita Obele Estate, Akure, Ondo State, Nigeria, for his spiritual and physical assistance in ensuring my success in all aspects of my life. In Jesus' name, Daddy, you will not be disappointed with your prize.

Pastor (Prof.) Peter Oluremi Adesoye's kind financial assistance at the start of my PhD studies is greatly appreciated. Sir may the good Lord continue to shower you with his blessings. I want to express my gratitude to Dr. Olutumise Adewale Isaac of the Department of Agricultural Economics at Adekunle Ajasin University in Akungba-Akoko, Ondo State, for his assistance and cooperation with this study's data analysis.

I shall not hesitate to thank the Maletes for being there for me when life's storms arose, Kea leboha. Dr. Messrs Odekunle Olusegun, Olubunmi Lawal, Dr. Olusola Johnson Adeyinka, Aisiolu Akinbayo, Ajibade Philemon Tunde, Oyewole Isreal, A/P Omolajaye Lanre, and others too many to list for their different contributions to the success of this study endeavor. God bless every one of you.

I owe immense gratitude to the Albert Ilemobade library at the Federal University of Technology, Akure, for allowing me to use their facilities, resources, and database during my doctoral studies. My thanks would be insufficient if I did not thank the ministries of agriculture in Ondo and Oyo states and the other government parastatals for allowing me to conduct this research in their states. The extension staff that worked tirelessly with farmers and me from our host communities to make this work happen deserve praise. I want to extend my gratitude to everyone who has contributed to the successful completion of this thesis. The Almighty shall handsomely reward you.

ABSTRACT

This study examined the effects of climate change on maize productivity in Southwestern Nigeria. A multistage sampling was utilized to select 540 respondents for the study. Both primary and secondary data were collected and analyzed using descriptive statistics, trend and growth rate function analysis, auto-regressive distributed lag (ARDL) (1979 – 2020), multinomial logistic regression (MNL), Double-hurdle model and two stage least square regression (2SLS) model. The descriptive results revealed that majority (36.8%) of the sampled respondents were between the ages of 46 and 55 and most (81.2%) of the sampled respondents were male. Similarly, 88.6% were married while their major occupation was farming.

The findings further revealed that 86.8% of the respondents had formal education while most of the maize farmers had between 11 – 15 years farming experience with farming as their major occupation. Results also revealed that farmers cultivated on rented farmland (45.0%) with farm size average of 2 hectares indicating that maize farmers were smallholders. Furthermore, it was revealed that most (94.2%) of the maize farmers were aware of climate change in the study area; only 78.6% stated that there was information on climate change. According to the farmers, the effects of climate change on crop production included (1) reduced crop production levels and (2) no production, which have been negatively affecting their livelihood in a variety of ways, including an increase in socioeconomic issues, a decrease in income, and an increase in unemployment.

In addition, the exponential growth rate results showed significant growth rates in all the variables (maize, output, temperature, amount of rainfall and humidity) except for Ondo and Oyo states where growth rates of temperature and relative humidity were negatively insignificant over the period. The time series cointegration test using ARDL model indicated a long run cointegration relationship among the variables. The result of the short-run dynamic coefficients associated with the long-run cointegration relationships indicated that Error Correction Model (ECM) was statistically significant at 1% and had values (-0.133 and -0.079635) respectively. The result showed that time had a significant impact on maize productivity and climate while climatic variables greatly influenced maize productivity both at short run and long run in the study area.

The main adaptation strategies employed by maize farmers were planting different varieties, practicing crop diversification, mixed cropping, soil conservation, use of agrochemicals and move to different site. The multinomial logistic regression model's (MNL) findings indicated that factors such as age, gender, marital status, education level, household size, major occupation, farming experience, and knowledge of climate change were statistically significant and had an impact on climate change adaptation in the study area.

The adoption intensity of climate change adaptation was studied using a double hurdle model. Most of the criteria were shown to be insignificant in determining the adoption intensity following the decision-making phase of adapting to climate change in the research area. Age, marital status, educational level, household size, land tenure, farm ownership, farm size, information on climate change, and farming experience were found to be determinants of climate change adaptation in the study area, whereas educational level, household size, major occupation, major source of income, information on climate change, climate change awareness, and farming experience were found to be determinants of climate change adaptation intensity.

The two-stage least square result revealed revenue to be endogenous and therefore was instrumented in the empirical analysis and significant exogenous variables that affect maize farmers' productivity include revenue, climate change adaptation adoption rate, age, gender, educational level, household size, farm ownership, farm size and farming experience.

Conclusively, the study shows that climatic variables and time had a significant impact on maize productivity in the study area. It was therefore recommended that government should develop productivity-enhancing measures that include formal agricultural education, simple access to agricultural inputs, credits, and extension services. Furthermore, there should be improvement of farmers' knowledge about the different adaptation strategies that were mentioned by the farmers in the study area.

Keywords: *Climate change, Climate change adaptation, Maize yield, Growth rate analysis, Cointegration, 2SLS model, Double-hurdle, MNL, Nigeria*

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

CHAPTER TWO

LITERATURE REVIEW

CHAPTER THREE

RESEARCH METHODOLOGY

CHAPTER FOUR

SOCIO-ECONOMIC CHARACTERISTICS OF MAIZE FARMERS AND ADAPTATION MEASURES

CHAPTER FIVE

TREND AND GROWTH RATE OF THE MAIZE YIELD AND CLIMATIC VARIABLES (1979-2020)

CHAPTER SIX

RELATIONSHIP BETWEEN MAIZE PRODUCTIVITY AND CLIMATIC VARIABLES FOR THE PERIOD 1979 TO 2020

CHAPTER SEVEN

CLIMATE CHANGE ADAPTATION MEASURES EMPLOYED BY MAIZE FARMERS IN THE STUDY AREA

CHAPTER EIGHT

FACTORS INFLUENCING CLIMATE CHANGE ADAPTATION AMONG MAIZE FARMERS IN SOUTHWESTERN NIGERIA

CHAPTER NINE

CLIMATE CHANGE ADAPTATION RATE AMONG MAIZE FARMERS IN SOUTHWESTERN NIGERIA

CHAPTER TEN

CLIMATE CHANGE EFFECT ON FARMERS' PRODUCTIVITY IN SOUTHWESTERN NIGERIA

CHAPTER ELEVEN

SUMMARY, CONCLUSIONS AND RECOMMENDATION

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATION

ADF	Augmented Dickey-Fuller
ADP	Agricultural Development Programme
AIC	Akaike Information Criterion
ARDL	Autoregressive Distributed Lag
CAGR	Compound Annual Growth Rate
CFCs	Chlorofluorocarbons
CGE	Computable General Equilibrium
CLRM	Classical Linear Regression Model
CUSUM	Cumulative Sum of Recursive Residuals
CUSUMQ	Cumulative Sum of Recursive Residuals of Square
ECM	Error Correction Model
EPIC	Erosion Productivity Impact Calculator
FAO	Food and Agricultural Organization
FPE	Final Prediction Error
GHGs	Greenhouse Gases
GIS	Geographical Information System

HCFCs	Hydrochlorofluorocarbon
HFCs	Hydrofluorocarbon
HQIC	Hannan-Quinn Information Criterion
IFAD	International Fund for Agricultural Development
IIA	Independence of Irrelevant Alternatives
IITA	International Institute of Tropical Agriculture
IPCC	Intergovernmental Panel on Climate Change
LR	Likelihood Ratio
MDS	Moving to a Different Site
MNL	Multinomial Logistic Regression
MNP	Multinomial Probit
NBS	National Bureau of Statistics
NIMET	National Meteorological Agency
OLS	Ordinary Least Square
SBIC	Schwarz Bayesian Information Criterion
UNFCC	United Nation Framework Convention on Climate Change
UNDP	United Nations Development Programme

USDA	US Department of Agriculture
USEPA	United States Environmental Protection Agency
VAR	Vector Auto-Regression
VECM	Vector Error Correction Model
WMO	World Meteorological Organization
2SLS	Two-Stage Least Square

CHAPTER ONE

INTRODUCTION

1.1 Background to the problem

Climate change, which threatens to alter the livelihoods of the world's most vulnerable people, has caused global concern. The scientific community and even farmers agree that climate change is real and that its effects are already being established (Oduniyi, 2018; Getu, 2014; Mandleni, 2011; IPCC, 2007). The repercussions of this problem affect a wide range of aspects of human life, including the economy, the environment, health, and agriculture. This problem affects every nation in the globe. Despite the fact that climate change threatens agricultural and socioeconomic development, agricultural production activities are more susceptible to it than other sectors (Ajetomobi *et al.,* 2011).

Agricultural productivity has been negatively impacted by interactions between climate change and agriculture despite their close connections (Coster and Adeoti, 2015; Ayinde *et al.,* 2010; Apata *et al.,* 2009; Mendelsohn *et al.,* 2001). Global agriculture is in danger due to the threat of climate change in the agricultural sector, according to Ochieng *et al.* (2016); however, the impact on agricultural production is expected to deteriorate over time and vary across countries and locations (Food and Agriculture Organisation 2016). As a result, the phenomenon is probably going to widen the economic and social divide between industrialized and developing nations (Abdullahi, 2018; Coster and Adeoti, 2015).

Climate change has become more concerning not only for the long-term development of any nation's socioeconomic and agricultural activities, but for the entirety of human existence (Ayinde *et al.,* 2010). Congruently, Ayinde *et al.* (2010) exposited the consequences of climate change because of vast alterations in local climate variability of people's experience which make the impact of the phenomenon be felt by millions of people across the globe. Hunger and food insecurity are becoming more likely because of climate change, especially in nations whose economy are heavily reliant on climate-sensitive industries like agriculture, fishing, and forestry (Tambo and Abdoulaye, 2011; Traerup and Mertz, 2011; Bryan *et al.,* 2009).

Many a time, the developing nations are being anticipated to be in danger to the effects of change in climate than those that are further advanced; and it was ascribed to the low capacity of the developing world to get acclimatized to the biased distribution of negative climate change impacts (Rose, 2015; Belloumi, 2014; Singh and Purohit, 2014). Furthermore, small-scale and subsistence farmers will suffer the most due to their reliance on rain-fed agriculture, rising temperatures, low adaptive capacity, high dependence on natural resources, inability to detect the occurrence of extreme hydrological and meteorological events due to low technology adoption, limited infrastructure, illiteracy, lack of skills, lack of awareness, and lack of capacity to diversify (Rose, 2015; Singh and Purohit, 2014).

Furthermore, because of their reliance on rain-fed agriculture, rising temperatures, low adaptive capacity, high dependence on natural resources, inability to detect the occurrence of extreme hydrological and meteorological events due to low technology adoption, limited infrastructure, illiteracy, lack of skills, lack of awareness, and lack of capacity to diversify, small-scale and subsistence farmers will suffer the most (Rose, 2015; Singh and Purohit, 2014). As a result, it has been predicted that Africa's temperatures will climb faster than the global average this century. Food crises and water scarcity, worsened by climate unpredictability and extreme events, are clearly a concern to Sub-Saharan Africa (SSA) in the current climate (Sultan and Gaetani, 2016). Droughts, excessive rains and floods, and hurricanes are examples of extreme occurrences that have an impact on agricultural output, rural family food security, and, as a result, rural livelihood.

Agriculture continues to be the primary source of livelihood for rural inhabitants in most African countries, accounting for a significant portion of GDP (FAO, 2016; World Bank, 2013; UNDP, 2012). Tetteh *et al.* (2014) defended this by stating that the bulk of the world's poor people reside in rural areas and rely on agriculture for a living as peasant farmers or in agricultural-related occupations. As a result, it is undeniable that agriculture is a source of income in Africa's developing and less developed countries, and the impact of climate change on livelihood is ongoing.

Africa’s agricultural growth is generally attributed to the cultivation of more land and mobilisation of a larger labour force, however, there has been a very limited improvement in yields and hardly any change in production techniques which still endanger people that are vulnerable on the continent (Blein *et al.,* 2013). Despite Africa's agricultural growth, agricultural production has been unable to meet the teeming population's larger and more diverse food needs. Climate change has had a significant influence on African agriculture, causing a severe shock to the economy.

Africa, as a developing continent, is anticipated to be hit harder by climate change than the developed world but contributing insignificantly to greenhouse gas emissions. This was attributed to the region's sensitivity being exacerbated by the interplay of agricultural, political, biophysical, and socioeconomic issues (Connolly-Boutin and Smit, 2016). Economists have referred to this as a case of negative external repercussions (Medugu, 2008). Although, beyond the increased intensity of climate change in Sub-Saharan Africa, it was predicted that changes in the frequency of extreme weather events like as droughts and floods, the gravity of rainfall, an increase in deserts, and changes in some disease vectors would occur (Connolly-Boutin and Smit, 2016; Ochieng *et al.,* 2016). In most parts of Sub-Saharan Africa, this will result in changes in growing seasons, diminished arable land, and lower agricultural production. It is a well-known truth that climate change has a constant impact on agricultural productivity, and the severity in today's world is unexplainable.

Climate change predominates across West Africa, including Nigeria, according to Sultan and Gaetani (2016), due to high climate variability, heavy reliance on rain-fed agriculture, restricted economies, and institutional abilities to respond to climate change and variability. Similarly, Roudier *et al*. (2011) stated that the persistent impact of climate change in West Africa is primarily due to temperature, which is anticipated to rise far faster than precipitation change by climate models. However, depending on whether rainfall drops or increases, rainfall changes, which are currently unknown in climate projections, can exacerbate or ameliorate this impact. Furthermore, as global warming proceeds, the negative impact on crop productivity in the region is predicted to worsen; nonetheless, the region is affected and prone to climate change and variability.

Odjugo (2010) claims that Nigeria's temperature is rising while rainfall is falling. This is due to climate change since the phenomena has resulted in increased rainfall in most coastal locations and decreased rainfall in continental interiors. As a result, the evidence from Nhemachena (2008) that a high increase in temperature due to frequent droughts, scarcity of underground water, and scarcity and spatial variability of rainfall pattern are the reasons Sub-Saharan African countries, including Nigeria, are exposed to climate change and variability is supported. Congruously, Odjugo (2010) established that the mean air temperature in Nigeria for a period of 105 years (1901-2005) was 26.6^{o}C and during the same period, the temperature rose by 1.1^{o}C. This is more than the 0.74^{o}C increase in world mean temperature since 1860, when scientific temperature measurement began.

Furthermore, Nigeria was anticipated to experience between the middle (2.5^{o}C) and high (4.5^{o}C) risk temperature increase by the year 2100 should the trend continue unabated. In respect of this, it was envisaged that higher temperature will intensify heat stress in crops and evapotranspiration in Nigeria. Afterwards, it is expected to affect the natural resources such as air and water, which are the major essential elements associated with climate change. It is indeed a reality that climate variability has led to great agricultural and economic loss in Nigeria as lots of natural disasters like flooding, storms have cleared rangeland, farmland, buildings, and fishing dams in 2011 and resulted in a serious agricultural loss worth billions of naira.

Furthermore, if current trends continue, Nigeria is expected to face a temperature increase between the moderate (2.5^{o}C) and high (4.5^{o}C) risk by 2100. In this regard, it was predicted that increasing temperatures in Nigeria will exacerbate heat stress in crops and evapotranspiration. Following that, it is projected to have an impact on natural resources such as air and water, which are the most important factors in climate change. Climate variability has indeed resulted in significant agricultural and economic loss in Nigeria, as numerous natural catastrophes such as flooding and storms removed rangeland, farms, houses, and fishing ponds in 2011, resulting in a terrible agricultural loss of billions of naira.

Similarly, delay and staggered rainfall is still experienced in some part of Nigeria especially the savannah belts of Nigeria where the small-scale farmers depend largely on rain-fed agriculture in crops and animal production (Maluga, 2013; Apata *et al.*, 2012). Given that Nigeria's agrarian community depend greatly on climatic elements which affect agricultural productivity (Nwajuba and Onyeneke, 2010), investigating the effect of climate change on maize production in Southwestern Nigeria may produce empirical results that will improve and consolidate the understanding of climate change, its impacts on maize production and adjustments in cropping patterns towards increased production.

1.2 Problem statement

Even though the climate change effect is universal, agricultural sector is often more at risk. Concerns have been raised about the vulnerability of poor nations to the impacts of climate change (Intergovernmental Panel on Climate Change (IPCC), 2007), and the vulnerability of the Nigerian agricultural sector to climate change is of interest to policy makers for agriculture is imperatively an important component of the Nigerian economy. Climate change is marked with increased intensity and frequency of storms, drought, and flooding, altered hydrological cycles and precipitation variance. All these have serious implications on future food availability, affordability, and sustainability (FAO, 2011; FAO, 2008; Schmidhuber and Tubiello, 2007).

Climate variability is rapidly becoming the most important environmental challenge facing mankind. There is variability in Nigerian rainfall and temperature. For instance, higher temperature lowers the yield of desirable crops and encourages weeds and pests' proliferation while changes in precipitation patterns increase the likelihood of short-run crop failure and long run production declines (Onyeneke, 2010; Odjugo, 2010; Nwaiwu, Onubuogu and Chukwu, 2015). Hence, climate variability creates a serious challenge for food production (Hoegh-Gulberg *et al.*, 2007). Nigerian agriculture, like many African countries is largely based on weather-sensitivity. This makes the sector vulnerable to climate change (Dinar *et al.*, 2006). This vulnerability has been demonstrated by the devastating effects of flooding in the Southwestern region of the country and various prolonged droughts that are currently witnessed in some parts of the Northern region. Due to these environmental threats resulting to decline in crop yields, some farmers in Nigeria are abandoning farming for non-farming activities (Apata, Ogunyinka, Sanusi and Ogunwande, 2010). Therefore, concerted efforts to combat these threats are required, particularly now that the country is considering agriculture as a potential solution to the present economic crisis. Natural disasters and climate variability constitute other key factors making people from less developed nations vulnerable to food insecurity. The impact of such phenomenon as drought, flood and land slide is more pronounced in regions where agriculture highly depends on rainfall (Ilaboya *et al.*, 2012). While drought and landslides constitute a major threat for food availability, excessive rain or flood has had a significant impact on the current hike in food prices. Thus, understanding farmers' responses and adaptation strategies to climatic variation is crucial to designing appropriate policy framework that will enhance adaptive and sustainable coping strategies. Therefore, it is pertinent to ask the following questions to understand how climate change can influence maize production in the study area.

1.3 Research Questions

The study seeks to answer the following research questions as informed by the problem statement:

1. What are the socio-economic characteristics of the respondents in the study area?
2. What are the trends and growth rates of the selected climatic variables and maize productivity recorded in the study area during the period 1979 to 2020?
3. What is the relationship between maize production and climatic variables in the study area?
4. What are the climate change adaptation strategies used by the targeted respondent in the study area?
5. What are the factors that influence climate change adaptation among maize farmers in the study area?
6. What is the rate of adopting climate change adaptation strategies by the respondents in the study area?
7. What is the effect of climate change on farmers' productivity in the study area?

1.4 Research Objectives

The general objective of the study is to examine the effects of climate change on maize productivity in Southwestern Nigeria. The specific objectives are:

1. To analyse the socio-economic characteristics of the respondents in the study area

2. To measure the trend and growth rates of selected climatic variables and maize output during the period 1979 to 2019

3. To estimate the relationship between maize production and climatic variables in the study area

4. To determine and discuss the adaptation strategies employed by maize farmers in the study area

5. To examine the factors influencing climate change adaptation strategies among maize farmers in the study area
6. To ascertain the respondents' adoption rates of climate change adaption techniques in the research area
7. To measure the effect of climate change on farmers' productivity in study area

1.5 Research Hypotheses

The following hypotheses were tested and are stated in null form ($H_0 : \beta = 0$):

(i) There is no co-integration between maize productivity and selected climatic variables

(ii) Climate change do not influence farmers' productivity

1.6 Significance of the Study

Climate change effect on agriculture have become a major concern to the entire populace and it is imperatively essential for the societies to recognize the phenomenon. Climate change ranges from drought, extreme heat waves, changes in weather conditions and increased temperatures among many others. According to IPCC (2007), there are serious concerns regarding the vulnerability of developing countries in the plight of climate change. Intrinsically, there is no gainsaying that changes in climatic situation has a negative impact on agricultural production and livelihoods of rural people who find solace in agriculture as agriculture is very important to the economic and social well-being of pastoral communities. Therefore, understanding climate change impact is essential to mitigate its unpleasant influence on development through long-term adaptation strategies that could moderate the adverse climatic effect on agricultural productivity of exposed communities.

Dwindling agricultural production, particularly in the face of rapid population growth, due to climate change (Oduniyi, 2018: Ajala, 2017) is evidence that the phenomenon is negatively influencing agricultural production and farmers' livelihood by reducing their agricultural produce in developing countries of Africa. However, agricultural produce is dropping enormously due to the deleterious effect of climate change in recent years which is affecting farmers' income in terms profit maximisation. Additionally, climate variability and change impact on livelihood include increased unemployment and poverty, decline in agricultural productivity, reduction in food security and conflicts of resource use. Consequently, this provides an adequate justification to investigate the impact of changing climate on agricultural productivity, in addition to examining ways in which rural farmers in Southwestern Nigeria can adapt to this menace.

Hence, this research work is projected to proffer a better understanding of attributes of climate change and food crop productivity. Also, the findings would produce some policy inferences which agricultural stakeholders and policy makers could employ to help farmers on various subjects of climate change impacts, practices and livelihood, which will adequately enhance farmers' way of life. The policy proposition of this study would be to position some drastic measures and practices to deal with the effects of climate change on farmers hence encouraging adaptation methods in ensuing betterment in living standard among the rural poor.

This study is expected to contribute to the body of knowledge and enhance better understanding on climate change impact on agricultural productivity and rural livelihood in Nigeria. Findings from this study will reveal the vulnerability of the rural household to climate change. Hence, it is anticipated to also serve as guide for the intervention agencies (i.e the ministry of agriculture and natural resources and Nigerian government) to know the appropriate measures/strategies to adopt.

1.7 Scope of the Study

The impacts of climatic change on maize productivity in Southwestern Nigeria were investigated in this study. The study included both primary and secondary data from NIMET and ADPs, including agro-climatological and maize productivity data. Maize farmers provided information for the study. The study also looked at how climate change has affected farmers in the study area's rural life.

1.8 Limitations of the study

This study suffered greatly from the lack of information during data collection because many of the farmers relied on their memories, which could be unreliable. Data collection took longer than it should have due to inadequate records.

The researcher presented and discussed the study and its importance at a symposium organised by the ministry of agriculture and environment in each state and this assisted in granting consent in carrying out the research in the study area. This also assisted in managing the limitations of the study by training the extension officers that assisted in data collection. The main purpose of the study and the solution it will proffer was also discussed with the farmers. The researcher also managed the limitations by triangulating primary data with secondary data.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

There have been incessant changes in climate, and this is extremely threatening agricultural productivity. It was alluded that agriculture depends on weather and climate whose anomaly has been impacting agricultural production negatively (Ozor *et al., 2010)*. Hence, the climate change concept, the effect of climate change on agricultural productivity and adaptation options were reviewed in this chapter. The chapter also critically appraised existing scholarly literature on different analytical frameworks in the study of climate change and agricultural productivity.

2.2 Concepts of Climate change

2.2.1 Climate

This is a long-term average of the meteorological conditions that prevail in a given location or environment. Climate is defined by the Food and Agricultural Organization (FAO) (2008) as the characteristics of the earth's lower surface atmosphere. Climate, according to IPCC (2007), is defined as "average weather condition" or a statistical representation of variability, mean, and important quantities over time. Climate is a long-term weather state that has a huge impact on all aspects of life through changing soil and vegetation. Climate also displays factors such as heat, moisture, and circulation in the atmosphere. Precipitation, temperature, and wind are all often utilized surface factors. Normal weather patterns such as storm strength, frequency, cold spells, and heat waves are referred to as climate (IPCC, 2007). Climate science is the study of past, present, and future changes in climate on a global, regional, and local scale.

2.2.2 Weather

This is defined as the atmospheric condition at a point over a brief period; nonetheless, it refers to daily oscillations in these parameters at a given site. Rainfall, wind, temperature, and humidity are all factors in the weather.

2.2.3 Climate variability

IPCC (2007) refers to climate variability as changes in the average state of the climate and other data on all temporal and spatial scales beyond individual weather occurrences. Adger (2003) expresses climate variability as the mean condition of climate across all temporal and spatial scales of weather occurrences. Climate variability, according to FAO (2008), is the ensuing consequence in the changes of ecosystem structures to meet human land use and livelihood potentials. Physical, economic, social, and cultural effects of climate change pose a danger to environmentally focused livelihoods. Climate variability has direct effects on natural and societal systems, causing vulnerability due to fluctuations in average temperatures, temperature extremes, and extreme weather events such as flooding and droughts. The World Meteorological Organization (WMO) requires that averages be calculated for 30 years in a row. The averages are utilized in climate change research and as a benchmark against which current circumstances can be measured.

2.2.4 Climate change

Climate change is any change in the climate through time, whether it is brought on by natural variability or human actions (IPCC, 2007). Additionally, over a comparable time frame, climate change is linked to human (directly or indirectly) effects on the earth's atmosphere (Ajala, 2017). Similarly, the United States Environmental Protection Agency (USEPA, 2014) defines climate change as a significant change in rain, wind, and temperature that lasts for a long time. Therefore, climate change describes changes in the average weather across time. A change in the distribution of meteorological occurrences or in the typical weather conditions could be considered a form of climate change. This might only apply to a certain area or ecosystem, or it might be universal. Even though they are not the same, climatic variability and climate change are commonly conflated.

2.3 The climate systems

2.3.1 The climate system

The climate system is incredibly complicated, and it affects the earth's climate under the effect of solar radiation (WMO, 1992). Atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere are all part of this system. The atmosphere, hydrosphere, cryosphere, biosphere, and lithosphere all have a role in the global climate system, as do their interactions (IPCC, 2007).

The interaction and feedback between these components, as depicted in Figure 2.1, have a significant impact on climate.

2.3.1.1 The atmosphere

The gaseous substance that surrounds the earth makes up the atmosphere. Nitrogen (N_2), with a volume mixing ratio of 78 percent, and oxygen (O_2), with a volume mixing ratio of 21 percent, are the two most important elements. Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3) are some of the other gases that exist in the atmosphere. These trace gases influence the amount of energy stored in the atmosphere, as well as the global temperature.

These greenhouse gases contribute significantly to the Earth's budget, with a total mixing ratio in dry air of less than 0.1 percent by volume (Ajala, 2017; Baede *et al.*, 2001). Nitrogen and oxygen have no contact with the earth's infrared emissions and only a limited interaction with solar radiation. Because industries contribute to global climate change, considering human influence on GHG emission levels is a critical component of comprehending it.

These greenhouse gases trap heat that is trying to escape to space in the lower atmosphere, making the world's surface hotter. This heat trapping is known as the natural greenhouse effect, and it keeps the earth 33 degrees warmer than it would otherwise be. Man-made greenhouse gas emissions have increased the natural greenhouse effect over the previous 200 years, potentially driving global warming (Enviropedia, 2016).

An essential component of understanding global climate change is considering the human effect on greenhouse gas emissions (GHGs). Businesses and human activities increase atmospheric concentrations of greenhouse gases like CO_2, which amplifies the natural greenhouse effect and may lead to a significant warming trend. There is an energy flow in both the climate system and the atmosphere (Ajala, 2017).

2.3.1.2 The hydrosphere

All the earth's subsurface and surface liquid is included in the hydrosphere. Fresh and saline water make up the subsurface water. Freshwater encompasses lakes, rivers, and aquifers, while saltwater water includes the sea and oceans. Climate regulation is fundamentally dependent on the oceans. The oceans absorb, store, and transmit a lot of energy, as well as dissolve and store a lot of carbon dioxide. Ocean current is the transfer of heat in the hydrosphere from the warm equator to the colder poles. The exchange of energy between the atmosphere and the oceans has an impact on climate change.

2.3.1.3 The cryosphere

The cryosphere is made up of sea ice, glaciers, and ice sheets that influence the earth's temperature. Because the cryosphere could reflect solar radiation rather than absorb it, temperature on the planet's surface would have been substantially higher, as more energy would have been absorbed by the earth rather than reflected, increasing global warming.

2.3.1.4 The biosphere

The biosphere refers to the areas of the earth's surface and atmosphere where living organisms can be found. In other words, it includes all living organisms on the planet (on the land and inside water). The process of energy absorbed from the sun and how it is returned to the atmosphere is controlled by land vegetation and soil. Long-wave radiation is a conduit via which part of this energy is returned to the atmosphere (Ajala, 2017).

2.3.1.5 The lithosphere

The lithosphere is the rigid outermost shell of a planet or natural satellite of the terrestrial type. It is composed of the crust and a region of the outer mantle that has been elastic for at least a few thousand years.

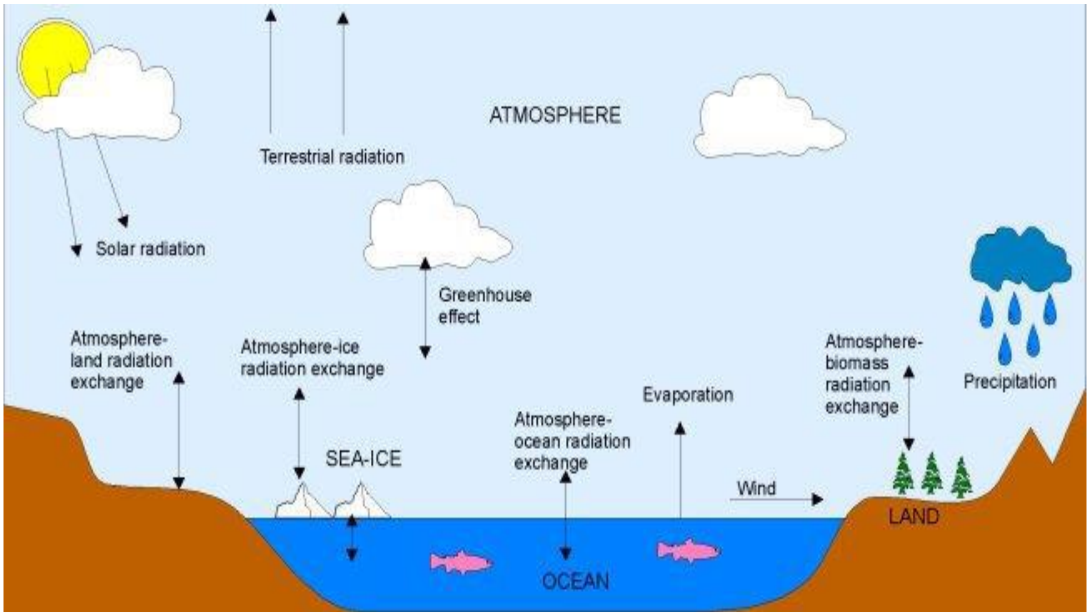

Fig. 2.1: Representation of the components view of the global climate system, their processes and interactions

Source: Ajala, 2017

2.4 Causes of Climate Change

The phenomenon climate change is the result of various human activity as well as some natural occurrences. "Climate forcing" or "forcing mechanism" refers to some of the natural causes of climate change (Nwankwoala, 2015). Externally (from extra-terrestrial systems) or internally (from humans) climate change can occur (from ocean, atmosphere, and land systems). A change in the sun's activity, for instance, could alter the amount of solar radiation that the earth's atmosphere and surface receive. Internal variations in the earth's climate can be caused by changes in atmospheric gas concentrations, the formation of mountains, volcanic activity, and changes in the surface or atmospheric albedo (Nwankwoala, 2015).

Deforestation, fossil fuel combustion, and population growth are among the most important ways in which human activities influence the amount of atmospheric greenhouse gases, according to the IPCC (2010), but fossil fuel combustion is the most important human activity influencing the amount and rate of climate change in greenhouse gas emissions. Similarly, when discussing greenhouse gas emissions as a driver of climate change, food production and the food chain are important factors to consider (Davis and Ziegler, 2009).

Carbon dioxide (CO_2), methane, and nitrous oxide are the most significant greenhouse gases directly emitted by humans. CO_2 is the most important greenhouse gas involved in recent climate change. CO_2 is naturally absorbed and exhaled as part of the carbon cycle, which includes animal and plant respiration, volcanic eruptions, and ocean-atmosphere interaction. Human activities such as the combustion of fossil fuels and land use changes release enormous amounts of carbon into the atmosphere, causing CO_2 levels to rise (Adenaiye, 2019).

Methane is created by both natural and man-made processes. Natural wetlands, agricultural activities, and fossil fuel extraction and transportation, for example. Human activities have increased the amount of methane in the atmosphere. Natural and human activities, mostly agricultural operations and natural biological processes, produce nitrous oxide. Nitrous oxide is also produced by fuel combustion and other processes. Since the beginning of the industrial

revolution, nitrous oxide concentrations have increased by about 18%, with a particularly significant increase towards the end of the twentieth century (Solomon *et al.*, 2007).
Ozone (O3) in the troposphere is a powerful greenhouse gas with a limited atmospheric lifespan. When nitrogen oxides and volatile organic compounds (VOCs) from autos, power plants, and other industrial and commercial sources are exposed to sunlight, a chemical reaction produces ozone. Ozone is a pollutant that can harm crops and ecosystems, in addition to trapping heat (National Research Council, 2010).

Chlorofluorocarbons (CFCs), Hydroclorofluorocarbon (HCFCs), Hydrofluorcarbon (HFCs), Perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) together called F-gases are often used in coolants, foaming agents, fire extinguishers, solvents, pesticides and aerosol propellants unlike water vapour and ozone, these F-gases have long atmospheric lifetime and some of their emissions will affect the climate for decades or centuries (NRC, 2010) see Figure 2.2.

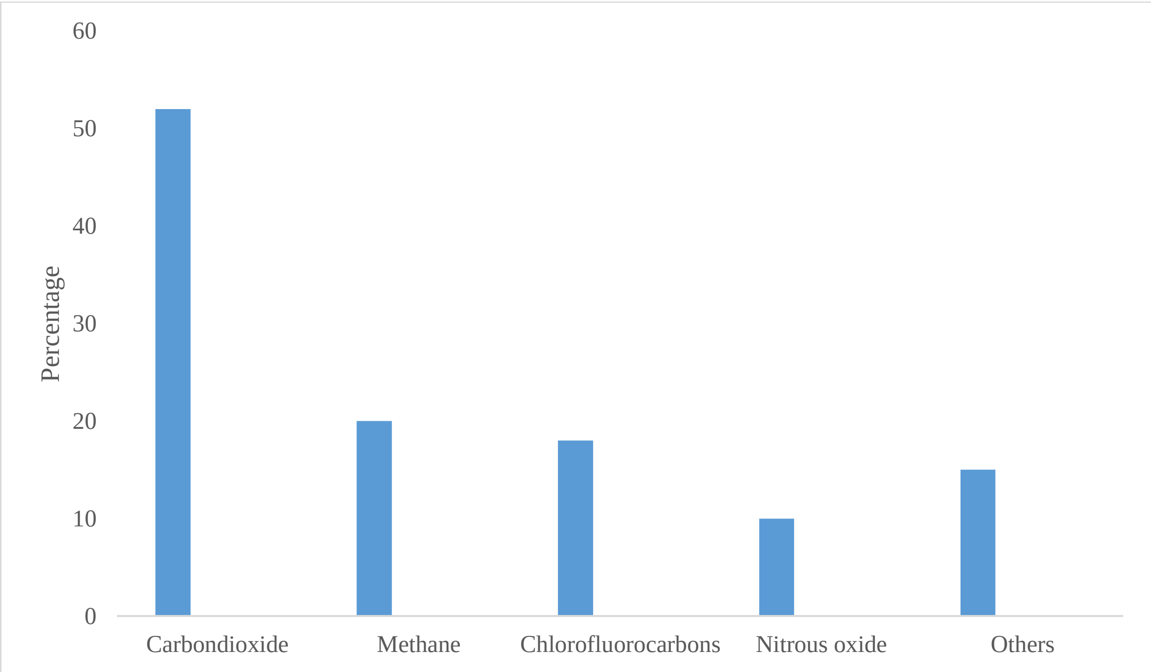

Fig. 2.2: Contribution of Greenhouse Gases (GHGs) to the Atmosphere

Source: IPCC (2007)

The anthropogenic element, which includes human activities such as industrialization, urbanization, agriculture, and fossil fuel combustion, is another cause of climate change.

Deforestation, land use change, water pollution, and agricultural practices are all human actions that reduce the number of carbon sinks (IPCC, 2007). Coal, oil, and gas combustion release greenhouse gases into the environment. In 2005, fossil fuels released around 27 billion tonnes of CO_2 into the atmosphere (IPCC, 2010). Heating homes and buildings, carrying and preparing food, traveling (for example, by vehicle, airline, bus, and train), purifying water to make it drinkable, heating and piping it into homes, manufacturing, and transportation, and so on all cause CO_2 emissions into the atmosphere (Anyandike, 2009).

Climate change is exacerbated by gas flaring. As part of its everyday oil drilling activities, Nigeria flares large amounts of carbon. Nigeria is one of the top emitters of greenhouse gases in Africa, with over 123 flaring sites in the Niger Delta region (Akinro *et al.*, 2008). The use of gas flares increased temperatures, making broad areas uninhabitable (Okali *et al.*, 2004). Furthermore, oil spills, blowouts, seismic explosions, and the dumping of untreated effluents directly into bodies of water, some of which serve as the only supply of water for the population, continue to deteriorate the Niger Delta environment. In this area, oil spills occur frequently (Odjugo, 2010).

Another major driver to climatic change in Nigeria is deforestation, which is defined as the permanent loss of forest cover (NEST, 2003). It resulted in the annual release of 5.9 billion tonnes of CO2. Because trees absorb carbon dioxide as they grow, it contributes significantly to carbon emissions. The fewer trees that are left to absorb carbon dioxide, the more carbon dioxide accumulates in the atmosphere (IPCC, 2007). As a result, there is no doubt that the globe is warming, and humans are the primary cause (Spore, 2002).

2.5 Climate projection in Africa

It has been revealed that Africa warmed by 0.7°C in most regions of the continent over the twentieth century, with precipitation decreasing in the semi-arid zone (south of the Sahara) and increasing in east and central Africa (Juana, Kahaka and Okurut, 2013). Temperature and precipitation trends were predicted to continue in the twenty-first century, accompanied by a rise in sea level and increased frequency of droughts and floods (IPCC, 2001); this illustrates temperature rises over Sub-Saharan Africa. A significant decrease in precipitation, according to Juana et al. (2013), would have an impact on water availability. According to the author, the average discharge of west African rivers has reduced by 40-60% since 1970, while the continent's water resources decreased by 2.8 times between 1970 and 1995.

According to Arnell (2004), the SRES scenario predicts that almost 370 million Africans will face increasing water stress by 2025, whereas roughly 100 million will experience reduced water stress by 2055 because of enhanced precipitation. Nyong (2005) averred that there would be a 75% reduction in river flow by 2100, affecting agriculture in the Nile basin. The El Nino/Southern Oscillation (ENSO) phenomenon, which involves the periodic warming of the tropical Pacific Ocean and related changes in air circulation, producing climatic disruption in many low-latitude regions, was also projected to cause major drought in Southern Africa (Juana et al., 2013).

2.6 Climate trend in Nigeria

There has been contrast between Nigeria's rainfall and temperature over the years, while temperature is increasing, there has been a decline in rainfall. In his view, Odjugo (2005) averred that there has been an increasing pattern in temperature trend of the country since 1901 while rainfall trend from the same period indicates a general decline. However, Nigeria's rainfall declined by 81mm, and the nation began to experience the biggest decline in rainfall from the early 1970s to the present. This period of rapid temperature rise coincides with a sharp decrease in rainfall in Nigeria, indicating a shifting climate.

Furthermore, Odjugo (2005, 2007) found that the number of rainy days in north-eastern Nigeria decreased by 53% and by 14% in the Niger-delta coastal areas. The findings of these research revealed that places that see maximum double rainfall are relocating southwards, and the brief dry season is occurring more frequently in July than it was in August before to the 1970s. These are significant climatic disruptions in Nigeria, suggesting indications of climate change.

2.7 Climate Change Effect on Agricultural Productivity

Agriculture is a necessary part of human life. Apart from food production, the importance of agriculture to each country's GDP, export revenues, and employment cannot be emphasized (Ajala, 2017). Regardless of technological developments in the field, climate remains a critical factor in agricultural productivity. Agriculture is affected by climate change because of local climate variability rather than global climate patterns. Agriculture yields and prices will suffer as a result of climate change (Yesuf *et al.,* 2008). Climate change (temperature, rainfall, and humidity), as well as the intensity and frequency of extreme weather events, will have a substantial impact on crop yields, potentially affecting agricultural output pricing (Ajala, 2017). Rudolf and Hermann (2009) argue that unfavorable weather can affect agricultural production at any stage of the process, from planting through harvesting. Climate change, for example, could have a negative influence on agricultural productivity, particularly during the critical growth stage of the crops.

2.7.1 Global Effect of Climate Change on Agriculture

The agricultural sector is critical to human survival and has a multiplier effect on any nation's socioeconomic development (Ogen, 2007; Stewart, 2000). Aside from food production, crop and livestock growing and raising, it contributes significantly to each country's gross domestic product, export revenues, and employment. Regardless of technological advancements in the business, climate remains critical to agricultural productivity. This agrees with Smith and Skinner (2002), who stated that climate has a significant impact on the productivity of physical production elements such as soil moisture and fertility in agriculture. The effects of increased climate fluctuation are apparent, and they are most noticeable in poor and least developed countries, where agriculture is primarily rain-fed and people have little options for acclimatization (Traerup and Mertz, 2011; Nwajuiba *et al.*, 2010; Onyenechere, 2010). Crop production is affected by climate change since it is a sensitive sector and one of the most vulnerable to climate change (Ajala, 2017). Crop growth, soil water availability, soil erosion, drought, flood, sea level rise, pest and disease infestation, and hence agriculture, food supply, fresh water supplies, and human health are all affected by climate change (Zoellick and Robert, 2009).

Climate change is having an influence all around the world, although there may be differences between affluent and poor countries (Coster and Adeoti, 2015; Mandleni, 2011; Ayinde et al., 2010). Third-world countries, according to Mendelsohn et al. (2001), will suffer the most from unfavorable consequences. Climate change poses a severe challenge to these countries, putting the poor at greater risk because they rely heavily on ecosystems. Similarly, the IPCC (2001) found that the poorest countries would suffer significant crop output declines in most tropical and sub-tropical regions as a result of decreased water availability and new or changing insect pest occurrence. Many rain-fed crops in Africa and Latin America are nearing their maximum temperature tolerance, causing yields to plummet in response to even minor climate changes;

agricultural production is expected to collapse by up to 30% by the twenty-first century (IPCC, 2001).

The impact of climate change means that the local climate variability that people have previously experienced and acclimated to is changing, and that this change is occurring at a rapid pace. Climate change threatens crop and livestock productivity, as well as the entire agricultural industry. According to the IPCC (2007), the cattle industry accounts for 40% of global agricultural production and provides livelihood and food security to nearly 1 billion people. Climate change has direct and indirect effects on cattle. Climate variables like air, temperature, humidity, wind speed, and other climate parameters have direct effect on animal performance like growth, milk production, and wool production (Ayinde *et al.*, 2011; Niggol and Mendelsohn, 2008). While climate change can have an indirect impact on livestock by affecting the quality and quantity of feedstuffs such as pasture, hay, and grain, as well as the severity and spread of livestock illnesses and parasites, it can also have a direct impact on livestock by affecting the severity and spread of (Ayinde *et al.*, 2011; Niggol and Mendelsohn, 2008). In Africa, where many people, particularly the impoverished, rely on local supply systems that are vulnerable to climate change, climate change has an influence on food and water supplies. Current food and water systems disruptions will have severe effects for development and livelihood. These are projected to exacerbate the challenges already posed by climate change in the fight against poverty (De Wit *et al.*, 2006). Depending on the scenario used, Parry *et al.* (2004) calculated that cereal production would decline by 200 to roughly 450 million tons by 2080.

Cline (2007) revealed that if carbon fertilization is not considered, world agricultural production capacity will drop by 16 percent. He claims that climate change will reduce agriculture output in Sub-Saharan Africa by 12% by 2080, while this figure might be as high as 60% in some African countries, with agricultural exports falling by up to a fifth in others. Climate change is also expected to cost West African countries up to 4% of their GDP in agricultural losses (Mendelson *et al.*, 2000). According to Pittock (2005), regional climate change, biological effects of increased atmospheric carbon dioxide, changes in floods, drought, extreme events, existing agricultural systems, adaptive capacity, population change, and technological innovation all influence the impacts of climate change on food production, prices, and food security.

2.7.2 Effect of Climate Change on Crop Production in Nigeria

The vulnerability of developing countries to climate change is a source of concern (IPCC, 2007). Nigeria will be severely impacted by climate change on crop production as a developing country (Odjugo, 2010). The southern part of Nigeria, which is known for heavy rainfall, is experiencing rainfall irregularities, while the northern part of the country is rapidly becoming arid due to desert encroachment (Obioha, 2008). Changes in climatic variables (temperature, rainfall, and humidity), as well as the intensity and frequency of extreme weather events, will affect crop yields and prices. It is a significant economic sector that provides raw materials for the processing industries as well as foreign exchange revenues (Mohammed-Lawal and Atte, 2006). Because Nigerian agriculture is primarily rain-fed, any change in climatic variables will inevitably affect its productivity.

Crop production is dependent on precipitation and temperature, but temperature and soil moisture are important for the length of the growing season and the development of crops, according to Calzadilla *et al.* (2013); however, high temperatures in arid and semi-arid areas will shorten the crop cycle and reduce crop production (IPCC, 2007). Climate change's impact on crop production, according to Adejuwon (2004), can be quantified in terms of crop growth, soil water availability, soil erosion, pest and disease incidence, sea level rise, and soil fertility decline. Low crop yields, reduced development, seedling drying after germination, an increase in pests and diseases, and poor fertilizer application due to rainfall delays have all been recognized as climate change consequences on crop production (Ozor, 2009).

It has been revealed that Nigeria is facing various ecological problems that may be linked to current climate variations (Adefolalu, 2007); as a result, smallholder farmers may face tragic crop failure, resulting in decreased agricultural productivity, increased hunger, poverty, malnutrition, diseases, and food insecurity (Zoellick *et al.*, 2009; Obioha, 2008). The impact of these changes is threatening Nigeria's food security, with some farmers abandoning farming in favor of non-farming activities as a result of environmental threats, resulting in lower agricultural yields (Apata *et al.*, 2010).

2.8 Maize Production (*Zea mays*)

Maize is grown all around the world, though yields vary greatly. It has the widest distribution of all cereal crops and the highest output potential. FAO (2012) estimated the total global production of maize as 875 226 tons, with the United States, China, and Brazil harvesting 31%, 24%, and 8% of the entire production, respectively. Maize is grown in every African country, from the coast to the savannahs and semi-arid parts of West Africa, and from sea level to mid and high altitudes in East and Central Africa (Abalu, 2001). Maize has evolved into the most important cereal crop in Sub-Saharan Africa and one of the world's most important cereal crops. Apart from being a staple crop that may be consumed directly, maize can be utilized for food and non-food products in almost all its sections (the International Institute of Tropical Agriculture (IITA), 2007). Maize is a staple grain in Nigeria with enormous socioeconomic value; yet, demand often exceeds supply. Nigeria produces roughly 8 million tons of maize in SSA, whereas Africa harvests 29 million hectares and Nigeria produces 3% of the overall production, followed by Tanzania (IITA, 2014).

2.9 Empirical Studies on Effect of Climate Change on Agricultural Production

Climate is imperatively important element for agriculture. In developing countries, the variability of climatic elements brings about changes that directly affect food production; likewise, this tends to cause climate associated insect infestations, weeds and diseases which could also cause damage to agricultural productivity (Ramirez, 2013).

This study looked at some of the literature on the consequences of climate change on agriculture. According to a study by Juana, Mangadi, and Strzepek (2012), a 20% drop in water availability due to climate change will result in a 12% decrease in agricultural output. Furthermore, Juana, Makepe, and Mangadi (2012) articulated a 10% drop in agricultural output in Botswana due to drought will result in an 8% drop in overall sectoral output. For disaggregated worldwide regions, Cline (2007) established the influence of carbon fertilization on agricultural production (measured in net income changes). As a result of global warming, agricultural productivity in developing countries is anticipated to fall by 9 to 21%. Meanwhile, carbon fertilization is expected to reduce agricultural yield in developed countries.

Some of the empirical studies used a Ricardian approach to measure the economic impacts of climate change on agriculture in Africa (Benhin, 2007; Kurukulasuriya and Mendelsohn, 2006; Seo and Mendelsohn, 2006; Mano and Nhemachena, 2006; Gbetibouo and Hassan, 2004). These studies ascertained that climate attributes (temperature and precipitation) significantly affect farm net revenue. Similarly, Seo and Mendelsohn (2007) used the same method to measure the impact of climate change on South American farms. The outcome showed that farming households are extremely vulnerable to warming. Van Passel *et al.* (2012) uses the same method to investigate impact of climate change on European agriculture, it was shown that farmland values across Europe are sensitive to climate even with the captured adaptation described by the Ricardian model; warming is expected to cause significant losses in Southern European agriculture. Coster and Adeoti (2015) investigated the economic impacts of climate change on maize output and farmer adaption options in Nigeria. The findings showed that maize net revenue is affected by climate change.

Furthermore, a descriptive analysis was utilized to determine that between 1907 and 2005, Nigeria saw an increase in temperature (1.1^{o}C) and a decrease in rainfall (81mm), indicating that Nigeria is experiencing the essential aspects of climate change (Bello *et al.*, 2012). Likewise, Odekunle *et al.* (2007) used a geospatial analysis to determine the impact of rainfall variability on crop yield in Nigeria's guinea savannah. The Geographical Information System (GIS) database creation and mapping techniques were used to create interactive maps of the crops production areas, areas harvested, and yield. Modelling rainfall and crop production is quite simple with GIS and the technology provides the capacity to incorporate geographically explicit data from many sources into various formats. Using an economy-wide global computable general equilibrium (CGE) model, Zhai *et al.* (2009) investigated the potential long-term implications of global climate change on agricultural production and commerce in the People's Republic of China. Adejuwon (2004) studied the effects of climate variability and climate change on crop productivity in Sub-Saharan West Africa using the Erosion Productivity Impact Calculator (EPIC) crop model. Also, Oyekale *et al.* (2009) measured the impact of climate variables on cocoa production using the Tobit regression model. Equally, Ramirez *et al.* (2013) investigated the effects of climate change on global grain production and the distribution of these effects between developed and developing countries up to 2060. According to their research, global grain production may fall by 1 percent to

8 percent, while prices might rise by 24 percent to 145 percent. Using multinomial regression analysis, Ayoade (2012) discovered a significant relationship between farmland change and climate change factors. In a study conducted by Phindile (2013), it was ascertained that rising and decreasing rainfall reduce maize yields. In the literature, time-series data has been used to measure the effects of climate change on agricultural production. Deschenes and Greenstone (2007) evaluate the economic impact of climate change on US agriculture using a time series technique. Blanc (2012), on the other hand, used a co-integration model to assess the influence of climate change on crop yields in Sub-Saharan Africa. To study the empirical analysis of agricultural production and climate change, Ayinde *et al.* (2010) used a time series analysis using granger causality test analysis. Their findings revealed that productivity increased continuously from 1987 to 2000 before declining in 2001. Chikezie *et al.* (2015) discovered an erratic climatic pattern that exhibited first-level stationarity of climatic variables in their investigation. The results of the Johansen co-integration approach revealed the presence of one co-integrating vector in each of the three models used in the study, indicating that climate change has impacted yam and maize output in the study area. In their study, Onubuogu and Esiobu (2014) corroborated the evidence of climate change on arable crops, as trend analysis found a continuous decline in the number of rainy days and relative humidity, while data on temperature level and sunshine duration revealed an increasingly significant trend. Furthermore, Duluora (2012) conveyed a trend analysis result of rainfall and temperature data for 30 years (1977 – 2006) using a 3-year running means and disclosed that the rainfall is relatively constant while temperature is on the increase. The popularity and extensive use of co-integration stems from the fact that it allows for the estimation of coefficients using data on non-stationary variables if the variables are co-integrated, or have a long-run relationship (Erdogdu, 2009).

2.10 Summary

This chapter discussed the idea of climate change, climate systems, and how the phenomenon affects agricultural production. Climate projections for Africa and Nigeria was also covered in this chapter. Likewise, numerous analytical methodologies and empirical investigations on the impact of climate change on agricultural production were evaluated.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter provides an overview of the study's methodology. Furthermore, it describes the study area's size and geographic location. It also explains the demographic and agro-ecological zones in relation to maize production. It also explains how sampling methods, data analysis, data reliability, and data validity work, as well as how variable measurements and econometric models were employed for inferential analysis to meet the study's goals. Incorporated into this chapter is the chapter summary.

3.2 Study Area

This study was conducted in the Southwestern region of Nigeria, which includes the states of Ekiti, Lagos, Ogun, Ondo, Osun, and Oyo. It is sometimes referred to as Nigeria's southwest geopolitical region. The region is situated between latitudes $6^{o}\,21^{1}$ and $8^{o}\,37^{1}$ North and longitudes $2^{o}\,31^{1}$ and $6^{o}\,00^{1}$ East, with a total geographical area of 77 818 square kilometres. It is home to an estimated 32.5 million people (National Bureau of Statistics, 2020). The study area shares land boundary with Edo and Delta states to the East, Kwara and Kogi states to the North, to the West by the Republic of Benin and to the South by the Gulf of Guinea on the Atlantic Ocean.

Nigeria's southwestern zone, which is in the coastal area of the nation, has humid to subhumid weather conditions. There are two distinct seasons in the region: the wet season (March through October) and the dry season (November through February). Southwest Nigeria experiences two distinct seasons, with the rainy season corresponding to the southwest monsoon wind from the Atlantic Ocean and the dry season relating to the northeast trade wind from the Sahara Desert (Oparinde and Okogbue, 2018). The region enjoys 1486 mm of yearly precipitation, temperatures that range from 21 to 28 ^{o}C, and a high humidity level of 77 percent (Oluwatunsin and Ojo, 2017).

The vegetation ranges from forest to savannah woodland or the forest-savannah transition zone (Adebanjo, 2013; Adebayo et al., 2011); these are classified as the freshwater swamp, the mangrove forest, the low land forest that extend into Ogun State as well as some areas of Ondo State, while there is secondary forest located towards the northern boundary where derived and southern savannah exist.

The area is highly populated, and because agriculture is the predominant form of employment, crops and livestock are produced there with few issues. The major agricultural activity of the farmers in this zone is crop production, which is carried out by over 90% of them in the savannah and rainforest zones but only by 37.82% in the swamp regions where fishing and fish farming are the main agricultural activities. Based on this, Lagos State was thus exempted from the study.

Food crops like maize, cassava, vegetables, and yam are cultivated in this region (Oparinde and Okogbue, 2018; Adebanjo, 2013; Fasola, 2007). The main cash crops in the zone are cocoa, oil palm and rubber. The cultivation of food crops, primarily maize (*Zea mays*), was the study's main area of interest.

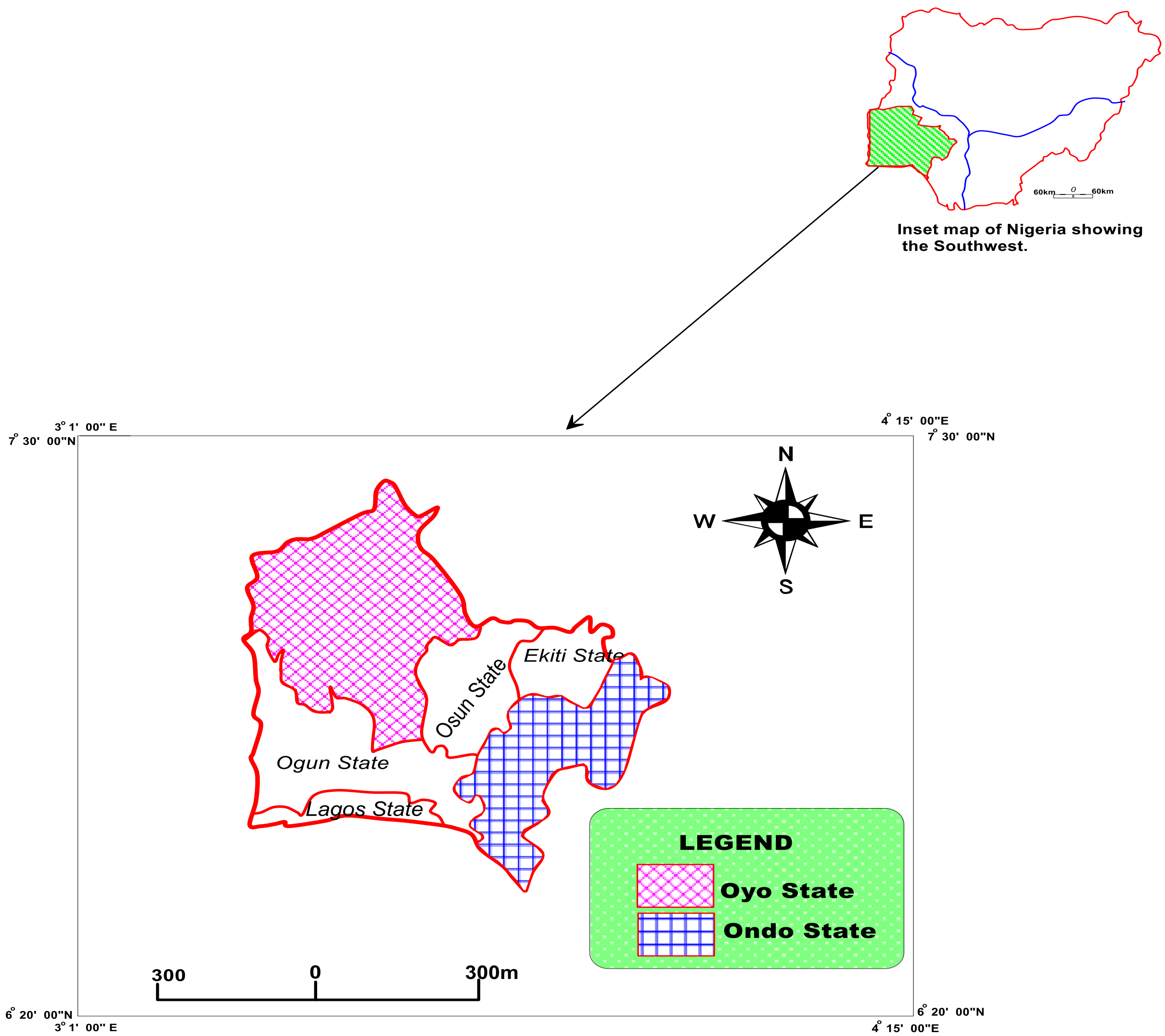

Fig 3.1 : Map of Southwest showing the study areas.

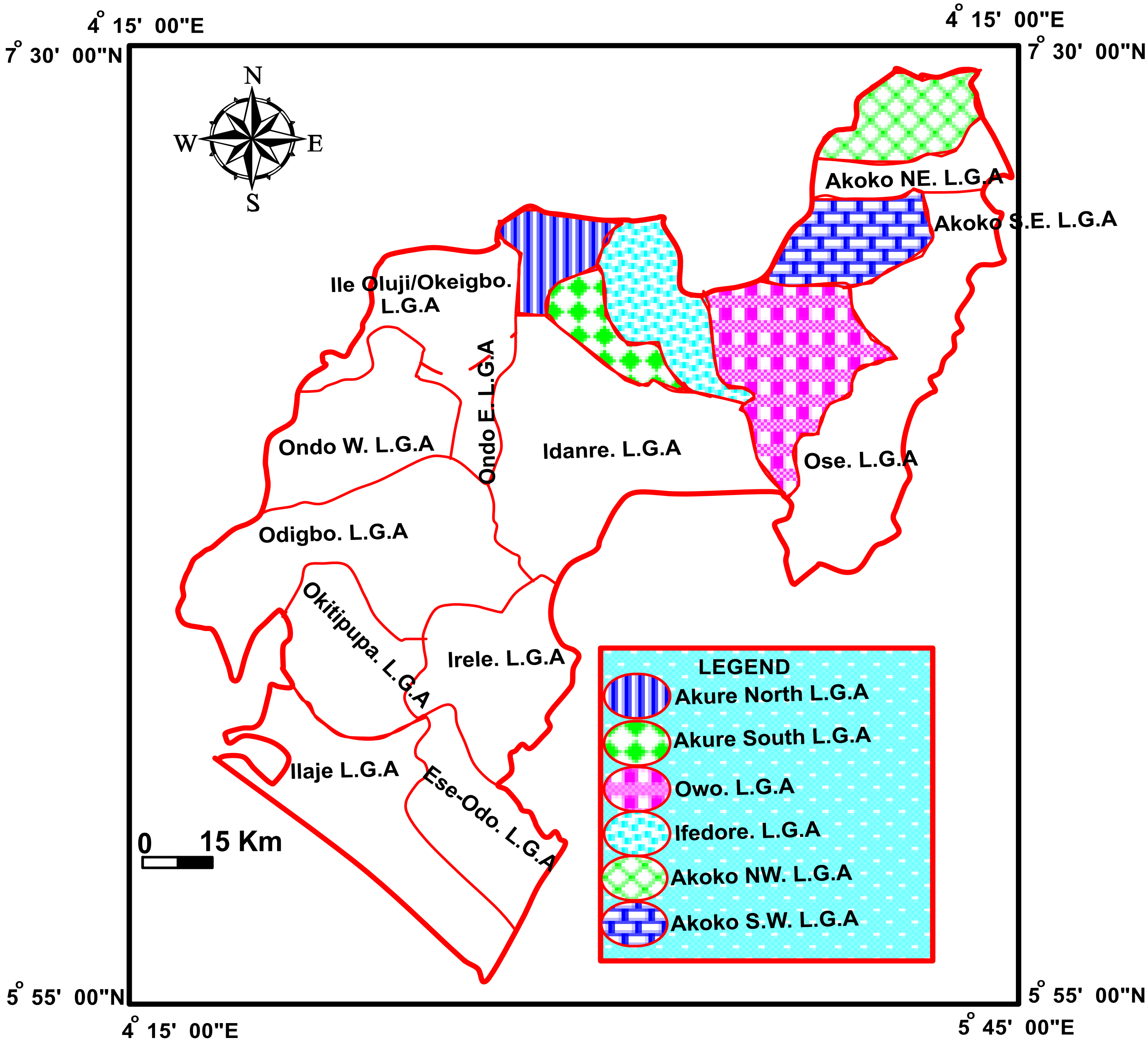

Fig 3.2 : Map of Ondo State showing the study areas.

Source:Ondo State Surveys,Akure

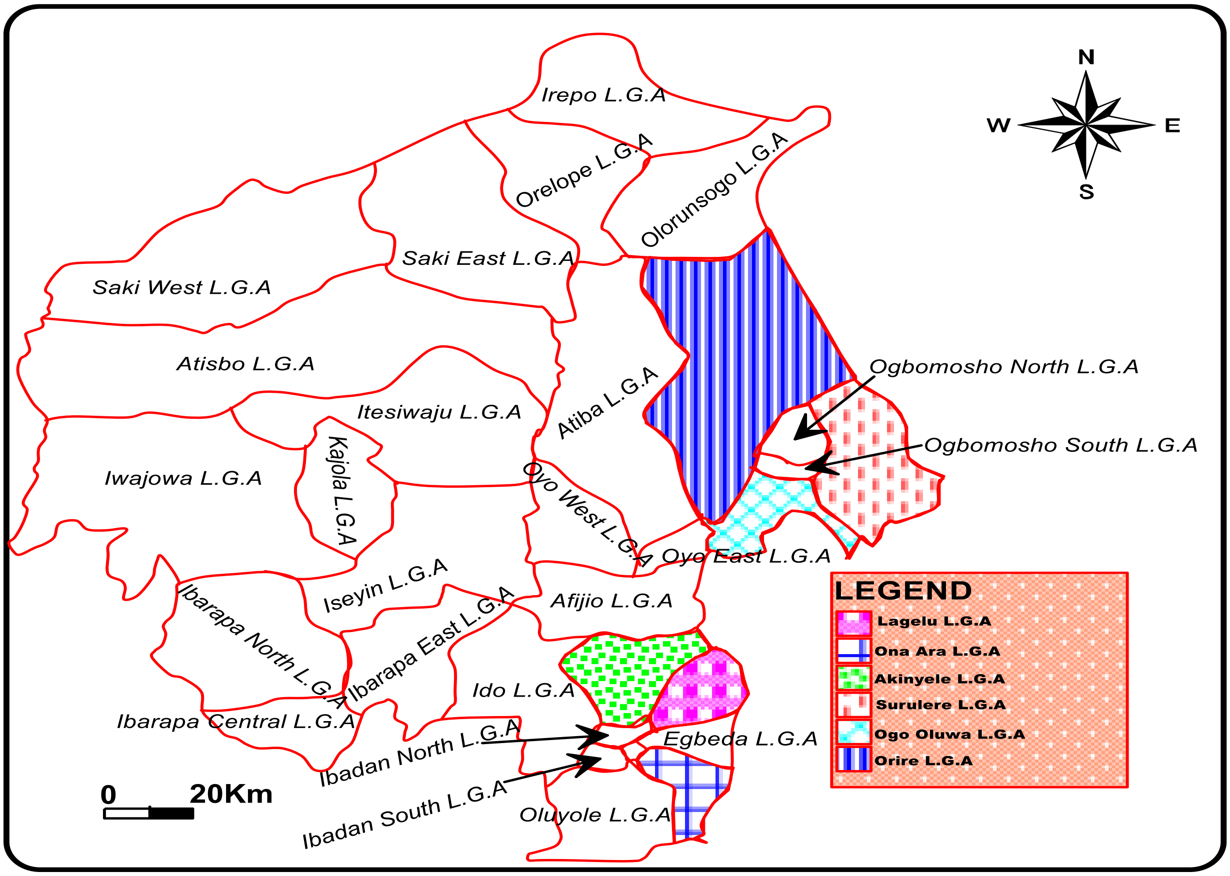

Fig 3.3 : Map of Oyo State showing study areas

Source:Ministry of Lands & Survey
Survey Division,Ibadan.

3.3 Research Design

Research design is a strategy and set of procedures for conducting research that spans the choices between broad hypotheses and thorough procedures for collecting and analysing data (Creswell, 2014). Similarly, the researcher's primary tool for finding answers to study questions is the research design (Polit and Beck, 2004). A research design, according to Fowler and Aaron (2010), is a comprehensive proactive plan for finding trustworthy answers to the study's asked questions as well as for handling some of the potential difficulties that can arise during the research process.

3.3.1 Research Approach

An approach to research identifies the actions, practises, attitudes, and techniques the researcher will use to accomplish the research's goal. In a similar vein, Creswell (2014) stated that a research approach is a set of strategies and a methodological procedure that includes a progression from general hypotheses to specific techniques for data collecting, analysis, and interpretation. This study employed a quantitative research methodology. Creswell (2014) defines a quantitative research approach as a strategy that focuses on numerical data collecting and simplifying it across groups of people or to elucidate a specific occurrence. In addition, it is a method that places a strong emphasis on quantifying data gathering and analysis.

3.4 Sample size and sampling techniques

A sample is defined as a "lesser (but ideally representative) group of units from a population used to ascertain truths about that population." For this study, the respondents were chosen using a multistage sampling procedure. Based on the two main agro-ecological zones of the region, a purposive random sampling was conducted in the study area (rainforest and savannah). Firstly, two (2) states were purposefully selected at random from among the five Southwestern states, taking into consideration the two main ecological zones in the region. The states that fall in the rainforest agro-ecological zone are Ondo, Ogun, and Osun while Ekiti and Oyo states are majorly savannah dominated agro-ecological area while Lagos state was excluded because fish farming/fishing is the major agricultural activities in the state.

For administrative reasons, each of the states were divided into agricultural zones by the state Agricultural Development Programme (ADP). For example, Oyo state has 33 local government areas (LGAs) which were divided into four agricultural zones while Ondo state has 18 local government areas which was also divided into four agricultural zones. Secondly, two (2) agricultural zones were selected in each of the two (2) states. The third stage involved the random selection of three extension blocks (local governments) from each agricultural zone, making twelve (12) extension blocks while there was also a purposive selection of three (3) farming communities where maize production is distinguished from the selected extension blocks.

Finally, there was a randomly selection of fifteen (15) registered maize farmers from each farming communities that was obtained from the state agricultural development programme and extension officers making a sample size of five hundred and forty (540) maize farmers. The population for the study was delimited to a homogenous group of subjects through inclusion/exclusion criteria. The criteria for inclusion were that farmers must have at least a year of farming experience and active in the production of maize crop. Maize farmers fitting the above criteria in the study area stood a chance to be chosen as a smaller convenient group of the target population. Table 3.1 shows the multi-stage sampling procedure used in the study. The researcher could only use five hundred (500) questionnaires during analysis because some of the filled questionnaires were not appropriately completed by the farmers while some were not returned.

Table 3.1: Summary of the Sample Location and Sample Size

State	Zone	Block	Farming Community	Number Interviewed	Actual Number Used
Ondo (Rainforest)	Akure	Akure North	Ita-Ogbolu	15	13
			Iju	15	14
			Igoba	15	14
		Akure South	Aponmu	15	15
			Oda	15	14
			Olokuta	15	13
		Ifedore	Ilaramokin	15	14
			Igbara Oke	15	14
			Ikota	15	14
	Owo	Akoko Northwest	Okeagbe	15	13
			Arigidi	15	15
			Erusu	15	13
		Owo	Ipele	15	14
			Ipenmen	15	15
			Emure Ile	15	14
		Akoko Southwest	Oka Akoko	15	13
			Akungba Akoko	15	14
			Oba Akoko	15	15
Oyo (Savannah)	Ibadan/Ibarapa	Lagelu	Lalupon	15	13
			Iyana Offa	15	14
			Kutayi	15	14
		Ona-Ara	Akanran	15	13
			Amuloko	15	15
			Badeku	15	15

		Akinyele	Moniya	15	14
			Alagbaa	15	13
			Arulogun	15	13
	Ogbomoso	Surulere	Iresa-Apa	15	14
			Iresa-Adu	15	15
			Oko	15	15
		Ogo-Oluwa	Ajaawa	15	15
			Lagbedu	15	13
			Otamokun	15	14
		Oriire	Ikoyi-Ile	15	14
			Oolo	15	12
			Ahoro-Dada	15	13
Total	**4**	**12**	**36**	**540**	**500**

Source: Author's computation, 2021

3.5 Data Collection

This study uses a quantitative research approach and the survey targeted mainly the maize farmers in Southwestern Nigeria. The study uses a cross-sectional and time-series data. The cross-sectional data were collected through a farm household survey while time-series data were collected on selected climatic variables (temperature, rainfall, and humidity) and maize output from 1979 – 2020 from National Meteorological Agency (NIMET) and State Agricultural Development Programme (ADPs) respectively. Demographics, socio-economic characteristics, climate change perceptions and constraints to climate change adaptation alongside agricultural production aspects were some of the information collected from the study area for the study.

Table 3.2: Data sources

S/N	Data	Number of Years	Sources
1	Meteorological parameters e.g Temperature, Rainfall, Relative Humidity	42 years (1979 – 2020)	National Meteorological Agency State Agricultural Development Programmes (ADPs)
2	Maize output	42 years (1979 – 2020)	Ministry of Agriculture and Natural Resources State Agricultural Development Programmes (ADPs)

Source: Author's computation, 2021

3.5.1 Research Instrument

A pre-tested and validated interview schedule was developed to collect information about respondents. The household interview was conducted with the aid of a well-structured questionnaire that contained both close ended and open-ended questions to gather data quantitatively. The questionnaire comprises matters relating to climate change perceptions and adaptation while climatic trends and maize production output were collected using time-series data The interviews only targeted maize farmers from Southwestern Nigeria. The survey questionnaire covered information on farmer's socio-economic characteristics, type of farm and non-farm activities, asset ownership, access to extension services and credit facilities, farmers group, different maize varieties, area planted, adaptation constraints and other relevant information.

3.5.2 Data Collection Procedure

Consent to carry out the study was granted by each state through the state's Agricultural Development Program (ADPs) offices of the Ministry of Agriculture and Environment and was passed in a communiqué to local governments and all the extension blocks where the investigation was carried out. A thorough questionnaire developed in English was used as the data collecting instrument, and field enumerators assisted in conducting structured face-to-face interviews with the farmers. Before data collection, the field enumerators received training, and the researcher oversaw them. The sample frame was created to meet the goals and guarantee that all statistical requirements for accuracy were strictly followed. The survey was conducted from February to May of 2021. The Nigerian Meteorological Agency (NIMET) and State Agricultural Development

Programme (ADPs) provided the secondary data on certain meteorological variables (temperature, rainfall, and humidity) and maize production for the period 1979 – 2020, respectively.

A well-structured questionnaire that includes both closed-ended and open-ended questions was used to conduct the household interview in order to collect quantitative data. The questionnaire comprises matters relating to climate change perceptions and adaptation while climatic trends and maize production output were collected using secondary data. The interviews only targeted maize farmers from Southwestern Nigeria. The questionnaire for the survey asked questions about the socioeconomic characteristics of the farmer, the nature of their farming and non-farming activities, their asset ownership, their access to credit and extension services, their farmer group, the various maize varieties they grew, the area they planted them, their difficulties with adaptation, and other pertinent information.

3.6 Reliability and Validity

This section attests to the validity of the research work through the methods used to collect the data. It demonstrates how the ambiguity test for the research instrument was conducted.

3.6.1 Validity

In quantitative research, validity refers to the degree of frankness with which the research's findings are expressed or whether the research measures what it set out to (Ajala, 2017). The objectives of this study, as well as the analytical models and the questionnaire, were critically evaluated by specialists in the field of agricultural economics who also checked the quality of the research material to make sure the right data were gathered. For the study to be considered scientifically valid, the researcher strictly adhered to the study's validity requirements.

3.6.2 Reliability

The ability to consistently produce the same results is referred to as reliability. This also implies measuring accuracy. Prior to data collection for this study, the questionnaire was pre-tested and piloted on twenty (20) respondents to improve its reliability. The pilot study was conducted in Ilaramokin in the Ifedore local government in Ondo State and Iresa-Apa in the Surulere local government in Oyo State. The questionnaire pre-testing was done to further ascertain the authenticity of the research instrument. It helped in ensuring clarity in the questionnaire by modification of ambiguous questions and overlapped questions were deleted.

The reliability test was accomplished by using the split half reliability correlation (using spearman-brown coefficient). The result was found to be reliable after the split-half correlation. Generally, correlation coefficient (r) values are considered good if $r \geq 0.70$. A reliability coefficient of 0.769 was obtained, which suggests that all sections of the instrument were reliable. The instrument demonstrated the capability of obtaining the same results when the researcher measures the same variable more than once or when more than one individual evaluates the same variable.

3.7 Data analysis and model specification

3.7.1 Data Analysis

Data analysis, which is an integral part of a research design, is the process of making meaning of data before presenting it clearly and understandably (Parahoo, 2006). As a result, data analysis entails the systematic arrangement and synthesis of research data as well as the testing of research hypotheses utilising the gathered data (Polit and Beck, 2010). To accomplish its goals, this study used a combination of descriptive and inferential approaches. Frequency distribution, percentages, the mean, and the standard deviation were used as descriptive analytical tools; while growth function model, unit root test analysis, auto-regressive distributed lag (ARDL) approach, multinomial logistic regression model, double hurdle analysis, and two stage least square regression analysis were used for inferential analytical purposes.

3.7.2 Model Specification

3.7.2.1 Descriptive Statistics

Descriptive statistics give researchers the ability to condense, summarise, and quantitatively explain data derived from empirical evidence (Polit & Beck, 2004). The socioeconomic characteristics of the farmers, climate change perceptions and adaptations, likewise the constraints to adaptation strategies were analysed descriptively while trend analysis was used to complement the descriptive analysis in analysing objectives one and four respectively.

3.7.2.2 Growth Function Model

The growth rate for this study was computed following Ekundayo (2019) and Oparinde and Okogbue, (2018), by fitting an exponential function in time to the data. The lead equation, which was then used for additional analysis, was chosen using standard economic, econometric, and statistical criteria. Oparinde and Okogbue (2018) assert that because this measure considers all observations, the computation of growth rates will be more accurate. The use of data at the beginning and end of a period, which has been shown to disregard crucial information, is one of several different methods with certain drawbacks for computing compound growth (Okoye et al., 2006; Amos, 2004).

The compound growth rates in this study measures the trend and growth rates of climatic variables and maize yield between 1979 and 2020 (a period of 41 years). It was calculated by fitting the exponential function in time to the data by using the following formula:

$Y = b_0 e^{bt}$ ………………………………………………………………………… (3.1)

After linearizing in logarithm, the equation becomes:

$LogY = b_0 + b_1 t$ …………………………………………………………………. (3.2)

Where:

Y = Dependent variables (Maize output and climatic variables)

t = Time trend variables

b_0, b_1 = Regression parameters to be estimated

The growth rate (r) is given by

$r = (e^{b_1} - 1)$ x 100 ……………………………………………………………… (3.3)

Where e is Euler's exponential constant (2.7183)

Data were added to the function to estimate production from 1979 to 2020. The integration of a quadratic equation in time variables to the data for the years 1979 and 2020 allowed the study to determine whether there had been any acceleration, deceleration, or stagnation in the growth rate of maize output.

$LogY = b_0 + b_1 t + b_2 t^2$ ………………………………………………………………. (3.4)

The quadratic time t^2 allows for the likelihood of acceleration, deceleration, or stagnation in growth during the period of study. If the P-value of the coefficient of t^2 is significant, this validates acceleration growth while negatively significant t^2 value confirms deceleration in growth; likewise, non-significant coefficient of t^2 implies stagnation.

3.7.2.3 Auto-Regressive Distributed Lag (ARDL) Approach

The primary objective of co-integration is to develop long-term equilibrium relationships between the variables that are of interest. ARDL is a relatively new but widely used method of co-integration; nonetheless, it is less frequently utilised than Vector Auto-regressive (VAR) Model, which is used in many co-integration studies to establish multivariate relationship.

The long-term relationships between climatic variables and maize output were investigated using the bounds testing (ARDL). To accomplish this, a preliminary analysis was conducted to determine the order of econometric integration (i.e., unit root test) before establishing the long-term equilibrium connection. To prevent model misspecification error, the proper lag lengths for each of the models were established. On establishing co-integration, how fast a shock is absorbed, that is error correction model (ECM) was examined.

3.7.2.3.1 Test for Stationarity

The unit root test analysis can be avoided in this method but it is of great importance to conduct stationarity test to confirm that there is no contravention in the assumption of ARDL (i.e regressors are purely *I(0),* purely *I(1)* or mutually co-integrated). This is because the presence of an *I(2)* series will cause the model to crash. Therefore, the stationarity status of all the variables were determined by Augmented Dickey Fuller (ADF) test following Pesaran, Shin and Smith (2001), Fatuase *et al.* (2016), Oparinde and Okogbue (2018), Oparinde, (2017), Ekundayo (2019). The model is as follows:

Constant term: $\Delta P_{it} = \alpha_1 + \varphi P_{it-1} + \sum_{t=1}^{n} \theta_i \, \Delta P_{it-1} + \varepsilon_{it}$ ……………………………. (3.4)

Constant term and Trend: $\Delta P_{it} = \alpha_1 + \alpha_{2t} + \varphi P_{it-1} + \sum_{t=1}^{n} \theta_i \, \Delta P_{it-1} + \varepsilon_{it}$

Where Δ is the first difference operator

P_{it} is variables being investigated for stationarity

α, φ, θ are parameters to be estimated

n is number of lags of the variables to be included

ε_{it} is the error term

The null hypothesis of the ADF unit root test is H_0: δ = 0 which suggests that there is no long-run relationship (the series is not stationary) and the alternate hypothesis is H_α: δ < 0 which reveals the existence of co-integration or long-run relationship between climatic variables and maize output (the series is stationary). The null hypothesis of no co-integration would be rejected if the ADF statistics falls above the upper bound critical value which would signify that the series is stationary. Equally, the null hypothesis cannot be rejected if the computed ADF statistics value is lower than the critical values which would imply that the time series is not stationary while the result would be inconclusive if the value falls between the lower and the upper bound.

3.7.2.3.2 Lag Order Selection

The establishment of the optimal lag for the model was done by lag selection criteria using Unrestricted Vector Auto-regression (VAR). Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Bayesian Information Criterion (SBIC) and Hannan-Quinn Information Criterion (HQIC) were employed for the VAR models. The model with the lowest value of estimated standard errors was preferred for the study, however they are computed as:

$AIC = \ln(\epsilon^2) + {}^{2k}/_{T}$ …………………………………………………………………. (3.5)

$SBIC = \ln(\epsilon^2) + {}^{2k}/_{T}\, lnT$ ……………………………………………………………. (3.6)

$HQIC = \ln(\epsilon^2) + {}^{2k}/_{T}\, lnT$ ……………………………………………………………. (3.7)

Where the ln is the natural log

ϵ^2 is the variance of the estimated residuals

K is the sample size

T is the number of parameters

3.7.2.3.3 ARDL Co-integration Model Test

This model is used to empirically examine and validate the presence of long-term equilibrium connections and dynamic interaction levels between variables. The study's underlying premise is that climatic factors (temperature, rainfall, and humidity) have an impact on maize productivity in the study area. Thus, it is hypothesised that climate variables and maize productivity will have a long-term relationship. Therefore, the study applied ARDL bounds testing approach to co-integration proposed by Pesaran *et al.* (2001). The bound test is computed primarily using an estimated error correction version of the autoregressive distributed lag (ARDL) version of the ordinary least square (OLS) estimator (Pesaran *et al.,* 2001). Bounds testing was utilized because of its advantages over other co-integration approaches which comprise:

a. Giving solution to the problem of endogeneity and failure to test the hypothesis on coefficients that are estimated in the long run with the method of Engle-Granger approach (Engle and Granger, 1987 cited in Mohammed *et al.,* 2014).
b. Doesn't require the integration of variables of interest of the same order unlike other co-integration approaches. The ARDL method is applicable regardless whether the underlying regressors are purely *I(1), I(0)* or mutually co-integrated.
c. It is better than multivariate co-integration method because it is appropriate for small samples (Mohammed *et al.*, 2014; Narayan, 2005)
d. Unlike other multivariate co-integration methods, co-integration relationship could be estimated in bounds testing by Ordinary Least Square (OLS) once the lag order of the model is identified which makes the approach simple.
e. The estimations of long and short run parameters are done separately in a single model in bounds test approach.
f. Different variables could be assigned different lag lengths as they enter the model in bounds testing.

The assumption that the variables had a long-run relationship was tested using an F-test of the joint significance of the coefficients of the lagged levels of the variables. According Pesaran *et al.* (2001) it was stated that there were two asymptotic critical values bounds provide a test for co-integration when the independent variables are $I(i)$ (where $0\leq i \leq 1$): a lower value assuming the regressors are I(0), and an upper value assuming purely I(1) regressors. Once the upper critical value is less than the F-statistic, the null hypothesis of no long-run relationship can be rejected regardless of the orders of integration for the time series. Conversely, if the lower critical value is greater than the test statistic, the null hypothesis cannot be rejected. Lastly, if the statistic is between the lower and upper critical values, the result is inconclusive. Therefore, the optimal lag length for the stated ARDL model was established based on the Akaike Information Criterion (AIC).

The null hypothesis of no co-integration (no long-run relationship) among variables (maize productivity and climatic variables) is given as:

$H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$

The other hypothesis (the existence of co-integration or long-run relationship) among variables is given as:

$H_1: \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq 0$

3.7.2.3.4 Model Specification for the bound testing (ARDL)

This approach to co-integration procedure is used to empirically analyse the long-run relationships and dynamic interactions among maize production, annual temperature, annual rainfall, and relative humidity. This study follows Oparinde and Okogbue (2018); Idumah *et al.* (2016) and Saravanakumar (2015) that related crop yield with some climate variables such as temperature and rainfall. The relationship between maize productivity and the selected climate variables are expressed as follows;

$MAIZ = f(lnTemp, lnRain, lnHumid)$ ………………………………………………... (3.6)

The ARDL model specification of equation (3.6) is implicitly expressed as unrestricted error correction model (UECM) to test for co-integration between the variables under study in correspondence to Pesaran *et al.* (2001):

$\Delta lnMAIZ_t = \beta_0 + \sum_{i=1}^{q} \beta_1 \Delta lnMAIZ_{t-i} + \sum_{i=0}^{q} \beta_2 \Delta lnTemp_{t-i} + \sum_{i=0}^{q} \beta_3 \Delta lnRain_{t-i} + \sum_{i=0}^{q} \beta_4 \Delta lnHumid_{t=i} + \omega_1 lnMAIZ_{t-1} + \omega_2 lnTemp_{t-1} + \omega_3 lnRain_{t-1} + \omega_4 lnHumid_{t-1} + e_t$ .... (3.7)

Once co-integration is established, the long-run relationship is estimated using the conditional ARDL model specified as:

$lnMAIZ_t = \beta_0 + \omega_1 lnMAIZ_{t-1} + \omega_2 lnTemp_{t-1} + \omega_3 lnRain_{t-1} + \omega_4 lnHumid_{t-1} + e_t$...(3.8)

The short-run dynamic relationship is estimated using an error correctional model specified as:

$$\Delta MAIZ_t = \beta_0 + \sum_{i=1}^{q} \beta_1 \, \Delta lnMAIZ_{t-i} + \sum_{i=0}^{q} \beta_2 \, \Delta lnTemp_{t-i} + \sum_{i=0}^{q} \beta_3 \, \Delta lnRain_{t-i} + \sum_{i=0}^{q} \beta_4 \, \Delta lnHumid_{t-i} + \delta ecm_{t-1} + e_t \quad (3.9)$$

Where:

MAIZ = Maize production output (mt)

Temp = Average Temperature (^{o}c)

Rain = Rainfall (mm)

Humid = Relative humidity (%)

β_0 = Constant term

e_t = White noise

$\beta_1 - \beta_4$ = Short run elasticities (coefficients of the first-differenced explanatory variables)

$ecm_{t-1} =$ Error correction term lagged for one period

$\omega_1 - \omega_4$ = Long run elasticities (coefficients of the explanatory variables)

$\delta =$ Speed of adjustment

Δ = First difference operator

ln $=$ Natural logarithm

q = Lag length

3.7.3 Multinomial Logistic Regression model

Hassan and Nhemachena (2008) claim that farmers can protect losses from temperature increases and rainfall decreases by taking adaptation strategies. This study's results revealed the significance of adopting adaptation measures to combat the threat posed by climate change to maize production and general human well-being. It also provided policy information on climate change adaptation to encourage maize farmers in the study area and the country to increase adaptation intensity.

Different models have been used in the analysis of several agricultural adoption decision studies, including Ordinary Least Square, Logit Regression Models, Probit Regression Models, and Tobit Regression Models for studies involving bivariate choices and Multinomial Logit, Multinomial Probit, Ordered Probit, and Ordered Logistic Models for studies involving multiple choices, among others. However, many technological adoptions in agriculture entail a two-step decision-making process: (1) being aware of the technology, and (2) deciding whether to embrace it or not. This was supported by a large body of literature on climate change adaptation. It was stated that there are two stages to combatting climate change: (1) realising that changes in the climate have occurred, and (2) deciding whether to take specific actions. This was ascertained in studies carried out in Ethiopia and South Africa respectively (Gbetibouo, 2009; Deressa *et al.*, 2008; Maddison, 2007).

Several studies where adoption decision used more than a step, models with two-step regressions have been employed; this is done to correct for the selection bias during the decision-making process (Ndambiri *et al.*, 2013). MNL and MNP are important probabilistic model to use when the choices are more than two, therefore, a binary choice model such as binomial logistic regression would not have been appropriate (Gujarati, 2003). The computational simplicity in calculating the choice probabilities made this study to employ the multinomial logistic regression model to examine the factors that influence climate change adaptation among farmers in the study area.

The multinomial logistic regression model is a regression model that generalizes the logistic regression model and allows for more than two discrete outcomes. It also permits the probability likelihood of categorically distributed dependent variables by a given set of independent variables (Gujarati, 2003). The assumption of this approach is that each independent variable has a specific value for each case, consequently, it assumes that the data are case specific. There is no need for the independent variables to be statistically independent from each other and collinearity is assumed to be low because it becomes difficult to differentiate between the impacts of several variables if they are highly correlated (Gujarati, 2003).

The dependent on the assumption of independence of irrelevant alternatives (IIA) by the model is a major constraint (limitation) of the model. The assumption states that the ratios of the probabilities of choosing any two alternatives remain the same irrespective of the number of alternatives available. For example, the relative probabilities of using new planting date or crop rotation as an adaptation strategy to climate change does not change if adoption of new technology is added to the choices as an additional probability. This allows the choice of A alternatives to be modelled as A-1 independent binary choices because one alternative is chosen as a base against which A-1 alternatives are compared against a time (Gujarati, 2003: McFadden, 1987).
The mathematical representation is:

$score(X_i, A) = \beta_A X_i$ ………………………………………………………………….. (3.12)

Where

$X_i = the\ vector\ of\ the\ explanatory\ variables\ describing\ i$

β_A = the regression coefficients that corresponds to outcome A and $score\ (X_i, A)$ of assigning observation i to category A

Gujarati (2003) position on discrete choice theory where observations represent people and outcomes represent choices, the score is considered the utility associated with person i, choosing outcome A and the predicted outcome is the one with the highest score. The fundamental arrangement for a multinomial logit model is like binary logistic regression just that MNL has a polythomous dependent variables which is the only disparity between the two regression models. For example, there are A possible outcomes rather than just two outcomes. The way to comprehend multinomial logit model effortlessly is to imagine for A possible outcomes, running $A-1$ independent binary logistic regression models, in which one variable is chosen as a "base" and then the other $A-1$ outcomes are independently regressed against the base variable. This would proceed as follows if variable A is used as the pivot:

$ln \frac{\Pr(Y_i = A-1)}{\Pr(Y_i = A)} = \beta_{A-1}.X_i$ ………………………………………………………………… (3.13)

The probabilities would be solved keeping in mind that the total probabilities must be equal to 1. Then, the logarithms must be converted to exponential functions, and this will give:

$\Pr(Y_i = A-1) = \Pr(Y_i = A)e^{\beta_{A-1}.X_i}$ …………………………………………………….. (3.14)

If the total probability is introduced to the equation, the equation that can be used to calculate the probabilities of other outcomes is obtainable. This will give:

$\Pr(Y_i = A) = \frac{1}{1+\sum_{A=1}^{A-1} e^{\beta_A X_i}}$ ……………………………………………………………. (3.15)

The coefficients have that capacity to show on the direction of the effect that an independent variable has on the dependent variable. Mcfadden (1987) stated that the degree of the effect can be acquired from the marginal effects. The independence of the alternatives would be tested by the Hausman test of independence. The marginal effects or elasticities which indicate how much the dependent variable will change if there is a corresponding change in the independent variable, can be calculated by taking the partial derivatives or differentiating the dependent variable with respect to the independent variable question (McFadden, 1987). Then the marginal effect of the j^{th} predictor, X_j on P_i can be expressed as:

Given that i = 1, 2, 3, 4…………. A for unordered responses.

$$\frac{\partial P_i}{\partial X_j} = P_i \left[\frac{\partial X'\beta_i}{\partial X_j} - \sum_A \left(P_A \frac{\partial X'\beta_i}{\partial X_j}\right)\right] \ldots \ldots (3.16)$$

The marginal effects or marginal probabilities, which are functions of probability itself, quantify the expected change in probability of a given option being chosen in relation to a unit deviation of an independent variable from the mean (Fatuase and Ajibefun 2014; Deressa *et al.*, 2008; Koch 2007; Green 2000).

The MNL model's explicit function is listed below.

$$Y^* = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + --------- + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{14} X_{14} + e_1 \ldots \ldots (3.17)$$

Where

$Y^* = dependent\ variable\ (\ adaptation\ measure\ options)\ which\ are$

1. Multi-cropping
2. Planting different varieties
3. Soil and water conservation techniques
4. Use of agrochemicals
5. Move to different farmland

Move to different farmland* was chosen as the base category while the X_{is} are the explanatory variables which are socio-economic, farm-specific, and institutional variables

$X_1 = Age\ of\ the\ respondents\ (years)$

$X_2 = Gender\ of\ the\ respondent\ (Dummy{:}\ 1 =\ male;\ 0 = Otherwise)$

$X_3 = Marital\ Status\ of\ the\ respondent\ (Classified)$

$X_4 = Educational\ Status\ (Classified)$

$X_5 = Household\ Size\ (Numbers\ of\ members)$

$X_6 = Tenure\ System\ (Classified)$

$X_7 = Farm\ Ownership\ (Classified)$

$X_8 = Farn\ Size\ (Hectares)$

$X_9 = Farming\ Experience\ (Number\ of\ years\ as\ a\ farmer)$

$X_{10} = Major\ Occupation\ (Dummy{:}\ 1 = Yes;\ 0 = Otherwise)$

$X_{11} = Source\ of\ Income\ (Dummy: 1 = Yes; 0 = Otherwise)$

$X_{12} = Climate\ chnage\ Information\ (Dummy: 1 = Yes; 0 = Otherwise)$

$X_{13} = Climate\ Change\ Awareness\ (Dummy: 1 = Yes; 0 = Otherwise)$

$X_{14} = Rainfall\ Perception\ (mm)$

$X_{15} = Temperature\ Perception$ (oC)

3.7.4 Double Hurdle Model

The double hurdle model was used to evaluate the rate of adoption of climate change adaptation methods by maize producers in the research area. This objective goes beyond determining whether to adopt adaptation strategies for climate change and instead focuses on assessing adoption intensity. It was suggested that mitigating climate change is a two-stage process: (1) raising awareness of climate change and (2) deciding whether or not to implement specific measures. This was ascertained in studies carried out in Ethiopia and South Africa respectively (Gbetibouo, 2009; Deressa *et al.,* 2008; Maddison, 2007). The two decisions can be made jointly or separately. The Tobit model has been a popular model for analysing adoption determinants when the decisions are jointly made and hence, the factors affecting the two level of decisions are taken to be the same (Asfaw *et al.,* 2011; Tambo and Abdoulaye, 2011; Bamire *et al.,* 2002). The dependent variable data can be classified into two groups in a Tobit model, the non-adopters is equal to a limit (usually zero) and the adopters usually above the limit (indicating technology use) (Bamire *et al.,* 2002).

However, when the two decisions are made separately, the double hurdle model is more suitable to use in analysing the intensity of climate change adaptation strategies adoption. Adoption of climate change adaptation may come before the rate (intensity) of adoption decision made by farmers, and this therefore explain that the variables in the two stages may differ from each other (Asfaw *et al.,* 2011). Double hurdle model was proposed by Cragg (1971), and this has been embraced for adoption studies in recent time (Asfaw *et al.,* 2011; Tambo and Abdoulaye, 2011; Shiferaw *et al.,* 2008; Teklewold *et al.,* 2006; Gebremendhin and Swinton, 2003).

The assumption of Double Hurdle model for the study is that farm households crossed two hurdles in choosing adaptation strategies to adapt to the negative impact of climate change in the study area. This shows that the parameters in the second stage of a Double Hurdle model vary from those in the first stage. Therefore, the first stage was the decision making to adopt or not and the second decision is about the rate (intensity) of adoption which depend on the first decision. The two stage questions in a typical Double Hurdle model for this study was: Do you adapt to climate change and if yes, what is the rate of adaptation strategies you used. The model allows for the possibility that the probability and intensity of adoption have different explanatory variables and variables appearing in both may have different effects.

The Double Hurdle model is expressed as:

$d^* = z_i' \alpha + e_i$ -- (1)

$d_i = 1 \; if \; d_i^* > 0 \; and \; if \; d_i^* \leq 0$ --- (2)

Where equation (1) and (2) are the first hurdle equation (Adoption decision)

$y^* = x_i' \beta + u_i$ -- (3)

$y_i = y_i^* \; if \; y_i^* > 0 \; and \; if \; d_i^* > 0$ --- (4)

$y_i = 0$ or otherwise -- (5)

Where equation (3), (4) and (5) are the second hurdle equation (Intensity of adoption)

Where d_i^* = latent variable that describes household decision to adopt

d_i = observed household decision to adopt and takes a value of 1 if the farmer adopts adaptation strategy and 0 otherwise

y_i^* = latent variable describing the rate of adoption

y_i = observed response on rate of adaptation strategy and is measured on the constraints in accessing adaptation strategies

z = vectors of variables explaining the decision to adopt adaptation strategy

x = vectors of variables explaining the intensity of adopting adaptation strategy

$\alpha \; and \; \beta$ = vectors of parameters

e_i = error term with mean 0 and variance 1

u_i = error term with mean 0 and variance σ

Based on the above assumption of independence of the two error terms, the maximum likelihood method of probit and truncated regressions was used to estimate the first and second hurdles respectively.

The model variables used in the double hurdle model were specified below:

$d^* = dependent\ variable\ (\ adoption\ of\ climate\ change\ adaptation)$

$y_i^* = dependent\ variable\ (climate\ change\ adaptation\ intensity)$

While the X_{is} are the explanatory variables which are socio-economic, farm-specific, and institutional variables

$X_1 = Age\ of\ the\ respondents\ (years)$

$X_2 = Gender\ of\ the\ respondent\ (Dummy{:}\ 1 =\ male; 0 = Otherwise)$

$X_3 = Marital\ Status\ of\ the\ respondent\ (Classified)$

$X_4 = Educational\ Status\ (Classified)$

$X_5 = Household\ Size\ (Numbers\ of\ members)$

$X_6 = Tenure\ System\ (Classified)$

$X_7 = Farm\ Ownership\ (Classified)$

$X_8 = Farn\ Size\ (Hectares)$

$X_9 = Farming\ Experience\ (Number\ of\ years\ as\ a\ farmer)$

$X_{10} = Major\ Occupation\ (Dummy{:}\ 1 = Yes; 0 = Otherwise)$

$X_{11} = Source\ of\ Income\ (Dummy{:}\ 1 = Yes; 0 = Otherwise)$

$X_{12} = Climate\ chnage\ Information\ (Dummy{:}\ 1 = Yes; 0 = Otherwise)$

$X_{13} = Climate\ Change\ Awareness\ (Dummy{:}\ 1 = Yes; 0 = Otherwise)$

3.7.5 Two Stage Least Square Regression

The effect of climate change on farmers' productivity in the study area was investigated using the Two Stage Least Square (2SLS) regression model, following Oduniyi and Tekana (2019), Adelekan and Omotayo (2017), and Ajayi and Oyekale (2012). The 2SLS is an extension of the OLS method and it is used when there is a correlation between the dependent variable’s error term and the independent variables. Gujarati (2003) demonstrates that simultaneous equation bias occurs when a single equation is estimated using OLS but contains one or more endogenous explanatory variables. The correct strategy would thus be to create a system of simultaneous equations and estimate it using a two-stage or three-stage least squares method, depending on the number of endogenous variables. The objective of this study was accomplished using a Two Stage Least Square (2SLS) regression model.

If we are to determine the coefficients of the linear model, mathematically written as:

$y = \alpha + \beta x + u$ ………………………………………………..…………………………… 1

The ordinary least squares (OLS) estimator is inconsistent when the observed independent variable x has measurement errors, and we want to estimate the regression coefficient on the "true" value of x. The simplest and most typical model connecting x true value to its observed value is as follows:

$x = T + e$ …………………………………………………………………….……….………… 2

Where T is the true value, e is the random error of measurement. Similarly, to equation 1

$x_{ji} = T_{ji} + e_{ji}$ ………………………………………………………………..………………… 3

Where x_{ji} is the observed value of j for individual i, T_{ji} is the true value of item j for individual i and e_{ji} is the measurement error.

$y_1 = \beta_0 + \beta_0 + \beta_1 x_{11} + ---------- \beta_k x_k + \varepsilon_i$ …………………………………… 4

y_1 is a dependent variable = Total Factor Productivity (TFP)

$y_1 = \beta_0 + \beta_0 + \beta_1 x_{11} + \beta_2 x_{21} + \beta_3 x_{31} ---------- \beta_k x_k + \varepsilon_i$ ………………….. 5

But some of the variables x_{ji} are correlated with the error term as shown in the equation 3 above. OLS estimation of this equation will be biased and inconsistent. Assuming there is a collection of q > p instruments, $z_{1i} \ldots \ldots z_{qi}$. Where variables p and q are called endogenous.

The two-stage least square estimator of β will be as follows:

Regress $\hat{x}_j = x_j$. Estimate β via the OLS estimate of the regression model.

$y_1 = \beta_0 + \beta_1 \hat{x}_{11} + \beta_2 \hat{x}_{21} + \beta_3 \hat{x}_{31} ---------- \beta_k \hat{x}_{k1} + \varepsilon_i$ ……………………… 6

y_1 indicates Total factor productivity, $\hat{x}_{11}, \ldots \ldots, \hat{x}_{k1}$ denote farming household characteristics, $\beta_0, \beta_1, \ldots \ldots \ldots \ldots \ldots \beta_k$ are regression parameters to be estimated, ε_i is the error term.

The X_{is} are the explanatory variables which are as follows:

$X_1 = Revenue\ (Naira)$

$X_2 = Adaptation\ Rate\ (Intensity)$

$X_3 = Age\ of\ the\ respondents\ (years)$

$X_4 = Gender\ of\ the\ respondent\ (Dummy: 1 = male; 0 = Otherwise)$

$X_5 = Marital\ Status\ of\ the\ respondent\ (Dummy: 1 = Married; 0 = Otherwise)$

$X_6 = Educational\ Status\ (Classified)$

$X_7 = Household\ Size\ (Numbers\ of\ members)$

$X_8 = Tenure\ System\ (Classified)$

$X_9 = Farm\ Ownership\ (Classified)$

$X_{10} = Farn\ Size\ (Hectares)$

$X_{11} = Farming\ Experience\ (Number\ of\ years\ as\ a\ farmer)$

$X_{12} = Major\ Occupation\ (Dummy: 1 = Yes; 0 = Otherwise)$

$X_{13} = Source\ of\ Income\ (Dummy: 1 = Yes; 0 = Otherwise)$

$X_{14} = Climate\ chnage\ Information\ (Dummy: 1 = Yes; 0 = Otherwise)$

$X_{15} = Rainfall\ Perception\ (mm)$

$X_{16} = Temperature\ Perception$ (oC)

3.7.6 The empirical specifications of model variables

The literature has revealed some inconsistencies in the link between several parameters (Bamire et al., 2002). To better understand climate change, its effects on agriculture, and the adoption of adaptation measures, many models have been developed to help in the selection of explanatory factors. The conceptual model utilised by Negatu and Parikh (1999) and Adesina and Zinnah (1993a) was incorporated into this study through the use of three broad types of explanatory factors. The model is a relationship between user context and technological attributes. Negatu and Parikh (1999) argue that this model integrates methodologies that presuppose that properties of a technology underlying user's agro-ecological, socio-economic, and institutional contexts play the primary role in the adoption decision and diffusion process. This model can take into consideration how potential users' views of a technology's features may influence their decisions to adopt it and, ultimately, the technology's diffusion. The model's implication is the significance of farmers' participation in the technology development process with the purpose of producing technologies with appropriate and acceptable qualities. The underlying assumptions of this model served as the foundation for this study.

The dependent variables for this study were as follows: climate change adaptation measures (MNL); climate change adaptation adoption and the rate of adopting climate change adaptation strategies (intensity of adoption) (Double Hurdle); Total factor productivity (Two-Stage Least Square). The choice of explanatory variables that was used for the study was influenced by theoretical behavioural hypotheses, empirical literature, and the collected data. This contains the following: (i) farming household and socio-economic characteristics (ii) climatic factors and (iii) farmers perception about adaptation. Climatic-related factors like farmer's awareness of change in climatic conditions was also integrated into the study. The explanatory variables that were used in the inferential analysis for the study are presented in Table 3.3.

There is no agreement in the literature on the role of age in the explanatory variable since the direction of the effect is usually location or technology specific (Bamire *et al.,* 2002; Adesina and Baidu-Forson, 1995). According to several studies (Hassan and Nhemachena, 2008; Bamire *et al.*, 2002; Anim, 1999), farmers' decisions to embrace adaptation strategies were unaffected by their age, whereas other studies (Bamire *et al.*, 2002; Anim, 1999) indicated that age has a statistically significant negative association with farmers' decisions to accept technology (Anley *et al.*, 2007; Featherstone and Godwin 1993; Gould et al., 1989). However, Adesina and Baidu-Forson (1995) discovered that in Burkina Faso, age is positively connected to the adoption of new agricultural technology. As a result, there is no consensus on the expected indication of age for this study. The notion is that old age is associated with more expertise, resources, or authority, which may provide them with more opportunities to try a new technology (Bamire *et al.,* 2002; Adesina and Baidu-Forson, 1995), and that older farmers will adapt to climate change. Furthermore, younger farmers have been found to be more aware about new methods and may be more prepared to absorb the risk and implement an adaptation strategy due to their longer planning horizons. Older farmers, on the other hand, may be more risk averse than younger farmers and are less likely to accept new technologies that will assist them in adapting to climate change (Adesina and Baidu-Forson, 1995).

Gender had been termed an important variable in the diverse adoption and climate change related studies. The expected sign for gender in this study will be positive because female farmers are expected to have lower probabilities of adapting to climate change and lower levels of area that will be planted than their male counterpart. This is so because male farmers were more involved in farming more than the female folks that are more involved in-house chores. Furthermore, Coster and Adeoti (2015) claimed that male dominance has been variously linked to the hard nature of peasant farming due to a heavy reliance on manual labour. Therefore, gender in this study was measured dichotomously with male farmers scored as one and female farmers scored as zero. Marital status was included as part of the household and socio-economic variable even though it has been expected to have no significant effect on farmers decision to adopt climate change adaptation strategy in the study area. This variable was classified.

Numerous studies on climate change and agricultural productivity have discovered that farmers' literacy levels have an impact on climate change adaptation decisions (Coster and Adeoti, 2015; Deressa *et al.*, 2009; Asfaw and Admassie, 2004). According to Madison (2007), educated farmers are more likely to respond to the threat posed by climate change by implementing at least one adaptation strategy. Similarly, Deressa *et al.* (2009) and Deressa *et al.* (2010) suggested that education of agricultural household heads increased the possibility of climate change adaptation. This study followed previous empirical investigations, and the premise was that farmer education status influences farmer decision to pursue adaptation option to combat climate change menace. A categorical scale was used to measure the variable. Additionally, farmer decision to choose climate change adaptation approach is likely to be affected by farm size, although the direction is not apparent *"a priori"*. Households with large farm sizes are thought to be more likely to adopt at least one adaptation technique because they are more willing to utilise a portion of their land to cultivate untested varieties, whereas households with limited areas of land may be more willing to accept technology that requires intense management.

Climate-related factors such as awareness of climate change and the possible benefit of taking action are additional predictor of adopting adaptation measures that may affect farmers' productivity, so they were included as an independent variable in the study. Farmers' understanding of changes in climate variables is critical for making adaptation decisions (Madison, 2007). Other research discovered that farmers' decisions to implement soil conservation measures were positively and significantly influenced by their awareness and perceptions of soil erosion problems (Anim, 1999; Gould *et al.*, 1989). As a result, this study anticipates that farmers who are aware of changes in climatic variables will implement adaptation strategies to assist them cope with or take advantage of the opportunities associated with these climatic changes.

Table 3.3: Description, measurement and 'a priori' expectations of study variables

Variables	Variable label	Measure/Value	Expected effect
Dependent variables			
Adaptation strategy	Adaptation measures options	Mean adaptation strategy	Will be determine by independent variables
Adopt	Adoption of climate change adaptation	Discrete but will be measured in dummy with 1 if farmer makes decision to adopt climate change adaptation strategy and 0 otherwise	Will be determine by independent variables
Intensity	Climate change adaptation intensity	Numbers of Adaptation Strategies	Will be determine by independent variables
Total factor productivity			Will be determine by independent variables
Independent Variables			
Farming household and socio-economic characteristics factors			
Age	Age of the farmers	Years	±
Gender	Gender	Dichotomous: male = 1; female = 0	+
Marital	Marital Status	Classified	-
Education	Educational Status	Classified	+
Household	Household Size	Numbers of members	+
Tenure	Land Tenure System	Classified	±
Farm ownership	Who owns the farm	Classified	±
Farm size	Total farm size	Hectares	+
Farmers experience	Number of years as a farmer	Years	+
Major Occupation	Major Occupation	Dichotomous: Yes = 1; 0 = NO	+
Major Source of Income	Is Farming your major source of income	Dichotomous: Yes = 1; 0 = NO	+
Climatic factors			
CC information	Farming household receive information on climate change	Dichotomous: Yes = 1; 0 = otherwise	+
Awareness	Climate change awareness	Dichotomous: Yes = 1; 0 = otherwise	+
CC awareness	Farming households are aware of changes in climatic variables	Dichotomous: Yes = 1; 0 = otherwise	+

3.8 Ethical Consideration

Research ethics is a set of behaviors that researchers must follow to respect participants' rights to privacy, integrity, and confidentiality. It is, on the other hand, a set of moral norms that gives guidelines and behavioral expectations for appropriate behavior toward participants, organizations, sponsors, and so on (De vos *et al.,* 2015). To guarantee that this study is ethically acceptable and adheres to the university's policy on ethics, data collection did not begin until the research proposal was approved by the University of South Africa's ethics committee (UNISA). The researcher additionally requested the formal authorization of the state's Agricultural Development Program offices to perform this study within the states. Letters were also written to several agricultural ministries and parastatals in charge of collecting agro-climatology and maize production data, requesting access to their databases and any other information that could have benefited the research.

The study used human participants; hence, each response was considered as an autonomous representative and informed of the research's positive implications on local agricultural productivity and climate change mitigation. The researcher took care to protect both the research subjects and the public. Participants' non-public information was treated with the utmost confidentiality, and the data was only used for the primary objective of this research. To prevent participant data from becoming public knowledge, the statistician who assisted with data transcription and analysis was required to sign a confidentiality agreement.

3.9 Summary

The study area, research design, sample size and data selection procedure were elucidated in this chapter. It also included sampling, data gathering, data analysis, and devices for data collection. A thorough analysis of the model definition and the reason for its use was conducted. The following chapter fully outlined the study's research findings.

CHAPTER FOUR

SOCIO-ECONOMIC CHARACTERISTICS OF MAIZE FARMERS AND ADAPTATION MEASURES

4.1 Empirical results and discussion

This chapter explains how the descriptive analysis findings of the study were interpreted and discussed. This chapter covered climate change-related facts and the respondents' adaptation strategies. The results were primarily presented in tabular and graphical formats. The findings were compared, and literature references were made.

4.2 Socio-economic aspect of the study

4.2.1 Age of the respondents

Table 4.1 shows the distribution of respondents by age group. Most respondents (36.8%) were between the ages of 46 and 55, 32.2% were above 56, 21.2% were between the ages of 36 and 45, and 9.8% were between the ages of 19 and 35. Farmers who were under the age of 18 were excluded from the study. Across the states, similar results were observed. About 10.0% of the respondents were between 19-35 in Ondo and Oyo States, respectively.

Furthermore, in Ondo and Oyo States, 20.3% and 22.1% of respondents were 36-45 years old, followed by 31.5% and 42.2% in the 46–55-year-old age bracket. In addition, according to the table, 38.2% of respondents in Ondo state were over 56 years old, while 26.1% of maize farmers in Oyo state were also over 56 years old. These findings suggest that maize farmers in the research area are over the dependent age range; that is, they are not in the economically active age range, implying that maize productivity is leaning on the decline. The findings also revealed that young people in the research area do not engage in farming but instead participate in various activities. The findings support previous research that shows young people do not view farming as a rewarding profession and choose to pursue other options (Oduniyi, 2018; Maponya and Mpandeli, 2012; Nwaru and Onuoha, 2010).

Additionally, according to Maponya and Mpandeli (2012), the computer and industrialization age allowed youngsters to focus on technology-related employment rather than agriculture. In addition, Binswanger-Mkhize (2014) maintained that youths' waning interest in farming adds to the low agricultural performance. As a result, if capable young men are not injected into the profession soon, maize productivity may suffer setbacks.

4.2.2 Gender of the respondents

Most respondents (81.2%) were male, with 78.9% of farmers in Ondo state and 83.5% in Oyo state likewise being male (Table 4.1). As a result, maize productivity in Southwest Nigeria is dominated by men. The findings are consistent with those of Nhemachena and Hassan (2007), who found that male-headed households had a higher percentage of those active in agricultural production. The justification for having a higher number of male farmers could be that they are more productive than their female counterparts because males are more labor efficient, which is in line with FAO (2011) presentation on rural employment and farm projects, which found that men were more productive than women in farming. Similarly, the male-dominated agriculture industry may be due to the arduous nature of agricultural activities. Coster and Adeoti (2015) established that difficult farming is associated with male authority because of a firm reliance on physical labor. Female farmers are more common in more minor energy-intensive elements of farming, such as processing and marketing, which attract fewer males. Furthermore, unlike males, women have restricted access to critical agricultural resources (e.g., land, loans, and other productivity-enhancing inputs) and are thus disadvantaged in farming (Rahman, 2009).

4.2.3 Marital status of the respondents

The result indicates that 4.2% of the sampled maize farmers were single. About 87% were married, 2.8% were divorced, and 4.4% were widowed. The empirical, analytical result further revealed that Ondo State had the higher (5.6%) number of single maize farmers while Oyo State had 2.8%. In Ondo State, the majority (88.8%) of the respondents were married, while 88.4% are the percentage of married respondents in Oyo state. The number of divorced maize farmers from Ondo and Oyo states were 4.0% and 1.6%, respectively, and about 2.0% and 4.0% of maize farmers were divorced in Oyo and the Ondo States, respectively seen in Table 4.1. This implies that most of the respondents were married; hence, marital status can affect agricultural productivity; that is, they will have more individuals in the home who will contribute to labor input, resulting in more family labor being available. Similarly, any member of the farming household's marital status may impact their awareness of climate change. The findings of this study, as well as those of Titus *et* *al.* (2015), Ayoade (2012), Nicolas *et al.* (2010), and Adebayo *et al.* (2008), all suggest that more married persons pursue agriculture as their primary occupation.

4.2.4 Educational qualifications of the respondents

The result shows that 2.4% of the pooled sample had no formal education; also, 2.4% of the respondents in Ondo state constituted participants with no formal education; likewise, 2.4% of maize farmers in Oyo state were accounted with no formal education. However, 86.8% represented respondents with formal education in the pooled sample, while 88% and 85.5% had formal education in Ondo and Oyo States, respectively. Out of the 86.6% that had formal education, 34.8% had primary school education, 35.2% attended secondary school, while 16.8% attended higher institutions at various levels (Table 4.1). Table 4.1 further revealed that 4.2% attended adult education programs, about 4.0% in Ondo and the Oyo States, respectively, while 6.6% of the maize farmers had one form of vocational training, about 5.0% and 8.0% of the maize farmers in Ondo and Oyo States went for vocational training. The result exhibited a satisfactory literacy level in formal education among farmers. This implies that the level of education can enhance farmers' understanding and embracing of improved farming methods to increase agricultural productivity, which is in line with Onubuogu *et al.* (2014) and Nhemachena and Hassan (2007). As a result, literacy level may influence respondents' climate change awareness and adaptation methods, consistent with Ibrahim *et al.* (2015), who said that farmers' educational standing might influence their level of climate change cognizance and the development of adaption measures.

Furthermore, as stated by Mugula and Mukuna (2016), Fatuase and Ajibefun (2014), Deressa *et al.* (2010), Deressa *et al.* (2008), and Maddison *et al.* (2007), the respondents' educational level would enable them to acquire knowledge and skills expected to increase their power to understand climate change impacts and their associated coping strategies. As a result, the farmers' literacy levels in the study area significantly impacted climate change perception. Similarly, (Asfaw and Admassie, 2004; Bamire *et al.*, 2002) explained that a farmer's ability to produce more in any given resource depends on his or her level of knowledge and learned information. However, it is said that education plays a vital role in agricultural awareness since educated individuals know how to gather information; similarly, educated farmers respond to climate change threats by using at least a few adaption techniques (Maddison, 2007).

4.2.5 Household size of respondents

The respondents' household size distribution is presented in Table 4.1. The findings depict that the household size 1-5 formed the majority (57.6%) of the total respondents, followed by household sizes 6-10 (35.2%); likewise, households 11-15 have 5.2%, and then household sizes greater than 15 (2.0%). The same trend was observed in the States. It was observed that 65.3% and 49.8% of the respondents had a family size of between 1 and 5 persons per house in Ondo and Oyo State, respectively. Furthermore, respondents with a family size of 6-10 in Ondo state are 31.1% and in Oyo state represent 39.4%, and respondents with 11-15 persons per house in Ondo state are made up of 1.2% and 9.2% in Oyo state respectively. Respondents that have a family size greater than 15 persons per house in both Ondo and Oyo State are 2.4% and 1.6%. The average household size in the study area was six people, while the average household size in Ondo and Oyo States was also six. According to the findings, high household size is sufficient to increase agricultural productivity, mainly if all family members are fully engaged in farming activities (i.e., the family members could be used as a source of manual labor on the farm and could also influence the adoption of new technologies or new farming practices). This is like the findings of Fatuase (2016), Mugula and Mkuna (2016), and Deressa (2009), who discovered that households with large farm sizes are more likely to engage in agricultural production, take advantage of high yields and adapt to climate change. However, Otitoju (2014) and Mano and Nhemachena (2006) suggested that a big household size does not imply a higher usage of family labor because non-farming activities can divert a portion of her labor force.

4.2.6 Occupation of the respondents

Table 4.1 depicts the distribution of maize producers in the study area by major occupation. Farming was discovered to be the primary occupation of 74.6% of farmers, with 25.4% having other occupations ranging from formal employment (12.2%), trading (7.2%), self-employment (2.0%), and business (2.0%), and 2.0% having no occupation. At the state level, 82.1% and 67.1% of respondents in Ondo and Oyo States chose farming as their primary occupation, whereas 5.2% and 19.3% of respondents in Ondo and Oyo States, respectively, are formally employed. In Table 4.1, traders, self-employed people, and business owners account for 6.8%, 1.6%, 2.0%, and 7.6%, 2.4%, 2.0%, respectively. The respondents' involvement in farming is thought to be a result of unemployment in the research area. Connolly-Boutin and Smit (2016) and Calzadilla *et al.* (2013)

found similar results. They claimed that farming was the primary source of income and employment for most people in developing countries and contributed significantly to national GDP.

4.2.7 Farming experience of the respondents

The assumption is that the more years in farming, the more experienced farmers should become, while farming experience is key to farmers' decision-making on the farm. As indicated in Table 4.1, the farmers have a considerable farming experience, with the modal farming experience of respondents was between 11 – 15 years (39.6%), followed by the respondents who have farming experience >20 years (25.4%) and 18.8% had between 6 – 10 years' experience in farming. Also, 8.0% and 8.2% of the respondents had a farming experience of 2 – 5 years and 16 – 20 years, respectively. This indicates that most farmers in the study area have some expertise in crop cultivation. This is likely to influence their decision positively. This finding supports the claims of Aminu and Okeowo (2016) and Ibrahim *et al*. (2015) that agricultural experience improves production. Long years of farming experience, according to Korir, Lagat, Mutai, and Ali (2015), will improve farmers' efficiency and market connections and make it easier to obtain farm inputs such as credit varieties and general management approaches. Farmers in the research region are expected to be educated about farming activities and changes in climatic conditions.

In Ondo State, 51.0% of the respondents had farming experience between 11 – 15 years, followed by farmers with over 20 years of experience (19.1%). Farmers that had between 2 – 5 and 16 – 20 years of farming experience are 6.0% and 6.0%, respectively, while 17.9% of the total respondents accounted for farmers with 6 – 10 years of farming experience, as shown in Table 4.1. This conforms to Ayinde (2008) and Olubiyo (2010), who expressed that 50% of the sampled household heads have more than 19 years of farming experience in Nigeria.

In Oyo State, Table 4.1 also revealed 31.7% and 28.1% of respondents with over 20 years of farming experience and between 11 – 15 years of farming, respectively. Also, 19.7% of the respondents have 6 – 10 years of farming experience, while those farmers with 16 – 20 years' experience accounted for 10.4%, and the remaining 10.0% of Oyo State respondents have between 2 – 5 years of farming experience.

4.2.8 Major source of income of the respondents

From Table 4.1, it was indicated that about 70%, 75%, and 73% of the respondents derived their income and livelihood from agriculture in Oyo State, Ondo State, and the pooled data, respectively. In comparison, 36.1%, 25.1%, and 27.2% reported otherwise. Going by the findings, the consequence is that agriculture was the primary source of income in the research region, which is consistent with the findings of IFAD (2011), which found that around 80% of rural households in SSA engaged in farming and 20% derived their income from non-farm activities. The findings support those of Oduniyi (2018), Ajala (2017), and Machethe (2004), who found that farming is the largest contributor to household income and the primary source of income for "poor" rural households.

4.2.9 Purpose of maize cultivation

Most of the respondents (53.8%, 49.0%, and 51.4%), as shown in Table 4.1, sold surplus produce after family consumption in the study area, while 35.2%, 32.3%, and 38.2% of the farmers were producing commercially. However, farmers producing for personal consumption were 13.9% and 12.9% in Ondo and Oyo States, respectively, and 13.4% of the total respondents. This is consistent with Yaro's (2006) findings that smallholder farmers sell excess output to meet their financial needs.

4.2.10 Land tenure system

The rights and institutions governing land access and usage can be defined as a land tenure system (Eze *et al.,* 2011). According to Table 4.1, the majority of farmers (45%) farm on rented/leased property, 18.2% of respondents privately own their farmland, 24.2% of farmers cultivate on communal land, and 2.8% of respondents occupy their farmland with permission to occupy. Furthermore, 9.8% of farmers obtained their land through other means, such as inheritance or land redistribution. This suggested that rented/leased land might be subject to restrictions, which could limit farmers' productivity by preventing them from adopting innovative farming practices and technologies that could help mitigate climate change and boost production on rented land. The study backs up Koirala *et al.* (2014), who stated that farming on rented land could stifle investment in land improvement. The findings contradict those of Ajiboye (2021), Oparinde (2017), and

Oladeebo *et al.* (2015), who claimed that a more significant percentage of farmland in southwestern Nigeria was inherited. The explanation could be that inherited lands are leased out if the individual who inherits them is not involved in agriculture. Also, inherited lands could be sold as family size increases, while the buyer could lease it out for agricultural purposes.

4.2.11 Farm ownership

According to Table 4.1, most (58.8%) of the farms were individually owned, while 61.4% of respondents in Ondo state own their farm and 56.2% of respondents in Oyo state own their farm. In comparison, 28.8%, 25.1%, and 32.5% (pooled sample, Ondo State and Oyo State) were owned by family members, and farmers' groups owned 7.0% of the farmland in the study area. Furthermore, 4.8% of the cropland in the study area is owned by corporations. Corporate organizations control 5.2% and 4.4% of farmlands in Ondo and Oyo states, respectively, and 0.6% of overall farmland in the research region belongs to trust. In contrast, the trust owns 1.2% of farmland in Ondo State. This finding showed that individuals are the primary farm owners, implying that each farm owner will allocate the necessary resources for the farming season. In South Africa's Limpopo Province, individual farmers retain most of the agricultural ownership, according to Maponya (2012).

4.2.12 Farm operatorship

According to Table 4.1, most respondents (59.6%) manage their farms, while 26.2% manage farms maintained by family members. The overall number of farms managed by farmers' groups in the research area was 4.0%, corporate organizations controlled 7.4% of the farms, and the trust managed the remaining 2.8%. The results appear to be the same at the state level, with 66.5% and 52.6% of respondents managing their farms alone in Ondo and Oyo states, respectively. Family members handle 21.9% and 30.5% of the farms in Ondo and Oyo states, respectively. In addition, in Ondo and Oyo States, 4.8% and 3.2% of respondents said farmers' groups, respectively, manage their farms; corporate bodies managed 8.4% and 7.4% of farms in Ondo and the Oyo States, respectively; and the trust managed the remaining 5.6% of farms in Oyo State, according to the respondents. Farmers preferred to manage their farms themselves due to the study's findings, indicating that they want to keep an eye on agricultural productivity. It could also be due to a lack of motivation, resources, and trust. This supports Ajala's (2017) conclusions that lessor-operated farms are inefficient due to a lack of security and insufficient incentives and returns on investment.

4.2.13 Farm size

Table 4.1 shows the distribution of farm size according to the respondents. According to the findings, most respondents (72.8%) are planting on farms ranging in size from 1 to 5 hectares. Farmers with farms ranging from 1 to 5 hectares account for 75.3% and 70.3% of respondents in Ondo and Oyo States, respectively. Farmers who planted on a farm of less than 1 hectare accounted for 4.0%, 3.6%, and 4.4% of the respondents in the study area (pooled, Ondo and Oyo states); 16.8% of the respondents cultivated on farms of 6 to 10 hectares, while the remaining 6.4% cultivated on farmland of 11 to 15 hectares. In the states of Ondo and Oyo, 14.3% and 19.3% of the participants farmed on land ranging from 6 to 10 hectares, while 6.0% and 6.8% farmed on land from 11 to 15 hectares. The findings are explained by the fact that most rural farmers in Southwestern Nigeria are smallholder farmers, which is in line with Adejare and Arimi (2013). Farm size is crucial in determining farmer production since farmers with larger farms have more financial resources, are better innovators, and produce higher income than farmers with smaller farms. They also have a better chance of coping with climate change (Oluwasusi and Tijani, 2013). According to Hassan and Nhemachena (2008), farm sizes allow farmers to diversify their crops and livestock, which helps to distribute climate change-related risk.

4.2.14 Total factor productivity

According to Table 4.1, most farmers (98%) have seen a decrease in production because their TFP indices are less than 1, while the remaining 2% of respondents in the study area have remained productively static. The state results followed the same pattern as the pooled result. In Ondo state, 98% of maize farmers experienced a fall in productivity, while the remaining 2% were productively moribund. Similarly, according to the state's TFP indices, 98% of Oyo state maize farmers were lagging in terms of productivity, while the remaining 2% were stagnant.

4.3 Information about climate change in the study

4.3.1 Respondents' awareness of climate change

Farmers were asked if they were aware of the phenomenon known as climate change. The majority (94.2%) said they were aware of climate change, while 5.8% said they were not (Figure 4.1). Farmers in Ondo and Oyo States (92.4% and 96.8%, respectively) were aware of climate change, whereas 7.6% and 3.2% of the respondents were unaware of the phenomena. This was expected because farmers have become more conscious of climate change in recent years due to increased information and awareness. In an investigation carried out in the Sahel Savannah agro-ecological zone of Borno State, Nigeria, Idrisa *et al.* (2012) asserted that most farmers were aware of climate change and its implications. This is also in line with Otitoju (2014), who claims that farmers' perceptions of climate change improve their awareness of the phenomenon and ability to make adaptation decisions. Farmers' understanding of changes in climate factors is vital for adaptation decision-making, according to Maddison (2007). According to this study, farmers who are aware of climate change are more likely to employ adaptation strategies to mitigate losses or capitalize on possibilities associated with the changes.

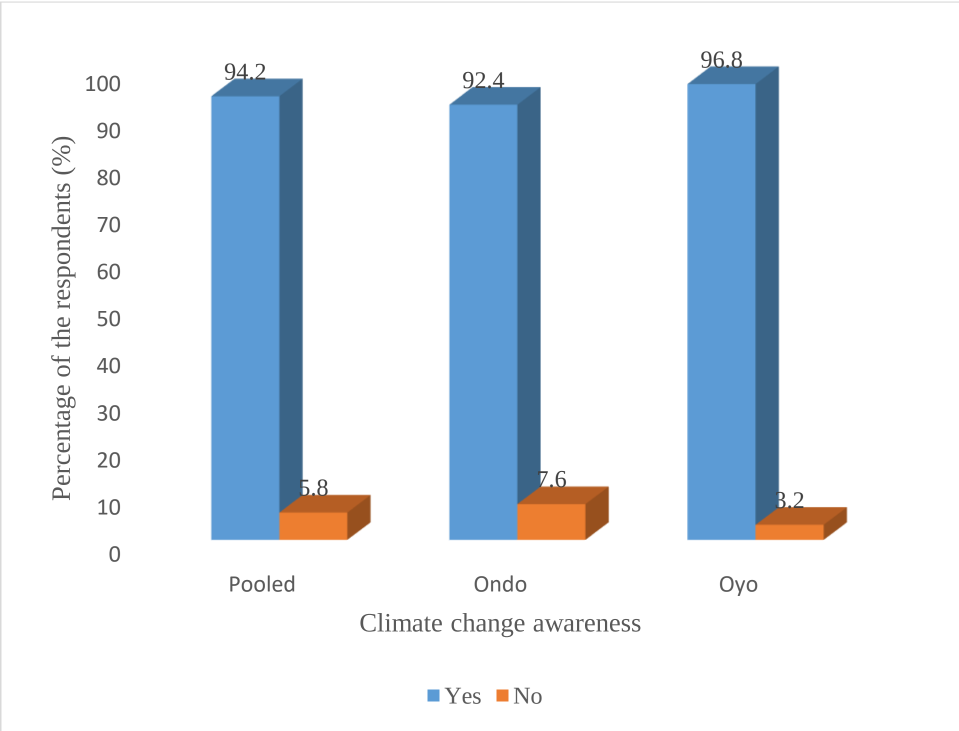

Figure 4.1: Climate change awareness

Source: Computed from Field data, 2021

4.3.2 Information received on climate change

The findings of the respondents' distribution based on the climate change information they received are depicted in Figure 4.2. According to the findings, 78.6% of respondents in the study region receive climate change information, with 72.1% and 86.7% of respondents in Ondo and Oyo States, respectively, having access to climate change information via various access methods. On the other hand, 21.4% of all respondents and 27.9% and 13.3% of respondents in Ondo and Oyo states said they receive no climate change information. This means that most farmers in the study area will be able to avoid the harmful effects of climate change due to the information they get on the subject. This is in line with the findings of Apata *et al.* (2009), Bryan *et al.* (2009), and Deressa *et al.* (2010), who found that having access to knowledge can help in climate change adaptation. Furthermore, according to Nhemachena (2007), farmers who receive information from extension officers are better able to react to climate changes.

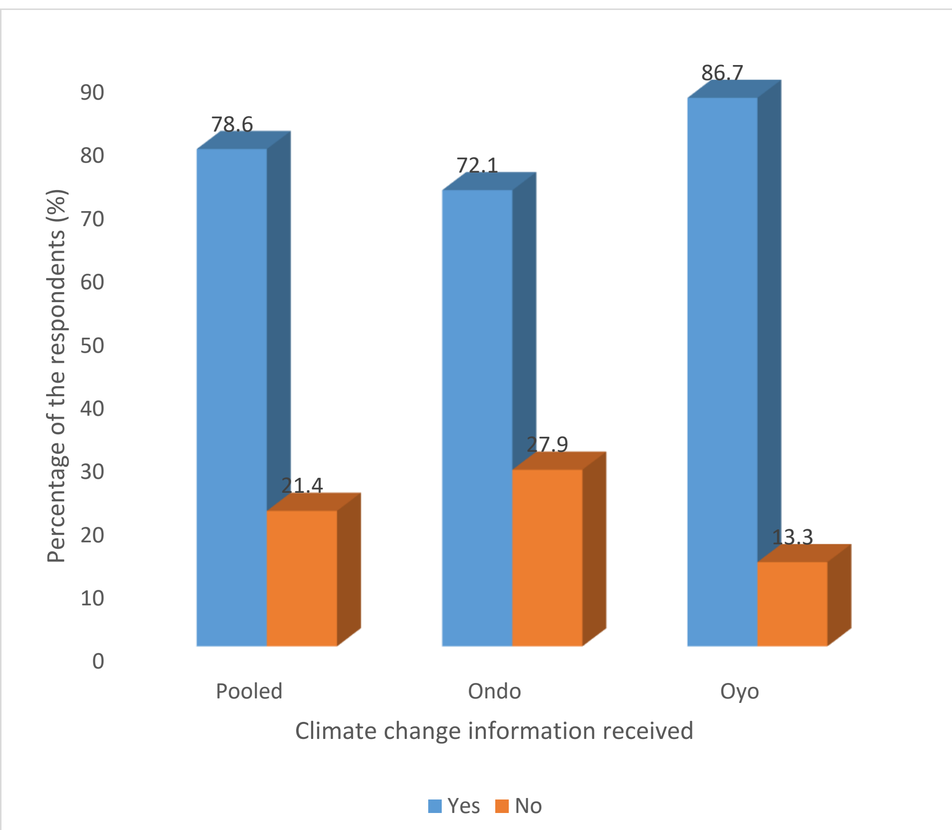

Figure 4.2: Climate change information received

Source: Computed from Field data, 2021

4.3.3 Source of information on climate change

The respondents who were aware of climate change gave various answers when asked how they learned about the phenomena. The outcome also revealed how important this information was to their understanding of climate change. Table 4.2 shows that most farmers (92.0%) learned about climate change through extension services, which was cited as a factor in their awareness of the issue. Furthermore, 85.2% cited the media as their primary source of information on climate change. According to the survey, 34.7% of farmers learned about climate change from formal schooling, and said it was crucial to their understanding of the phenomena. In comparison, only 42.5% said non-formal education was their source of climate change information. As shown in Table 4.2, 71.3% of farmers learned about climate change through other individuals such as friends, family, and fellow farmers.

In comparison, 65.8% relied on their observations of the weather system to improve their knowledge of climate change. This finding implies a practical extension system in the study area and efficient information dissemination using a top-down approach, which has contributed to their understanding of climate change and may help them adopt an adaptation strategy to mitigate the phenomenon's adverse effects. Access to extension services is also projected to improve farmer production in the research area. The findings support those of Apata *et al.* (2009), Bryan et al. (2009), and Deressa *et al.* (2010), who found that access to extension services influenced climate change adaptation significantly.

In the states of Ondo and Oyo, respectively, 37.5% and 32.0% of respondents had received formal education regarding climate change. In comparison, 39.7% and 45.2% had received non-formal education, such as adult schools and evening classes. The majority (94.6%) of farmers in Oyo State are aware of climate change as a result of their interactions with extension agents. In comparison, the majority (89.2%) of farmers in Ondo State are similarly aware. The effect of accessing climate change information through extension services aligns with Nhemachena (2007), who claims that farmer engagement with extension services promotes climate change knowledge and adaptation ability.

Furthermore, 83.2% and 87.1% of respondents in the states of Ondo and Oyo, respectively, had heard about climate change through the media (print and electronic). In Ondo State, 71.1% of respondents heard about climate change from other people, while 71.0% of respondents in Oyo State learned from friends and family. In Ondo and Oyo States, 72.0% and 59.8%, respectively, depended on their observations of the weather.

Table 4.2: Frequency distribution of respondents by their source of climate change information

	Pooled (N = 473)		Ondo (N = 232)		Oyo (N = 241)	
Source of Information	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Formal Schooling	164	34.7*	87	37.5*	77	32.0*
Non-Formal Schooling	200	42.5*	92	39.7*	109	45.2*
Media	403	85.2*	193	83.2*	210	87.1*
Extension Services	435	92.0*	207	89.2*	228	94.6*
Other People	340	71.3*	165	71.1*	171	71.0*
Own Observation	311	65.8*	167	72.0*	144	59.8*

* Multiple Responses

Source: Computed from Field data, 2021

4.4 Farmers' observation of climate change

4.4.1 Farmers' general observation of climate change

Farmers' general observations of climate change, as shown in Table 4.3, revealed that many respondents, 242, or 96.4% in Ondo State, observed changes in some of the climatic variables (rainfall, temperature, humidity, and wind), which has been affecting their productivity in various ways. In comparison, 3.6% of respondents, or nine farmers, did not observe changes in the climatic variable. Similarly, all participants in Oyo state had seen variations in several meteorological indicators (rainfall, temperature, humidity, and wind). In Table 4.3, it was also noted that 98.2% of the total respondents claimed to have observed climate changes due to the various climatic variables. In comparison, only 1.8% of those polled said they had not seen any changes in the weather. Temperature and rainfall have been the two significant climatic variables that have changed dramatically in recent years. This could be the outcome of Nigeria's recent unexpected meteorological conditions, such as delayed/erratic rainfall in the rainforest agro-ecological zone and rising temperatures in the Savannah. Farmers have seen various shifts in meteorological circumstances in the last two or three decades, according to Agbola and Ojeleye (2007). Gbode *et al.* (2019) reported strong warming trends in Nigeria's Coast, Savannah, and Sahel regions, as well as a rising tendency in annual averages of daily maximum and minimum temperatures in most sections of the country (Gbode *et al.*, 2019).

Table 4.3: Frequency distribution of respondents according to climate change observation

	Pooled Sample (N = 500)		**Ondo (N = 251)**		**Oyo (N = 249)**	
Climatic changes	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Yes	491	98.2	242	96.4	249	100.0
No	9	1.8	9	3.6	0	0
Total	**500**	**100.0**	**251**	**100.0**	**249**	**100.0**

Source: Computed from Field data, 2021

4.4.2 Specific changing climatic variables

Since most respondents claimed to have noticed changes in climatic variables, the respondents were asked which of the climatic variables was changing in the study area. The results showed that 339 respondents (67.8%) said the temperature in the study area was changing. In comparison, 146 respondents (29.2%) said they have been experiencing changes in rainfall (delayed/ erratic) in the study area, and a total of 15 respondents (3.0%) said they have been experiencing strong wind recently. This means that when temperatures rise, low-density rainfall falls, and high winds blow, the evaporation rate rises, resulting in drought. This is in line with the discovery that the annual averages of daily maximum and minimum temperatures are rising in most parts of Nigeria (Gbode *et al.*, 2019). Furthermore, the findings are consistent with Kassahun (2009), who found that the mean temperature had risen.

In Ondo State, slightly more than half of the respondents (52.6%) reported temperature variations, 44.2 percent said there were changes in precipitation (rainfall), and 3.2 percent said they were experiencing high wind. Most respondents from Oyo State (83.1%) claimed that temperature is changing dramatically, while 14.1 percent said rainfall had changed recently, and 2.8 percent said that strong wind had changed recently. The discrepancy in results could be attributed to their geographical location (rainforest and savannah agro-ecological zone). The findings support Gbode *et al.* (2019) and Kassahun (2009), who found that the annual mean temperature has risen.

Table 4.4: Frequency distribution of respondents according to changing climatic variables

	Pooled Sample (N = 500)		**Ondo Sample (N = 251)**		**Oyo Sample (N = 249)**	
Changing climatic variables	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Rainfall	146	29.2	111	44.2	35	14.1
Temperature	339	67.8	132	52.6	207	83.1
Wind	15	3.0	8	3.2	7	2.8
Total	**500**	**100**	**251**	**100**	**249**	**100**

Source: Computed from Field data, 2021

4.4.3 Perception of long-term rainfall

According to Table 4.5, 63.2% of farmers believe there will be inconsistent/delayed precipitation (rainfall) in the study area. In the long run, 36.2% believe there will be a decrease in precipitation (rainfall), and only 0.6% believe there will be an increase in rainfall in the study area in the long run. In Ondo State, the majority (78.5%) predicted that rainfall would be delayed or inconsistent in the long run, while 20.3% predicted that rainfall would drop and 1.2% predicted that rainfall would increase. In Oyo State, more than half of the respondents (52.2%) predicted a drop in precipitation in the long run, while 47.8% predicted either delayed or unpredictable rainfall. This suggests that in the long run, there will be changes in rainfall (particularly inconsistency and reduced amounts), which may impact agricultural productivity (Nhemachena *et al.*, 2014; Moyo *et al.*, 2012). According to Maddison (2007), farmers believe that temperatures will rise while rainfall will decrease. The findings were also compared to previous research conducted in Africa's semi-arid regions (Moyo *et al.*, 2012; Nyanga *et al.*, 2011; Rao *et al.*, 2011; Slegers 2008; Maddison 2007).

Table 4.5: Frequency distribution of respondents according to perceptions on long-term rainfall changes

Long term rainfall perception	**Pooled Sample (N = 500)**		**Ondo Sample (N = 251)**		**Oyo Sample (N = 249)**	
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Increased rainfall	3	0.6	3	1.2	-	-
Decreased rainfall	181	36.2	51	20.3	130	52.2
Other (delayed/erratic)	316	63.2	197	78.5	119	47.8
Total	**500**	**100.0**	**251**	**100.0**	**249**	**100.0**

Source: Computed from Field data, 2021

4.4.4 Perception on long-term temperature

From Table 4.6, the majority of the sampled maize farmers (94.6%), 94.4%, and 94.8% (pooled sample, Ondo, and Oyo states) thought the temperature was rising. In comparison, 2.8%, 5.6%, and 5.2% of respondents (Pooled sample, Ondo state, and Oyo state, respectively) predicted a temperature drop in the long term, while 2.6% of the pooled sample predicted no change. This supports Maddison's (2007) assertion that farmers in Africa reported an increase in temperature when rainfall decreases.

Table 4.6: Frequency distribution of respondents according to perceptions on long-term temperature changes

	Pooled Sample (N = 500)		Ondo State (N = 251)		Oyo State (N = 249)	
Long term temperature perception	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Increased Temperature	473	94.6	237	94.4	236	94.8
Decreased Temperature	14	2.8	14	5.6	13	5.2
No changes	13	2.6	-	-	-	-
Total	**500**	**100**	**251**	**100**	**249**	**100**

Source: Computed from Field data, 2021

4.4.5 Climate change impact on crop production

4.4.5 Climate change impact on crop production

The empirical result of how climate change has affected crop production in the study area is shown in Table 4.7. According to the findings, climate change has not improved crop production output in the studied area. According to the pooled sample results, 75.2% of respondents (the majority) reported that their production level has decreased, 13.2% reported no production due to climate change's impact on farming activities, and 11.6% reported no change in production in the study area.

At the state level, most farmers in Ondo and Oyo States (80.1% and 70.3%, respectively) stated that crop production is decreasing due to climate change. In comparison, 8.0% and 18.5% stated that they face the challenge of no production in Ondo and Oyo States, respectively. Farmers in Ondo and Oyo States expressed no change in production at 12.0% and 11.2%, respectively. The result shows there is variance in the effect of climate variables on maize productivity in the research area based on seasonal characteristics and crop length of days, which conforms to Eregha, Babatolu, and Akinnubi (2014). The findings are also in line with Agbola & Fayiga (2016) and USDA (2007), which stated that climate change has both positive and negative effects on agriculture and livelihood. Farmers become discouraged when agricultural production declines, which can lead to a change in livelihood (i.e., financial livelihood), especially in rural areas. Climate change could lead to rural-to-urban migration across the country. Food scarcity could become another unforeseen consequence of climate change's undesirable consequences if no prompt efforts are taken to address these challenges. Crop yields were also influenced by climate change-related elements such as rainfall, temperature, extreme weather events, CO2 levels in the atmosphere, and climate variability (Akinnagbe *et al.*, 2014).

Table 4.7: Frequency distribution of respondents according to how climate change is affecting crop production

	Full Sample (N = 500)		Ondo (N = 251)		Oyo (N = 249)	
How climate change affect crops	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
No change	58	11.6	30	12.0	28	11.2
Decreased Production	376	75.2	201	80.1	175	70.3
No Production	66	13.2	20	8.0	46	18.5
Total	**500**	**100.0**	**251**	**100.0**	**249**	**100.0**

Source: Computed from Field data, 2021

4.4.6 Climate change impact on the livelihood

As seen in Table 4.8, there were various responses to how climate change had impacted farmers' livelihoods. Climate change has exacerbated socio-economic problems in the study area, according to many respondents (92.4%). Changes in climatic variables increased unemployment in the study area by damaging farmlands, according to 94.0% of respondents. Contrastingly, climate change increased their cultivated practices and reduced their cultivated land, according to 69.6% and 52.2% of respondents, respectively.

The results for states follow the same pattern as those for the pooled sample. Changes in climatic variables exacerbate their socio-economic problems, according to 90.0% and 81.5% of respondents in Ondo and Oyo States, respectively. In addition, 90.8 % and 97.2% of respondents in the Ondo and Oyo states believe climate change is increasing unemployment. According to 90.8% and 97.2% of farmers in both states, income loss is another critical concern posed by climate change to livelihood. Furthermore, 69.7% of respondents in Ondo State and 69.5% of their counterparts in Oyo State said climate change is increasing cultivated practices in their area. In contrast, 54.2% and 50.2% said climate change affects farmers' livelihood by reducing cultivated farmlands. According to the report, climate change poses a threat to the livelihood of farmers in the study area. The findings supported Nhemachena *et al.* (2014) findings that climate change has harmed agricultural-based livelihoods in Southern African nations such as South Africa, Zambia, and Zimbabwe. Dinar *et al.* (2008) reported that climate change has resulted in severe livelihood losses in Africa.

Table 4.8: Frequency distribution according to climate change impacts on livelihood

	Pooled Sample (N = 500)		**Ondo (N = 251)**		**Oyo (N = 249)**	
Climate change impact on livelihood	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Increased socio-economic problems	462	92.4*	246	98.0*	216	86.7*
Reduced income	470	94.0*	228	90.8*	242	97.2*
Increased unemployment	429	85.8*	226	90.0*	203	81.5*
Reduced cultivated lands	261	52.2*	136	54.2*	125	50.2*
Increased cultivated practices	348	69.6*	175	69.7*	173	69.5*

* Multiple Responses

Source: Computed from Field data, 2021

4.4.7 Climate change impact on agricultural production

The influence of climate change on agricultural production is seen in Table 9. Climate change affects crop yield in Ondo and Oyo States, according to most farmers (96.0% and 94.4%, respectively). A loss in land fertility is another impact of climate change on agricultural production in the research area, according to 91.2% and 74.1% of respondents from Oyo and Ondo states, respectively. Furthermore, crop illnesses have been growing because of climate change, according to 64.9% of maize farmers in Ondo State and 56.6% of maize farmers in Oyo State.

Climate change reduced agricultural yields in 95.2% of the pooled sample. In comparison, 82.6% said changes in climatic factors led to a drop in land fertility in the study area, and 60.8% said climate change increased illnesses affecting crop productivity in the area. The findings support Benhin's (2006) hypothesis that the effects of climate change on agricultural production vary depending on the farming method. Smallholder crop producers would be particularly hard hit, with net revenues estimated to plummet by 90% by 2100. As a result, increased climate change in the research area could harm agricultural production.

Table 4.9: Frequency distribution according to climate change impacts on agricultural production

	Pooled Sample (N = 500)		Ondo (N = 251)		Oyo (N = 249)	
Climate change impact on agricultural production	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Reduced land fertility	413	82.6*	186	74.1*	227	91.2*
Reduced crop yield	476	95.2*	241	96.0*	235	94.4*
Increased crop disease	304	60.8*	163	64.9*	141	56.6*

* Multiple Responses

Source: Computed from Field data, 2021

4.4.8 Impact of climate change on food security

Table 10 shows that the effect of climate change on food security elicited diverse answers from the participants. Most farmers in Ondo, Oyo, and the pooled sample (94%, 96.4%, and 91.6%) claimed that climate change affects food scarcity. About 85.0% said food prices in the study area are rising, with the same trend seen in Ondo and Oyo States (84.1% and 85.9%, respectively), while maize farmers in Ondo, Oyo, and the pooled sample (21.1%, 11.2%, and 16.2%) said climate change has resulted in a lack of local markets. The result implies that climate change stressors could result in seasonal crop failure and long-term production challenges, leading to food insecurity owing to a drop in food availability. According to Codjoe and Owusu (2011) and Yaro (2006), low crop yields restrict people's access to food because households usually sell surplus at the market as a source of income.

Table 4.10: Frequency distribution according to the effect of climate change on food security

Climate change impact on food security	Pooled Sample (N = 500)		Ondo (N = 251)		Oyo (N = 249)	
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Scarcity of food	470	94.0*	242	96.4*	228	91.6*
Increased food prices	425	85.0*	211	84.1*	214	85.9*
Lack of local market	81	16.2*	53	21.1*	28	11.2*

* Multiple Responses

Source: Computed from Field data, 2021

4.5 Summary

This chapter discusses the results of the descriptive and socioeconomic characteristics of the respondents. Climate change and its impact on agricultural production and livelihood were explored.

CHAPTER FIVE

TREND AND GROWTH RATE OF MAIZE YIELD AND CLIMATIC VARIABLES (1979 – 2020)

5.1 Introduction

Between 1979 and 2020, this chapter examined the trend and growth rate of maize yield as well as climate variables in Southwestern Nigeria. This chapter discusses the descriptive statistics of the time series variable used in the analysis, as well as the growth rate and its movement. The findings were mostly presented in tabular format, with literature comparisons and references.

5.2 Trend of maize yield and climatic variables in Southwestern Nigeria (1979 – 2020)

Tables 5.1 and 5.2 summarize the statistical characteristics of the variables used in this research. From 1979 to 2020, the variables include maize yield (mt/ha), rainfall (mm), relative humidity (percent), and temperature (^{o}c), totaling 42 years of observation. Table 5.1 shows that the lowest and highest maize yields in Ondo State were 0.160000 (mt/ha) and 5.853000 (mt/ha), respectively. 1.817484 (mt/ha) is the average maize yield. The standard deviation and Jarque-Bera value for maize yield were 1.046576 (mt/ha) and 28.92266, respectively, indicating that the observations were clustered around the mean value. The series of maize yields were normally distributed across the study period since the Jarque-Bera value for maize yield is more than 5% significant value. The state's average rainfall is 142.0295 mm, with a standard deviation of 20.48807. The Jarque-Bera value of 0.532825 indicates that the variates were not far from the central point in Ondo State, where the minimum rainfall value is 105.2791 mm, and the maximum value is 190.8792 mm. This period received a total of 5965.240 mm of rainfall. The minimum and highest relative humidity values were also discovered to be 53.69000 and 76.08566 percent, respectively. The variates were normally distributed given the values of Jarque-Bera and standard deviation of 51.88999 and 4.086760, respectively. Furthermore, the mean temperature is 27.73545 ^{o}c, and the minimum and maximum temperature is 26.36875 ^{o}c and 39.25000 ^{o}c. The temperature's Jarque-Bera value is 288.1257, and the standard deviation is 2.523572. This indicated that the variables were normally distributed for the study.

Table 5.1: Summary statistics of Time Series Regression Variables from 1979 – 2020 for Ondo State

Statistics	Y	X_1	X_2	X_3
Mean	1.817484	142.0295	70.08915	27.73545
Median	1.959959	143.7889	70.88418	26.91458
Maximum	5.853000	190.8792	76.08566	39.25000
Minimum	0.160000	105.2791	53.69000	26.36875
Std. Dev.	1.046576	20.48807	4.086760	2.523572
Skewness	0.815847	0.112900	-1.567790	3.332233
Kurtosis	6.723548	2.496526	7.451917	13.96486
Jarque-Bera	28.92266	0.532825	51.88999	288.1257
Probability	0.000001	0.766123	0.000000	0.000000
Sum	76.33433	5965.240	2943.744	1164.889
Sum Sq. Dev.	44.90818	17210.21	684.7661	261.1049
Observations	42	42	42	42

Note: Y, X_1, X_2 and X_3 signifies Maize Yield (mt/ha), Rainfall (mm), Relative Humidity (%) and Temperature (^{o}c)

Source: Computed from NIMET and ADP Data, 2021

The statistical summary of Oyo State variables is shown in Table 5.2. The average maize yield is 1.551895 (mt/ha), with the minimum and maximum values being 0.160000 (mt/ha) and 3.317000 (mt/ha), respectively. The residual (Jarque-Bera) and standard deviation values of maize yield were 0.942221(mt/ha) and 0.896669 (mt/ha). This indicates that the variables have a normal distribution. The average rainfall in Oyo State was 110.4850 mm, with residual and standard deviation values of 0.667485 and 21.46440, respectively. The observations were closed to the mean value and had a normal distribution. In addition, the minimum and maximum rainfall are 70.60410 mm and 155.7830 mm. Relative humidity maximum and minimum values in Oyo State were 82.73000% and 25.80000%, while its residual and standard deviation values were revealed to be 108.8226 and 10.73496. The average temperature in Oyo State for the study was 29.62460 ^{o}c as the minimum, and maximum values range from 26.20000 ^{o}c to 32.80830 oc. The residual value was 5.229855 ^{o}c which established the normality of the variable distribution.

Table 5.2: Summary statistics of Time Series Regression Variables from 1979 – 2020 for Oyo State

Statistics	Y	X1	X2	X3
Mean	1.551895	110.4850	71.10338	29.62460
Median	1.510108	109.5722	72.70000	30.58000
Maximum	3.317000	155.7830	82.73000	32.80830
Minimum	0.160000	70.60410	25.80000	26.20000
Std. Dev.	0.896669	21.46440	10.73496	2.255563
Skewness	0.216974	0.189647	-2.194697	-0.229424
Kurtosis	2.408307	2.512602	9.551151	1.333282
Jarque-Bera	0.942221	0.667485	108.8226	5.229855
Probability	0.624309	0.716238	0.000000	0.073173
Sum	65.17960	4640.369	2986.342	1244.233
Sum Sq. Dev.	32.96463	18889.55	4724.815	208.5901
Observations	42	42	42	42

Note: Y, X_1, X_2 and X_3 signifies Maize Yield (mt/ha), Rainfall (mm), Relative Humidity (%) and Temperature (^{o}c)

Source: Computed from NIMET and ADP Data, 2021

5.3 Trend analysis and growth rate of maize yield and climatic variables (1979 – 2020)

Table 5.3 shows the trend analysis and growth rate of maize yield and climatic variables. The outcome demonstrated positive and negative trends in the variable across the studied period. Except for Ondo and Oyo States, where relative humidity and rainfall were negatively insignificant, the variables showed favorably statistically significant coefficients at the 1% significance level. This means that time is a determinant of climate variables and maize yield in the research location. The rationale for the result in Ondo State is that a unit increase in time increases maize yield and temperature by 0.06 mt/ha and 0.004 ^{o}c, respectively. At the same time, rainfall remains stable and relative humidity drops by 0.001%. Comparably, Oyo State's result is like Ondo State's. In the study area, a unit increase in time causes a 0.059 unit increase in maize yield and a 0.004 ^{o}c increase in temperature. At the same time, relative humidity remains consistent, and rainfall decreases by 0.001 mm.

It was further indicated in Table 5.3 that maize yield (66.655; P < 0.001) and temperature (20.578; P < 0.001) for Ondo State were statistically significant at the 1% level during the study period.

This signifies that the explanatory variables influenced both the model's maize yield and the temperature variables. At the 5% level, rainfall (0.016; $P > 0.05$) and relative humidity (1.491; $P > 0.05$) were not significant during the time. Explanatory variables' influence on rainfall and relative humidity in the model was minimal, according to the theory. Table 5.3 also revealed that the independent variables in maize yield, rainfall, relative humidity, and temperature explain the inequalities in the dependent variable with R^2 values of 62.5%, 0%, 3.6%, and 34.0%, respectively. In contrast, in Oyo State, the R^2 values revealed that the independent variables explained the variation in the dependent variable in maize yield, rainfall, relative humidity, and temperature variables with R^2 values of 69.9%, 0.7%, 0.1%, and 38.3%. According to the findings, time substantially impacted climate factors and maize yield in the research area. According to the findings, the time substantially impacted climate factors and maize yield in the research area.

The growth rate for the variables under investigation is also shown in Table 5.3. A positive growth rate was recorded for maize in both states (6.18% and 6.08%). The findings could result from many agricultural programs implemented by different governments during the maize revolution (e.g., operation feed the nation, green revolution program, national accelerated food production program, and fadama program). This, however, confirms a study by Ajetomobi *et al.* (2010) showing that various agricultural policies of different governments have favorably benefited maize productivity in the study area. Correspondingly, in both Ondo and Oyo States, there was a positive growth rate evidence for temperature (0.40%). This result signifies that the temperature in the research area is rising. The growth rate result for rainfall in Ondo State is 0%, showing that rainfall is stable in the state. The growth rate result for relative humidity in Oyo State is 0%, suggesting that relative humidity is stable. Relative humidity grew at a negative rate in Ondo State, whereas rainfall grew at a negative rate in Oyo State. The implication is that there is an increasing trend in the growth rate of maize yield and temperature in both states while a decreasing nominal growth rate for relative humidity and rainfall in Ondo and Oyo State, respectively. Also, the growth rate for rainfall and relative humidity were insignificantly constant.

Table 5.3: Estimated Growth Rate for the Variables (1979 – 2020)

Dependent Variable	b_0	b_1	R^2	F-value	Growth Rate (%)
Ondo Maize yield	-119.133 (0.000)	0.06 (0.000)	0.625	66.655***	6.18365
Ondo Rainfall	5.425 (0.157)	0.000 (0.899)	0.0000	0.016	0.000
Ondo Relative Humidity	6.152 (0.000)	-0.001 (0.229)	0.036	1.491	-0.09995
Ondo Temperature	-4.294 (0.140)	0.004 (0.000)	0.340	20.578***	0.400801
Oyo Maize yield	-117.79 (0.000)	0.059 (0.000)	0.699	92.715***	6.07752
Oyo Rainfall	7.447 (0.151)	-0.001 (0.590)	0.007	0.295	-0.09995
Oyo Relative Humidity	3.389 (0.514)	0.000 (0.868)	0.001	0.028	0.000
Oyo Temperature	-4382 (0.008)	0.004 (0.000)	0.383	24.835***	0.400801

Note: Figures in parentheses are the P-values

*** represent significance at 1%

Source: Computed from NIMET and ADP Data, 2021

5.4 Movement of growth rates of maize yield and climatic variables

The quadratic equations in time variables were estimated to see if there was any movement (acceleration, deceleration, or stagnation) in maize yield growth rates and climate factors. Table 5.4 demonstrates that the coefficients of maize yield and temperature are positive but significant at 1%, indicating an acceleration in maize yield and temperature growth over the period studied; contrastingly, Ondo State rainfall and relative humidity were negatively insignificant during the same time. In Oyo State, maize yield and temperature were positively significant at 1%, showing the acceleration of maize yield and temperature growth. Still, rainfall was negatively insignificant, and relative humidity was positive, however insignificant, according to Table 5.4. The implication drawn from this finding is that maize yield and temperature in the study area have steadily increased over time. According to Harrison *et al.* (2011), the upward movement of these variables in the research area could be due to the influence of increasing temperature on the phenological development of maize plants. Furthermore, the research area's increasing maize yield growth rate could be due to the stability and proper implementation of government agriculture and food security programs such as National, Special Program on food security (NSPFS), Agricultural Transformation Agenda (ATA), Root and Tuber Expansion Program (RTEP) and National Economic Empowerment and Development Strategy (NEEDS).

Table 5.4: Quadratic Equations in Time Variables for the variables (1979 – 2020)

Dependent Variable	**b_0**	**b_1**	**b_2**	**R^2**	**F-value**
Ondo Maize yield	-59.309	184.264 (0.000)	1.491 (0.000)	0.623	66.052***
Ondo Rainfall	5.186	8.596 (0.009)	-6.017 (0.899)	0.000	0.016
Ondo Relative Humidity	5.204	103.350 (0.000)	-2.391 (0.227)	0.36	1.503
Ondo Temperature	-0.496	-173.136 (0.558)	9.542 (0.000)	0.341	20.714***
Oyo Maize yield	-58.747	121.562 (0.000)	1.474 (0.000)	0.697	92.064***
Oyo Rainfall	6.064	-26.250 (0.022)	-3.445 (0.591)	0.007	0.294
Oyo Relative Humidity	3.822	32.076 (0.146)	1.066 (0.869)	0.001	0.027
Oyo Temperature	-0.494	105.950 (0.531)	9.703 (0.000)	0.382	24.734***

Note: Figures in parentheses are the P-values

*** represent significance at 1%

Source: Computed from NIMET and ADP Data, 2021

5.5 Summary

This chapter explains the trend and growth rate analysis results of maize yield and climatic variables in the research area from 1979 to 2020. The Jarque-Bera results show that the variable distribution is normal. The outcome demonstrated both positive and negative trends in the variables across the period in question. In both states, maize yield and temperature grew upbeat, while rainfall and relative humidity remained stable. In contrast, relative humidity and rainfall grew negatively in Ondo and Oyo State, respectively. The quadratic equations in time variables were also estimated to see if any movement (acceleration, deceleration, or stagnation) in maize yield growth rates and climate factors in the study area.

CHAPTER SIX

RELATIONSHIP BETWEEN MAIZE PRODUCTION AND CLIMATIC VARIABLES FOR THE PERIOD 1979 TO 2020

6.1 Introduction

This chapter presented the statistical findings and discussed the association between climatic variables and maize production in the research area from 1979 to 2020. The data is primarily presented in the form of tables. The findings were discussed, and they were compared and connected to literature where feasible.

6.2 Unit Root Test Analysis

In regression analysis, it is required that series must be stationary prior to the estimation of the relationship between the series (variables) to avoid having a spurious regression. Although, the ARDL model used in this study does not require to test for the unit roots of the variables; nonetheless, it is imperatively essential to carry out the unit root test analysis because of the existence of a second order integration *I(2)* of any series used in the estimation will invalidate the use of ARDL. This agree with Quattara (2004) who stated that the computed F-statistics provided by Pesaran *et al.* (2001) is quashed in the presence of *I(2)* variables because bounds test are basically based on the assumptions that the variables are *I(0)* or *I(1)* or mutually co-integrated.

The unit root analysis result validates the usage of ARDL model as the most suitable technique for co-integration in this study. This study used the standard Augmented Dickey-Fuller (ADF) unit root test to verify the order of integration of the variables included in the analysis. The results of the unit root tests were conveyed in table 6.1. It was shown that in Ondo State, rainfall and relative humidity were stationary at level, *I(0)* while maize yield and temperature were stationary at first difference *I(1)*. Also, in Oyo state there was a similar result where rainfall and relative humidity were stationary at level, *I(0)* while maize yield and temperature were stationary at first difference *I(1)*. Having ascertained that the series are a combination of *I(0)* and *I(1)* which can be used under ARDL unlike the Johansen co-integration approach; this provided the rationale for choosing ARDL model which was proposed by Pesaran *et al.* (2001) for the study.

Table 6.1: Results of the Unit Root (ADF) Test

Variables	Level [I(0)]		First Differences [I(1)]	
	Constant	Prob.	Constant	Prob.
Ondo				
Y	-2.253846 (0)	0.1914	-7.966092 (0) ***	0.0000
X_1	-4.708956 (0) ***	0.0004	-6.162144 (2) ***	0.0000
X_2	-4.886217 (0) ***	0.0003	-7.043375 (1) ***	0.0000
X_3	-1.944895 (0)	0.3092	-7.496978 (1) ***	0.0000
Oyo				
Y	-1.847991 (0)	0.3528	-6.874795 (0) ***	0.0000
X_1	-4.140782 (0) ***	0.0023	-9.480481 (0) ***	0.0000
X_2	-4.927672 (0) ***	0.0002	-6.319356 (3) ***	0.0000
X_3	-2.916451 (0)	0.0521	-6.719925 (0) ***	0.0000

Notes:

1. Y, X_1, X_2 and X_3 connote Maize Yield (mt/ha), Rainfall (mm), Relative Humidity (%) and Temperature (°c)
2. ***, **, * indicate the significant level at 1%,5% and 10% respectively
3. The figures in parentheses for the Augmented Dickey-Fuller (ADF) statistics represents the lag length of the dependent variable used to obtain the white noise residuals
4. The null hypothesis is that the series is non-stationary, or contains a unit root, this was rejected based on MacKinnon (1996) critical values. The lag length was selected based on SIC criteria ranged from lag zero to lag 9

Source: Computed from NIMET and ADP Data, 2021

6.3 Lag Order Selection Criteria Analysis

To determine the optimal number of lags for the model, Unrestricted Vector Autoregression (VAR) by lag selection criteria was modelled to the time series data. The VAR lag order selection criteria result followed the rule-of-thumb, where the model that gives the lowest value of estimated standard errors of the criteria was chosen for the study to make the model better i.e the lower the value, the better the model. The lowest value for each estimator fell under lags one for both Ondo and Oyo States. The results in table 6.2 and 6.3 explained the optimal lag length of the model across the states. The indication was that the optimal lag was one (1) based on the estimation of all criteria i.e Likelihood ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion

(AIC), Schwarz's Bayesian Information Criterion (SBIC) and Hannan-Quinn Information Criterion (HQIC) for both Ondo and Oyo States. Based on this results, Schwarz's Bayesian Information Criterion (SBIC) was chosen for the determination of the optimum lag length of ARDL model. ARDL (1,0,0,0) model was selected as a common consequence of the SBIC criterion.

Table 6.2: VAR Lag Order Selection Criteria in Ondo State

Lag	LogL	LR	FPE	AIC	SC	HQ
0	86.90351	NA	1.67e-07	-4.251462	-4.080840	-4.190245
1	150.2804	110.5033	1.48e-08	-6.681045	-5.827937*	-6.374957*
2	162.3285	18.53558	1.87e-08	-6.478385	-4.942790	-5.927427
3	186.7991	32.62746*	1.30e-08*	-6.912774*	-4.694692	-6.116946

Source: Computed from NIMET and ADP Data, 2021

Table 6.3: VAR Lag Order Selection Criteria in Oyo State

Lag	LogL	LR	FPE	AIC	SC	HQ
0	32.20559	NA	2.77e-06	-1.446441	-1.275819	-1.385223
1	91.45637	103.3091*	3.03e-07*	-3.664429*	-2.811321*	-3.358341*
2	103.2235	18.10331	3.87e-07	-3.447360	-1.911765	-2.896402
3	122.0416	25.09077	3.60e-07	-3.591877	-1.373795	-2.796048

Notes:

*indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Source: Computed from NIMET and ADP Data, 2021

6.4 Co-integration Test Based on ARDL Bounds Testing Approach

As posited in the methodology, a co-integration analysis based on ARDL bounds test approach was examined using a general-to-specific modelling approach guided by the short data span and SBIC respectively to select a maximum lag order of 1 for the conditional ARDL-VECM. There was an estimation of OLS regression and then tested for the joint significance of the parameters of the lagged level variables when added to the regression analysis. However, the OLS regression results obtained from the model are of “no direct interest” to the bounds testing approach to co-integration test. The F-statistic test the null hypothesis of no long-run relationship exists between the variables (i.e. the coefficients of the lagged level are zero). The F-statistics were estimated using the Wald Test of coefficients in the ARDL-OLS regressions.

In Ondo State, Table 6.4 revealed the value of calculated F-statistic value for $F_{lnY}|(lnY|lnX_1|\ lnX_2|\ lnX_3)$ to be 3.86, this was higher than the upper bound critical value of 3.67 at 5% level of significance. Therefore, the null hypothesis of no levels relationship was rejected; this implies that there is a long-run relationship among the variables when maize yield was regressed against explanatory variables of rainfall, relative humidity and temperature.

Table 6.5 shows the result of the regression analysis of Oyo State. Maize yield as the dependent variable been regressed against explanatory variables of rainfall, relative humidity and temperature. The F-statistic value of the analysis is 3.62, this result was higher than the level bound (2.79) but lower than the upper bound level (3.67) which made it inconclusive because the F-statistic value comes between *I(0)* and *I(1)* bound but at the 10% level of significance the F-value was higher than the upper bound critical value of 3.2. Hence, the null hypothesis of no co-integration was rejected at 10% significant level; this indicated that there is a long-run relationship among the variables when the dependent variable is regressed against the explanatory variables.

These results are similar with the findings of some studies that used ARDL to study the relationship between climatic variables and crop production in Southwest Nigeria (Ekundayo (2019); Oparinde (2017). Furthermore, there is a conformity between the result of this study and the findings of Ayinde *et al.* (2011) who stated that there is a long run relationship between climatic variables (rainfall and temperature) and crop productivity in Nigeria using Johansen co-integration test.

Table 6.4: Results of Co-integration Test Based on ARDL Bounds Test Approach (Ondo State)

F-Bounds Test			**Null Hypothesis: No levels relationship**	
Test Statistic	**Value**	**Signif.**	**I(0)**	**I(1)**
F-statistic	3.863021	10%	2.37	3.2
K	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66

Computed F-Statistic: $F_{lnY}|(lnY|lnX_1|\ lnX_2|\ lnX_3) = 3.86$

Where lnY = lnMAIZEYIELD, lnX_1 = lnRAINFALL, lnX_2 = lnRELATIVEHUMIDITY, lnX_3 = lnTEMPERATURE

Note: Critical Values are cited from Pesaran *et al.* (2001)

Source: Computed from NIMET and ADP Data, 2021

Table 6.5: Results of Co-integration Test Based on ARDL Bounds Test Approach (Oyo State)

F-Bounds Test			**Null Hypothesis: No levels relationship**	
Test Statistic	**Value**	**Signif.**	**I(0)**	**I(1)**
F-statistic	3.621671	10%	2.37	3.2
K	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66

Computed F-Statistic: $F_{lnY}|(lnY|lnX_1|\ lnX_2|\ lnX_3) = 3.62$

Where lnY = lnMAIZEYIELD, lnX_1 = lnRAINFALL, lnX_2 = lnRELATIVEHUMIDITY, lnX_3 = lnTEMPERATURE

Note: Critical Values are cited from Pesaran *et al.* (2001)

Source: Computed from NIMET and ADP Data, 2021

The rejection of the null hypotheses of no levels relationship in the two states implies the existence of co-integration, that is, the series exhibit a long run relationship when maize yield was regressed against explanatory variables of rainfall, relative humidity and temperature. This also means that variables are connected and can be combined in linear function. Thus, both the long and short run model must be estimated.

6.5 Long Run Estimate Analysis

The long-run estimate analysis results were presented in Tables 6.6 and 6.7. The long run coefficients of ARDL (2,0,1,0) for Ondo State was communicated in Table 6.6. The probability value of the F-statistics is 0.0000 which validates the overall model to be statistically significant at 1% while the R-squared and adjusted R-squared are 90% and 88% respectively which indicate the model is best fit. The result revealed rainfall to positively impacted maize yield in the long run ($P<0.01$) while temperature had a negative significant influence on maize yield in the long run ($P<0.05$). The result implies that a unit increase in rainfall would bring about 2.75% increase in maize productivity while there will be 3.9% decrease in the productivity of maize with a unit increase in temperature in the study area. The positive relationship between rainfall and maize yield justifies the importance of rainfall in the growth and development of maize since there has been report of increased temperature, climate variability and climate change in the study area recently. Equally, increased rainfall could become harmful to the plant at the long run which could cause erosion, flooding and leaching. Furthermore, the inverse relationship between temperature and maize can be attributed to excessive solar radiation on the earth that brings about extreme weather, increasing temperature and seasonal variability which leads to reduction of maize yield as a result of loss of water, increased evapo-transpiration, increased evaporation and loss of nutrients in the soil for the plant. This result corresponds with the findings of Ekundayo (2020), Oparinde (2017), Kumar and Gautam (2014) and Ayinde *et al.* (2010) that expressed that increase or decrease in the rainfall patterns affects the output that leads to a rise or fall in output.

In Oyo State, the long run coefficient of ARDL (1,0,0,0) were reported in Table 6.7. There was justification of the overall model to be significant at 1% ($P<0.01$) at 0.0000, the R-squared and adjusted R-squared are 91.9% and 91.0% respectively which suggest the model is best fit. However, there was no significant relationship between maize yield and climatic variables at long run estimate. This could be as a result that climate data failed to show the evidence of climate change perceived by farmers over a long-term period; still this is in tandem with Ajala (2017), who stated that farmers can accurately perceive change and climate variability and impacts on agriculture and livelihoods for short-term period when comparing farmers' perceptions and empirical climate change evidence in Ehlanzeni district of Mpumalanga province of South Africa.

Table 6.6: Result of the ARDL Long-run Relationship for Ondo State

Levels Equation

Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
X1	2.745201***	1.088478	2.522054	0.0026
X2	-10.66472	11.20992	-0.951365	0.3483
X3	-3.912452**	1.755675	-2.228460	0.0324
C	45.77278	62.22896	0.735554	0.4672

EC = Y - (2.7452*X1 -10.6647*X2 -3.9125*X3 + 45.7728)

Note:

1. Y, X_1, X_2 and X_3 signifies Maize Yield (mt/ha), Rainfall (mm), Relative Humidity (%) and Temperature (^{o}c)
2. ***,**,* implies the level of significance 0.01, 0.05, 0.10 respectively
3. ARDL (2,0,1,0) selected based on Schwarz information criterion

Source: Computed from NIMET and ADP Data, 2021

Table 6.7: Result of the ARDL Long-run Relationship for Oyo State

Levels Equation

Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
X1	-0.410584	2.543911	-0.161399	0.8727
X2	-5.522838	4.720621	-1.169939	0.2497
X3	3.391794	7.933871	0.427508	0.6716
C	14.87420	36.58788	0.406533	0.6868

EC = Y - (-0.4106*X1 -5.5228*X2 + 3.3918*X3 + 14.8742)

Note:

1. Y, X_1, X_2 and X_3 signifies Maize Yield (mt/ha), Rainfall (mm), Relative Humidity (%) and Temperature (^{o}c)
2. ***, **, * implies the level of significance 0.01, 0.05, 0.10 respectively
3. ARDL (1,0,0,0) selected based on Schwarz information criterion

Source: Computed from NIMET and ADP Data, 2021

6.6 Short Run Estimate Analysis-Vector Error Correction Model (VECM)

This study achieved the short run dynamic coefficients connected with the long-run co-integration relationships by analysing the Error Correction Model (ECM) based on ARDL bounds test approach. The obtained results for the short run coefficients of ARDL (2,0,1,0) and (1,0,0,0) model for Ondo and Oyo States were distinctly conveyed in Table 6.8 and 6.9.

Table 6.8 communicated the findings of the short run coefficients of ARDL (2,0,1,0) model for Ondo State and there was a confirmation of a short run relationship among the variables by the empirical result. The study revealed rainfall to be positively and statistically significant with maize yield at 1% over the period while temperature had a negative significant association with maize yield at 5% in the short run. Also, the result showed that relative humidity is negatively insignificant to maize yield in the study area.

The long run relationship among the variables was validated by the statistically significant negative coefficient of ECM (Cointeq (-1)*) which also correspond with Yilmaz (2014) who stated that ECM measures the response of the endogenous variable to changes in the independent variables before the endogenous variable converges to the equilibrium level. Oparinde and Okogbue (2018) stated that negatively low ECM in absolute value indicate a slow adjustment. Therefore, ECM value for Ondo State model was statistically significant at 0.01 significant level and had a value of -0.133 which means there is low speed of adjustment from short run to the long run if there is any disequilibrium in the system. Furthermore, a unit increase in D(rainfall) caused 0.57 increase in maize yield, this corresponds with Ayinde *et al.* (2011) that reported changes in rainfall will positively affects agricultural production in Nigeria while a unit increase in temperature caused 0.29 decrease in maize yield. This could be ascribed to the harmful effect of extreme heat on maize plant. This agrees with Idowu *et al.* (2011) who stated that high temperatures smoother crops.

Furthermore, Table 6.9 indicated that there exists a short run relationship among the variables in the Oyo State model of ARDL (1,0,0,0). The result revealed temperature had a positive coefficient and significant relationship with maize productivity in the short run while relative humidity is negatively statistically significant to maize yield in the short run. The verity of long run relationship among the variables was justified by the statistically significant negative coefficient of ECM (Cointeq (-1)*). Negative and statistically significant ECM explain that there is efficient adjustment process in restoring equilibrium. Negative and low ECM in absolute value indicate a slow adjustment. Hence, ECM for Oyo State study is statistically significant at 1% and had a value of -0.079635. The inference is that about 7.96% of disequilibria in maize enterprise from the previous year's shock converge to the long run equilibrium in the current year. Likewise, a 1% increase in temperature will cause 0.27 increase in maize yield while a unit increase in relative humidity would cause approximately 4.4% decrease in maize productivity. The negative association involving relative humidity and maize productivity could be attributed to the production of enabling environment created by increase relative humidity for the growth of pathogens that attack maize plant. Similarly, CO_2 uptake is drastically reduced in the presence of high relative humidity. The result is in uniform with Oparinde (2017) who stated a unit increase in temperature will increase cassava output in Southwestern Nigeria and 1% increase in relative humidity will also decrease cassava production.

Table 6.8: Result of ARDL Short-run Relationship (Ondo State)

ECM Regression				
Case 2: Restricted Constant and No Trend				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(X1)	0.574817***	0.160535	3.580635	0.0011
D(X2)	-0.273422	0.597499	-0.457610	0.6502
D(X3)	-0.291315**	0.138110	-2.109294	0.0426
CointEq(-1)*	-0.133868***	0.034862	-3.839941	0.0005
R-squared		*0.294373*	*Mean dependent var*	*0.070441*
Adjusted R-squared		*0.256231*	*S.D. dependent var*	*0.305678*
S.E. of regression		*0.263623*	*Akaike info criterion*	*0.243446*
Sum squared resid		*2.571394*	*Schwarz criterion*	*0.370112*
Log likelihood		*-1.868917*	*Hannan-Quinn criter.*	*0.289244*
Durbin-Watson stat		*2.111054*		

Note:

1. Y, X_1, X_2 and X_3 means Maize Yield (mt/ha), Rainfall (mm), Relative Humidity (%) and Temperature (^oc)
2. ***,**,* implies the level of significance at 1%, 5%, 10% respectively

Source: Computed from NIMET and ADP Data, 2021

Table 6.9: Result of ARDL Short-run Relationship (Oyo State)

ECM Regression				
Case 2: Restricted Constant and No Trend				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(X1)	-0.032697	0.204191	-0.160128	0.8737
D(X2)	-0.439809*	0.220739	-1.992438	0.0539
D(X3)	0.270104***	0.033566	8.046952	0.0000
CointEq(-1)*	-0.079635***	0.022977	-3.465839	0.0014

R-squared	*0.180653*	*Mean dependent var*	*0.065949*
Adjusted R-squared	*0.180653*	*S.D. dependent var*	*0.261088*
S.E. of regression	*0.236331*	*Akaike info criterion*	*-0.023079*
Sum squared resid	*2.234094*	*Schwarz criterion*	*0.018716*
Log likelihood	*1.473115*	*Hannan-Quinn criter.*	*-0.007860*
Durbin-Watson stat	*2.142141*		

Note:

1. Y, X_1, X_2 and X_3 signifies Maize Yield (mt/ha), Rainfall (mm), Relative Humidity (%) and Temperature (^{o}c)
2. ***,**,* denotes the significant level at 0.01, 0.05, 0.10 respectively

Source: Computed from NIMET and ADP Data, 2021

6.7 Diagnostic Test for ARDL Model

These are the tests for the Classical Linear Regression Model (CLRM) assumptions to make a reasonable inference and trustworthy conclusion with regard to coefficients in a model; however, the model must fulfil the CLRM assumptions. It was assumed that once a model satisfies all the assumptions of CLRM, it can be taken as a true model (Yahaya, Salisu and Umar, 2015) but Wolde-rufael, (2010) stated that a model can still be used if there is no serious deviation from the CLRM assumptions. The most important CLRM assumptions are independence of error terms, homoscedasticity, normality of the distribution, stability, and specification of the model. Though the ARDL is only based on the assumption of serially uncorrelated residuals, this study tests for other assumptions such as no heteroskedasticity, normal distribution and stability of the model to confirm how close is the model to the true model for reliable and valid inferences.

6.7.1 Serial Correlation

As shown in Table 6.10 and 6.11, the results of Breusch-Godfrey Serial Correlation LM Test for both states indicated the P-value of the F-statistic and Obs*R-squared to be greater than 0.05 (i.e P-value > 0.05). The implication of these results is that there is no evidence of serial correlation in this model.

Table 6.10: Results of Breusch-Godfrey Serial Correlation LM Test (Ondo)

Breusch-Godfrey Serial Correlation LM Test			
F-statistic	0.377624	Prob. F(2,31)	0.6886
Obs*R-squared	0.951337	Prob. Chi-Square(2)	0.6215

Source: Computed from NIMET and ADP Data, 2021

Table 6.11: Results of Breusch-Godfrey Serial Correlation LM Test (Ondo)

Breusch-Godfrey Serial Correlation LM Test			
F-statistic	1.031905	Prob. F(2,31)	0.3672
Obs*R-squared	2.346291	Prob. Chi-Square(2)	0.3094

Source: Computed from NIMET and ADP Data, 2021

6.7.2 Heteroskedasticity

For a model to have a good regression, the data set must be free from heteroskedasticity that is, it must be homoskedastic. Table 6.12 and 6.13 revealed the value of the Probability of Chi-Square to be higher than 0.05 (i.e 5% level of significance) which means the data set for this study is free from heteroscedasticity and good for regression analysis.

Table 6.12: Results of white heteroskedasticity (Ondo)

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	0.273759	Prob. F(6,33)	0.9453
Obs*R-squared	1.896572	Prob. Chi-Square(6)	0.9290

Source: Computed from NIMET and ADP Data, 2021

Table 6.13: Results of white heteroskedasticity (Oyo)

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	0.811617	Prob. F(4,36)	0.5261
Obs*R-squared	3.391520	Prob. Chi-Square(4)	0.4946

Source: Computed from NIMET and ADP Data, 2021

6.7.3 Normality Test

This study used histogram normality test to determine the evidence of normality of the data set used in the investigation. It was discovered in figures 6.1 and 6.2 that the probability value is 0.000000 for both Ondo and Oyo States. This denotes that there is no evidence of normality in the data sets for the two States. The P-value of the two states is statistically significant at 1% which means the null hypothesis of normality for Jarque-Bera is rejected.

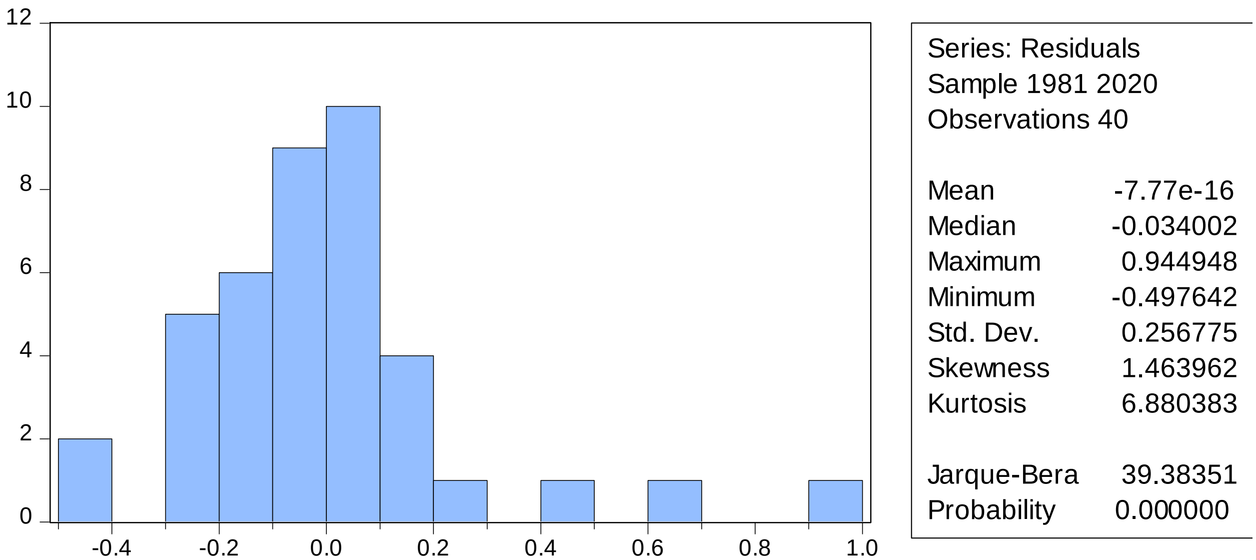

Figure 6.1: Jarque-Bera Normality Test for Ondo

Source: Computed from NIMET and ADP Data, 2021

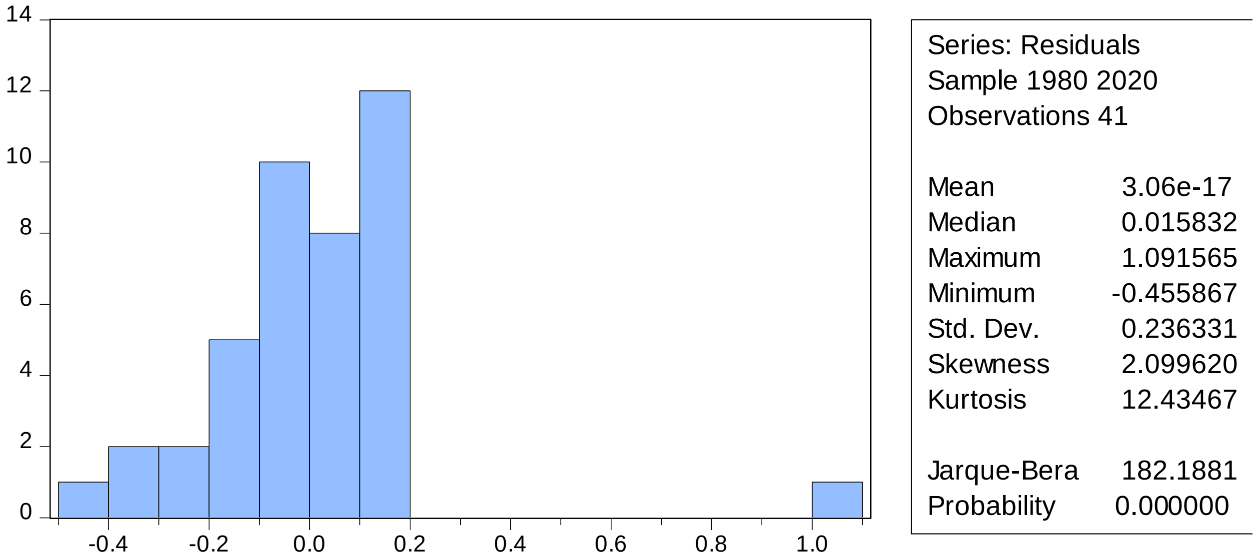

Figure 6.2: Jarque-Bera Normality Test for Oyo

Source: Computed from NIMET and ADP Data, 2021

6.7.4 Stability Tests

This study tested for parameter stability by using cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares recursive residuals (CUSUMq) plots of Brown *et al.* (1975) for the ARDL model for the short and long run models. The movement of the CUSUM and CUSUMq in between or outside the critical boundary line at 5% level of significance indicates parameter stability or instability. According to figure 6.3a and 6.4a, the CUSUM statistics (i.e the blue line) lies in between the critical boundary line at 5% significance, this shows the evidence of stability in model parameters of Ondo and Oyo State in the short run. Contrarily, the CUSUMq statistic for the model coefficients crossed the critical line (figure 6.3b and 6.4b) indicating instability in the ARDL model in the long run for both state. However, the CUSUMq for Ondo State shows that although the CUSUMq touched the critical line which indicate instability but did not significantly deviate from the line that explain that the ARDL co-integration equation does not show serious deviation from the true model.

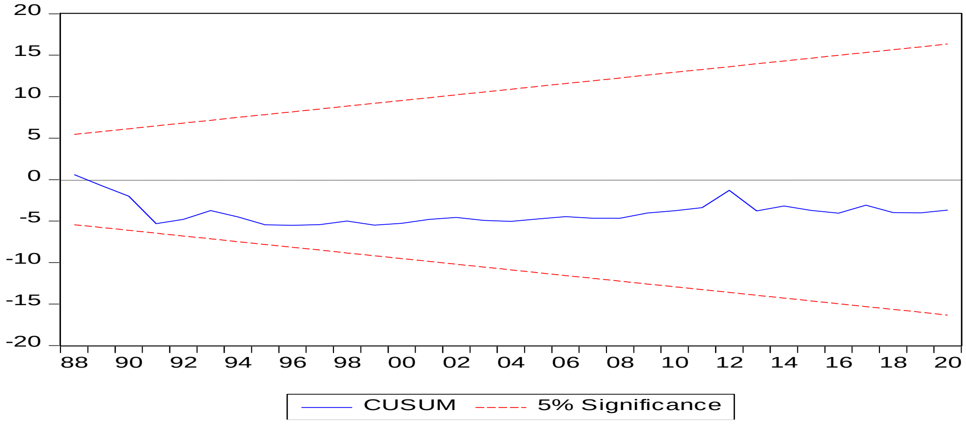

Figure 6.3a: Plot of the Cumulative Sum of Recursive Residuals (CUSUM) Test for ARDL Model in Ondo State

Source: Computed from NIMET and ADP Data, 2021

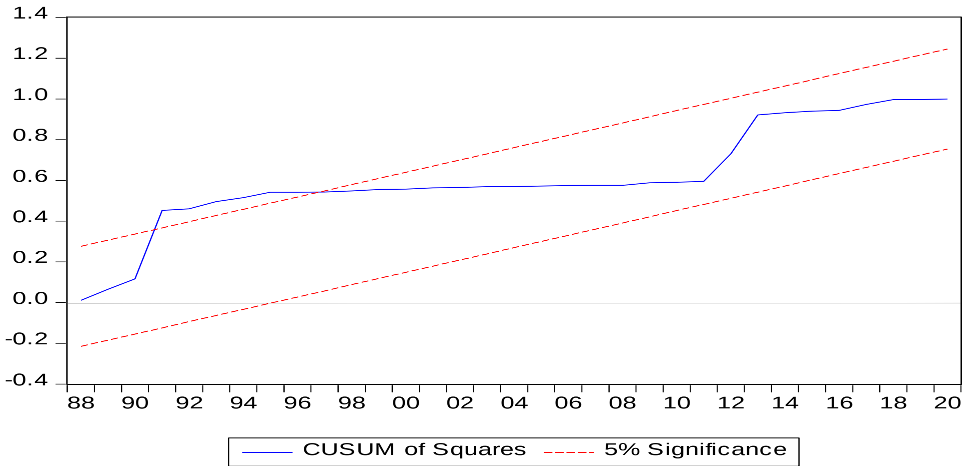

Figure 6.3b: Plot of the Cumulative Sum of Recursive Residuals of Square (CUSUMq) Test for ARDL Model in Ondo State

Source: Computed from NIMET and ADP Data, 2021

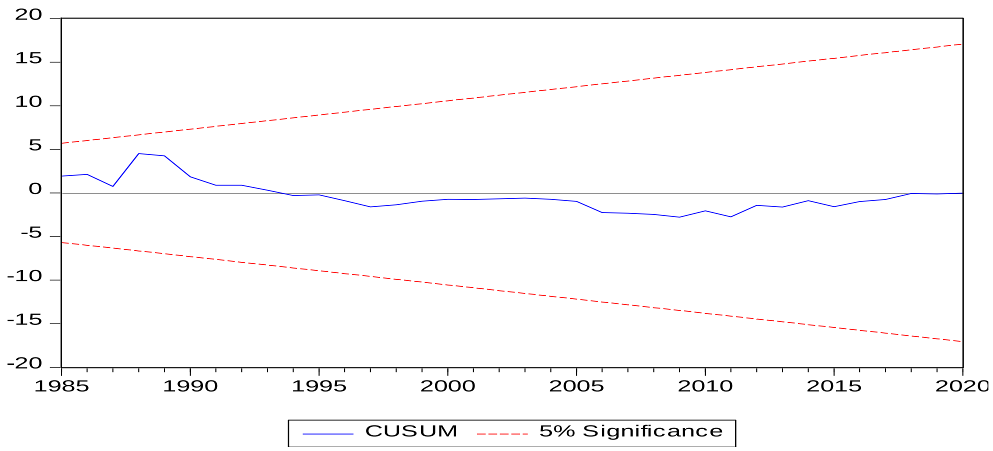

Figure 6.4a: Plot of the Cumulative Sum of Recursive Residuals (CUSUM) Test for ARDL Model in Oyo State

Source: Computed from NIMET and ADP Data, 2021

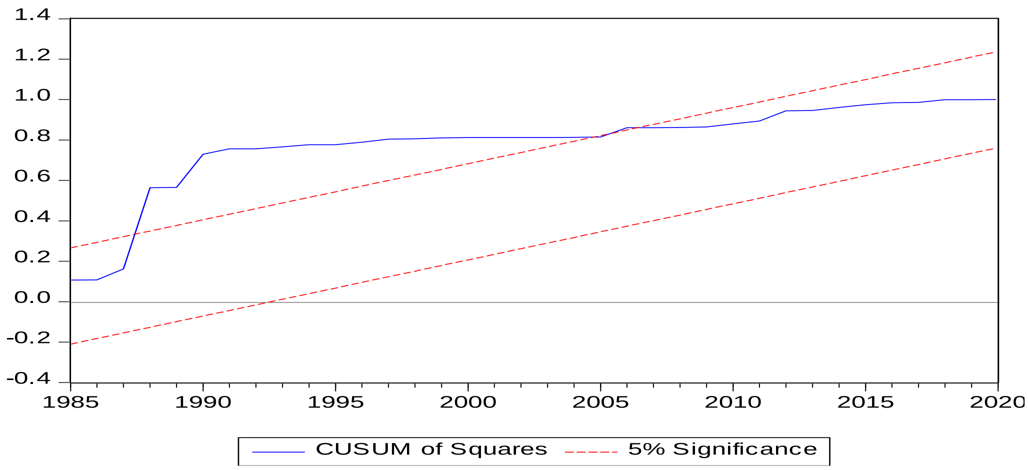

Figure 6.4b: Plot of the Cumulative Sum of Recursive Residuals of Square (CUSUMq) Test for ARDL Model in Oyo State

Source: Computed from NIMET and ADP Data, 2021

The instability of the model parameters at the long run could be due to several agricultural policies been implemented by successive government in Nigeria, this could also be as a result of not implementing policies from different research on climate change.

6.8 Summary

This chapter explicitly explain the results of relationship between maize productivity and climatic variables for the period 1979 to 2020 in the study area. Unit root test analysis by Augmented Dickey Fuller analysis was carried out to substantiate the usage of ARDL model while the lag order selection criteria used was Schwarz Bayesian Information Criterion (SBIC). Co-integration analysis based on ARDL bounds testing approach was employed to test whether there was relationship among the variables. Likewise, there was a diagnostic test for the ARDL model used in the study. The long run relationship among the variables was validated by the statistically significant negative coefficient of ECM (Cointeq (-1)*). The study established that rainfall and temperature were positively and negatively statistically significant in the long run and short run for Ondo State while in Oyo State temperature and relative humidity were positively and negatively significant in the short run. The diagnostic test showed an instability of the model parameters in the long run for the two states but ARDL co-integration equation for Ondo State does not show serious deviation from the true model.

CHAPTER SEVEN

CLIMATE CHANGE ADAPTATION MEASURES EMPLOYED BY MAIZE FARMERS IN THE STUDY AREA

7.1 Introduction

This section explicates the adaptation strategies employed by farmers in the study area. It also discusses inquiries made about farmers' perceptions and awareness about climate change as they are prerequisites to climate change adaptation. The results were linked with appropriate literatures.

7.2 Climate change adaptation strategies used by maize farmers in the study area

The study inquired about farmers' perceptions and awareness about climate change as they are prerequisites to climate change adaptation. This section deals with farm-level climate change adaptation methods used by farmers in the study area in 2019 – 2020 cropping season.

7.2.1 Awareness of effects of climate change by maize farmers

The farmers were asked whether they are aware about the phenomenon climate change. The result revealed majority (94.2%) were aware of changes in climate while 5.8% claimed they were not aware (Figure 7.1). The trend is the same in the sampled states as farmers in Ondo and Oyo States (92.4% and 96.8%) knew about climate change however, 7.6% and 3.2% of the respondents were not aware of the phenomenon climate change. This has been anticipated because there has been information and awareness regarding climate change in recent years among farmers. The result is in agreement with Idrisa *et al.* (2012) who averred that most farmers were aware of climate change and its effects in an investigation carried out in the Sahel Savannah agro-ecological zone of Borno State, Nigeria. This is also in conformity with Otitoju (2014) who stated that farmer's perception of climate change enhances their awareness of the phenomenon and their adaptation decision making. Maddison (2007) found farmers' awareness of changes in climate variables is important for adaptation decision making. This study concluded that farmers that were aware of the changes in climate took up adaptation measures that help them lessen losses or take advantages of the opportunities related with the changes.

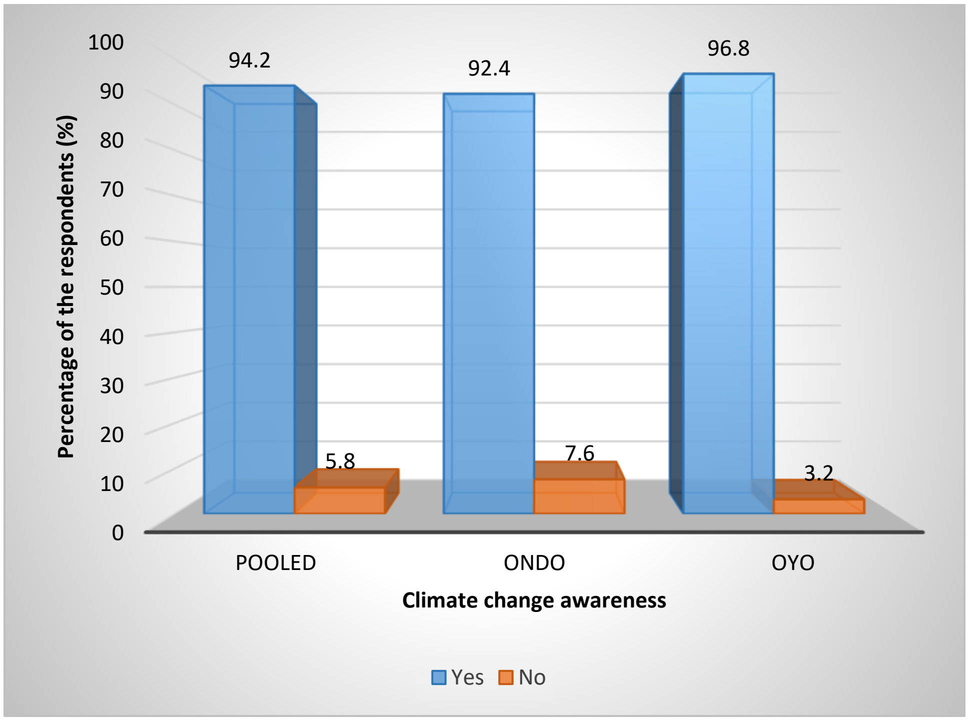

Figure 7.1: Climate change awareness

Source: Computed from Field data, 2021

7.2.2 Farmers' perception on climate change

The perceptions of respondents were sought for on climatic variables (rainfall and temperature) over the years. Table 7.1 revealed that 63.2% of the farmers stated that there has been inconsistent/delayed precipitation (rainfall) in the study area while 36.2% maintained a decrease in the amount of precipitation (rainfall) and only 0.6% of the respondent pinpointed increase in the amount of rainfall in the study area. In Ondo State majority (78.5%) indicated that they have experienced delayed or inconsistence rainfall and the expression of 20.3% of the respondents was that rainfall is decreasing while 1.2% thought rainfall increased. Slightly more than half (52.2%) of the respondents in Oyo State declared a decrease in precipitation in the state while 47.8% stated that the state experienced either a delayed or erratic rainfall. This implies that there would be changes in rainfall in the long run (especially inconsistent as well as reduced amounts) that may affect agricultural productivity (Nhemachena *et al.*, 2014; Moyo *et al.*, 2012). Maddison (2007) stated that farmers opined to increase in temperatures while rainfall will decrease. The result was also compared to other studies conducted in other semi-arid environments of Africa (Moyo *et al.*, 2012; Nyanga *et al.*, 2011; Rao *et al.*, 2011; Slegers 2008; Maddison 2007).

From Table 7.2, it was conveyed that majority (94.6%) of the farmers in the pooled sample perceived increase in temperature, as 94.4% and 94.8% (Ondo and Oyo states) of the sampled maize farmers perceived temperature to increase while 2.8%, 5.6% and 5.2% (pooled sample, Ondo state and Oyo state) pinpointed a temperature decrease over the years while 2.6% of the respondents from the pooled sample maintained that temperature is not changing. This substantiates the verity of Maddison (2007) who articulated that the farmers avowed increase in temperature as rainfall will decrease in Africa.

Table 7.1: Frequency distribution of respondents according to perceptions on rainfall

Long term rainfall perception	**Pooled Sample (N = 500)**		**Ondo Sample (N = 251)**		**Oyo Sample (N = 249)**	
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Increased rainfall	3	0.6	3	1.2	-	-
Decreased rainfall	181	36.2	51	20.3	130	52.2
Other (delayed/erratic)	316	63.2	197	78.5	119	47.8
Total	**500**	**100.0**	**251**	**100.0**	**249**	**100.0**

Source: Computed from Field data, 2021

Table 7.2: Frequency distribution of respondents according to perceptions on temperature

	Pooled Sample (N = 500)		**Ondo State (N = 251)**		**Oyo State (N = 249)**	
Long term temperature perception	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Increased Temperature	473	94.6	237	94.4	236	94.8
Decreased Temperature	14	2.8	14	5.6	13	5.2
No changes	13	2.6	-	-	-	-
Total	**500**	**100**	**251**	**100**	**249**	**100**

Source: Computed from Field data, 2021

7.2.3 Farmers' perception on the effects of climate change on maize productivity in the study area

The empirical result of how climate change has affected maize productivity in the study area was shown in Table 7.4. It was discovered that there was no revelation of improvement of maize productivity in the study area by climate change. The pooled sample result averred that 75.2% (majority) reported that their productivity level has been reduced while 13.2% stated that they experienced no production due to the influence of climate change on farming activities and 11.6% of the respondents ascertained no change in productivity in the face of climate change in the study area.

At the state level, majority of the farmers (80.1% and 70.3%) in Ondo and Oyo States maintained that they are experiencing maize productivity decrease as climate is changing, about 8.0% and 18.5% testified to been facing with the challenge of no production in Ondo and Oyo states while farmers that expressed to have no change in productivity in Ondo and Oyo States were 12.0% and 11.2% respectively. The result shows that there is variation in the effect of climate variables on maize productivity in the study area depending on seasonal properties and length of days of the maize which conforms to Eregha, Babatolu and Akinnubi (2014).

These findings substantiated Agbola and Fayiga (2016) and USDA (2007) that climate change has both optimistic and damaging impacts on agriculture. Decline in agricultural productivity discourages farmers and this may lead to change in livelihood (i.e financial livelihood) especially in the rural environment. This could also lead to rural-urban migration in the country. Food scarcity could be another aftermath of unfavourable effects of climate change if no swift efforts were put forward to control these challenges. In addition, according to Akinnagbe et al. (2014), climate change-related parameters such precipitation, temperature, extreme weather, atmospheric CO2 concentration, and climate variability all have an impact on maize yields.

Table 7.3: Frequency distribution of respondents according to how climate change is affecting maize productivity

	Full Sample (N = 500)		**Ondo (N = 251)**		**Oyo (N = 249)**	
How climate change affect crops	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
No change	58	11.6	30	12.0	28	11.2
Decreased Production	376	75.2	201	80.1	175	70.3
No Production	66	13.2	20	8.0	46	18.5
Total	**500**	**100.0**	**251**	**100.0**	**249**	**100.0**

Source: Computed from field data, 2021

7.2.4 Adaptation strategies employed by maize farmers in the study area

The result showed multiple responses on how farmers in the study area adapted to climate change (Table 7.5). Majority of the respondents (73.4%) employed planting of different crops (mixed cropping) as means of adaptation strategy used in the study area. It was stated that planting other crops with maize complement productivity and increase income from maize production. Similarly, about 66% of the farmers adopted planting of different varieties as an adaptation strategy in the study area while 64.4% identified using different planting dates to guard against climate change in the study area. Furthermore, 69.6% of the respondents indicated moving to a different farmland as a strategy as climate change adaptation, likewise, the use of agrochemicals was employed by 53.4% of the respondents in study area. Again, a fracture of the respondents (11.0%) chose irrigation as an adaptation strategy for maize production in the study area. This could be as a result that Southwestern Nigeria experience rainfall more than any other parts of the country. The aforementioned adaptation strategies corroborate the findings of Nhemachena and Hassan (2007) that mentioned different varieties, crop diversification and different planting dates as main farm-level adaptation strategies in Southern Africa.

In Ondo and Oyo State, 78.5% and 68.3% chose planting of different crops as an adaptation strategy followed by 70.5% and 61.8% that used planting of different maize varieties to combat climate change phenomenon. About 69.3% and 59.4% of farmers in Ondo and Oyo state employed different planting date as an adaptation strategy while moving to a different farmland was chosen by 70.9% and 68.3% of maize farmers in Ondo and Oyo states. The use of agrochemicals was indicated by 57.8% and 49.0% of the respondents as an adaptation strategy while irrigation was an adaptation strategy chosen by 11. 6% and 10.4% of the respondents in Ondo and Oyo states respectively.

Table 7.4: Major adaptation measures employed by maize farmers in the study area

	Pooled sample (N = 500)		**Ondo (N = 251)**		**Oyo (N = 249)**	
Adaptation options	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Planting different crops	367	73.4*	197	78.5*	170	68.3*
Planting different varieties of maize	331	66.2*	177	70.5*	154	61.8*
Use different planting dates	322	64.4*	174	69.3*	148	59.4*
Move to different farmland	348	69.6*	178	70.9*	170	68.3*
Change the use of chemicals, fertilizers and pesticides	267	53.4*	145	49.0*	122	49.0*
Increase irrigation system	55	11.0*	29	11.6*	26	10.4*

* Multiple Responses

Source: Computed from field data, 2021

7.3 Summary

Climate change adaptation measures employed by maize farmers in the study area were elucidated in this chapter. The chapter discussed farmers' perceptions and awareness about climate change as they are prerequisites to climate change adaptation. It was revealed that maize farmers in the study area adopted various strategies including planting of different crops, planting of different maize varieties, using different planting dates, moving into a different farmland, the use of agrochemicals and use of irrigation system as measures to combat the menace of climate change.

CHAPTER EIGHT

FACTORS INFLUENCING CLIMATE CHANGE ADAPTATION AMONG MAIZE FARMERS IN SOUTHWESTERN NIGERIA

8.1 Introduction

The results of the multinomial logistic regression model, which indicated how socioeconomic, institutional, climatic, and farm variables influenced maize farmers' choice of climate change adaptation methods in the study area, are presented in this section. The findings were discussed and compared to the relevant literature.

8.2 Factors influencing maize producers' choice of climate change adaptation options in the study area

This section conveyed the factors that are influencing climate change adaptation in the study area. A multinomial logistic regression (MNL) model presented in equation 3.16 of chapter three was employed to achieve the objective. The dependent variable for this study was mean adaptation strategy and was determined in a way that different observations regarding climate change adaptation strategies were censored at minimum and maximum (by dividing the number of climate change adaptation strategies employed by individual farmers by all climate change adaptation strategies available in the study area). Consequently, the value of dependent variable ranges between zero (0) and one (1).

The MNL results were unacceptable in terms of significance level of the parameters estimates when all the identified adaptation options were analysed. The identified adaptation strategies were then categorised by grouping closely related strategies together. In this case, planting different varieties of crops and use different planting dates were grouped together; soil conservation, water conservation and irrigation system were also categorized together. Likewise, move to different farmland and change amount of farmland were also categorized together. Alternatively, the study utilized five adaptation measures as the choices employed by the farmers. Consequently, the choice set in the restructured MNL model comprised the following adaptation options: planting different crop (multi-cropping), planting different varieties, soil and water conservation, agrochemicals and move to different farmland.

The MNL adaptation model was run with these restructured adaptation strategies and the parameter estimates showed some level of significance. The MNL model estimation for this study was embarked upon by regulating one category which is referred to as the "base category" or "reference category". The base category for this analysis was move to different farmland (MDS). It was revealed from the MNL result that various socio-economic factors, farm-specific variables, climatic variables, and institutional variables influence the farmers' choice of farm-level climate change adaptation strategies in the study area. The estimated coefficients should be compared with the base category in the case of MNL. As revealed in Table 8.1, the MNL diagnostic test revealed that all the parameters showed goodness of fit. The highly significant chi-square test ($p < 0.0001$) (for the pooled sample, Ondo and Oyo states) signifies that the models have a strong explanatory power.

Table 8.1: Diagnostic Tests Result of the MNL regression Analysis

Parameters	Pooled Sample	Ondo State	Oyo State
No. of observation	500	251	249
LR chi-square (59)	817.01	383.59	381.45
Prob. > chi-square	0.0000	0.0000	0.0000
Pseudo-R^2	0.6443	0.6401	0.6389
Log likelihood	-225.54694	-107.81631	-107.78231

Source: Computed by Author, 2021

Results of the parameter estimates (the estimated coefficients along with the robust standard errors) from the MNL models were presented in Table 8.2, 8.4, 8.6 (for pooled data, Ondo state and Oyo state) respectively. The MNL parameter estimates of the model present only the direction of the independent variables effect on the dependent variables; the estimates do not represent the actual number of probabilities. Therefore, the marginal effects from the MNL, which measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable were stated and discussed. Marginal effects of the explanatory variables were presented in Tables 8.3, 8.5 and 8.7.

The result shows that there is a statistically significant positive relationship between age and the probability of choosing multi-cropping ($p < 0.05$) and planting different varieties ($p < 0.05$) as adaptation strategies among maize farmers in the study area as an adaptation strategy compared to moving to different farmland (Table 8.2), *ceteris paribus*. The implication is that older farmers had higher probability of planting different crops (multi-cropping) and planting different varieties relative to moving to different farmland. Furthermore, older farmers had the ability to cope with climate change and climate variability in the study area than their younger counterparts because of the experiences gathered as they age. Likewise, older farmers are believed to have more farming experience than the younger farmers which should help them to be vaster in their knowledge of climate change and variability and how to choose the best on farm-level climate change adaptation strategies in the study area. This is consistent with Deressa *et al.* (2008) which found that age of the household head influenced climate change adaptation in Ethiopia. Contrarily, Obayelu, Adepoju and Idowu (2014) and Nhemachena (2008) opined that age is inversely related to the probability of choosing and using adaptation strategy. The study's findings suggest that age might be used to measure experience since as a farmer gets older and more knowledgeable, he or she may become more productive and possess better decision-making skills.

As revealed in Table 8.3, a unit increase in age of the respondents increases the likelihood of using multi-cropping, agrochemicals compared to moving to a different farmland by marginal effects of 15.7% and 2.7% respectively. In Ondo and Oyo states, a unit increase in age will increase moving to a different farmland by 3.2% and 3.11% at ($p < 0.05$) (Table 8.5 and 8.7) level of significance. This result established that as the age of the farmer increased, the chances of climate change adaptation using multi-cropping, agrochemicals and moving to a different farmland increased in the study area.

The study revealed a significant negatively correlation between gender and climate change adaptation strategies in the study (Table 8.2, 8.4 and 8.6). It has been asserted in literature that gender is a sensitive and important element in the study of climate change and agriculture. Contrary to expectations and literature (Birungi and Hassan, 2010; Deressa *et al.*, 2009; 2008 and Asfaw and Admassie, 2004) that male-headed households are more likely to adapt to climate change, the result stated that female respondents in Southwestern Nigeria adapted to climate change by employing multi-cropping, planting different varieties, using soil and water conservation and agrochemicals because rural female farmers are involved in small-scale farming to have a sustainable livelihood.

The result is in line with Maponya (2012) who revealed that there is more involvement of females in agricultural practices than men. Correspondingly, the study of Nhemachena and Hassan (2007) found out that women are experienced and competent in several farming activities while male counterparts may venture into other off farm/non-agricultural activities. Moreover, the inverse relationship between gender and climate change adaptation in the study area could be that female farmers in the study area are empowered, better sensitized, trained and equipped to reducing climate change vulnerability among rural households through women in agriculture program organise by Nigerian government and other gender-based program locally and internationally. The outcome of Bayard *et al.* (2007) also agrees with the result of this study that female farmers are quick to embrace practices that conserve natural resources and its management than their male counterparts.

Furthermore, the result may also be because of full concentration of the few women that are into agriculture and majorly maize farming (food crop production) in the study area than their male counterparts that may venture into other off farm/non-agricultural activities. Thus, future research on gender and climate change adaptation in the study area could reveal more information about factors influencing adaptation to climate change based on gender. Also, research on inequalities experienced by women in the discourse of climate change and agricultural production is another future research focus area.

The marginal effects in Table 8.3 stated that a unit increase in gender will decrease adaptation of planting multiple crops, planting different varieties, soil and water conservation and the use of agro chemicals by 4.0%, 14.6%, 0.01%, 3.5% and 5.0% respectively in the study area compared to moving to different farmland.

Marital status of the respondents has a statistically negative relationship with the probability of choosing and using soil and water conservation and planting different varieties of maize in the study area (Table 8.2, 8.4 and 8.6) which means unmarried respondents are likely to plant different varieties and apply soil and water conservation to adapt to climate change in the study area. This indicates a unit increase in marital status of the respondents would decrease the use of planting different varieties by 0.0681536 (6.8%), 0.0718984 (7.2%) and 0.0717653 (7.2%) respectively (Table 8.3, 8.5 and 8.7). Furthermore, the marginal effect in Tables 8.3, 8.5 and 8.7 showed that one unit increase in marital status would result in 0.02% decrease in choosing and using soil and water conservation in the study area.

There is an inverse relationship between educational level of the respondents and the probability of choosing and using planting different varieties and soil and water conservation as an adaptation strategy (Table 8.2). The implication is that a unit increase in education would lead to a decrease of 3.6% in planting different varieties and 0.02% in soil and water conservation respectively in the study area (Table 8.3) all other factors held constant.

The parameter estimate result from Ondo State revealed the use of soil and water conservation as an adaptation strategy in relative to moving to a different farmland is statistically significant and negative (P = -3.984998) (Table 8.4). This means a unit increase in the number of years of schooling would result in 0.13% decrease in the probability of choosing and using soil and water conservation in Ondo State (Table 8.5). In Oyo State, the relationship between educational level and soil and water conservation as an adaptation strategy is negative and statistically significant ($P < 0.01$). The marginal effect in Table 8.7 revealed a unit increase in educational level would cause a 0.12% decrease in the probability of choosing and using soil and water conservation in Oyo State.

Contrary to *"a priori"* expectations, which predicted that respondents' literacy levels would positively influence climate change adaptation in the study area, one explanation for the inverse relationship between education and adaptation strategies may be that farmers were not adequately informed about the effects of climate change and coping mechanisms. Because of their advanced degree of related skill, it is anticipated that a farmer who is aware about climate change and various adaption measures will likely revolutionise. The findings of this study and those of Otitoju (2013) are consistent in that, in Southwestern Nigeria, the likelihood that a farm household will select multiple crop varieties and multiple planting dates as climate change adaptation strategies is negatively correlated with the education of the household head. This study also supports the findings of Birungi and Hassan (2010), who discovered that adoption of terracing and inorganic fertilisers as land management practises in Uganda was inversely related to education. Bayard *et al.* (2007) discovered a similar relationship between education and adoption of rock walls as a soil conservation practise in Forte-Jacques. But the findings of this study negate the assertions made by Oduniyi (2018), Maddison (2007), Asfaw and Admassie (2004), and Bamire *et al.* (2002) that knowledgeable and seasoned farmers ought to be more aware of and conversant about climate change adaptation.

According to Table 8.2, household size is statistically significant ($P < 0.05$) and had a negative association to planting different varieties which conforms to Otitoju (2013) who stated that household size has an inverse relationship to climate change adaptation likewise the use of agrochemicals is positively statistically significant ($P < 0.05$) to household size as an adaptation strategy compared to moving to a different farmland. The inference is that smaller household adapted to climate change by choosing to plant different varieties while the larger household adopted the use of agrochemicals as an adaptation strategy to climate change with other factors held constant. The marginal effect of this result is that a unit increase in household size will decreases the likelihood of using planting different varieties by (1.9%) and increase in the use of agrochemicals by (0.07%) (Table 8.3).

The household result for both Ondo and Oyo states revealed that for most of the adaptation methods, increasing household size did not significantly increase the possibility of choosing any of the adaptation methods, although the coefficient on the adaptation options has a negative sign. Despite the fact that it is not significant, it could be inferred that smaller household size has a better chance of adapting to climate change using all the adaptation methods.

Table 8.2 showed major occupation to be significant ($P < 0.05$) and had a negative association with multiple cropping and planting different varieties ($P < 0.10$) in the study area. According to Tables 8.4 and 8.6 the parameter estimate of major occupation in Ondo and Oyo states were negatively significant to multiple cropping as an adaptation strategy compared to moving to different farmland. The implication is that respondents based their livelihood on farming are likely to adapt to climate change by choosing and using multiple cropping and planting different varieties unlike respondents that have other means of survival. Similarly, at the state level, respondents whose major source of living is maize farming adopted multi-cropping as an adaption to climate change. The outcome is in line with Connolly-Boutin and Smit (2016) and Calzadilla *et al.* (2013) who stated that farming provided the main livelihood and employment for majority of the population of most developing countries.

The marginal effect of this result is that an increase in major occupation will reduce the choice of multiple cropping and planting different by 21.5% and 6.2% respective in the study area as reflected in Table 8.3. In Oyo State, a unit increase in farmer's major occupation will cause the choice of multiple cropping to dwindle by 18.7% (Table 8.7) while a unit growth in occupation will also reduce multi-cropping as an adaptation strategy in Ondo State by 18.7% (Table 8.5) likened to moving to different farmland.

Farming as major source of income is positively correlated with soil and water conservation and the use of agrochemicals in the study area (Table 8.3) compared to moving to a different farmland. This means a unit increase in the source of income would increase the probability of choosing and using soil and water conservation by 0.02% and agrochemicals by 1.6% in the study area (Table 8.3). This could be as a result that farming is the important source of income for "poor" rural households and this support findings of Oduniyi (2018), Ajala (2017) and Machethe (2004).

Table 8.4 and 8.6 presented the use of soil and water conservation as an adaptation strategy to be positively significant ($P < 0.01$) in both states signifying a unit increase in major source of income would increase the probability of choosing and using soil and water conservation by 0.0001737 (0.02%) in Ondo State and 0.0001745 (0.02%) in Oyo State respectively (Tables 8.5 and 8.7).

Land tenure has a positive significant relationship with the probability of using multi-cropping, planting different varieties and the use of agrochemicals in the study area, Ondo State and Oyo State as established in Tables 8.2, 8.4 and 8.6, respectively. The implication is that land tenure types such as communal, permission to own and others increases the probability of choosing and using multi-cropping, planting different varieties and the use of agrochemicals as an adaptation strategy compared to moving to a different farmland. The marginal effect showed that an additional unit added to land tenure would increase the probability of choosing and using multi-cropping by

0.0996978 (10.0%), 0.141065 (14.1%) and 0.141307 (14.1%) likewise move to different farmland by 3.4%, 3.6% and 3.7% in the study area, Ondo and Oyo states respectively (Tables 8.3, 8.5 and 8.7). The study of Birungi and Hassan (2010) stated that investing in land management is increased by land tenure security which agrees with the outcome of this study.

Farm ownership had a negative and significant effect on climate change adaptation strategies in the study area (Table 8.2). This signified a negative correlation between the farm ownership and adaptation strategies. A unit increase in farm ownership would result in 32.7% decrease in choosing and using multiple cropping, 15.7% decrease in choosing and using planting different varieties, 0.05% of choosing and using soil and water conservation and 1.1% of choosing and using moving to different farmland (Table 8.3).

Table 8.4 revealed the use of soil and water conservation as an adaptation strategy to be negatively significant ($P < 0.01$) in Ondo State indicating one-unit increase in farm ownership decreases the likelihood of choosing and using soil and water conservation by 0.05% (Table 8.5). Similarly, there was a negative and significant impact on soil and water conservation and farm ownership in Oyo State (Table 8.6) meaning a unit increase in farm ownership as a variable in Oyo State would cause a 0.04% decrease in the probability of choosing and using soil and water conservation (Table 8.7). The result implies an individually owned farm is more likely to take up adaptation strategies than joint ownership form of farm because there is tendency to invest more on personally owned farm. This corroborate Maponya (2012) that land ownership is expected to influence adoption if the invention involves investments that are attached to land. Likewise, Gbetibouo (2009) discovered that farm owners adopted new technologies more frequently than tenants, an argument that justified numerous efforts to reduce farm and tenure insecurity.

As presented in Table 8.2, the coefficient estimates of farm size had a positive significance ($P = 1.82$) on planting different varieties and ($P = 5.17$) on soil and water conservation in the study area, *ceteris paribus*. This means a marginal increase in farmer's farm size would lead to 8.7% and 0.01% in the probability of choosing and using planting different varieties and soil and water conservation, respectively, in the study area (Table 8.3). In Ondo and Oyo states, soil and water conservation have a positively statistically significant relationship (Table 8.4 and 8.6) with farm size indicating the usage of soil and water conservation as an adaptation strategy is increasing as the size of the farm also increase.

The justification is that farm size is always linked with wealth (i.e large farm size could be capital intensive); hence, the larger the farm size, the more possibility of choosing an adaption strategy in the study area. Additionally, most farmers' engaging in small-scale farming were poor and could be less resourceful in combating climate change by adopting soil and water conservation method while most farmers with large farm size have the resources and they are expected to invest in climate change adaptation strategy like irrigation system, farm management practices that will conserve soil and water. Therefore, this study affirmed the view of McBride (2003) cited in Gbetibuouo (2009) who maintained that given the uncertainty and the fixed transaction and information costs associated with innovation, there may be a critical lower limit on farm size that prevents smaller farms from adopting adaptation strategies. It follows that the innovations with large fixed transaction and/or information costs are less likely to be adopted by smaller farms.

As expected, information on climate change received by the farmers in the study area is positively significant to all the adaptation strategies. Table 8.3 further revealed that information received on climate change by the farmers increases the likelihood of using multi-cropping by 40.8%, planting different varieties by 14.0%, using agrochemicals by 8.4% compared to moving to a different farmland in the study area. Climate change information in the study area increased farmer's awareness therefore, increasing farmer's knowledge on the phenomenon and how to adapt. The result is in uniformity with Bryan *et al*. (2009) and Deressa *et al.* (2009), which stated that climate change information had a significant positive impact on climate change awareness and facilitate adaptation strategies among farmers.

As presented in Table 8.2, farming experience is positively significant to climate change adaptation in study area. As expected with the assumption that farming experience positively influence climate change adaptation and it is also key to farmers decision making on the farm. The outcome revealed that as farming experience increases, the probability of choosing multi-cropping, planting different varieties, soil and water conservation and the use of agrochemicals increases in the study area. Therefore, a unit increase in farming experience would probably increase the likelihood of adopting multi-cropping, planting different varieties, soil and water conservation, and agrochemicals by 1.1%, 0.5%, 0.003%, and 0.2% respectively compared to moving to a different farmland (Table 8.3). Through more effective relationships with extension services and a better social network, farmers with greater expertise may adopt more climate change adaptation strategies.

In Ondo State, the use of planting different varieties and soil and water conservation were positive and significant at ($P < 0.01$) (Table 8.4) implying a marginal increase in farming experience will increase the probability of planting different varieties by 0.6% and soil and water conservation by 0.03% (Table 8.5). The Oyo State result revealed in Table 8.6 planting different varieties and soil and water conservation to be positively correlated with farming experience which indicate that a unit addition to farming experience enhances the probability of farmers to choose and use planting different varieties by 0.5% and soil and water conservation by 0.02% (Table 8.7). The findings are consistent with those of Onyeneke *et al.* (2018), Abegunde, Sibanda, and Obi (2020), who found that farming experience considerably improves the possibility that people will adopt technology to change how they manage and produce their crops.

As presented in Table 8.2, precipitation increase would likely influence farmers to adapt to climate change through the adoption of multi-cropping and planting different varieties while soil and water conservation as an adaptation strategy happen to work in opposite direction. Table 8.3 revealed that a unit increase in rainfall would increase the probability of using multiple cropping (3.9%), planting different crop varieties (2.2%) and using agrochemicals (44.1%) compared to moving to a different farmland. The results indicate that, with more rainfall, farmers will increase the use of agrochemicals to combat proliferation of pest, diseases and weeds that may be associated with intensifying rainfall likewise farmers may venture in planting water resistant varieties and different crops that are water friendly. Farmers could also move to different farmland to avoid soil erosion and leaching due to upsurge rainfall intensity.

Tables 8.2, 8.4 and 8.6 revealed temperature to be statistically negative and significant to multi-cropping as an adaptation strategy in the study area. Unlike precipitation, the possibility of climate change adaptation adoption works in opposite direction as temperature snowballed. The implication is that proliferation in temperature lessen the inconveniences caused by rainfall intensification on crop productivity in the study area. Relatedly, the results confirm that increase in temperature significantly decreases the chance of choosing and using multi-cropping in the study area.

Table 8.2: Parameter estimates of MNL analysis of factors that influence Climate change adaption strategies used in maize productivity in the Study Area (Pooled Data; N = 500)

	Coefficients			
Explanatory Variables	**Multi-Cropping**	**Planting different varieties**	**Soil and water conservation**	**Agrochemicals**
Age	1.418611*** (0.36)	1.444012*** (0.35)	-0.2987185 (0.48)	0.7505124 (0.49)
Gender	-2.003332*** (0.65)	-4.186865*** (0.93)	-7.664579*** (2.75)	-2.498031* (1.28)
Marital Status	-1.052133 (0.82)	-2.250518*** (0.84)	9.873671*** (3.17)	-0.9261075 (2.21)
Educational Level	-0.1433509 (0.82)	-0.6141536** (0.25)	-6.539945*** (1.81)	0.4243942 (0.54)
Household Size	-0.0255574 (0.14)	-0.3314237** (0.14)	-0.2033414 (0.32)	0.741522** (0.32)
Major Occupation	-2.426538*** (0.69)	-0.7562273* (0.45)	0.6519891 (0.83)	-18.98243 (1029.59)
Major source of Income	0.7770673 (1.01)	-0.5657702 (1.01)	9.564339*** (2.70)	2.351767* (1.21)
Land Tenure	1.115042*** (0.22)	1.346386*** (0.22)	0.1443334 (0.37)	0.938072*** (0.28)
Farm Ownership	0.1280107 (0.59)	-1.674142*** (0.62)	-19.23411*** (5.20)	1.714966 (1.14)
Farm Size	0.6574239 (0.73)	1.819293** (0.76)	5.168793*** (1.73)	0.7489252 (0.83)
Information on Climate Change	4.348749*** (1.04)	3.919496*** (0.88)	8.316911*** (2.22)	4.26668*** (1.20)
Farming Experience	0.093625** (0.04)	0.1660214*** (0.04)	1.506503*** (0.45)	0.1034338* (0.05)
Perceived Rainfall	20.767*** (1.74)	2.807668*** (1.00)	-11.59874*** (3.59)	-0.8100582 (0.89)
Perceived Temperature	-2.970214*** (1.08)	-19.91903 (3611.27)	-12.35261 (2322.54)	-17.92104 (4257.07)
Constant	-40.03151 (MS)	18.99353 (3611.27)	52.61967 (2322.54)	21.99523 (4379.81)

Note:

1. Figures in Parentheses are the standard errors
2. ***, **, * signifies level of significance at 1%, 5% and 10% respectively
3. Move to different farmland is the base category

Source: Author's computation, 2021

Table 8.3: Results of the marginal effect from MNL analysis on factors influencing climate change adaption strategies used by maize farmers in the study area (pooled data; N = 500)

	Coefficients				
Explanatory Variables	**Multi-Cropping**	**Planting different varieties**	**Soil and water conservation**	**Agrochemicals**	**Move to different farmland**
Age	0.1571788*** (0.004)	0.0389905 (0.282)	0.0000494 (0.652)	0.0277486** (0.025)	0.0458693*** (0.001)
Gender	0.0402283 (0.736)	0.1459038* (0.073)	0.000136 (0.665)	-0.0350053* (0.061)	-0.0501387** (0.021)
Marital Status	-0.117523 (0.442)	0.0681536 (0.464)	-0.0002391 (0.649)	-0.018626 (0.274)	-0.0282499 (0.322)
Educational Level	0.080554*** (0.001)	0.036244 (0.223)	0.0001475 (0.653)	-0.0025532** (0.045)	-0.0029651 (0.690)
Household Size	0.0148778 (0.502)	0.0190383 (0.231)	7.30e-06 (0.675)	-0.0006847 (0.806)	-0.00113 (0.825)
Major Occupation	-0.2149519 (0.984)	-0.0618743 (0.994)	-0.0001074 (0.615)	-0.0354947 (0.966)	-0.0443844 (0.986)
Major source of Income	0.0735726 (0.664)	0.1137716 (0.230)	-0.000175 (0.663)	0.0155263 (0.474)	0.0262127 (0.476)
Land Tenure	0.0996978*** (0.004)	0.0093914 (0.691)	0.0000279 (0.655)	0.0212314** (0.012)	0.034155*** (0.000)
Farm Ownership	0.3278753* (0.051)	0.1565558** (0.049)	0.0004552 (0.651)	0.0036979 (0.761)	0.0107004 (0.618)
Farm Size	-0.0733833 (0.622)	-0.0870741 (0.402)	-0.0001092 (0.659)	0.0109203 (0.518)	0.0142164 (0.598)
Information on Climate Change	0.4081831** (0.010)	0.1396217 (0.152)	-0.0000493 (0.723)	0.0841775*** (0.008)	0.1375429*** (0.000)
Farming Experience	0.0108891 (0.361)	0.0049687 (0.283)	0.0000317 (0.654)	-0.0016883 (0.161)	-0.0024169 (0.139)
Perceived Rainfall	3.917789*** (0.000)	2.239417*** (0.000)	0.0010969 (0.649)	0.4415025** (0.013)	0.789733*** (0.000)
Perceived Temperature	1.282302 (0.996)	1.50742 (0.996)	0.000382 (0.995)	-0.0211223 (0.997)	0.0266524 (0.999)

Note:

1. Figures in Parentheses are the p-values

2. ***, **, * signifies level of significance at 1%, 5% and 10% respectively
3. Move to different farmland is the base category

Source: Author's computation, 2021

Table 8.4: Parameter estimates of MNL analysis of factors that influence climate change adaption strategies used in maize productivity in the study area (Ondo State; N = 251)

Explanatory Variables	Coefficients			
	Multi-Cropping	**Planting different varieties**	**Soil and water conservation**	**Agrochemicals**
Age	0.9614082** (0.44)	1.016347** (0.45)	-0.2002743 (0.53)	0.3543257 (0.583)
Gender	-1.692232* (0.95)	-5.004337*** (1.60)	-4.132888* (2.25)	-2.393349 (1.75)
Marital Status	-0.9565786 (1.03)	-2.317202* (1.24)	5.3012* (2.79)	-0.9400923 (2.40)
Educational Level	-0.1970176 (0.31)	-0.3413521 (0.43)	-3.984998*** (1.31)	0.6353421 (0.71)
Household Size	-0.0953217 (0.17)	-0.2779054 (0.20)	-0.0841315 (0.32)	0.6759601 (0.42)
Major Occupation	-2.537836** (1.08)	-0.5907481 (0.79)	-0.0629131 (0.85)	-19.38107 (1668.51)
Major source of Income	1.244215 (1.68)	-1.001329 (1.80)	7.151412*** (2.59)	2.510814 (1.69)
Land Tenure	1.144575*** (0.30)	1.144907*** (0.30)	-0.0148806 (0.47)	0.8859213** (0.38)
Farm Ownership	0.6135313 (0.85)	-1.572734 ((1.03)	-12.59559*** (3.81)	1.755764 (1.49)
Farm Size	0.0634681 (1.07)	1.778776 (1.15)	2.970939* (1.56)	0.6737529 (1.13)
Information on Climate Change	3.951659*** (1.46)	4.20062*** (1.30)	5.676598*** (2.07)	3.799947** (1.58)
Farming Experience	0.0777495 (0.60)	0.1813293*** (0.60)	0.9441525*** (0.33)	-0.0834203 (0.07)
Perceived Rainfall	21.10062*** (2.32)	3.06995** (1.47)	-7.183029*** (2.68)	-0.6140918 (1.27)
Perceived Temperature	-2.801486* (1.52)	-20.4835 (5243.61)	-15.02602 (3465.75)	-18.29487 (6461.50)
Constant	-39.54991 (MS)	19.7262 (5243.62)	40.19541 (3465.77)	23.24902 (6673.46)

Note:

1. Figures in Parentheses are the standard errors
2. ***, **, * signifies level of significance at 1%, 5% and 10% respectively
3. Move to different farmland is the base category

Source: Author's computation, 2021

Table 8.5: Results of the Marginal Effect from MNL Analysis on Factors Influencing Climate Change Adaption Strategies used by Maize Farmers in the Study Area (Ondo State Data; N = 251)

Explanatory Variables	Coefficients				
	Multi-Cropping	**Planting different varieties**	**Soil and water conservation**	**Agrochemicals**	**Move to different farmland**
Age	0.1232849 (0.103)	0.0252154 (0.567)	0.0000552 (0.765)	0.0110624 (0.164)	0.0313359** (0.049)
Gender	0.0816517 (0.633)	0.2032809 (0.117)	0.0000802 (0.780)	-0.0153132 (0.289)	-0.0435718 (0.162)
Marital Status	-0.1038872 (0.603)	0.0718984 (0.550)	-0.0002256 (0.757)	-0.0114902 (0.383)	-0.0278534 (0.419)
Educational Level	0.0316911 (0.685)	0.0009327*** (0.000)	0.0001306 (0.759)	-0.0012817 (0.731)	-0.0069129 (0.522)
Household Size	-0.0094696 (0.755)	0.0052669 (0.783)	-7.16e-07 (0.960)	-0.0012823 (0.475)	-0.0041357 (0.499)
Major Occupation	-0.1871387 (0.994)	-0.0852536 (0.994)	-0.0001382 (0.731)	-0.0218468 (0.977)	-0.0498466 (0.988)
Major source of Income	0.1722286 (0.553)	0.1830269 (0.202)	-0.0001737 0.774	0.0125398 (0.544)	0.0404239 (0.496)
Land Tenure	0.141065*** (0.004)	0.0313116 (0.341)	0.0000583 (0.761)	0.012929 (0.109)	0.0364735*** (0.000)
Farm Ownership	0.3816287 (0.079)	0.1709686 (0.160)	0.0004862 (0.757)	0.011528 (0.330)	0.0239109 (0.412)
Farm Size	-0.1553227 (0.486)	-0.128305 (0.358)	-0.0001117 (0.764)	-0.0015315 (0.905)	-0.0036009 (0.923)
Information on Climate Change	0.3770883 (0.102)	0.0825937 (0.491)	-9.61e-07 (0.993)	0.0423976 (0.104)	0.122937 (0.019)
Farming Experience	0.0111894 (0.424)	0.0059139 (0.314)	0.0000298 (0.759)	-0.0005155 (0.515)	-0.0020444 (0.325)
Perceived Rainfall	4.111445*** (0.000)	2.010041*** (0.001)	0.0014309 (0.759)	0.2593284 (0.137)	0.7487193*** (0.000)
Perceived Temperature	1.249314 (0.997)	1.327601 (0.997)	0.0004965 (0.997)	-0.0087743 (0.998)	-0.0141138 (0.999)

Note:

1. Figures in Parentheses are the p-values
2. ***, **, * signifies level of significance at 1%, 5% and 10% respectively
3. Move to different farmland is the base category

Source: Author's computation, 2021

Table 8.6: Parameter Estimates of MNL Analysis of Factors that Influence Climate Change Adaption Strategies used in Maize productivity in the Study Area (Oyo State; N = 249)

Explanatory Variables	Coefficients			
	Multi-Cropping	**Planting different varieties**	**Soil and water conservation**	**Agrochemicals**
Age	0.9595543** (0.44)	1.011126** (0.45)	-0.2037616 (0.53)	0.3522096 (0.58)
Gender	-1.687429* (0.95)	-5.001426*** (1.60)	-4.096613* (2.25)	-2.39551 (1.75)
Marital Status	-0.9498759 (1.03)	-2.310773* (1.24)	5.27494* (2.80)	-0.9258883 (2.40)
Educational Level	-.196456 (0.31)	-0.3385127 (0.43)	-3.991611*** (1.31)	0.346841 (0.71)
Household Size	-0.095736 (0.17)	-0.2783868 (0.20)	-0.0810654 (0.33)	0.6752342 (0.42)
Major Occupation	-2.537952** (1.08)	-0.591015 (0.79)	-0.0832468 (0.85)	-19.38258 (1661.28)
Major source of Income	1.240202 (1.68)	-1.005911 (1.80)	7.155604*** (2.58)	2.517608 (1.69)
Land Tenure	1.144123*** (0.30)	1.140993*** (0.30)	-0.0150843 (0.47)	0.8828286** (0.38)
Farm Ownership	0.614651 (0.85)	-1.567714 (1.03)	-12.58574*** (3.81)	1.751062 (1.49)
Farm Size	0.0597335 (1.07)	1.761738 (1.15)	2.912505* (1.58)	.6631363 (1.13)
Information on Climate Change	3.945649*** (1.46)	4.193741*** (1.30)	5.616012*** (2.09)	3.795165** (0.25)
Farming Experience	0.0779955 (0.06)	0.1814911*** (0.06)	0.9495371*** (0.33)	0.0838529 (0.73)
Perceived Rainfall	21.15013*** (2.32)	3.086466** (1.47)	-7.137284*** (2.68)	-0.6038603 (1.27)
Perceived Temperature	-2.798632* (1.51)	-20.53837 (5365.76)	-15.07097 (3562.68)	-18.27525 (6478.65)

Constant	-39.64483 (MS)	19.78578 (5365.76)	40.45723 (3562.69)	23.23446 (6688.26)

Note:

1. Figures in Parentheses are the standard errors
2. ***, **, * signifies level of significance at 1%, 5% and 10% respectively
3. Move to different farmland is the base category

Source: Author's computation, 2021

Table 8.7: Results of the Marginal Effect from MNL Analysis on Factors Influencing Climate Change Adaption Strategies used by Maize Farmers in the Study Area (Oyo State Data; N = 249)

Explanatory Variables	Coefficients				
	Multi-Cropping	Planting different varieties	Soil and water conservation	Agrochemicals	Move to different farmland
Age	0.1233699 (0.103)	0.025449 (0.563)	0.0000556 (0.765)	0.0110606 (0.164)	0.0317505** (0.049)
Gender	0.0821075 (0.632)	0.2030532 (0.117)	0.0000793 (0.780)	-0.0151849 (0.292)	-0.0440728 (0.163)
Marital Status	-0.1032781 (0.605)	0.0717653 (0.550)	-0.0002253 (0.757)	-0.0114982 (0.384)	-0.0280315 (0.423)
Educational Level	0.0320542 (0.682)	0.0007934 (0.985)	0.0001313 (0.759)	-0.0012121 (0.745)	-0.0070195 (0.522)
Household Size	-0.0095395 (0.754)	0.0052253 (0.784)	-8.58e-07 (0.952)	-0.0012896 (0.474)	-0.0042074 (0.498)
Major Occupation	-0.1872096 (0.994)	-0.0848269 (0.994)	-0.0001384 (0.731)	-0.0217983 (0.977)	-0.0506604 (0.988)
Major source of Income	0.1710055 (0.556)	0.1824791 (0.202)	-0.0001745 (0.774)	0.0123927 (0.549)	0.0409329 (0.497)
Land Tenure	0.141307*** (0.004)	0.0315945 (0.337)	0.0000587 (0.761)	0.0129404 (0.109)	0.0370169*** (0.000)
Farm Ownership	0.3824568* (0.078)	0.1705111 (0.160)	0.0004879 (0.757)	0.011767 (0.324)	0.0242443 (0.412)
Farm Size	-0.1541415 (0.489)	-0.1271195 (0.362)	-0.0001102 (0.764)	-0.0016088 (0.900)	-0.0037061 (0.922)
Information on Climate Change	0.3769612 (0.102)	0.0825884 (0.491)	1.45e-06 (0.990)	0.0422931 (0.104)	0.1246245 (0.019)
Farming Experience	0.0113069 (0.421)	0.0053260 (0.315)	0.0000201 (0.759)	-0.0005006 (0.526)	-0.0020869 (0.323)

Perceived Rainfall	4.119767*** (0.000)	2.011732*** (0.001)	0.0014409 (0.759)	0.2604887 (0.137)	0.7615802*** (0.000)
Perceived Temperature	1.254189 (0.997)	1.32911 (0.997)	0.0005004 (0.997)	-0.0082609 (0.999)	-0.0142152 (0.999)

Note:

1. Figures in Parentheses are the p-values
2. ***, **, * signifies level of significance at 1%, 5% and 10% respectively
3. Move to different farmland is the base category

Source: Author's computation, 2021

8.3 Summary

This chapter presented the results of factors influencing climate change adaptation in the study area. A multinomial logistic regression model (MNL) was applied to investigate the factors influencing farmers' choices of climate change adaptation methods. Five climate change adaptation options were incorporated as dependent variables in the study which were integrated into the model and the explanatory variables include different socio-economic, institutional, climatic and farm characteristics factors. The marginal effects from MNL, which measure the anticipated change in probability of a specific choice being made with respect to a unit change in an independent variable, were presented and discussed for their easy interpretation. The results from the marginal analysis suggested that most of the socio-economic variables, institutional factors, climatic variables and farm characteristics factors influence the choice of adaptation techniques to climate in Southwestern Nigeria.

CHAPTER NINE

CLIMATE CHANGE ADAPTATION ADOPTION RATE AMONG MAIZE FARMERS IN SOUTHWESTERN NIGERIA

9.1 Introduction

The adoption rate of climate change among maize farmers in the study area was examined in this section. It was suggested that combatting climate change is a two-stage process: (1) raising knowledge of the reality of climate change; and (2) deciding to adapt and the rate at which a particular adaptation technique is adopted. Several adaption studies have confirmed this (Gbetibouo, 2009; Deressa et al., 2008; Maddison, 2007). As a result, the double hurdle model was used to determine the rate at which respondents in the study area adopted climate change adaptation measures. The findings were addressed considering existing research.

9.2 Climate change adaptation adoption rate among maize farmers in the study area

The maximum independent likelihood estimates of the independent double hurdle model is presented in Tables 9.1, 9.2 and 9.3 respectively for the pooled data, Ondo State and Oyo State. The log-likelihood ratio (LR) of 98.25, 59.92 and 47.21 as well as the information criteria confirmed the model's dependability. These findings suggest that the independent double hurdle model can effectively describe elements influencing the two-stage choice associated with the adoption decision of climate change adaptation and the rate of adaptation employed in the study area. According to Ondo and Oyo, the models' great explanatory power is indicated by the highly significant chi-square test ($p = 0.0000$) for the pooled sample. The first hurdle coefficients showed how explanatory variables influence the chance of choosing a climate change adaptation strategy, while the second hurdle coefficients showed how explanatory variables influence the rate of use of an adaptation method.

9.2.1 Determinants of adopting climate change adaptation strategy by the respondents in the study area

This section considers the result of the probit regression (first hurdle) in Tables 9.1; 9.2 and 9.3. It was revealed that farmers' decision to adopt climate change adaptation strategies was influenced by various factors. Farmers' perception about changes in climatic variables and attributes of different stated adaptation options were important determinants to adopting climate change adaptations.

The revelation of the double hurdle results shows that the coefficient of age is positive and highly significant to farmers making decision to adopt adaptation strategy in the study area (Tables 9.1; 9.2 and 9.3). This indicates that older farmers are more likely to adopt climate change adaptation strategy by choosing at least one adaptation option in the study area. This could be because of age being associated with farming experience. This is in line with Adesina and Baidu-Forson (1995) that found out that age is positively related to the adoption of new agricultural technology in Burkina Faso. Also, the result conforms to Deressa *et al.* (2008) who averred that age of the household head influenced adaptation to climate change.

The results (Table 9.1) show that respondents' marital status has a significant impact on whether they choose a plan for coping with climate change. The conclusion drawn from the results is that married farmers decide to implement adaption strategies, but unmarried respondents are more likely to decide on such strategies. In Ondo State, the coefficient of marital status is positive and not statistically significant. It could be inferred that married farmers in the state are likely to make climate change adaptation decision while the result from Oyo State revealed marital status to be positively significant ($p < 0.10$) and is an indication that married farmers has greater tendency to adopt climate change adaptation strategy. This implies that marital status can influence adoption decision because they will have more people in the home who will contribute to their knowledge of climate change and adaptation. Also, married farmers tend to have more people in the home who will contribute to labour input, hence, availability of more family labour to make use of different adaptation technologies on the farm. The result is in uniform with Nicolas *et al.* (2010) and Adebayo *et al.* (2008) who alluded that agriculture is primarily practiced by more married people.

The result shows that the relationship between literacy level of the respondents and climate change adoption decisions was positive and significant at $p < 0.01$ (Table 9.1). This was expected, as results of numerous studies from literature had discovered farmers' literacy level to influence adoption decisions (Asfaw and Admassie, 2004; Bamire *et al.*, 2002). Madison (2007) also stated that educated farmers are likely to respond to climate change menace by making at least one adaptation option.

According to Table 9.2, the first hurdle result for Ondo State established educational level of the respondents to be positively significant at 10% which indicates that the higher the farmer's literacy level, the better respondents adapt to climate change. Comparably, the Oyo State result revealed educational level of the respondents to be highly significant and positive in influencing climate change adaptation adoption. These results agree to Deressa *et al*. (2010) who asserted that education of farming household heads increased the likelihood of adapting to climate change.

The result shows that there is a positive and significant relationship between household size and the likelihood of adopting climate change adaptation strategy by the respondents in Southwestern Nigeria (Table 9.1) and in Oyo State (Table 9.3) while the relationship between household size and climate change adaptation adoption decision is positive but not statistically significant in Ondo State. This implies that respondent with larger household adapted to climate change by embracing adaptation strategy, *ceteris paribus.* This is in harmony with Fatuase (2016), Mugula and Mkuna (2016) and Deressa (2009) that larger household were more likely to engage in more agricultural production and are more likely to adapt to climate change.

In Table 9.1, the major occupation of the respondents is significant ($P < 0.01$) and has a positive correlation with the choice to use an adaptation strategy in the study area, while Tables 9.2 and 9.3 show that the major occupation of the respondents in Ondo and Oyo State is positively significant at 5%. As a result of the additional revenue they are earning, it was implied that respondents who did not rely solely on farming would be able to make adaptation decisions.

Table 9.1 showed land tenure to be significant ($P < 0.10$) and had a negative association with climate change adaptation adoption. The indication is that privately owned land increases the probability of choosing adaptation strategies most importantly, different technologies to cope to the negative effect of the phenomenon. Furthermore, privately owned land will reduce the cost incurred on lease. However, Birungi and Hassan (2010) stated that investing in land management is enhanced by land tenure security which agrees with the result of this study.

Tables 9.1, 9.2 and 9.3 revealed an inverse relationship between farm ownership and adoption of climate change adaptation strategy in the study area, Ondo State and Oyo State respectively. This shows that farm ownership and adoption of climate change adaptation strategy are negatively correlated. The indication is that individually owned farms are more likely to make adaptation decision than jointly owned farms. Similarly, there is possibility to invest more on individually owned farms. The result substantiates Maponya (2012) and Gbetibouo (2009) that ownership of the farm increases the probability of taking up adaptation strategies in their studies carried out in Limpopo province of South Africa.

As shown in Table 9.1, when all other parameters were held constant, the coefficient estimates of farm size had a significant positive effect (P = 0.78) on the adoption of an adaptation strategy in the research area. According to Tables 9.2 and 9.3, the size of the farm has a positive significant nexus with the adoption of climate change adaptation in the states of Ondo and Oyo. This suggests that farmers who operate large farms are more likely to adapt to climate change in the research area. The conclusion supports Gbetibuouo's (2009) research, which was done in the South African region of Limpopo, that a larger farm improves the likelihood that it will adopt adaptation measures. This shows that since large-scale farmers have more capital and resources, they are more likely to adapt. They can therefore afford to invest in on farm technologies, which has high upfront expenditures. The result is also in line with research by Udimal *et al.* (2017), which found that farmers with larger farms are more likely to adopt new technologies because they can afford to set aside a portion of their land to test them out and, should they be successful, do so fully, as opposed to those with smaller farms.

Information on climate change is a major variable of interest in this study, and this is highly statistically significant and positively influence the decision to adopt climate change adaptation in the study area (Table 9.1). This implies that climate change information received by the respondents increase the likelihood of making decision to adapt to changes in climate by adopting adaptation strategies.

Table 9.2 presented climate change information received by the farmers in Ondo State to be positive and significant ($P < 0.10$); likewise, Oyo State at 1% significance level (Table 9.3). This means that climate change information in the study area would increase farmer's awareness therefore, increasing farmer's knowledge on the phenomenon which could lead to adaptation decision. The results conform to Bryan *et al*. (2009) and Deressa *et al.* (2009), which stated that climate change information had a significant positive impact on climate change awareness and facilitate adaptation strategies among farmers. This is in line with "*a priori"* expectation. Additionally, this study substantiates Nhemachena and Hassan's (2007) findings that farmers who are cognizant of the effects of climate change are more likely to choose adaptation strategies like planting new varieties

A statistically positive relationship is found between climate change adoption decision and farming experience of the respondents (Tables 9.1, 9.2 and 9.3). This is in line with "*a priori"* expectation. The indication is that increase in farming experience will increase the probability of deciding to adopt climate change adaptation strategy because farming experience is key to farmer's decision making on the farm. This supports the claim made by Abegunde *et al.* (2020) that farming experience significantly raises the likelihood that people will accept technology and alter how they manage and grow their crops.

Table 9.1: The result of Double Hurdle Analysis of rate of adopting climate change adaptation strategies by the respondents in the Study Area (Pooled Data; N = 500)

	First Hurdle		**Second Hurdle**	
Variables	**Coefficients**	**Std. error**	**Coefficients**	**Std. error**
Age	0.4292631***	0.0923658	0.0084786	0.0080602
Gender	-0.0867956	0.207259	-0.0050689	0.016403
Marital Status	0.5416114*	0.2865261	-0.0255151	0.0159566
Educational Level	0.22588***	0.679298	0.0127364*	0.0065864
Household Size	0.1112156**	0.048326	-0.0063724**	0.0030956
Major Occupation	0.2982465***	0.0948997	0.0172545**	0.0073877
Major source of Income	-0.3203718	0.2514613	0.0073877***	0.0205945
Land Tenure	-0.134384*	0.0739598	-0.0083079	0.0053105
Farm Ownership	-1.197697***	0.1679274	-0.0042355	0.0145734

Farm Size	0.7799769***	0.2296685	0.0232041	0.016186
Information on Climate Change	1.000444***	0.2352388	-0.1091475***	0.0211576
Climate Change Awareness	-0.1836246	0.3041295	-0.0690356**	0.0269517
Farming Experience	0.0754922***	0.0120907	0.0037425***	0.0010523
Constant	-3.70965***	1.089105	0.5756938***	0.0780375
No. Of observation	500			
Wald chi^2 (14)	122.30			
Prob > chi^2	0.0000			
Log likelihood	98.247267			

Note:

***, **, * means significance at $P < 0.01$, $0.01 < P \leq 0.05$ and $0.05 < P \leq 0.10$ respectively

Source: Author's computation, 2021

Table 9.2: The result of Double Hurdle Analysis of rate of adopting climate change adaptation strategies by the respondents in Ondo State (N = 251)

	First Hurdle		Second Hurdle	
Variables	**Coefficients**	**Std. error**	**Coefficients**	**Std. error**
Age	0.2638176**	0.1135992	0.0097101	0.0098646
Gender	-0.0937391	0.2876943	-0.0117878	0.0222196
Marital Status	0.3708441	0.3464543	-0.0240551	0.0203203
Educational Level	0.169363*	0.0936615	0.0187789**	0.0086926
Household Size	0.0646439	0.0628189	-0.0029179	0.0041605
Major Occupation	0.2728071**	0.133716	0.0241474**	0.0101818
Major source of Income	-0.3496298	0.3571971	-0.0897456***	0.0291633
Land Tenure	-0.1166574	0.1048999	-0.0115529	0.0072082
Farm Ownership	-1.210876***	0.2346192	-0.0052966	0.0199509
Farm Size	0.5445356*	0.3121896	0.0328757	0.0225255
Information on Climate Change	0.8657502***	0.3273457	-0.1038486***	0.0288317
Climate Change Awareness	-0.0757532	0.4320896	-0.065024*	0.0363042
Farming Experience	0.0518953***	0.0154562	0.0036881***	0.0013668

Constant	-1.917988	1.386463	0.5051212***	0.103819
No. Of observation	251			
Wald chi^2 (14)	54.01			
Prob > chi^2	0.000			
Log likelihood	59.923601			

Note:

***, **, * means significance at $P < 0.01$, $0.01 < P \leq 0.05$ and $0.05 < P \leq 0.10$ respectively

Source: Author's computation, 2021

Table 9.3: The result of Double Hurdle Analysis of rate of adopting climate change adaptation strategies by the respondents in Oyo State (N = 249)

	First Hurdle		Second Hurdle	
Variables	**Coefficients**	**Std. error**	**Coefficients**	**Std. error**
Age	0.7172434***	0.1632223	0.0045602	0.0143744
Gender	-0.10039	0.3187426	0.0073716	0.0244589
Marital Status	0.9187943*	0.5342416	-0.0259454	0.0254842
Educational Level	0.3048912***	0.1054951	0.0051379	0.0102335
Household Size	0.1855028**	0.0818442	-0.0116405**	0.004735
Major Occupation	0.3716251**	0.1487453	0.0086568	0.0107762
Major source of Income	-0.164411	0.3716566	-0.0746433**	0.0293428
Land Tenure	-0.1693996	0.112026	-0.0037395	0.0079126
Farm Ownership	-1.253781***	0.2498686	-0.0034528	0.0210668
Farm Size	1.203797***	0.3662986	0.0118302	0.0232759
Information on Climate Change	1.305178***	0.3572813	-0.1247093***	0.0312951
Climate Change Awareness	-0.3851276	0.4477169	-0.0651144	0.0406999
Farming Experience	0.1122616***	0.0199078	0.0041171**	0.0016958
Constant	-6.798851***	1.977601	0.6715333***	0.1189246
No. Of observation	249			
Wald chi^2 (14)	67.69			

Prob > chi^2	0.000
Log likelihood	47.20478

Note:

***, **, * means significance at $P < 0.01$, $0.01 < P \leq 0.05$ and $0.05 < P \leq 0.10$ respectively

Source: Author's computation, 2021

9.2.2 Determinants of the intensity of adopting climate change adaptation strategy

The section examined the second part of the double hurdle model analysis which is regarded as the rate (intensity) of climate change adaptation adoption as shown in Tables 9.1; 9.2 and 9.3 respectively. The results revealed that after the decision-making part of adapting to climate change in the study area, most of the factors were no longer important in deciding the rate of adoption.

Amazingly, the most important variables in climate change adaptation adoption decision does not significantly determine the rate of adopting climate change adaptation in the study area. These variables include age, marital status, land tenure, farm ownership and farm size. Similarly, education level of the farmers, household size, major occupation, information received on climate change and farming experience of the respondents were statistically significant in both hurdles.

The second hurdle result (Truncated Regression) as revealed in Table 9.1 showed the coefficient of literacy level of the respondents to be positively significant ($P < 0.10$), implying that respondents with higher education may use different types of adaptation strategies likewise putting more lands for technology adoption to adapt to the negative impact of climate change. In Ondo State, the coefficient of educational status is positive and statistically significant (Table 9.2) but surprisingly, educational level of the respondents had a positive coefficient but not significant relationship with climate change adaptation intensity. The result is in tandem with *"a priori"* expectation that higher and better education influences the adoption and usage of more complex technology to combat climate change phenomenon. This is in line with the findings of Ganiyu *et al.* (2018), who claimed that family size, education level, and extension service are the primary determinants of the rate of technology adoption among food crop farmers in Oyo State, Nigeria. Similar results were found in studies by Akpan *et al.* (2012), Weyessa (2014), and Ganiyu *et al.* (2018) on the adoption rate of technologies in various farm products. These studies showed that sex, experience, yield, age education, family size, and extension agents were the factors that were observed to affect the adoption rate.

Household size was negatively significant at 5% in Southwestern Nigeria and Oyo State, respectively, according to the second hurdle result, in contrast to the first hurdle result where this variable was both significant and positive. The results indicated that although the size of a farming household affects decisions regarding adaptation to climate change, smaller households are more likely to intensify and engage in diverse types of adaptation. This might be because people of the research area are leaving agriculture in quest of non-farm employment, even though it has been suggested that participation in non-farm activities hinders involvement in farm production activities. The outcome agrees with Uttam *et al.* (2018).

Major occupation of the respondents in the second hurdle is positive and statistically significant at $P < 0.05$ in the pooled sample and Ondo state result (Table 9.1 and 9.2). This signifies a positive correlation with adaptation intensity. This implied that respondents with other means of livelihood aside farming can make adaptation intensity decision and have the financial capability to invest more on any form or adaptation methods.

Table 9.1 revealed major source of income to be statistically significant and positive in the second hurdle which shows that if farmers have more source of income apart from farming, then there is likelihood of such farmers to experiment on new technologies to adapt to climate change unlike smallholders that are still struggling with income from the proceed from there farm. At state level, the coefficients of major source of income are negatively significant to the rate of climate change adaptation strategies in Ondo and Oyo State (Tables 9.2 and 9.3). This imply that farming as the major source of income may reduce the intensity of adopting climate change strategies in the two states. This could be as a result that smallholder farmers were risk averse.

Information on climate change is another variable that is statistically significant in both hurdles and confirms its essentiality in the adoption of climate change adaptation strategies. This variable is inversely significant related to climate change adaptation intensity (Tables 9.1, 9.2 and 9.3). The indication is that the more information about the negativity of climatic variables information the farmers are exposed to could reduce the intensity of adaptation strategy in the study area.

As expected, farming experience of the respondents is positive and significant to the rate of adopting climate change adaptation (Table 9.1) in the study area. Farming experience is important to farmer's decision making on the farm and this increases the likelihood of employing more adaptation options on more agricultural lands than someone without farming experience. In Ondo State, farming experience is highly statistically significant to climate change adaptation intensity ($P < 0.01$). Similarly, Oyo State has the same result which shows how farmers' experience is imperatively important to agricultural productivity. This is in line with Aminu and Okeowo (2016) and Ibrahim *et al.* (2015), that farming experience would positively impact productivity.

9.3 Summary

This chapter expounds climate change adaptation rate among the respondents in the study area. The study affirmed that there were two stages (decision to adapt and intensity of adaptation) involved in coping with climate change phenomenon. The study revealed the meanings of climate change adaptation and adaptation intensity and how the decision could be made either separately or jointly. The study used a double hurdle model to analyse the adoption rate of climate change adaptation in the study area because it is believed that adoption may come before intensity. It was discovered in the study that age, marital status, education, household size, land tenure, farm ownership, farm size, information received on climate change and farming experience influenced climate change adaptation adoption decision while education, household size, major occupation, major source of income, information received on climate change and farming experience were the influencing variables for adoption intensity in the study area.

CHAPTER TEN

CLIMATE CHANGE EFFECT ON FARMERS' PRODUCTIVITY IN SOUTHWESTERN NIGERIA

10.1 Introduction

In this chapter, the impact of climate change on agricultural productivity was discussed. The impact of climate change on farmer productivity in the study area was examined using two-stage least square regression. The findings were addressed considering existing research.

10.2 Two-stage least square regression model estimates

The causal effect of climate change on farmer productivity was estimated using the instrumental variable (IV) technique of the Two-Stage Least Square (2SLS) estimator. In the productivity model, the outcome demonstrated that revenue was endogenous. First, the occurrence of multicollinearity in the 2SLS regression model with instrumental variables was investigated. The estimated eigenvalue of the pooled data was 7.23, which was less than the critical value of 10 (Gujarati and Porter, 2009; Shiferaw *et al.*, 2008), indicating that multicollinearity was not a problem. The critical value of 10 was bigger than the Ondo state model's minimum eigenvalue of 4.87 and the Oyo state model's minimum eigenvalue of 4.67, showing that multicollinearity is not a concern in the state models.

At the 1% level of significance, the overall test of probable endogeneity in the model produced Durbin (score) chi^2 (1) = 15.089 (p-value = 0.0076) and Wu-Hausman F (1,466) = 12.08546 (p-value = 0.0097). As a result, the null hypothesis that all the variables are exogenous was rejected. This implies that endogeneity should be considered during the estimation procedure. Furthermore, the partial R-squared value (0.421 or 42.1%) is far greater than the critical nominal 5% Wald test values, and the first-stage ordinary least square (OLS) regression estimates of F-statistics for joint significance of instruments are also highly significant, F (2,466) = 10.2388 (p-value = 0.0000). Consequently, the null hypothesis that the instruments are weak is rejected. Thus, instrumental variables have the explanatory power for the endogenous variable.

In the state model, Durbin (score) chi^2 (1) = 12.25 (p-value = 0.00024) and Wu-Hausman F (1,223) = 10.5182 (p-value = 0.00059) at 1% level of significance for Ondo state likewise for the Oyo state model, a Durbin (score) chi^2 (1) = 11.07 (p-value = 0.00016) and Wu-Hausman F (1,223) = 10.163 (p-value = 0.000198) at 1% level of significance showed that the null hypothesis that all the variables in the model were exogenous cannot be accepted. This suggests that the endogeneity problem must be addressed. Because the partial R-squared value (41.9%) for Ondo state and (46.4%) for Oyo state were considerably greater than the critical nominal 5% Wald test values, the model rejects the null hypothesis that the instruments were weak. Furthermore, the first-stage OLS regression estimates of F-statistics for joint significance of instruments, F (2, 223) = 4.87295 (p-value = 0.0085) and F (2, 223) = 4.67384 (p-value = 0.0103), are highly significant for both states. This demonstrates that instrumental variables can explain the endogenous variable.

The Sargan test was used to check whether the instrument was correlated with any of the error term in the system (over identification). The Sargan (score) chi^2 (1) = 0.02405 (p-value = 0.8768) for pooled sample, chi^2 (1) = 0.915279 (p-value = 0.3387) and chi^2 (1) = 0.847239 (p-value = 0.3573) for Ondo and Oyo state models. The null hypothesis is accepted since the instrumental variable is valid and not linked with the error term.

10.2.1 Results and discussion

The result of the 2SLS models for farmers' productivity in Southwestern Nigeria, Ondo and Oyo states are shown in Table 10.1, 10.2, 10.3 respectively. For the pooled sample, the following variables, revenue, climate change adaptation adoption rate, gender, educational level, farm ownership and farming experience were positively significant with productivity while farmer's age and farm size had significant inverse association with productivity (Table 10.1).

In Ondo state, revenue, climate change adaptation adoption rate, educational level, household size, major occupation and farm ownership had positive significant relationship with productivity while major source of farmer's income and farming experience were negatively significant with farmers' productivity (Table 10.2). However, Table 10.3 established revenue, climate change adaptation adoption rate, land tenure, household size and farm ownership to be positively significant in Oyo state while age was inversely significant to farmer's productivity.

The positive coefficients suggest that the variables have the power to influence an increase in the farmer's productivity level. Any increase in the value of such a variable would result in a rise in productivity. Because the relationship is inverse, every rise in the variable's value will result in a drop in productivity. The result revealed farmers' revenue to be positively significant at 5% in the pooled sample and Oyo state results while farmers' revenue was statistically significant at 10% and positive in Ondo state. This infers that higher revenue increases farmers' productivity by employing the appropriate climate change adaptation.

As indicated in Table 10.2, climate change adaptation rate was positively statistically significant at $P < 0.01$ as the same variable was significant and positive in Ondo and Oyo state at 1% and 10% respectively. Farmers' acceptance of climate change adaptation enhances farm productivity in the study research area, according to the findings.

It was found that age has a negatively significant effect on farmers' productivity in the study area (Table 10.2), *ceteris paribus*. In Ondo state, age has a negative coefficient but not statistically significant (Table 10.3) while age as a variable in Oyo state is inversely significant to productivity at 10% level of significance (Table 10.4). The assumption is that older farmers are less productive than younger farmers who are more technologically savvy. This result validates the findings of Boughton *et al.* (2007) who projected an inverse coefficient for maize productivity in Mozambique. Olwande and Mathenge (2012), Reyes *et al.* (2012), Siziba *et al.* (2011), and Rios *et al.* (2009) are some of the other studies that support a negative estimated coefficient for age.

Gender has a coefficient of 0.1472 ($P = 0.098$) in the 2SLS result for the pooled data, making it positively significant at 10% (Table 10.2). This could be explained by male farmers' ability to be more labour efficient, as well as female farmers' lack of access to production resources such as land, credit, and other productivity-enhancing inputs (Rahman, 2009). The findings support Oparinde's (2021) claim that male gender boosts farm output. It also agrees with Oyakhilomen (2014), who found a favorable association between gender and maize farmer income in Kaduna State, Nigeria.

As demonstrated in Table 10.2, the respondents' educational degree had a favorable influence on productivity that was highly statistically significant at 1%. With all other factors held constant, educated farmers were able to increase their yield by adopting newly learned technologies. This was to be expected, given multiple studies in the literature shown that a farmer's educational level has a beneficial impact on productivity (Kondo, 2019; Ouma and Abdulai. 2009; Barrett, 2008). This is in line with the findings of Kondo (2019), Enete and Igbokwe (2009), Randela *et al.* (2008), Onoja and Unaeze (2008), who stated that education will provide the family with improved production and administrative abilities, resulting in higher productivity and output. The positive significant relationship between farmers' educational level and productivity in Ondo state is in line with *"a priori"* expectations. The implication is that the level of education can enhance farmers' understanding and adoption of better agricultural methods to improve farm productivity which is in harmony with Onubuogu *et al.* (2014) and Nhemachena and Hassan (2007).

Farm size was shown to be significant ($P < 0.01$) and had a positive relationship with maize productivity in the study area (Table 10.2). The findings show that the larger the farm, the greater the opportunity for farmers to increase their productivity. This finding justifies the study of Rios *et al.* (2009), who discovered that farmers in Tanzania and Vietnam who had more land per worker are more productive. The findings contradict those of Anang (2019) and Larson *et al.* (2012), who established that productivity decreases with farm size. As a result, it is anticipated that as the size of the farm grows, so will the farmer's productivity.

According to Table 10.2, household size was positively insignificant with farmer productivity in the pooled sample, although it could be inferred that larger households would increase maize productivity in the area if members were involved in agricultural activities. At the 1% significance level, the findings from Ondo and Oyo states revealed a significant positive association between household size and farmer productivity (Tables 10.3 and 10.4). This means that large agricultural households could enlarge productivity, especially if family members are engaged as farm labour. They could also influence the adoption of new technology or farming techniques, reducing the impact of climate change on maize output. This is consistent with the findings of Fatuase (2016), Mugula and Mkuna (2016), and Deressa (2009), who found that large rural households were more likely to engage in agricultural production.

Farming experience is positively significant to farmer's productivity in the study area (Table 10.2). This is in line with the *"a priori"* expectation because it is important to farmer's decision making on the farm. The pooled result validates the outcome of Aminu and Okeowo (2016), Ibrahim *et al.* (2015) that farming experience would positively impact productivity. Surprisingly, farming experience had a negative and significant effect on productivity in Ondo state (Table 10.3). This signified a negative correlation between farming experience and farmer's productivity level. This could be that farmers with little experience probably were more receptive to changes and adoption of new techniques of maize farming unlike their experienced counterparts in the state. This could also be because of adverse effect of conservatism of the maize farmers in the state, who believed they already knew the best method and technology in maize farming more than what the extension agents had to offer them. The result corresponds to Onoja and Unaeze (2008), that discovered a negative significant relationship between farming experience and rice farmers in their study carried out in Enugu state, Nigeria.

According to Table 10.2, it was indicated that farm ownership positively influences maize productivity in the study area. Equally, the state results showed that farm ownership is statistically significant and positive at 5% level of probability in Ondo state (Table 10.3) while the same variable is significant at 1% level in Oyo state (Table 10.4). It can be deduced from the result that cooperate farms tends to produce more compared to individually own farms.

In Oyo state, land tenure is statistically significant and beneficial to farmers' productivity at a 1% significant level (Table 10.4). The reasoning is that improving land security boosts maize productivity in Oyo state, and vice versa. The findings are consistent with those of Iheke (2010), who observed that uncertain property rights over land reduces land activity dramatically by discouraging farmers from investing meaningfully in land because the land is returned to the owner after the planting season.

As indicated in Table 10.3, major occupation of the respondents is positively significant to farmer's productivity in Ondo state at $P < 0.05$. It may be assumed that farmers in Ondo state who have other sources of income than farming have the financial means to invest more in the farm and, as a result, increase agricultural productivity. Equally, major source of income of the respondents was found to be negatively significant to productivity in Ondo state (Table 10.3). The implication is that agriculture is the primary source of income, which could have an impact on agricultural productivity. Even though the coefficients of source of income in the pooled sample and Oyo state models are negatively insignificant, it is reasonable to believe that farming is the primary source of revenue for maize farmers in the research area.

Table 10.1: Two-stage least square regression analysis result of the effect of climate change on farmers' productivity (Pooled Sample)

TFP	Coefficients	Standard Error	Z-Statistics	P>|Z|
Revenue	2.80e-07	1.29e-07	2.17	0.030**
Adaptation Rate	0.0165276	0.0061266	2.70	0.007***
Age	-0.0280615	0.0059412	-4.72	0.000***
Gender	0.1471682	0.0888273	1.66	0.098*
Marital Status	-0.0175971	0.0416709	-0.42	0.673
Educational level	0.6716415	0.2086512	3.22	0.001***
Household Size	0.0003976	0.0080363	-0.05	0.961
Major Occupation	0.0275184	0.0185156	1.49	0.137
Major Source of Income	-0.0342028	0.0495088	-0.69	0.490
Land Tenure	0.0057027	0.0159124	0.36	0.720
Farm Ownership	0.1281312	0.0674234	1.90	0.057 *
Farm Size	0.0280615	0.0059412	-4.72	0.000***
Information on Climate Change	0.0159042	0.0396779	0.40	0.689
Farming Experience	0.0000401	3.92e-06	10.23	0.000***
Increased Rainfall	0.0701198	0.0530754	1.32	0.186
Increased Temperature	0.0701198	0.0502191	0.40	0.686
Constant	0.2385381	0.223192	1.07	0.285

Note:

TFP signifies Total Factor Productivity

***, **, * means significance at P < 0.01, 0.01 < P ≤ 0.05 and 0.05 < P ≤ 0.10 respectively

Source: Author's computation, 2021

Table 10.2: Two-stage least square regression analysis result of the effect of climate change on farmers' productivity (Ondo State)

TFP	Coefficients	Standard Error	Z-Statistics	P>|Z|
Revenue	2.24e-06	1.14e-06	1.96	0.052*
Adaptation Rate	0.2089749	0.0505596	4.13	0.000***
Age	-0.0038406	0.0229946	-0.17	0.867
Gender	0.0124324	0.0553455	0.22	0.822
Marital Status	-0.02122	0.0606314	-0.35	0.726
Educational level	0.5207655	0.1610753	3.23	0.001***
Household Size	0.1868859	0.0460784	4.06	0.000***
Major Occupation	0.0544351	0.0268778	2.03	0.043**
Major Source of Income	-0.3377472	0.1198238	-2.82	0.005***
Land Tenure	-0.0023302	0.0234536	-0.10	0.921
Farm Ownership	0.3373239	0.1416919	2.38	0.017**
Farm Size	-0.0139122	0.0549402	-0.25	0.800
Information on Climate Change	0.0147105	0.054221	0.27	0.786
Farming Experience	-0.1504919	0.058255	-2.58	0.010***
Increased Rainfall	0.0607458	0.0792782	0.77	0.444
Increased Temperature	0.0452127	0.0687282	0.66	0.511
Constant	0.1487539	0.3409359	0.44	0.663

Note:

***, **, * means significance at P < 0.01, 0.01 < P ≤ 0.05 and 0.05 < P ≤ 0.10 respectively

Source: Author's computation, 2021

Table 10.3: Two-stage least square regression analysis result of the effect of climate change on farmers' productivity (Oyo State)

TFP	Coefficients	Standard Error	Z-Statistics	P>|Z|
Revenue	4.94e-06	2.46e-06	2.01	0.044**
Adaptation Rate	0.2665908	0.1472135	1.81	0.070*
Age	-0.0595544	0.0325386	-1.83	0.067*
Gender	0.0144127	0.0590058	0.24	0.807
Marital Status	0.0308665	0.072797	0.42	0.672
Educational level	0.0055842	0.0194626	0.29	0.774
Household Size	0.166939	0.0589062	-2.83	0.005***
Major Occupation	0.0057809	0.0258618	0.22	0.823
Major Source of Income	-0.0085369	0.0697502	-0.12	0.903
Land Tenure	0.0086005	0.0031763	2.71	0.007***
Farm Ownership	0.3693163	0.1194137	3.09	0.002***
Farm Size	0.0043627	0.0575167	0.08	0.940
Information on Climate Change	0.0200189	0.0563788	0.36	0.723
Farming Experience	0.0046756	0.0034598	1.35	0.177
Increased Rainfall	0.0851619	0.068124	1.25	0.211
Increased Temperature	-0.9558625	0.4020281	-2.38	0.20
Constant	0.2765832	0.3220655	0.86	0.390

Note:

***, **, * means significance at $P < 0.01$, $0.01 < P \leq 0.05$ and $0.05 < P \leq 0.10$ respectively

Source: Author's computation, 2021

10.3 Summary

This chapter delves deeper into the effects of climate change on farmer productivity in the study area. The causal effect of climate change on farmers productivity was estimated using the Two-Stage Least Square (2SLS) estimator of the instrumental variable (IV) technique. A thorough estimation test was carried out to ensure that the assumptions underlying the usage of 2SLS for the study were satisfied. Farmers' revenue was found to be endogenous, thus it was included in the empirical study. Revenue, climate change adaptation adoption rate, age, gender, educational level, household size, farm ownership, farm size, and farming experience are all significant exogenous variables that affect maize farmers' productivity.

CHAPTER ELEVEN

SUMMARY, CONCLUSION AND RECOMMENDATIONS

11.1 Summary

The study investigated climate change impacts on maize productivity in Southwestern, Nigeria. The study used a scientific technique to examine the socio-economic characteristics of maize farmers; the trend and growth rate of maize yield and climatic variables between 1979 and 2020; the relationship that existed between some selected variables and maize yield in the study area; adaptations measures used by maize farmers; factors that influence climate change adaptation measures used by maize farmers in the study area; and the rate of adoption of adaptation measures by maize farmers in the study area; and the effect of climate change on farmers' productivity in the study area.

This research used both cross-sectional and time-series data. The cross-sectional data was gathered via a well-structured questionnaire, while the time-series data was obtained from NIMET and ADPs and covered the years 1979 to 2020. Only 500 questionnaires were found to be suitable for analysis after a multistage sampling approach was employed to choose 540 respondents for the study. To address each of the study's objectives, descriptive statistics, trend and growth function analysis, auto-regressive distributed lag model, multinomial logistic regression, and double hurdle as well as two-stage least square regression were used as the analytical methods.

The socio-economic characteristics results revealed that majority of the respondents (36.8%) were between age ranges 46-55 years while 38.2% of the respondents in Ondo state are >56 years of age and 42.2% of maize farmers in Oyo state were between age ranges 46-55. Maize production in the study area was dominated by male farmers, about 81.2% were male in the study area whereas in Ondo state 78.9% of the farmers were male and 83.5% of the respondents in Oyo state were also male. Findings from the result indicated that 88.6% of the pooled sample were married and 88.8% of farmers in Ondo state were also married and Oyo state recorded 88.4% married maize farmers.

Few of the respondents (2.4%) had no formal education in the study area. In Ondo and Oyo states, the average size of a farmer's household was roughly 6 people, with 65.3% and 49.8% of respondents having families of between 1 and 5 people per household, respectively. Most farmers (74.6%) stated farming as their primary occupation, with 82.1% of respondents from Ondo state and 67.1% of respondents from Oyo state stating farming as their main occupation. In the pooled sample, 39.6% of the farmers had 11–15 years of farming experience, while 51.0% and 28.1% of maize farmers from Ondo and Oyo states, respectively, had 11–15 years of farming experience. Renting was a key source of land for the respondents, with 45.0%, 51.0%, and 39.0% (pooled, Ondo and Oyo states) correspondingly renting their farmed land. The bulk of the farms (58.8%) were independently owned, and roughly 59.6% managed their own farm, according to the findings. Farmers in the research region had an average farm size of roughly 2 hectares, indicating that maize farmers were smallholders.

The average maize yield value for Ondo and Oyo states were 1.817484mt/ha and 1.551895mt/ha respectively over the period under study. The average rainfall was 190.88mm and 155.57mm while the average relative humidity was 76.08% and 82.73% for Ondo and Oyo states. Furthermore, the average temperature for the two states were 26.37 for Ondo state and 26.20 for Oyo state. The result recorded a positive growth rate values of 6.18%, 0.40% and 0% in maize yield, temperature and rainfall while relative humidity recorded a growth rate of -0.099 for Ondo state. Similarly, positive growth rate values for maize yield, temperature and relative humidity of 6.08%, 0.40% and 0% were reported in Oyo state were as Oyo rainfall had a negative growth rate of -0.099. The result further revealed acceleration in the growth of maize yield and temperature of Ondo and Oyo states in the period under consideration.

The results of co-integration test using autoregressive distributed lag (ARDL) model revealed rainfall and relative humidity to be stationary at level *I(0)* while maize yield and temperature were stationary at first difference *I(1)* in both states using augmented dickey fuller test of statistics. The result is an affirmation of long run association among the variables when maize yield was regressed against explanatory variables rainfall, relative humidity and temperature. The long run estimate results revealed rainfall to be positively significant with maize yield while temperature had a negative impact on maize yield in Ondo state and there was no significant relationship between maize yield and climatic variables at long run in Oyo state. The ECM value from the Ondo state model was statistically significant at 1% and had a value of -0.133, implying that 13.3 percent of disequilibria in maize yield from the previous year's shock converge to the long run equilibrium in the current year, according to the short run dynamic coefficients results associated with the long run co-integration relationships. The negatively significant ECM value of -0.079635 for Oyo state, on the other hand, indicated that the state's equilibrium was restored slowly and efficiently. In Oyo state, almost 7.96% of disequilibria in the maize enterprise from the previous year's shock had converged to the long run equilibrium this year.

The study found that 94.2% of respondents in the study area were aware of climate change, with 92.4% and 96.8% claiming awareness in Ondo and Oyo states, respectively. Farmers' perception on climate change elicited a variety of responses. The combined result revealed that 63.2% of farmers in the research area perceived delayed/erratic rainfall, with 78.5% in Ondo state and 47.8% in Oyo state. Farmers in the pooled, Ondo, and Oyo states reported that rainfall was decreasing at 36.2%, 20.3%, and 52.2%, respectively. The respondents' perceptions of temperature revealed a range of replies, with 94.6% stating an increase in temperature in the study area, 2.8% reporting a decrease, and 2.6% maintaining no change in temperature. According to the state results, 94.4% and 94.8% of maize farmers in Ondo and Oyo states, respectively, said the temperature is rising, while 5.6% and 5.2% revealed a dwindling temperature.

The adoption intensity of climate change adaptation was studied using a double hurdle model. Most of the criteria were shown to be insignificant in determining the adoption intensity following the decision-making phase of adapting to climate change in the research area. Age, marital status, educational level, household size, land tenure, farm ownership, farm size, information on climate change, and farming experience were found to be determinants of climate change adaptation in the study area, whereas educational level, household size, major occupation, major source of income, information on climate change, climate change awareness, and farming experience were found to be determinants of climate change adaptation intensity in the pooled data. Climate change adaptation was influenced by age, educational level, major occupation, farm ownership, farm size, information on climate change, and farming experience in Ondo state, while climate change adaptation rate was determined by educational level, major occupation, major source of income, information on climate change, climate change awareness, and farming experience. Climate change adaptation intensity in Oyo state is determined by household size, major source of income, information on climate change, climate change awareness, and farming experience, as well as age, marital status, educational level, household size, farm ownership, farm size, information on climate change, and farming experience.

The 2SLS result showed revenue to be endogenous and therefore was instrumented in the empirical analysis and significant exogenous variables that affect maize farmers' productivity include revenue, climate change adaptation adoption rate, age, gender, educational level, household size, farm ownership, farm size and farming experience in the pooled sample. The result from Ondo state revealed revenue, climate change adaptation adoption rate, educational level, household size, major occupation, source of income and farming experience influence productivity while in Oyo state, revenue, climate change adaptation adoption rate, age, household size, land tenure, farm ownership affect farmers' productivity.

11.2 Conclusion

The study was conducted to fill a perceived gap in the literature by looking into the effects of climate change on maize productivity in Southwestern Nigeria. Based on the outcomes of this investigation, the following conclusions were reached:

1. Most maize farmers in the study area were experienced and knowledgeable about how climatic conditions affect maize yield.

2. Time had a significant impact on maize productivity and climate in the study area

3. Climatic variables greatly influenced maize productivity both at short run and long run in the study area.

4. The study area's climate change adaption techniques are influenced by farmers' perceptions and awareness of climate change.

5. Climate change adaptation in the research area was influenced by socio-economic, institutional, farm, and climatic variables.

6. Climate change adaptation adoption intensity in the research region is not significantly influenced by the most important variables in determining climate change adaptation adoption decision.

7. Farmer's income, adaptation intensity, gender, educational level, farm ownership and farming experience had impact on maize farmer's productivity in the study area.

11.3 Recommendations

Based on the findings of this study, the following policy recommendations were made:

1. The government should develop productivity-enhancing measures that include formal agricultural education, simple access to agricultural inputs, and agricultural diversification.

2. The findings demonstrated that female respondents in Southwestern Nigeria were better adapted to climate change than male respondents, defying predictions, and literature that rural female farmers participate in small-scale farming to maintain a sustainable livelihood. It is strongly advised that the government develop programs that promote women to work in agriculture.

3. When designing and implementing agricultural policies, the government should constantly incorporate farmers' perceptions of climate change.

4. There ought to be enhancement of farmers' knowledge about different adaptation strategies that were mentioned by the farmers in the study area.

5. A proactive land use act should be enacted to provide farmers in the study region with more secure land ownership, allowing them to invest and implement a long-term adaptation strategy.

11.4 Suggestions for future research

Future research projects in the following areas are required:

1. Future research on gender and climate change adaptation could give more knowledge about the elements that influence gender-based adaptation to climate change.

2. Another potential research target area will be inequalities perceived by women in the rhetoric of climate change and agricultural productivity.

3. Relationship between climatic variables and agricultural productivity using other co-integration approaches in the study area and Nigeria should undergo further research.

4. Climate change adaptation using indigenous knowledge system in the study area and Nigeria at large.

5. Climate change effects on other food crops such as legumes, sorghum, millet, tubers etc should be researched in the study area and Nigeria.

11.5 Contribution to knowledge

The purpose of the study was to fill a knowledge gap about how climate change affect maize productivity in southwest, Nigeria. The study provided information on various empirical frameworks for addressing the research issues, and it is anticipated that the study will provide research findings that might be used by present and future students, decision-makers, and planners. This would assist in the creation of appropriate policies and mitigation strategies that would decrease the negative effects of climate change on agricultural productivity and farm households' means of sustenance.

This study provided information on the connections between climatic variables and maize yield; it was discovered that climatic variables (rainfall, temperature, and humidity) have negative effects on maize yield as well as agricultural output outside of certain climatic limits. The study also discovered that the climate in the study area and maize productivity were significantly influenced by time. Given that climate forecasts show an increase in climatic variability in the future, these contributions are helpful to stakeholders in the agricultural sector who are involved in creating and implementing appropriate policies for adaptation and mitigation.

The study would also make a significant contribution to communicating the many empirical and methodological approaches used in describing trends and variability of climatic parameters and assessing the response of agricultural output to climatic changes and socio-economic variables. The research's methodology and empirical analytical strategies could be built upon by future studies looking at the impact of climate variability on efforts to increase agricultural yield.

Even though the study was carried out in southwestern part of Nigeria, the study would also provide research findings to policy makers in Nigeria and other developing nations, which would aid in the design of policies, adaptation, and mitigation strategies that can significantly lessen the negative effects of changing climate factors on crop yield and farming households' livelihood. Concerned decision-makers and planners may use the study's findings as a basis for a proposal to analyse the potential impact of climate change on agriculture, food availability, food affordability and food security.

REFERENCES

Abegunde, V.O., Sibanda, M. and Ajuruchukwu, O. (2020). Determinants of the adoption of climate-smart agricultural practices by small-scale farming households in King Cetswayo district municipality, South Africa. *Sustainability*, Vol. 12(1).

Adejuwon, S.A. (2004). Impacts of climate variability and climate change on crop yield in Nigeria. *Paper presented at the stakeholders' workshop on assessment of impacts and adaptation to climate change (AIACC), conference centre, Obafemi Awolowo University, Ile-Ife, Osun State,* pp 271-279

Agbola, P. and Fayiga, A.O. (2016). Effects of climate change on agricultural production and rural livelihood in Nigeria. *African Journal Online,* Vol, 15 No. 1. ISSN: 1596 – 5511

Ajala, S. B. (2017). Perceived effects of climate change on agricultural production of smallholder crop farmers in the Lowveld areas of Mpumalanga Province, South Africa. An MSc dissertation submitted to Department of Agriculture and Animal Health, College of Agriculture and Environmental Sciences, University of South Africa.

Ajetomobi, J., Abiodun, A. and Rashid, H. (2011). Impacts of climate change on rice farming in Nigeria. *Tropical and Subtropical Agroecosystems*, Vol. 14; pp 613-622

Akpan, S.B., Veronica, S.N. and Essien, U.A. (2012). A double-hurdle model of fertilizer adoption and optimum use among farmers in Southern Nigeria. *Tropicultural*, 30 (4): pp. 249-253

Anang, B.T. (2019). Effect of off-farm work on agricultural productivity: empirical evidence from northern Ghana. *Agricultural Science and Technology*, Vol. 11, No. 1: 49-58

Apata, T.G., Samuel, K.D. and Adeola, A.O. (2009). Analysis of climate change perception and adaptation among arable food crop farmers in Southwestern Nigeria. *Contributed Paper Prepared for Presentation at the International Association of Agricultural Economists' Conference, Beijing, China,* August 16-22, 2009.

Ayinde, O.E., Ajewole, O.O., Ogunlade, I., and Adewumi, M.O. (2010). Empirical analysis of agricultural production and climate change: A case study of Nigeria. *Journal of Sustainable Development in Africa*, Vol. **5**, No. 6.

Ayinde, O.E., Muchie, M. and Olatunji, G.B. (2011). Effect of climate change on agricultural productivity in Nigeria: A co-integration model approach. *Journal of Human Ecology,* 35(3), pp 189-194.

Ayoade, A. R. (2012). Determinants of climate change on cassava production in Oyo State, Nigeria. *Global Journal of Science Frontier Research: Agriculture and Biology.* Vol.12(3)

Baede, A. P. M., E. Ahlonsou, Y. Ding, and D. Schimel, (2001). The climate system: An overview. In: Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [J. T. Houghton, Y. Ding, D. J. Griggs, M. Noquer, P. J. van der Linden, X. Dai, K. Maskell and C. A. Johnson (eds.)].

Bayar, Y. (2014). Effect of foreign direct investment inflows and domestic investment on economic growth: Evidence from turkey. *International journal of Economics and Finance.* 6(4): 69-78.

Bello, O.B., Ganiyu, O.T., Wahab, M.K.A., Afolabi, M.S., Oluleye, F., Mahmud, J., Azeez, M.A. and Abdumaliq, S.Y. (2012). Evidence of climate change impacts on Agriculture and food security in Nigeria. *Journal of Environmental Studies,* 5(1): 123-156

Belloumi, M. (2014). Investigating the impact of climate change on agricultural production in Eastern and Southern African countries. *AGRODEP Working Paper 0003. Washington DC: International Food Policy Research Institute.*

Blein, R., Bwalya, M., Chimatiro, S., Dupaigre-Faivre, B., Kisira, S. and Wambo-Yamdjeu, A. (2013). African agriculture, transformation and outlook. *NEPAD,* pp 72

Boughton, D., Mather, D., Barrett, C.B., Benfica, R., Abdula, D., Tschirley, D. and Cunguara, B. (2007). Market participation by rural households in a low-income country: An asset-based approach applied to Mozambique. *Faith and Economics.* Vol. 50: pp 64-101.

Bryan, E., Deressa, T.T., Gbetibuouo, G.A. and Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa options and constraints. *Environmental Science and Policy,* Vol. 12. pp 413-426

Chikezie, C., Ibekwe, U.C., Ohajianya, D.O., Orebiyi, J.S., Ehirim, N.C., Henri-Ukoha, A., Nwaiwu, U.O., Ajah, E.A., Essien, U.A., Anthony, G. and Oshaji, I.O. (2015). Effect of climate change on food crop production in Southeast, Nigeria: A Co-Integration Model Approach. *International Journal of Weather, Climate Change and Conservation Research,* Vol.2, No.1, pp 47-56

Coster, A.S., and Adeoti, A.I. (2015). Economic effect of climate change on Maize production and farmers' adaptation strategies in Nigeria: A Ricardian approach. *Journal of Agricultural Science,* Vol. **7**, No. 5.

Connolly-Boutin, L. and Smit, B. (2016). Climate change, food security and livelihoods in sub-Saharan Africa. *Regional Environmental Change*, Vol 16, No. 2; pp 385-399

Creswell, J.W. (2014). *Research designs: Qualitative, quantitative and mixed methods approaches (4th Edition)*. Sage publication, Thousand Oaks, California, USA.

Deressa, T., Hassan, R.M., Alemu, T., Yesuf, M. and Ringler, C. (2008). Analysing the determinants of farmers' choice adaptation methods and perceptions of climate change in the Nile Basin of the Ethiopia. *IFPRI Discussion Paper 00798.* September, 2008.

Deuschênes, O. and Greenstone, M. (2007). The economic impacts of climate change: Evidence from Agricultural output and random fluctuations in weather. *The American Economic Review,* Vol. 97, No. 1, pp 354-385

De vos, A.S., Strydom, H., Fouche, C.B. and Delport, C.S.L. (2015). *Research at grassroots: For the social sciences and human service professions.* (4th edition). Van Schaik Publishers, South Africa

Ebe, F.E., Obike, K.C., Ugboaja, C.I. and Ezelu, C. (2018). Effect of land tenure security on food productivity among arable crop farmers in Isuikwuato local government area of Abia State, Nigeria. *Nigerian Agricultural journal*, Vol. 49, No 2: pp 211-217

Engle, R.F. and Granger, C.W.J. (1987). C0-integration and Error Correction: Representation, Estimation and Testing. *Econometrica*, 55: 251-276.

Ekundayo, B.P. (2019). The effects of climate change on cassava production in Southwest Nigeria. PhD thesis. Department of Agricultural and Resource Economics. Federal University of Technology, Akure.

Eregha, P.B., Babatolu, J.S. and Akinnubi, R.T. (2014). Climate change and crop production in Nigeria: An error correction modelling approach. *International Journal of Energy Economics,* Vol. 4, No 2: pp 297-311

Food and Agriculture Organisation, FAO. (2010). Climate change adaptation and mitigation: new initiatives and update on agriculture, forestry and fisheries proceedings: *Thirtieth FAO regional conference for the Near East. December 4th-8th, 2010, Khartoum, the Republic of Sudan.*

Food and Agriculture Organisation, FAO. (2011). The state of food and agriculture – An FAO perspective, Rome.

Food and Agriculture Organisation, FAO. (2016). The state of food and agriculture. *Climate change, agriculture, and food security.* Pp 4

Fasola, T.R. (2007). Controlling the advancement of savanna into Southwestern Nigeria. *Zonas Aridas,* Vol. 11, No. 1; pp 251-259

Galindo, L.M., Reyes, O. and Alatorre, J.E. (2015). Climate change, irrigation and agricultural activities in Mexico: A Ricardian analysis with panel data. *Journal of Development and Agricultural Economics,* Vol. 7, No. 7; pp 262-273. Doi: 10.5897/JDAE2015.0650

Ganiyu, M.O., Oladeebo, J.O. and Omotayo, A.O. (2018). Analysis of poverty level and land management practices among maize-based food crop farmers in Oyo State, Nigeria. *Journal of Agricultural Economics and rural Development,* vol. 4, No. 1; pp 397 - 407

Getu, A. (2014). The effects of climate change on livestock production, current situation and future consideration. *African Journal of Animal Production and Husbandry,* Vol. 1, No. 3; pp 029-034

Golafshani, N. (2003). *Understanding reliability and validity in qualitative research. The Qualitative Report.* (Vol. 8. No. 4, pp 597-607) Available at: http://www.nova.edu/ssss/QR/QR8-4/golafshani.pdf. Retrieved July 30th, 2015.

Granger, C.W.J. (1983). Cointegrated variables and error correction models. UCSD discussion paper, 83-139

Granger, C.W.J. and Weiss, A.A. (1983). Time series analysis of error-correcting models' in studies in Econometrics, time series and multivariate statistics. New York: Academic Press, 255-278, (fourth edition). McGraw-Hill, New York

Idumah, F.O., Mangodo, C., Ighodaro, U.B., and Owombo, P.T. (2016). Climate change and food production in Nigeria: Implication for food security in Nigeria. *Journal of Agricultural Science,* Vol. 8, No. 2; pp 74-83

Iglesias, A., Garrote, L., Quiroga, S. and Moneo, M. (2012). A regional comparism of the effects of climate change on agricultural crops in Europe. *Climate Change*, Vol. 112, pp29-46

Intergovernmental Panel on Climate Change (2007). Climate change: Impacts, adaptation and vulnerability. *Working Group II Contribution to the Fourth Assessment Report of IPCC.* United Kingdom, Cambridge University press.

Juana, J.S., Makepe, P.M., and Mangadi, K.T. (2012). Empirical analysis of the impact of drought on Botswana economy, presented at the *AERC/UNU-WIDER climate change workshop, Helsinki, 25-29.* September, 2012

***Keele, L. and Suzanna, D. (2004). Not just for cointegration: Error correction models with stationary data.

Khanal, U., Wilson, C., Lee, B.L. and Hoang, V. (2018). Climate change adaptation strategies and food productivity in Nepal: A counterfactual analysis. *Climatic Change*, Vol. 148; pp 575 – 590

Kumar, R. and Gautam, H. (2014). Climate change and its impact on Agricultural productivity in India. *Journal of climatology and weather forecasting*, Vol. 2(1); pp 109

Kurukulasuriya, P. Mendelsohn, R. (2006). A Ricardian analysis of the impact of climate change on African cropland. *CEEPA Discussion No 8. Centre for Environmental Economics and Policy in Africa, University of Pretoria*

Kurukulasuriya, P. and Rosenthal, S. (2003). Climate change and agriculture: a review of impacts and adaptations. *Climate Change Series paper* No. 91. Environmental Department and Agriculture and Rural Development Department, World Bank, Washington DC.

Larson, D.F., Otsuka, K., Matsumoto, T. and Kilic, T. (2012). Should African rural development strategies depend on smallholder farms? An exploration of the inverse productivity hypothesis. *Policy research Working Paper 6190.* Washington, DC: World Bank, Agriculture and Rural Development Team.

Lee, C. and Chiu, Y. (2011). Nuclear energy consumption, oil prices and economic growth: Evidence from highly industrialized countries. *Energy Economics*, 33 (2), 236-248

Maddison, D. (2007). The perception of and adaptation to climate change in Africa. *Policy Research Working Paper 4308.*

Mandleni, B. (2011). Impact of climate change and adaptation on cattle and sheep farming in the Eastern Cape province of South Africa. PhD thesis. Department of Environmental Management. University of South Africa.

Narayan, P.K. (2005). The saving and investment nexus for China: Evidence from cointegration tests. *Applied Economics,* 37: 1979-1900.

National Bureau of Statistics (NBS) (2010). *Statistical bulletin.* National Bureau of Statistics, Abuja

Ndambiri, H.K., Ritho, C.N. and Mbogoh, S.G. (2013). An evaluation of farmers' perceptions of and adaptation to effects of climate change in Kenya. *International Journal of Food and Agricultural Economics,* Vol. 1, No. 1; pp 75-96. ISSN 2147-8988

Nhemachena, C. (2008). Agriculture and future climate dynamics in Africa: Impacts and adaptation options. PhD thesis. Department of Agricultural Economics, Extension and Rural Development. University of Pretoria.

Obioha E.E (2009). Climate change, population drift and violent conflict over land resources in Northeastern Nigeria. *Journal of Human Ecology*, 23(4): 311-324

Oduniyi, O.S. (2018). Implication of climate change on livelihood and adaptation of small and emerging maize farmers in the Northwest Province of South Africa. PhD thesis. Department of Environmental Science. University of South Africa.

Odjugo, P.A.O. (2010). Regional evidence of climate change in Nigeria. *Journal of Geography and Regional Planning,* Vol. 3, No. 6; pp 142-150

Odjugo, P.A.O. (2007). The impact of climate change on water resources; global and regional analysis. *The Indonesian Journal of Geography,* 39, 23-41.

Odjugo, P.A.O. (2005). An analysis of rainfall pattern in Nigeria. *Global Journal of Environmental* Science, 4 (2), 139-145.

Olutunmise, A.I., Okogbue, E.C. and Omonijo, A.G. (2017). Assessing relationship between selected climate variables, human diseases and crop production using ARDL Approach-the example of Ondo State, Nigeria. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*. Vol.17, issue 3 pp 253-264

Olwande, J. and Mathenge, M. (2012). Market participation among poor rural households in Kenya. *In Paper Presented at the International Association of Agricultural Economists Triennial Conference, Brazil. (18-24 August).*

Onubuogu, G.C. and Esiobu, N.S. (2014). Trends, perceptions and options of arable crop farmers to climate change in Imo State, Nigeria: A logit multinomial model approach. *World journal of Agricultural Sciences,* Vol. 2(5), pp 108-122. ISSN 2329-9312

Onyeneke, R.U., Igberi, C.O., Uwadoka, C.O. and Aligbe, J.O. (2018). Status of climate-smart agriculture in Southeast Nigeria. *GeoJournal,* Vol. 83, No. 2: pp 333-346.

Onyenweaku, C.E. and Ezeh, N.O.A. (1987). "Trend in production, area and productivity in cocoyam in Nigeria 1960/61-1981/84", Paper presented at the conference organized by the

Root Crop Research Institute, Umudike.

Oparinde, L.O. (2017). Effect of production and climate-risks on small-holder cassava and maize farmers' output in Southwestern Nigeria. PhD thesis. Department of Agricultural and Resource Economics. Federal University of Technology, Akure.

Oparinde, L.O., and Okogbue, E.C. (2018). Analysis of climate-related risk and maize production in Southwest, Nigeria. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*. Vol.18, issue 1 pp 287-298

Otitoju, M.A. (2013). The effects of climate change adaptation strategies on food crop production efficiency in Southwestern Nigeria. PhD thesis. Department of Agricultural Economics. University of Nigeria.

Oyakhilomen, O. (2014). Gender influence on the income of maize farmers in Giwa Local Government Area of Kaduna State. *Russian Journal of Agricultural and Socio-Economic Sciences,* 1(25): 14 – 18

Oyekale, A., Bolaji, M. and Olowa, O. (2009). The effects of climate change on cocoa production and vulnerability assessment in Nigeria. *Agricultural Journal.* Retrieved from http://www.medwelljournals.com/fulltext/?doi=aj.2009.77.85

Ozor, N., Madukwe, M.C., Enete, A.A., Amaechina, E.C., Onokola, P., Eboli, E.C., Ujah, O. and Garforth, C. J. (2010). Barriers to climate change adaptation among farming households of Southern Nigeria. *Journal of Agricultural Extension.* 14(1) June *2010.*

Panda (2016). Exploring climate change perceptions, rainfall trends and perceived barriers to adaptation in a drought affected region in India. *National Hazards.* Doi 10.1007/s11069-016-2456-0

Pesaran, M.H., Shin, Y., and Smith, R.J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics.* Vol. 16, pp 289-326. Doi: 10.1002/jae.616

Polit, D.F. and Beck, C.T. (2004). *Nursing research: Principles and methods (7th Edition).* Lippincott Williams and wilkins, New York.

Reyes, B., Donovan, C., Bernsten, R. and Mareda, M. (2012). Market participation and sale of potatoes by smallholder farmers in the central highlands of Angola: A double hurdle approach. *In Selected Paper Prepared for Presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Brazil. (18-24 August).*

Rios, R.A., Shively, G.E. and Masters, W.A. (2009). Farm productivity and market participation: Evidence from LSMS data. *Paper presented at the International Association of Agricultural Economics Conference, Beijing, China, August 16-22.*

Rose, R.M. (2015). The impact of climate change on human security in the Sahel Region of Africa. *Donnish Journal of African Studies and Development.* Vol. 1, No. 2: pp 009-014

Roudier, P., Sultan, B., Quirion, P. and Berg, A. (2011). The impact of future climate change on West Africa crop yields: what does the recent literature say? *Global Environmental Change* Vol 21, issue 3, pp 1073-1083.

Rudolf, W. and Herman, W. (2009). Climate risk and farming systems in rural Cameroon. Institute of development and agricultural economics. University of Hannover Germany. Pp 21-24

Sango, I. (2013). An investigation of communal farmers' livelihoods and climate change challenges and opportunities in Makonde rural district of Zimbabwe. Doctor of literature and Philosophy research thesis. Department of Environmental Science. University of South Africa.

Saravanakumar, V. (2015). Impact of climate change on yield of major food crops in Tamil Nadu, India. *SANDEE Working Paper* No. 91-15.

Singh, A. and Purohit, B. (2014). Public health impacts of global warming and climate change. *Peace Review: A Journal of Social Justice*, Vol. 26, No 1: pp 112-120.

Siziba, S., Kefasi, N., Diagne, A., Fatunbi, A.O. and Adekunle, A.A. (2011). Determinants of dereal market participation by sub-Saharan Africa smallholder farmer. *Learning Publics Journal of Agriculture and Environmental Studies.* Vol. 2, No 1: pp 80-193

Tambo, J.A., and Abdoulaye, T. (2011). Climate change and agricultural technology adoption: The case of drought tolerant maize in rural Nigeria. *Mitigation Adaptation Strategy Global Change.* Vol. 17, pp 277-292. Doi 10.1007/s11027-011-9325-7

Tetteh, E.M., Opareh, N.O., Ampadu, R. and Antwi, D.K.B. (2014). Impacts of climate change: Views and perceptions of policy makers on smallholder agriculture in Ghana. *International Journal of Sciences: Basic and Applied Research.* Vol. 13, No. 1: pp 79-89

Traerup, S.L.M. and Mertz, O. (2011). Rainfall variability and household coping strategies in Northern Tanzania: a motivation for district – level strategies. *Regional Environmental Change*, Vol. 11, No 3: pp 471-481

Udimal, T.B., Jincai, Z., Mensah, O.S. and Caesar, A.E (2017). Factors influencing the agricultural technology adoption: The case of improved rice varieties (Nerica) in the Northern Region Ghana. *Journal of Economics and Sustainable Development* Vol. 8, No 8. pp 137 – 148. ISSN 2222-1700

United Nations Framework Convention on Climate Change, UNFCCC. (2011). Application of methods and tools for assessing impacts and vulnerability and developing adaptation responses. Background paper by UNFCCC Secretariat. FCCC/SBSTA/2011/INF.13. UNFCCC. Bonn, Germany.

Weyessa, B.G. (2014). A double-hurdle approach to modelling of improved tef technologies adoption and intensity use in case of diga district of east wollega zone. *Global Journal of Environmental Research*, Vol. 8, No. 3; pp 41 - 49

World Bank (2013). The bank annual world development report. Retrieved January 4th, 2019, from https://www.worldbank.org/EXTAR2009/Resources/9304887-1377201212378/9305896-1377544753431/1_Annual report 2013_EN.pdf

World Meteorological Organization (1992). A guide to meteorological instruments and method observation: seventh edition

Yesuf, M., Difalce, S., Deressa, T., Ringler, C. and Kohlin, G. (2008). The impact of climate change and adaptation on food production in low-income countries: Evidence from the Nile Basin, Ethiopia, International ‘Food Policy Research Institute Discussion (IFPRI) Paper No. 00828. Environment and Production Technology Division. IFPRI, Washington D.C.

APPENDIX A: SOCIO-ECONOMIC CHARACTERISTICS TABLE

Table 4.1: Frequency distribution of respondents by their socio-economic characteristics

Variable	Pooled Sample (N=500)		Ondo State (N=251)		Oyo State (N=249)	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Age (years)	**Mean = 3.9**		**Mean = 3.98**		**Mean = 3.85**	
19-35	49	9.8	25	10.0	24	9.6
36-45	106	21.2	51	20.3	55	22.1
46-55	184	36.8	79	31.5	105	42.2
>56	161	32.2	96	38.2	65	26.1
Total	**500**	**100.0**	**251**	**100.0**	**249**	**100.0**
Gender	**Mean = 1.19**		**Mean = 1.21**		**Mean = 1.17**	
Male	406	81.2	198	78.9	208	83.5
Female	94	18.8	53	21.1	41	16.5
Total	**500**	**100.0**	**251**	**100.0**	**249**	**100.0**
Marital Status	**Mean = 2.07**		**Mean = 2.02**		**Mean = 2.13**	
Single	21	4.2	14	5.6	7	2.8
Married	443	88.6	223	88.8	220	88.4
Divorced	14	2.8	10	4.0	4	1.6
Widowed	22	4.4	4	1.6	18	7.2
Total	**500**	**100.0**	**251**	**100.0**	**249**	**100.0**
Educational Status	**Mean = 4.47**		**Mean = 4.45**		**Mean = 4.48**	
No formal education	12	2.4	6	2.4	6	2.4
Adult education	21	4.2	11	4.4	10	4.0
Vocational training	33	6.6	13	5.2	20	8.0
Primary	174	34.8	95	37.8	79	31.7
Secondary	176	35.2	86	34.3	90	36.1
Post-Secondary	84	16.8	40	15.9	44	17.7
Total	**500**	**100.0**	**251**	**100.0**	**249**	**100.0**
Household Size	**Mean = 5.47**		**Mean = 5.45**		**Mean = 5.50**	
1-5	288	57.6	164	65.3	124	49.8

6-10	176	35.2	78	31.1	98	39.4
11-15	26	5.2	3	1.2	23	9.2
>15	10	2.0	6	2.4	4	1.6
Total	**500**	**100.0**	**251**	**100.0**	**249**	**100.0**
Major Occupation	**Mean = 1.53**		**Mean = 1.46**		**Mean = 1.59**	
Farming	373	74.6	206	82.1	167	67.1
Employed	61	12.2	13	5.2	48	19.3
Trading	36	7.2	17	6.8	19	7.6
Self-employed	10	2.0	4	1.6	6	2.4
Business	10	2.0	5	2.0	5	2.0
No occupation	10	2.0	6	2.4	4	1.6
Total	**500**	**100.0**	**251**	**100.0**	**249**	**100.0**
Farming Experience	**Mean = 5.24**		**Mean = 5.14**		**Mean = 5.34**	
2 – 5 years	40	8.0	15	6.0	25	10.0
6 – 10 years	94	18.8	45	17.9	49	19.7
11 – 15 years	198	39.6	128	51.0	70	28.1
16 – 20 years	41	8.2	15	6.0	26	10.4
>20 years	127	25.4	48	19.1	79	31.7
Total	**500**	**100.0**	**251**	**100.0**	**249**	**100.0**
Farming as major income	**Mean = 1.31**		**Mean = 1.25**		**Mean = 1.36**	
Yes	364	72.8	188	74.9	159	63.9
No	136	27.2	63	25.1	90	36.1
Total	**500**	**100.0**	**251**	**100.0**	**249**	**100.0**
Purpose for maize cultivation	**Mean = 2.22**		**Mean = 2.18**		**Mean = 2.25**	
Personal consumption	67	13.4	35	13.9	32	12.9
Selling of surplus	257	51.4	135	53.8	122	49.0
Commercial purposes	176	35.2	81	32.3	95	38.2
Total	**500**	**100.0**	**251**	**100.0**	**249**	**100.0**

Land Tenure	**Mean = 3.04**		**Mean = 3.19**		**Mean = 2.89**	
Owned	91	18.2	39	15.5	52	20.9
Communal	121	24.2	52	20.7	69	27.7
Permision to own	14	2.8	7	2.8	7	2.8
Renting	225	45.0	128	51.0	97	39.0
Others	49	9.8	25	10.0	24	9.6
Total	**500**	**100.0**	**251**	**100.0**	**249**	**100.0**
Who owns the farm	**Mean = 1.60**		**Mean = 1.60**		**Mean = 1.59**	
Individual	294	58.8	154	61.4	140	56.2
Family members	144	28.8	63	25.1	81	32.5
Farmers group	35	7.0	18	7.2	17	6.8
Corporation	24	4.8	13	5.2	11	4.4
Trust	3	.6	3	1.2	0	0
Total	**500**	**100.0**	**251**	**100.0**	**140**	**56.2**
Who manages the farm	**Mean = 1.68**		**Mean = 1.53**		**Mean = 1.82**	
Individual	298	59.6	167	66.5	131	52.6
Family member	131	26.2	55	21.9	76	30.5
Farmer's group	20	4.0	8	3.2	12	4.8
Corporation	37	7.4	21	8.4	16	6.4
Trust	14	2.8	0	0	14	5.6
Total	**500**	**100.0**	**167**	**66.5**	**249**	**100.0**
Farm size	**Mean = 2.26**		**Mean = 2.24**		**Mean = 2.27**	
<1	20	4.0	9	3.6	11	4.4
1-5	364	72.8	189	75.3	175	70.3
6-10	84	16.8	36	14.3	48	19.3
11-15	32	6.4	17	6.8	15	6.0
Total	500	100.0	251	100.0	249	100.0
Total Factor Productivity		**Mean = 0.43**		**Mean = 0.46**		**Mean = 0.40**
<1	490	98.0	246	98.0	244	98.0
1	10	2.0	5	2.0	5	2.0

Total	500	100.0	251	100.0	249	100.0

Source: Computed from Field data, 2021

APPENDIX B: QUESTIONNAIRE

RURAL HOUSEHOLD QUESTIONNAIRE SURVEY

DEPARTMENT OF AGRICULTURE AND ANIMAL HEALTH

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

UNIVERSITY OF SOUTH AFRICA

CLIMATE CHANGE EFFECTS ON MAIZE PRODUCTIVITY IN SOUTHWESTERN NIGERIA.

Dear respondent, I am **Seun Boluwatife Ajala,** a PhD student with the University of South Africa. I would like to conduct a study in your area which is part of the requirement towards the fulfilment of my studies for a doctoral degree in Agriculture with the university. The study is simply for academic, and your participation is completely voluntary and highly appreciated.

Questions pertaining to your farming household and characteristics will be asked. The findings of the study will be disseminated through reports, conferences, seminars, and journal articles. The interview will take about 30 minutes. You are assured that the information provided will only be used for research purposes and your identities are confidentially kept, however, it will not be linked to your responses. Furthermore, no information will be disclosed to a third party without your consent.

You have the right to withdraw the interview at any time without any penalty. Thank you for your participation. If you have any question, please feel free to contact Seun Boluwatife by email ajalaseunb@gmail.com or 57634270@mylife.unisa.ac.za. You can also reach him on +2347067958482

Firstly, we would like to talk with you about climate change. Climate change is a change in climate that is attributed directly or indirectly to human activity that alters the composition of global atmosphere and which is in addition to natural climate variability observed over comparable time periods (UNFCCC, 1992). This may take several forms such as unusual timing of seasons, changes in temperature and rainfall pattern, more frequent and severe extreme weather events (floods, droughts, storms,……..) more frequent salinity intrusion, a rise in sea level compared with average sea level for several previous years.

Have you ever heard about Climate change? 1. Yes 2. No

Has your farm household been cultivating maize for at least 10years? 1. Yes 2. No

Please, go ahead with respondents answering “Yes” to the above questions, otherwise terminate the interview

Instructions to answer the questions

The questions come in different forms and so require different forms of answers. The questions are largely closed-ended types whereby you select your answer from a given set of options by means of ticking in the box corresponding to your chosen answer. The other type of questions is open-ended, whereby in your own words you give the answer in the spaces/s provided.

Questionnaire number:

State: Please tick the appropriate box

STATE	Osun	Oyo	Ondo	Ogun	Ekiti
ZONE					

SECTION A:

SOCIO-ECONOMIC CHARACTERISTICS OF THE RESPONDENT (FARMER)

1	2	3	4	5	6	7
Age, Actual Then Indicate the corresponding age range that you fall into <18years ……….....1 19 – 35 years ….. 2 36 – 45 years…... 3 46 – 55 years …. 4 > 56……………. 5	Gender Male..…..1 Female….2	Marital Status Single………....1 Married……….2 Divorced.….….3 Widowed.….…4 Separated……..5 Other (Specify)……..6	Educational Status Post-Secondary……….…….6 Secondary………….……..5 Primary……….……….4 Vocational Training…………..…. 3 Adult Education……….……. 2 No formal Education…..…….…...1	Size of the household	Major Occupation Farming……. ….. 1 Employed…….… 2 Trading……….… 3 Self-employed….. 4 Business………... 5 Pensioner……..… 6 No occupation….. 7	Is farming your major source of income Yes…... 1 No……. 2

8. Indicate by making a tick why you are cultivating maize

	Response
Personal consumption --- 1	
Mostly own, but small surplus is sold out -------------------- 2	
Commercial purposes --- 3	
Industrial purposes -- 4	
Other, please specify -- 5	

LAND CHARACTERISTICS

9. Land tenure system

Private (own)	Communal	Permission to own	Renting	Other (Specify)

10. Who owns the farm?

Individual	Family members	Farmers' group	Corporation/ Company farm	Trust	Other (Specify)

11. Who manages the farm?

Individual	Family members	Farmers' group	Corporation/ Company farm	Trust	Other (Specify)

12. What is the size of the farm? Write the actual farm size, then go ahead by ticking the range the farm size falls into in the box below

<1 hectare	1 – 5 hectares	6 – 10 hectares	11 – 15 hectares	16 – 20 hectares	>20 hectares

SECTION B:

CLIMATE CHANGE INFORMATION AND AWARENESS; PLEASE TICK IN THE APPROPRIATE BOX BELOW.

1. Do you receive information on climate change?

Yes	No

2. Is there any awareness on climate change in your locality?

Yes	No

3. Are you aware of climate change?

Yes	No

NB: If “No”, please go to next section on “perceptions of climate change”.

4. If Yes in 3, do you agree with the following statement

	Response	Code
Climate change results in increased frequency of droughts in the areas		1 = Strongly agree 2 = Agree 3 = Undecided 4 = Disagree 5 = Strongly disagree
Climate change results in increased frequency of floods in the areas		
Some of the activities being done by human beings contribute to climate change		
Uncontrolled burning of forests contribute to climate change		
Exhaust fumes (CO_2) from vehicles contribute to climate change		
Emissions (CO_2) from industries contribute to climate change		
Uncontrolled cutting down of trees contribute to climate change		
There are many ways human can implement mitigation strategies on climate change		
Planting of trees will help to mitigate climate change		
Some areas will receive more rainfall while others will receive less rainfall than they used to receive		

5. If yes in 3, did you get to know about climate change from the following

	1 = Yes 2 = No
Learnt from formal schooling	
Learnt from non-formal schooling (adult education)	
Read or hear about it in media (newspapers, magazines, newsletters, radio, television, internet etc.)	
Extension system	
From other people	
Own observation	
Other	

6. If responded Yes in 5, please rank the responses starting with the most important in contributing to your knowledge of climate change

	Response	Code
Learnt from formal schooling		1 = Most important 2 = Second most important
Learnt from non-formal schooling (adult education)		
Read about it in print media (newspapers, magazines, newsletters etc.)		
Heard it from electronic media (radio, television, internet etc.)		
Extension system		

From other people		3 = Third most important 4 = fourth most important
Own observation		
Other		

7. Does the information you get make any difference in your production?

Yes	No

SECTION C:
FARMERS' OBSERVATION ON CLIMATE CHANGE

1. Have you observed any climatic changes?

Yes	No

2. If yes, which of the climatic variables is changing?

Rainfall	Drought	Increased Temperature	Strong wind	No wind	Other (specify)

3. What perceptions did you have on long term rainfall changes?

Increase rainfall	
Decrease rainfall	
Rainfall has not changed	
No changes of rainfall are observed	
Other, (specify)	

4. What perceptions did you have on long term temperature changes?

Increase temperature	
Decrease temperature	
Temperatures has not changed	
No changes in temperature are observed	
Other, (specify)	

5. What perceptions did you have on long term wind changes?

Increase whirl wind	
Increase in normal wind	
Wind blowing has no changed	
No changes in wind blowing have been observed	
Other, (specify)	

6. Have you experienced the following in your area?

Floods	Drought	Strong wind	Increased temperature	Decreased temperature	Frost	Other (specify)

7. How has climate change affected your crops?

	Response	Code
Increased production		1
No change in production		2
Decreased production		3
No production		4
Other (specify)		7

8. What impacts has climate had on your livelihood?

	Response	Code

Increased socio- economic problems		1
Decreased socio- economic problems		2
Reduced income		3
Increased income		4
Increased unemployment		5
Reduced cultivated lands		6
Reduced cultivated practices		7
Increased cultivated land		

9. What impacts has climate had on agricultural production?

	Response	Code
Increased land fertility		1
Reduced land fertility		2
Increased crop yield		3
Reduced crop yield		4
Increased crop diseases		5
Decreased crop diseases		6
Increase livestock production		7
Reduced livestock production		8
Other, specify		9

10. What impacts has climate change had on food security?

	Response	Code
Increased employment		1
Decreased employment		2
Increased income		3
Reduced income		4
Scarcity of food		5
Reduced food prices		6
Increased food prices		7
Lack of local markets		8
Other (specify)		9

SECTION D:
FARMERS ADAPTATION MEASURES

1. For how long have you been a farmer?

Never	Less than 2 years	Between 2-5 years	Between 6-10 years	Between 11-15 years	Between 16-20 years	21 years and more

2. Did you adapt/cope to climate change?

Yes	No

3. What are the perceived adaptations options?

	Response	Code
Plant different crops (multi-cropping)		1
Plant different varieties of crops		2
Crop diversification		3
Use different planting dates		4
Move to different farmland		5
Planting of cover crops		6
Crop rotation		7

Change the amount of land		8
Change crops farming to livestock farming		9
Change to mixed farming (planting crops and livestock together)		10
Change from farming to non-farming		11
Increase irrigation system		12
Change the use of chemicals, fertilizers, and pesticides		13
Increase water conservation		14
Soil conservation		15
Use insurance		16
Use subsidies		17
Use prayer		18
Other, specify		19
No perceived adaptations		20

4. What measures did you take to adapt to climate change?

5. If you did not adapt, what made you not to adopt adaptation measures?

	Response	Code
Lack of information		1
Lack of money		2
Not aware of climate change		3
Do not know what to do		4
Lack of technical-know-how		5
Distance to weather stations		6
Distance to input markets		7
Differences in agro ecological zones		8
Other, specify		9
Not applicable		10

SECTION E:
MAIZE PRODUCTION

1. How long has your farming household been growing maize? (Years) ___________________
2. How much agricultural land do you own? _______________
3. How much was your planted area of maize last planting season? ________________
4. What was your maize output last year? (Ton/year)
5. What are the varieties of maize been planted? Mention them ……………….; …………….; …………….
6. Do you have good quality maize seed after harvest? (1) Yes [ ] (2) No [ ]
7. Is there any profit generated at the end of the planting season? Yes [ ] No [ ] N/A [ ]

FARM HOUSEHOLD INCOME AND ASSETS

8. Please let us know how much your farm household earns from the following sources (after tax and cost)

S/N	Sources	Amount (Naira)	Period (Yearly/Monthly)
1	Maize		
2	Other crops		
3	Livestock		
4	Off-farm jobs		
5	Other income (Specify)		

9. (i) Do you diversify to other crops? (1) Yes [ ] (2) No [ ]

   (ii) If yes, what is(are) the crop(s)? ………………………………………………………………

   (iii) How long have you been diversified to other crops? ……………………… years

10. Information cost and benefits before adaptation strategies

S/N	Cost incurred	Amount (Naira)
1	Land preparation	
2	Planting Materials (seed)	
3	Labour	
4	Other Inputs	
5	Area Expansion under cultivation	
6	Pest Management	
7	Other Costs	
8	Yield/Output	
9	Revenue	

11. If you have challenges coping with the effects of climate change, please kindly state why you did not cope and the perceived solutions
    ………
    ………
    ………
    ………………………………………………………………………………………………

Thank you for your time.
Compiled by: Ajala Seun Boluwatife, University of South Africa

APPENDIX C: CONSENT FORM

UNISA university of south africa

PARTICIPANT INFORMATION SHEET

Ethics clearance reference number: **2020/CAES_HREC/155**

Research permission reference number:

Title: CLIMATE CHANGE EFFECTS ON MAIZE PRODUCTIVITY IN SOUTHWESTERN NIGERIA

Dear Prospective Participant

My name is **AJALA** Seun Boluwatife and I am conducting a research with Dr. Chagwiza Claire, a senior lecturer in the Department of Agriculture and Animal Health towards a PhD at the University of South Africa. We are inviting you to participate in a study entitled Climate Change effects on maize productivity in Southwestern Nigeria

WHAT IS THE PURPOSE OF THE STUDY?

This study is projected to proffer a better understanding of attributes of climate change and food crop productivity. Also, the findings would produce some policy inferences which agricultural stakeholders and policy makers could employ to help farmers on various subjects of climate change impacts, practices and livelihood, which will adequately enhance farmers' way of life. The policy proposition of this study would be to position some drastic measures and practices in order to deal with the effects of climate change on farmers hence encouraging adaptation method in ensuing betterment in living standard among the rural poor.

WHY AM I BEING INVITED TO PARTICIPATE?

The study is for maize farmers to adapt to climate change effect on production and livelihood in the study area because maize is a major food crop in Nigeria. The major reason of choosing the smallholder maize farmers is because of the adverse negative effect of climate change on crop production without the ability to adapt to the menace especially in the developing countries.

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

The details of the smallholder maize farmers will be obtained from the state Agricultural Department Program (ADP) offices. A total of 540 participants will be interviewed in this study so as to have a robust result.

WHAT IS THE NATURE OF MY PARTICIPATION IN THIS STUDY?

The study involves audio/video taping / questionnaires / surveys / focus groups / semi-structured interviews, etc. during data gathering and each session will take approximately 15 minutes to be completed.

CAN I WITHDRAW FROM THIS STUDY EVEN AFTER HAVING AGREED TO PARTICIPATE?

Participating in this study is voluntary and you are under no obligation to consent to participation. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a written consent form. You are free to withdraw at any time and without giving a reason but it won't be possible once you have submitted the questionnaire.

I understand that I may withdraw from the interview/project at any time. I therefore participate voluntarily until I request otherwise.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?

This research will proffer a better understanding of farmers' to climate change phenomenon and its effects on maize productivity. Findings from this study will reveal the vulnerability of the rural household to climate change. Hence, it will also serve as guide for the intervention agencies to know the appropriate measures/strategies to adopt. The findings will also produce some policy inferences for encouraging effective adaptation strategies, which will be valuable to local maize farmers in Southwestern geopolitical zone of Nigeria and the country at large.

ARE THEIR ANY NEGATIVE CONSEQUENCES FOR ME IF I PARTICIPATE IN THE RESEARCH PROJECT?

There are no negative consequences for participating in this research.

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

WILL THE INFORMATION THAT I CONVEY TO THE RESEARCHER AND MY IDENTITY BE KEPT CONFIDENTIAL?

The opinions of the farmer /participant are viewed as strictly confidential and only members of the research team will have access to the information. No data published in thesis and journals will contain any information through which farmer/participant may be identified. Your anonymity is, therefore ensured.

Also, based on the focus group discussion where farmers/participants will come together to have discussion about climate change and maize productivity; While every effort will be made by the researcher to ensure that you will not be connected to the information that you share during the focus group, I cannot guarantee that other participants in the focus group will treat information confidentially. I shall, however, encourage all participants to do so. For this reason I advise you not to disclose personally sensitive information in the focus group.

HOW WILL THE RESEARCHER(S) PROTECT THE SECURITY OF DATA?

Hard copies of your answers will be stored by the researcher for a period of five years in a locked cupboard/filing cabinet *at the University of South Africa* for future research or academic purposes; electronic information will be stored on a password protected computer. Future use of the stored data will be subject to further Research Ethics Review and approval if applicable.

WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICIPATING IN THIS STUDY?

There shall be no payment by the researcher to the participant, but the researcher will make the participants comfortable during all forms of data gathering.

HAS THE STUDY RECEIVED ETHICS APPROVAL

This study has received written approval from the Research Ethics Review Committee of the College of Agriculture and Environmental Sciences, Unisa. A copy of the approval letter can be obtained from the researcher if you so wish.

The study has also received a written approval from the ministry of Agriculture and the State ADP office.

HOW WILL I BE INFORMED OF THE FINDINGS/RESULTS OF THE RESEARCH?

If you would like to be informed of the final research findings, please contact **AJALA** Seun Boluwatife on +2347067958482 or ajalaseunb@gmail.com. The findings are accessible for a period of two years after the research has been conducted. Should you require any further information or want to contact the researcher about any aspect of this study, please contact **AJALA** Seun Boluwatife on the above phone number or email address.

Should you have concerns about the way in which the research has been conducted, you may contact Chagwiza Claire (PhD) on cchags@gmail.com or Fax number 0866045382

Contact the research ethics chairperson of the CAES General Ethics Review Committee, Prof MA Antwi on 011-670-9391 or antwima@unisa.ac.za if you have any ethical concerns.

Thank you for taking time to read this information sheet and for participating in this study.

AJALA Seun Boluwatife

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

CONSENT TO PARTICIPATE IN THIS STUDY

I, __________________ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunity to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable).

I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.

I agree to the recording of the <insert specific data collection method>.

I have received a signed copy of the informed consent agreement.

Participant Name & Surname.. (Please print)

Participant Signature.. Date....................

Researcher's Name & Surname.. (Please print)

Researcher's signature... Date....................

APPENDIX D: UNISA ETHICS APPLICATION OUTCOME

UNISA university of south africa

UNISA-CAES HEALTH RESEARCH ETHICS COMMITTEE

Date: 22/01/2021

Dear Mr Ajala

NHREC Registration # : REC-170616-051
REC Reference # : 2020/CAES_HREC/155
Name : Mr SB Ajala
Student #: 57634270

Decision: Ethics Approval from 21/01/2021 to 31/01/2026

Researcher(s): Mr SB Ajala
ajalaseunb@gmail.com

Supervisor (s): Dr C Chagwiza
cchags@gmail.com

Working title of research:
Climate change effects on maize productivity in southwestern Nigeria

Qualification: PhD Agriculture

Thank you for the application for research ethics clearance by the Unisa-CAES Health Research Ethics Committee for the above mentioned research. Ethics approval is granted for five years, **subject to submission of yearly progress reports. Failure to submit the progress report will lead to withdrawal of the ethics clearance until the report has been submitted.**

The researcher is cautioned to adhere to the Unisa protocols for research during Covid-19.

Due date for progress report: 31 January 2022

Please note the points below for further action:

1. The sampling procedure requires further clarification. The researcher must stipulate whether the population is homogenous or not. Slovin's formula can only be used if this is the case for simple random sampling. This will influence the data collection approach and should therefore be clarified before data collection commences.

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

2. Further detail is required on the statistical analysis – the researcher should define the methods by using the study variables.
3. The researcher is advised to consult some references on how to write the alternative hypothesis, as it is currently incorrect.

*The **minimal risk application** was **reviewed** by the UNISA-CAES Health Research Ethics Committee on 21 January 2021 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher will ensure that the research project adheres to the relevant guidelines set out in the Unisa Covid-19 position statement on research ethics attached.
2. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
3. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the Committee.
4. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
5. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
6. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
7. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data require additional ethics clearance.
8. No field work activities may continue after the expiry date. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

Note:

The reference number ***2020/CAES_HREC/155*** *should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Yours sincerely,

Prof MA Antwi
Chair of UNISA-CAES Health REC
E-mail: antwima@unisa.ac.za
Tel: (011) 670-9391

Prof SR Magano
Acting Executive Dean : CAES
E-mail: magansr@unisa.ac.za
Tel: (011) 471-3649

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

APPENDIX E: PERMISSION LETTERS

ONDO STATE AGRICULTURAL DEVELOPMENT PROJECT

Obafemi Awolowo Avenue, Alagbaka Quarters,
P.M.B. 622, Akure, Ondo State.

23rd November, 2020

AJALA SEUN BOLUWATIFE (57634270)
College of Agriculture and Environmental Sciences
Department of Agriculture and Animal health
University of South Africa

RE: CLIMATE CHANGE EFFECTS ON MAIZE PRODUCTIVITY IN SOUTH WESTERN, NIGERIA

Kindly refer to your letter dated 26th October, 2020 on the above mentioned subject matter.

2. In view of this, the department will allow you to have access to the document(s) needed for the study and will also provide you with all the data related to the study in Ondo State.

3. In addition, the department will link you up with Extension Officer(s) to aid your interview schedule process for proper documentation.

4. The department will be glad to be briefed concerning the outcome and recommendations of research work.

5. Wishing you best of luck in your study.

Sule M.A.

....

Director, Agric Extension Services

ONDO STATE AGRO-CLIMATOLOGICAL PROJECT

MINISTRY OF AGRICULTURE,
A. D. P. PREMISES, ALAGBAKA, AKURE, ONDO STATE
WEATHER MONITORING AND SOIL ANALYSIS
Office of the Project Manager

Ondo STATE
IṢẸ́ LOOGÚN ÌṢẸ́

14th October, 2020.

AJALA SEUN BOLUWATIFE (57634270),

College of Agriculture and Environmental Services,

Department of Agriculture and Animal health,

University of South Africa.

Re: CLIMATE CHANGE EFFECTS ON MAIZE PRODUCTIVITY IN SOUTHWESTERN NIGERIA

Kindly refer to your letter dated 22nd June, 2020 on the above mentioned subject.

- The Department will allow you to access on the document (s) needed solely for the study research purposes.
- The Department can only provide you with the historical agroclimatological data for Ondo State.
- The Department will also allow you to have a discussion\interview session with the officials of the department pertaining to this research work.
- The Department will appreciate it if in return can get the findings and recommendations of the research.

Hoping this will assist in ensuring that you finish your research.

The Department wishes you all the best.

OFFICE OF THE PROJECT MA...
MINISTRY OF AGRIC

Akintomide S.A.

(Project Manager)

08035784219

OYO STATE AGRICULTURAL DEVELOPMENT PROGRAMME

Please reply to:
Qrt. 804, Agodi Reservation,
Secretariat Road, off Total Garden
IBADAN OYO STATE NIGERIA
Box 7300, Secretariat, Post Office
Ibadan.
E-mail: Ibadan : oysadep2005@yahoo.com

Programme Headquarters
P. O. Box 278,
Saki,
Oyo State Nigeria

Date: 28th October, 2020

Your Ref. No:

Our Ref. No:

RE: REQUEST FOR ASSISTANCE WITH RESEARCH WORK ON MAIZE PRODUCTIVITY IN SOUTHWESTERN NIGRERIA

Reference to the letter dated on the 10^{th} September, 2020 and submitted to Oyo State Agricultural Development Progamme by SEUN BOLUWATIFE AJALA with student No (57634270). PhD candidate from the College of Agriculture and Environmental Science University of South Africa focusing on the research work on the above subject mention above.

The programme will support you to have access on the documents needed for your secondary and primary data and give you better information and also allow you to have discussion/interview session with the farmers and officials of the programme pertaining to this research work.

I wish you a better stay in Oyo State and South-west.

Adegbite V.O
Planning Officer

OYO STATE AGRICULTURAL DEVELOPMENT PROGRAMME
SIGN:
DATE:

Established by the Oyo State Agricultural Development Programme Edict
(Edict No 8 of 1989)