The Economic Impact of Climate Change and Farmers' Adaptation Strategies for Yam Production in Cross River State, Nigeria

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ABSTRACT

This thesis addressed the economic impact of climate variability and farmers' adaptation options for yam production in Cross River State, Nigeria for the purpose of developing improved extension and agricultural policies that embrace the challenges faced by smallholders. The specific objectives were: to analyse the impact of climate variables on yam production at the State level for the period 1996-2017; to investigate the socio-economic factors that affect the net revenue of yam farmers at the farm level; to evaluate yam farmers' perceptions of, and adaptation strategies to changes in the weather patterns they are experiencing in the study area and any barriers to adaptation; to determine the most important factors that affect farmers' choice of adaptation to climate change; and to validate the models used through the engagement of experts in relevant fields to get their opinions on the study recommendations for a new strategy for smallholders growing yam on their holdings.

This research adopted the mixed method approach, including a two-stage online survey to gain expert opinions on the study's main recommendations. Data was collected from secondary and primary sources; secondary data from government statistical publications and primary data from 209 yam farmers through a structured questionnaire, and from 27 experts through online survey. Quantitative data was analysed using inferential statistics which included the co-integration analysis, ordinary least square (OLS) regression analysis, chi-square tests, independent sample T-test, and Logit regression analysis. Qualitative data was analysed using percentages, interquartile range and standard deviation.

The findings of the study revealed that increasing temperature had a negative impact on yam production in Cross River State. Also, the variables that had statistically significant effects on the net revenue of farmers in response to climate change were number of years in farming, household size, access to the weather forecast and tenure status. The findings further revealed that the adaptation strategies taken by the farmers to cope with climate change included the use of improved variety, changing planting date, planting of trees, use of inorganic fertiliser, reducing bush burning, expansion of farm size, off-farm employment and cultivation of different varieties of crops. The most common barrier observed by the farmers in the study area was the lack of credit facilities.

The main contribution to knowledge made by this research was the development of a framework for achieving a better output and net revenue in yam farming under a climate change situation, a framework that was validated by a panel of expert in the field.

DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of the University of Gloucestershire and is original except where indicated by specific reference in the text. No part of the thesis has been submitted as part of any other academic award. The thesis has not been presented to any other education institution in the United Kingdom or overseas.

Any views expressed in the thesis are those of the author and in no way represent those of the University.

Signed ……………………………………… Date ……01/06/2021……

DEDICATION

This thesis is dedicated to the Almighty God, the giver of life, wisdom, knowledge, understanding and guidance for the achievement of the success in this research work. Also, to my dearest parents, Late Prof. Udofia Iton and Dr. (Mrs.) Atim Iton for their perfect parenting.

PUBLICATIONS FROM THIS RESEARCH

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Chapter 1: Introduction to Research

Climate change and its impacts on the agricultural sector is one of the most critical concerns in the world today (Intergovernmental Panel on Climate Change (IPCC)), 2018; Elijah, Osuafor & Anarah, 2018). Therefore, to lessen the influence of climate change on agricultural production, farmers need to recognise the types of changes that are occurring and respond accordingly by adopting the appropriate adaptation strategies available (Elijah et al., 2018; Enete, 2014).

This chapter introduces the focus of this study and also presents the research strategy. The background of the study introduces smallholders, climate change and its impact on agriculture and the need for adaptation by farmers to climate change. It presents the research aim and objectives, followed by the research hypotheses, which leads to the research approach. The chapter ends with the thesis structure, a brief description of each chapter and the framework for the thesis.

1.1 Background and Context

This study focusses on farmers and their livelihood strategies with particular reference to smallholders in Cross River State, Nigeria and in relation to their main staple crop, which is yam.

1.1.1 Agriculture and smallholders in Africa

Smallholder family farming is a small farm that relies mainly on family labour. According to the International Food Policy Research Institute (IFPRI, 2013), a smallholder farmer is the backbone of agricultural production in most developing countries, contributing up to four-fifths of the food in the area. In many regions, crops such as sorghum, yams, cassava, cowpeas, millet, corn, cocoyam, sweet potatoes, and rice are the most common products of small-sized farms (IFPRI, 2013). Smallholder farmers in tropical Africa, utilise non-complex production methods and bush-fallow practices and plant in areas of one-half to two hectares each, add to around two-thirds of farm production (FAO, 2008). A significant proportion (80 - 90 per cent) of farms in Nigeria are smallholder family farms with an average area of 1.2 ha and with limited mechanisation (Apata, Samuel & Adeola, 2009). These farms depend on the available labour force, which is primarily family labour (Apata et al., 2009). Therefore, smallholder farmers produce a significant quantity of the food consumed by Nigerians. Additionally, small-scale farmers rely on their own competence in the use of the essential production equipment available to them. However, they do make a substantial and vital contribution to national production accounting for some 99 per cent of total crop output (Mgbenka, Mbah & Ezeano 2016).

These farmers, however due to several challenges they face, produce below expectation (Arimi, 2014). Many of these challenges are addressed in section 1.1.2. In the past 20 years, the government of Nigeria have made attempts to increase agricultural production, but many of these initiatives have not yet produced intended outcomes. The reasons for these failures are several barriers that stand contrary to smallholder farming in Nigeria such as economic, political and financial barriers. Besides, the problem can also be a reluctance of smallholders to undertake changes in techniques for agriculture, which has helped elsewhere in the establishment of a diversity of large-scale farming and processing technologies (Mgbenka et al., 2016). For this reason, smallholder farmers in Nigeria are mostly unable to produce adequately for their localities. This situation is primarily a result of insufficient access to inputs, support facilities, markets and credit facilities, which would allow farmers to improve their productivity and sales capacities (Arimi, 2014; Mgbenka et al., 2016). Furthermore, climate change is a factor that can further influence productivity detrimentally in Nigeria (Mgbenka et al., 2016; IPCC, 2018).

1.1.2 Climate change

Climate change is regarded as a change in the condition of the climate that can be recognised statistically by variations in the mean value (such as rainfall and temperature), and the change of its properties, and where this change perseveres for a prolonged period, mainly decades or longer (Deschênes & Greenstone 2007; IPCC, 2018). Consequently, climate variation gives rise to higher temperatures, varying precipitation patterns and quantities, an increased frequency as well as the intensity of extreme climate events such as floods, droughts, and heatwaves (IPCC, 2007; Jalloh, Nelson, Thomas, Zougmore, & Roy-Macauley, 2013; Udoimuk et al., 2014). This situation poses a significant threat to farmers in West Africa (Jalloh et al., 2013); for example, higher temperatures lower the yield of some crops (Pender & Gebremedhin, 2008). There is a prediction that the 21st century will experience increased temperatures, more variable rainfall and extreme climate events such as floods, droughts and rising sea levels, which will impact negatively on agricultural yield. This prediction is particularly worrying for Sub-Saharan African countries (Isik & Devadoss, 2006; World Bank, 2010; IPCC, 2018) and is predicted to impact significantly on smallholder livelihoods unless adaptation and mitigation strategies are developed and disseminated. The predicted impacts of climate change in Nigeria and especially in Cross River State are discussed more fully in chapter 3 of the study.

However, the government of Cross River State has made efforts to intervene and mitigate the impact of climate change in the state using the Green Carnival programme. The Green Carnival is an initiative of the Ben Ayade administration aimed at sustaining the natural resources of the State. To fulfil the determination to provide protection against the weather and to tackle climate change, the Cross River Governor, Professor Ben Ayade mandated residents to plant 4.2 million trees in one month. The Governor gave the charge for tree planting at the 2021 wet season Green Carnival held in Calabar, the capital of Cross River State, south-south Nigeria (Offiong, 2021).

1.1.3 Climate Change and Nigerian Agriculture

Agriculture is one of the most climate-sensitive sectors in Nigeria. It is climate-sensitive because agricultural production is mostly rain-fed; primarily dependent on predictable seasonal rainfall and therefore it follows that any change in climate is bound to have a direct impact on production and on the socio-economic status of communities across the country (Egbe, Yaro, Okon & Bisong, 2014). Impact factors that affect crop growth include: soil water availability, soil erosion, changes in the occurrence of pest and disease, rises in sea-level and a decline in soil fertility (Adejuwon, 2004; Easterling et al., 2007; Boko et al., 2007; Dinar et al., 2008; Thomas-Hope, 2017). All of these influence the welfare of rural people, especially those involved in primary production. Although the danger of climate change is worldwide and can impact on many sectors, agricultural production practices are largely more vulnerable to climate change compared to other sectors (Mbanasor, Nwachukwu, Agwu & Onwusiribe, 2015).

The predicted reduction experienced in food crop yields is most significant in developing countries because the economic dependence on agriculture is higher than in other parts of the world (Stern, 2006). In addition, the rural (and to an extent urban) economy can be directly impacted in relation to food scarcity and reduced employment.

Consequently, climate variations can raise the danger of food insecurity for some susceptible groups, particularly the underprivileged who mostly rely on agriculture (Jalloh et al., 2013). Crop agriculture is enormously vulnerable to climate variations, and this is reflected in the expectation that climate variations will harm agricultural productivity in the 21st century (IPCC, 2007; World Bank, 2010; Sarker, Alam & Gow, 2012) especially in Nigeria (Niang et al., 2014) if nothing is done. The major contributing determinants of the impact consist of rising atmospheric carbon dioxide concentration, fluctuations in temperature and rainfall, increase in pests and diseases, and fluctuations in extreme events like heat stress, drought and floods (Niang et al., 2014). Nevertheless, climate variation may be of advantage to agriculture, but that depends on the nature of the change (Abildtrup et al., 2006); in other words, there are likely to be many losers but perhaps some winners. There is an anticipation that the outcome of climate variation on agriculture will differ from place to place, and that depends on the situational causal factors (Sarker et al., 2012; Uleberg, Hanssen-Bauer, van Oort & Dalmannsdottir, 2014). Moreover, evaluating several studies that cover different areas and crops, a report by IPCC (2014), stated that the adverse effect of climate variation on crop productivity is more rampant compared to the positive effects.

Notably, the Nigerian agricultural sector's susceptibility to climate variation is of concern to the government since agriculture is a crucial sector in the economy (Ater & Aye, 2012). It is thus, of high importance to Nigeria, and particularly in Cross River State (which is in the tropical rain forest agro-climatic zone) to address the issue of climate variation in the agricultural sector because agriculture here is primarily rain-fed and is the main occupation of the people in rural areas (Enete, 2014).

1.1.4 Adaptation to climate change

Adaptation is regarded as deviations in methods, practices, or structures to restrain or counterpoise the possible dangers or to manipulate the opportunities related to fluctuations in climate. It is an alteration in ecological, social, or economic systems in response to the real or projected climatic situations and their effects or impacts (Chukwuone, 2015). Smit, Burton, Klein, and Street (1999), define adaptation to climate change as an alteration in natural or human systems to cope with the real or expected climatic situations or dangers. Kurukulasuriya and Mendelsohn (2008), refer to adaptation as a planned decision to limit the harmful impacts of climate variation.

Adaptation to climate variation is expedient if farmers are to counterpose the anticipated adverse effects of changing climate (Kabubo-Mariara & Karanja, 2007; Stern, 2006; Hassan & Nhemachena, 2008). It can preserve the source of revenue of farmers and guarantee food sufficiency (Bryan, Deressa, Gbetibouo & Ringler, 2009). Adaption options can lessen the likely harmful effects of climate disparity and strengthen the benefits related to climate change (IPCC, 2007; Bradshaw, Dolan & Smit, 2004; Reid, Smit, Caldwell & Belliveau, 2007). According to IPPC (2007), the adaptation options or strategies in agriculture include changing of planting times, crop diversification, crop rearrangement and improved land management practices, e.g., erosion control and soil conservation via the planting of trees. Adaptation can, therefore, reduce vulnerability as this action maintains, preserves and improves the practicality of food crop production (IPCC 2001; Arimi, 2014). As a part of this study, it is essential to consider which adaptive strategies are best suited to smallholders in Cross River State, especially those growing yams.

1.1.5 Introduction to Cross River State, Nigeria

The study took place in Cross River State, (C.R.S.) Nigeria. The State belongs to the south-south geopolitical zone in Nigeria. It is situated between latitudes 5°32'N and 4°27' North and longitudes 7°50' and 9°28' East. The state lies within the tropics and shares borders with the Cameroon Republic in the East, Benue State in the north, Enugu and Abia States in the west and Akwa-Ibom State in the south (Boundaries Commission Newsletter, 2010). Located in the Niger Delta region of Nigeria, the state covers an area of 20,156 square kilometres with a population of 3.7 million and a population density of 190 inhabitants per square kilometre (NPC, 2006).

The State experiences two distinct seasons - the wet season and dry season. The wet season starts about February/March and continues till October/November, while the dry season begins about November/December and continues till January /February (Oyenuga, 1967; Fonta et.al., 2011).

The mean annual rainfall is 1,300mm to 3,000mm across the State. The highest temperature is between February and March and does not exceed 37^{0}C and the lowest between May and October and does not go below 15^{0}C and this also varies by location. The vegetation of the State comprises of four different features which range from Mangrove Swamp (wetland), through the rainforest, to derived savannah and finally montane parkland (Ettah & Angba, 2013).

Moreover, the two significant soil types found in the area are the deep laterite fertile soil and dark clayey basalt soil (Ettah & Angba, 2013). The weather conditions and the wide range of vegetation types give the farmers in Cross River State advantage in the cultivation of crops like oil palm, cocoa, cassava, yams, plantain, rice, maize, sweet potatoes and a wide range of vegetables including waterleaf, *telfera*, *amaranthus spp*, okra, pepper, etc.

Historically, the people of Cross River State are Christians, and the common occupations here are farming, trading and teaching. Cross River State indigenes are also engaged in fishing and poultry farming. Additionally, the map of Cross River State and the vegetation are presented in Chapter 6 of this thesis.

1.4 Research aim and objectives

The main aim of this research is to analyse the economic impact of climate change and resultant farmers' adaptation strategies for yam production in Cross River State, Nigeria to develop improved extension policies that respond to environmental challenges and embrace both technical and behavioural challenges faced by smallholders. The research aim is underpinned by specific objectives, which are to:

1. Analyse the impact of climate variables on yam production at the state level for the period 1996-2017;
2. To investigate the socio-economic factors that affect the net revenue of yam farmers at the farm level;
3. Evaluate yam farmers' perceptions of, and adaptation strategies to changes in the weather patterns they are experiencing in the study area and any barriers to adaptation;
4. Determine the most important factors that affect farmers' choice of adaptation to climate change and build these into recommendations for improved State extension for yam farmers and their communities, and to,

5. Validate the models used through the engagement of experts in relevant fields to get their opinions on the study recommendations for a new strategy for smallholders growing yam on their holdings.

1.2 Statement of the research problem

Studies have shown that climate alteration adversely influences Africa's agriculture (Onyeneke & Madukwe, 2010; Jalloh et al., 2013; Thomas-Hope, 2017) and that adaptation is an important policy strategy for restraining the harmful effects of climate variation (Kurukulasuriya & Mendelsohn, 2006; Eregha, Babatolu & Akinnubi, 2014). In Nigeria, there have been reports that there have previously been cases of severe flood in the country's southern coastal zones and also severe land dilapidation including: serious coastline erosion, persistent gully erosion in the rain forest zone and central guinea savannah zone, and land cover deviations as a result of inconsistency in rainfall brought about by climate alteration (Chukwuone, 2015).

The production expectations of many farmers have often been dashed due to either late arrival of rainfall or excessive rainfall that results in flooding and soil loss; furthermore, it is predicted that this will get worse (Onyeneke & Madukwe, 2010). Consequently, climate change is likely to undermine any advances in poverty reduction and sustainable development because it affects the resources that are important for rural livelihoods in Nigeria (Adejuwon, 2004; Onyeneke & Madukwe, 2010). For this reason, small-scale farmers in Nigeria are disadvantaged, also they are deficient in access to important information necessary for their agricultural practices to become more resilient (Mgbenka et al., 2016).

Although the cultivated area of yam (a staple food for these smallholders) in Nigeria has increased, the rate of increase in production has declined significantly from the average 27.5 per cent of yield between 1986 and 1990 period to 3.5 per cent in the 1996 to 1999 periods. This decline in average productivity per hectare has been more severe, from 14.9 per cent yield in 1986-1990 to 2.5 per cent between 1996-1999. This could be as a result of some factors such as inadequate access to farm credits, poor access to extension services and poor access to farm inputs (CBN, 2003; Adegbite, Adesiyan, Agbaje & Omoloye, 2005; FAO, 2007). This scenario indicates that smallholders are struggling, and they need help in moving forward as it is necessary for smallholders to use wisely the available resources at their disposal to the best of their ability for increased yield and sustainability of yam production both environmentally and economically ~ this is the focus of this PhD study.

1.3 Justification of the study

The study took place in Cross River State, Nigeria for the following reasons: the dominance of yam production in the area; the State has a high vulnerability to prolonged duration of rainfall (extreme rainfall) which could lead to flooding; increases in days with excessive rain and increased flooding over mangrove and rainforest ecological zones (Egbe et al., 2014).

Additionally, cassava and yams are the most important food crops in Nigeria (Jalloh et al., 2013) and yams are the leading staple food for the people of Cross River State. Great importance is attached to the crop because of its different uses (see chapter 2). Therefore, there is a need to gain as much information as possible on how to increase yam production sustainably. Also, it is essential to understand the economic and food security status of yam farmers to recommend possible adaptation strategies that will meet their needs. Notably, it is necessary to consider yam (a root and tuber crop) in terms of a potential crop surplus in Nigeria. Thus, it could become an important export crop that augments the economic livelihoods of farmers in the state (Jalloh et al., 2013).

1.5 Research hypothesis

The hypotheses of the study are stated in the null form thus;

- H_0 1: There is no significant impact of climate change on yam production in Cross River State for the period 1996-2017.
- $H_0$2: Climate change does not have a significant impact on yam farmers' net revenue.
- $H_0$3: Socio-economic factors do not influence the choice of adaptation strategies used by yam farmers in the study area.

1.6 Research approach

This mixed-method research incorporates the collection of both quantitative and qualitative data, informing a pragmatic methodological approach to the research objectives. A review of related literature was carried out to provide the concepts and theoretical framing of the study (chapters 2, 3, 4 and 5). Data collection was from both secondary sources (gathered from government statistical database), and primary sources (gathered from field survey) and details of the approach to data analysis are in chapter 6. Moreover, a flow chart showing the method of primary data collection for the research is presented in chapter 6, Figure 6.3. The production function model facilitated the addressing of the first two objectives of the research, while descriptive statistics and logit modelling were used to address the last three objectives. Regression analysis and details of these analyses are in chapter 5. Furthermore, a two-stage online survey, which formed the final part of the research, was employed to gain experts' opinion on the study recommendations and the details are in chapter 9.

1.7 Research strategy

This study dealt with the two levels of impact of climate change on yam production, which are the aggregate time-series data for the State level and the cross-sectional survey data for farm level. This thesis, however, has three essential pieces of empirical research. The first element analyses the time series aggregate data for the climatic and yam variables and investigates the impact of climate change on yam production in Cross River State. The second piece of the research uses a cross-sectional survey data to measure the effects of climate variability on the net revenue of yam farmers at the farm level. The third element is related to adaptation, which is essential to offset the effects of climate variation in agriculture. Smallholders' perception of, and adjustment to, changes in the weather patterns and what determines their choice of adaptation, including any barriers to adoption are assessed using farm-level survey data for the State. It examined farmers' perceptions concerning climate change, which partly influences their adaptation decision making. It also explored several facets of farmers' adaptation as well as the adaptation strategies farmers have taken so far in their farming practice. The most important factors that affect farmers' choice of adaptation to climate change were determined and were used to develop a strategy for smallholder support along with recommendations for improved state extension for yam farmers and their communities. Finally, this element examined the barriers farmers face while taking on the recommended adaptation measures.

In the final stage, the study employed the two-stage online survey to refine and validate the models used in the study through the engagement of experts in the field of economics, yam production, rural livelihoods, extension and agricultural policy. Here, the aim was to obtain experts' opinion on the study recommendations. This method allowed the establishment of an objective consensus with the choice of models used.

The first element of this research used data from secondary sources such as the Central Bank of Nigeria statistical bulletin and the Cross River State government database for the period 1996-2017; the second and third pieces collected data from primary source obtained from a survey of Cross River State yam farmers conducted by the researcher in 2017.

1.8 Thesis structure

This study comprises of ten chapters, including this introductory chapter. This first chapter introduces the research and looks at issues on agriculture, smallholders, climate variation and adaptation in connection with the Nigerian setting. It outlines the problems and justification for the study, specifies the aim and objectives, reveals the research approach, the hypothesis underlying the study, and then presents the research strategy thereby setting the context for the research.

The next Chapter 2 provides a brief overview of Nigerian agriculture which stresses on food crop production. It discusses the land use for agriculture in Nigeria and reveals the food staples in the different agricultural zones. The chapter further introduces yam as the indicator crop for the study, the production trend of yam in Nigeria and its economic importance. This is followed by the policies to support agriculture in Nigeria. The chapter closes with a summary of the present-day Nigerian agriculture.

Chapter 3 reviews the existing literature that deals with climate alterations and agriculture as a whole, and in Nigeria in particular. It explores the causes and outcome of climate change and future projections in Africa and Nigeria. It further describes the different types of climate in as well as the climate situation specific to Nigeria. It further presents the impact of climate alteration on agriculture and food production, and also its effects on food security. Later in the chapter, the models employed in analysing climate change impact are explored.

Chapter 4 explores the adaptation strategies, barriers to adaptation and determinants of farmers' choice to adaptation measures. It also captures the role of government and extension in agriculture and adaptation. It further discusses the models for analysing the determinants of adaptation options used by smallholders. This chapter ends with providing the empirical results of climate change and adaptation studies and the gaps that exist in literature.

Chapter 5 explains in more detail the methodology used in this research. It provides the research method, research paradigm, theories and models employed in this research.

Chapter 6 defines the study site, survey design and process of undertaking the farm survey in Cross River State. The data collected from a field survey offered the primary evidence used in this research. Apart from defining the survey method, there is a presentation of descriptive statistics of the farm level accumulated data. The approach adopted in this study is holistic since it comprises the state-level time series data and the farm household level data of Cross River State.

Chapter 7 presents the findings and discussion of the research. The findings at every stage are revealed and compared with that of other studies. It describes farmers' socio-economic and demographic characteristics in the study area and their technical and behavioural factors relating to climate variation and adaption. The chapter further examines yam farmers' perceptions of, and adaptation strategies to, changes in weather patterns they are experiencing, as well as the constraints to adaptation. The findings and discussion extend to chapters 8 and 9.

Chapter 8 investigates the impact of climate variability on yam production in Cross River State using the time series data. It provides a trend analysis of yam production and climate variables as well as the level of yam production in the study area.

Chapter 9 explores the factors that affect yam farmers' net revenue in the presence of climate change using the Ordinary Least Square model. It also investigates the determinants of farmers' choice to adaptation under climate change by employing the Logit model to analyse data Moreover, this chapter documents the online survey on refining and validating the models used in the study through the engagement of experts in the field of yam production, rural livelihoods, agricultural economics and extension, agricultural policy and related fields using a two-stage online survey approach. The opinions gathered from the experts are, however, presented and discussed.

Finally, chapter 10 presents an overview of the findings of the study in the summary section and brings forth the conclusion of the study. The chapter also suggests policy recommendations based on the findings of the study, presents the contribution of the research to existing knowledge and closes with the study limitations and direction for future research. The research design is however presented in Figure 1.1.

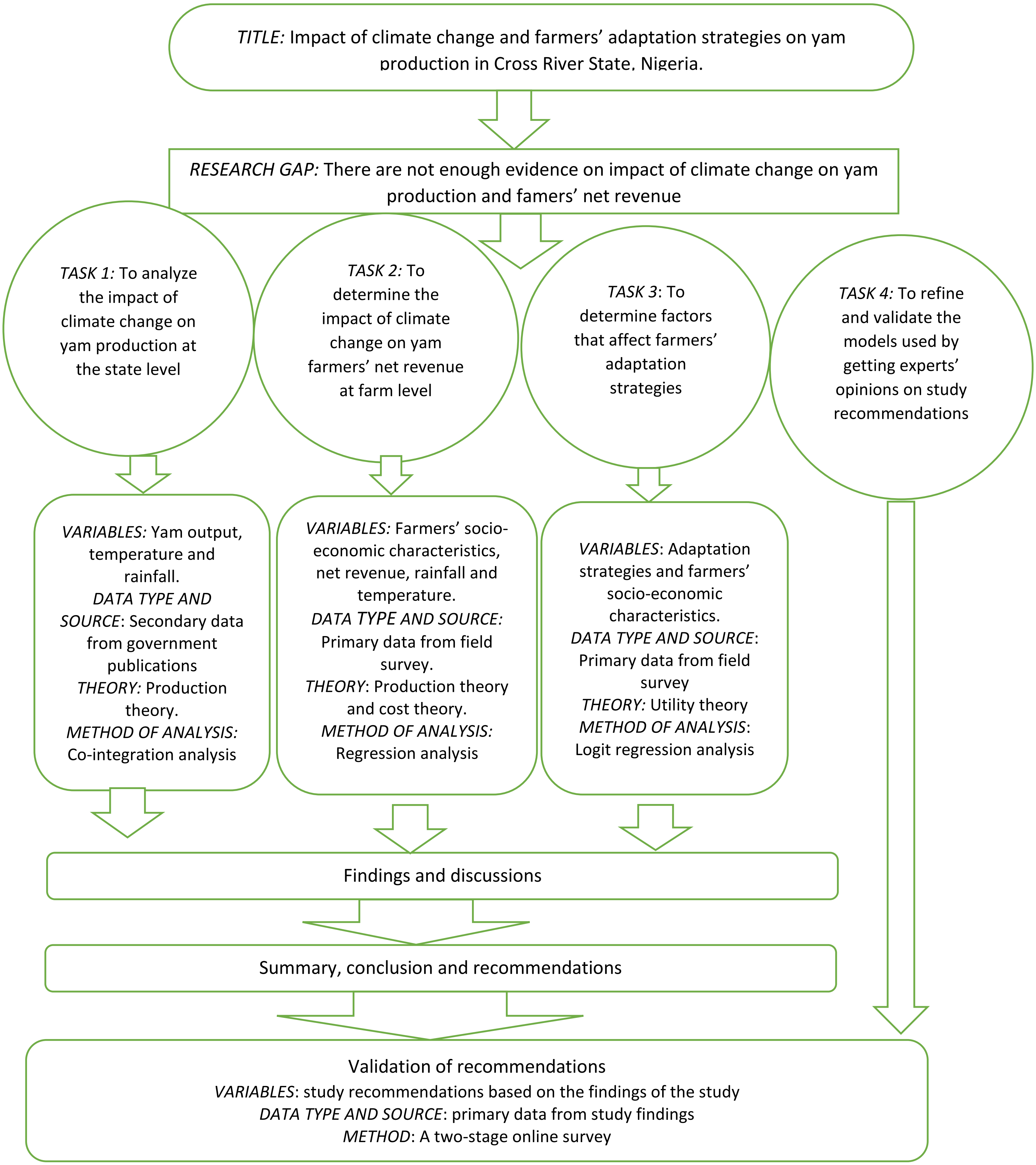


Figure 1.1: Thesis design

Chapter 2 Agriculture in Nigeria and food staples

This chapter explores the agricultural sector gross domestic product (GDP), the imports and exports of commodities and the agricultural situation of Nigeria. It explains the effect of the petroleum boom in Nigeria and how it affected the decrease in GDP in agriculture as a result of the shift of focus from agriculture to oil in the early 1970s. The chapter gives information on the types of farms found in Nigeria and the types of land use for agriculture. It further highlights the agro-ecological zones and the important staple crops cultivated in each zone. The chapter also reviews the indicator crop for the study, yam, and gives information on its production quantity and trends. The analysis carried out provides information on the trends in yam production in Nigeria. Further, the responsibilities of the Nigerian government (federal government, state government and local government) in agriculture, as well as the policy to support agriculture, are captured here. Finally, the chapter ends with a summary of Nigerian agriculture today from the viewpoint of the government and its agricultural policy.

2.1 Agricultural sector in Nigeria

Agriculture is an important sector in Nigeria, based on a mix of subsistence and commercial production; therefore, it can be argued that Nigeria is predominantly an agricultural society. Agriculture contributes 21.9 per cent of the national GDP and employs about 70 per cent of formally employed people in Nigeria (Ogbanga, 2018). At a subsistence level, about 70 per cent of the people engage in agricultural production (Federal Ministry of Agriculture and Water Resources [FMAWR], 2008). Agricultural properties are characterised by small and scattered communities and simple tools are used in cultivation. Large-scale agriculture is also practised, but this is not the focus of this study. Nevertheless, the small-scale farmers in Nigeria practice subsistence agriculture. Subsistence agriculture occurs when a farmer produces food just sufficient to feed the household or the local community (group, tribe etc.), pay taxes and sometimes leave a little surplus to sell in better years. The primary priority of subsistence agriculture is self-sufficiency, which is achieved by cultivating a wide range of crops. Animals are also kept where possible (FAO, 2016; Akpan & Essien, 2019). Other examples of subsistence farming are bush fallowing and the wet rice agriculture. Bush fallowing is a system of farming where the farmer cultivates one piece of land for some years and abandons it for some years with the intension of returning when the fertility of the soil is naturally restored. During this fallow period, the farmer cultivates another piece of land. (FAO, 2016).

Nigeria's vast and varied climatic zones enable it to cultivate different varieties of crops, for example, maize, cassava and yam. Nigeria, however, has a challenge of decreasing agricultural productivity which started with the initiation of the petroleum boom in the early 1970s. The prosperity in the oil sector gave rise to a change in the labour market as labour opportunities opened up in the oil sector. This adjustment resulted in an adverse effect on the level of productivity on farm of both food (home consumed) and cash crops. Jointly, farm production degenerated into a low yield economy, both per unit of land and per worker because of factors such as lack of technology, activities of nature such as drought, inadequate transportation and infrastructure, and trade limitations (Adejuwon, 2004; CBN, 2007; FMAWR, 2008).

Table 2.1 shows the food crops produced in Nigeria in tonnes from 1980 to 2017 where the quantity of yam produced increased from more than 5 million tonnes to 47 million tonnes. This increase in yam production for this period may have been because of the introduction of some agricultural policies at that time which favoured yam production. Such policies include the root and tuber expansion programme introduced in 2003, the agricultural transformation agenda in 2012 and the agricultural promotion policy in 2016. More information about these policies are presented in table 2.6.

Table 2.1: Production in tonnes of food crops produced in Nigeria in three reference periods

Tonnes produced in	**1980**	**2000**	**2017**
Cassava	11,500,000	32,697,000	57,134,478
Cocoyam	208,000	3,886,000	3,175,842
Guinea Corn	3,690,000	7,711,000	6,939,335
Maize	612,000	4,107,000	764,678
Melon seed	94,000	345,000	569,398
Millet	2,824,000	5,814,000	1,468,668
Rice, paddy	1,090,000	3,298,000	6,070,813
Sesame seed	15,000	72,000	460,988
Yam	5,250,000	26,210,000	47,942,712

Source: CBN, 2018

2.2 Role of agriculture and economic growth in Nigeria

Conventionally agriculture is considered as the backbone of the Nigerian economy with the numerous parts it has to play in the development of the country. Among the roles traditionally played by the agricultural sector in a rising economy are, but not limited to, the following;

(i) It supplies satisfactory food for an increasing population;

(ii) It contributes suitable raw materials to a rising industrial sector;

(iii) It constitutes the primary basis of employment;

(iv) It forms the principal basis of foreign exchange earnings, and

(v) It provides a market for the produce of the industrial sector (Odozi, Patience, Awaebe & Agbugui, 2018).

The possible contribution of agriculture to a nation's economic growth has been an issue of considerable argument amongst development economists (Izuchukwu, 2011; Odozi et al., 2018). Some authors claimed that growth in the general economy is dependent on the development of the agricultural sector (Gollin, Parente & Rogerson, 2002; Izuchukwu, 2011; Ogbanga, 2018). Added to this, the growth in agrarian industry may perhaps be important for national production growth through its impact on rural revenues and supply of resources for modification into an industrialised economy (Thirtle, Lin & Piesse 2003; Izuchukwu, 2011; Ogbanga, 2018). Moreover, Johnston and Mellor (1961) posit five inter-sectoral linkages explaining agriculture's contribution to economic growth. The first linkage is the provision of excess labour to firms in the industrial sector. Secondly, the provision of food for local consumers. Thirdly, providing a market for industrial production. Fourthly, regulation of domestic savings and industrial investments; and finally, provision of foreign exchange obtained from agriculture export earnings used to finance the importation of intermediate and capital goods.

Additionally, Izuchukwu (2011) reported that agriculture makes an indirect contribution to economic growth through providing of healthier food for consumption by the underprivileged, ensuring food is available, ensuring food price is stable and reducing poverty. Furthermore, the agricultural sector is vital in supporting both developing and developed countries (Izuchukwu, 2011; Ogbanga, 2018). Hence, agricultural growth contributes significantly to the achievement of economic development.

However, the decline in agricultural production in Nigeria began with the advent of the petroleum boom in the early 1970s. The boom in the oil sector brought about a shift in development from agriculture to oil and gas, which led to the fall in cash crops (Kale & Doguwa, 2015). Also, a series of policies which focused on petroleum were developed and implemented, and as a result there was a lack of focus on agriculture. This is further developed in the agricultural GDP in section 2.3. This distortion in turn produced adverse effects on the production levels of both food and cash crops (Ekperiware, Moses & Olomu, 2015).

2.2.1 The contribution of agriculture to the development of the Nigerian economy

Although Nigeria has a significant endowment in black oil and other mineral resources, the stability of her economy is still mainly dependent on the agricultural sector (Izuchukwu, 2011; Iwuchukwu & Igbokwe, 2012; Olomola & Nwafor, 2018; Ogbanga, 2018). Agriculture is vital in the Nigerian economy concerning national production and job generation. It accounts for 21.9 per cent of GDP of the country with crops making up 80 per cent of this contribution (Izuchukwu, 2011; Olomola & Nwafor, 2018). Agricultural production further provides food and fibre to meet the needs of the large and increasing population of the country. Agro-industrial companies rely on the sector for raw materials (Olomola & Nwafor, 2018; Ogbanga, 2018).

With regards to employment, the sector still takes the lead in economic activities. It provides employment for about 70 per cent of the adult labour force (Izuchukwu, 2011). It, therefore, remains the foremost employment sector of most of the Nigerian populace employing two-thirds of the labour force (Izuchukwu, 2011; Ogbanga, 2018). Recent studies revealed that in Nigeria, farming is the source of employment of more than half of the adult inhabitants (Olomola & Nwafor, 2018; Ogbanga, 2018). Its yield makes the most significant sole factor that impacts on the standard of living of people in the rural and to an extended urban area too. Moreover, nearly 90 per cent of the rural inhabitants take part in work linked to the crop production sub-sector which offers more than half of the agricultural income. Likewise, the crop sub-sector underpins the processing industries via the provision of raw materials (Izuchukwu, 2011; Ogbanga, 2018).

2.3 Agricultural sector Gross Domestic Product, import and export in Nigeria

Prior to 1960, agriculture was the dominant sector of the country's economy. However, a notable shift in agriculture emerged with the discovery of oil at the Niger Delta in 1965 which resulted in agriculture being neglated by the federal government in terms of policy development and implementation (Ewubare & Kakain, 2017). According to NBS (2020), oil and gas represents only about 9 per cent of Nigeria's GDP, but accounts for about 50 per cent of government revenues and over 90 per cent of export earnings. The total GDP of Nigeria in 2020 was worth 432.294 billion dollars. In the same year, agriculture contributed 24.14% while oil industry contributed 8.7% (World Bank, 2021).

In the last one and a half-decades the agricultural sector's contribution to Gross Domestic Product (GDP) showed a sharp decrease from 42.7 per cent in 2000 to 40.8 per cent in 2010 (Olomola, 2013; Odozi et al., 2018). It reduced more to 28.4 per cent in the third quarter of 2017. On the other hand, agricultural growth decreased by 1.5 per cent in 2016 when likened with the growth rate value of 4.5 per cent in the third quarter of 2017. Generally, the agriculture growth rate declined from 4.2 per cent (between the period 2011-2013) to 4.0 per cent between 2014 and 2016 (National Bureau of Statistics-NBS, 2017; Odozi, et al., 2018).

The significance of agriculture in the Nigerian economy, as well as the economy of other countries, is determined as the value-added by the agricultural sector as per cent of GDP. Agriculture, however, includes forestry, hunting, and fishing, in addition to the planting of crops and rearing of livestock (World Bank, 2019). Figure 2.1 presents the agricultural sector as per cent of GDP. Data for that indicator was from the World Bank, which provided information for Nigeria from the year 1981 to 2017. The data gathered showed that the average value agriculture contributed to Nigeria's GDP during that period was 22.9 per cent, with a minimum of 12.2 per cent in 1981 and a maximum of 36.9 per cent in 2002. In 2017, the agricultural sector made a contribution of about 20.8 per cent to the GDP of Nigeria (World Bank, 2019).

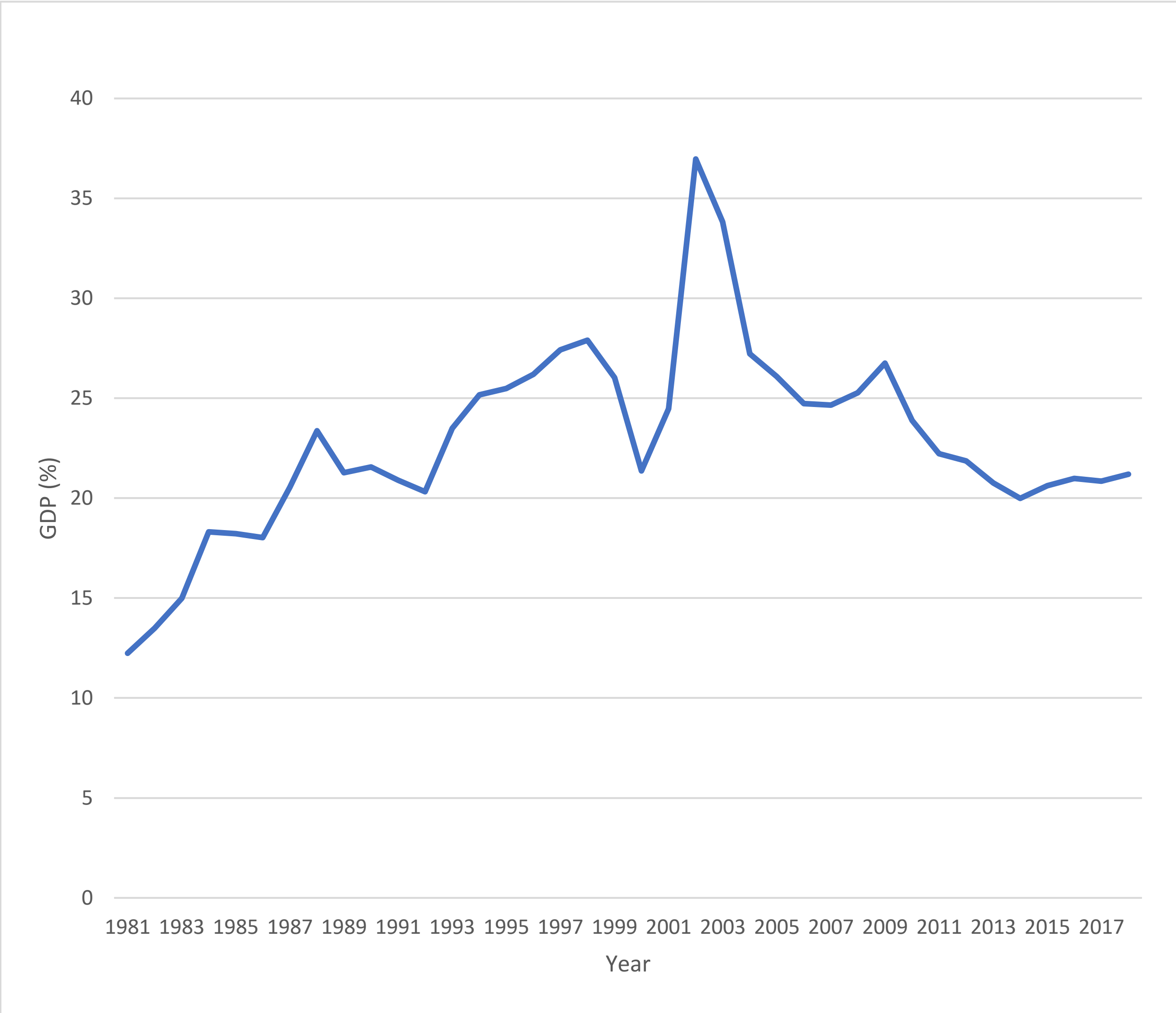


Figure 2.1: GDP share of agriculture in Nigeria

Source: World Bank, 2019

The majority of the Nigerian population consume predominately grains. In 1980, sorghum and millet accounted for 80 per cent of the entire grain production in Nigeria. Even so, the demand for rice, of which the bulk was imported, increased intensely during the 1970s. The importation was curtailed later during the foreign exchange scarcities of the 1980s. Moreover, cocoa and groundnuts were the two main export crops in Nigeria until petroleum exceeded both in 1965 (Olomola & Nwafor, 2018). In the 1960s and earlier part of the 1970s, cocoa, cotton, groundnuts, oil palm products, and rubber were the major export crops (Olomola & Nwafor, 2018).

Even though Nigeria was the world's principal exporter of groundnuts in the early 1970s, groundnuts dropped from the export ranking by the end of the 1970s due to the intense Sahel drought of 1972-1974 and the attack of viral disease in 1975 (Adejuwon, 2004). Subsequently, based on the positioning of exportation by the country, cocoa alone continued to be of export importance after 1975. This situation was as a result of the government restoring cocoa production in the late 1970s and 1980s via reforestation programmes and producer price supports which was assisted by the World Bank. Afterwards, the rise in cocoa production (up to 200,000 tons in 1988) placed Nigeria in the third position amongst the world cocoa producers, following Ivory Coast and Ghana (Adejuwon, 2004; Olomola & Nwafor, 2018).

In the late 1980s, Nigeria lessened the ingrained prejudice against agricultural activity by deregulating farm prices, sustaining subsidies on fertiliser and farm exports, and placing an embargo on the importation of food items. Regardless of yielding to the increase in incentives to the local farming industries, agricultural production was poor. This position was due to the insufficient transport system and power networks, a shortage of suitable technology, and the unproductive use of rural credits (Olomola & Nwafor, 2018). Even though the local production of food did not reduce on a per capita basis, food became less obtainable during this period. This situation was partly due to the lack of incentives for producers to invest in preservation (Olomola & Nwafor, 2018).

Concerning Nigerian export drive, the government of the nation has ranked the production of different goods such as beans, cocoa, cashew, cassava (starch, chips and ethanol), ginger, sesame, oil palm, yams, horticulture (fruits and vegetables), beef and cotton for exportation. As a result of this, there has been an interest by the government in supplying additional testing laboratory equipment, improving the production of crops, publicising market intelligence on exportation and consumer preferences, and also reinforcing the link with appropriate ministries, departments and agencies in encouraging agricultural exports (Olomola & Nwafor, 2018). The aim, therefore, is to put in place a high-quality standard for Nigerian goods based on stringent information and procedures that guard food safety for local consumption and exportation (Olomola & Nwafor, 2018; Ogbanga, 2018).

The above reviews, therefore, confirms that the Nigerian economy is dependent on the agricultural sector.

2.4 Farm types and employment profile in the agrarian sector

The agricultural industry can be seen clearly as a range of upstream and downstream activities that go on in the sub-sectors of crops, livestock, forestry or fisheries. The primary agricultural production activities that make up the upstream economic activities are the planting of crops and rearing of animals, weeding of farm and nurturing of livestock and harvesting from which the main products arise. On the other hand, the post-harvest or secondary activities are the actions that make up the downstream activities. The secondary activities increase the value of the primary goods, enhancing their quality and further rendering them less vulnerable to spoilage. The main downstream product activities comprise of storage, processing into midway or finished (final) products, marketing and distribution via local and export trade (Manyong, Kling, Makinde, Ajala & Menkir, 2003; Odozi, et al., 2018).

However, the employment in the agricultural sector is categorised by the National Bureau of Statistics (NBS, 2017) as paid employment, self-employment in farming, self-employment in non-farming, paid apprentice and unpaid household workers. According to Odozi, et al. (2018), several employment areas where skilled and unskilled workers can be employed are within these broad groups. Examples of skilled employment areas are extension agencies, research and academic, seed production companies, fertiliser industry, pesticide industry, banking and insurance, agro-processing and agri-marketing. In contrast, farms may have skilled workers, but most are unskilled. Nevertheless, in the current establishment survey undertaken by the NBS, these employment areas are not distinct, which limits obviously the forecasting of employment. Even so, small farms are the prevailing employers of labour (Odozi et al., 2018). This figure translates in the year 2009 to forty-two million (42.95) small farms. Out of this number, crop production farms make up 40 per cent, livestock (30 per cent), poultry (26 per cent) and fish (4 per cent) (NBS, 2012; Odozi, et al., 2018).

In the rural areas where agricultural activities predominate, there is a high rate of unemployment estimated at 25.6 per cent (NBS, 2011). However, many of these individuals will be part of the informal economy practicing subsistence agriculture. While the evidence for Nigeria is consistent with the NBS economic theory that predicts a declining agricultural employment share as development progresses, the double challenge of high rural unemployment and low-capacity utilisation manufacturing suggests a distorted structural change. Thus, the pressing problem is one of how to commercialise the agricultural sector and raise productivity to boost employment uptake (Odozi et al., 2018). Nevertheless, increased agricultural activities are required to generate employment prospects, but it is insufficient as the employment engagement capacity of growth is also critical. Regrettably, the engagement capacity of the sector is said to be low (Ajakaiye, Jerome, Olaniyan, Mahrt & Alaba, 2016). The table below (Table 2.2) presents the distribution of small farms in Nigeria between 2006 and 2009.

Table 2.2: Distribution of small farms in Nigeria, 2006-2009

Farm type (Millions)	2006	2007	2008	2009
Crop	15.52	15.73	15.10	17.03
Fish	1.70	1.73	1.75	1.87
Livestock	12.94	12.42	14.29	12.67
Poultry	9.63	11.31	10.95	11.38
Total	39.78	41.20	42.09	42.95

Source: NBS, 2017

2.5 Agricultural land use in Nigeria

Agricultural land denotes the area of land that is either arable farming, covered by permanent crops, and/or under permanent pastures. According to FAO (2014), arable land comprises of land covered with temporary crops, momentary fields for mowing or meadow, land under market or kitchen gardens, and land momentarily uncultivated. Note that land uninhabited due to shifting cultivation is left out.

In 1990, statistics showed that 82 million hectares of land, out of the entire land area in Nigeria (which is around 91 million hectares) were classified as arable. Despite this, just about 34 million hectares (or 42 per cent of the cultivable area) were under cultivation as of then with the bush fallow system practised on the majority of this land (NBS, 2017). Fallow periods vary depending on climate and vegetation and can range from 5-8 years to over 20 years; what is clear though is that fallow periods are declining and impacting on soil fertility negatively (Ogbanga, 2018). An additional 8 million hectares of land was permanent pasture, but the majority of this land possessed the possibilities to encourage crop growth. Forests and woodland spread up to 20 million hectares of land and the majority of this land possessed agricultural opportunities as well (FAO, 2014; NBS, 2017; Ogbanga, 2018). Table 2.3 shows the percentage of arable land as well as the area covered with permanent crops in Nigeria following this data in 1990 over the period 1994 to 2016.

Table 2.3: Arable land and land under permanent crops, 1994-2016

Land type	1994	1999	2004	2009	2010	2011	2012	2016
Agricultural land (% of land area)	72.70	77.85	81.80	81.47	83.67	83.67	79.05	77.70
Arable land (% of land area)	34.04	38.43	36.23	37.33	39.53	39.53	38.43	37.30
Arable land (hectares per person)	0.29	0.29	0.24	0.22	0.23	0.22	0.21	0.21
Permanent cropland (% of land area)	5.38	6.15	3.29	3.51	3.51	3.51	3.51	7.36

Source: FAO, 2014; NBS, 2017

It is not surprising that the country which accommodates the highest population of the African region, also possesses by far the most significant area under agriculture. In the year 2013, rain-fed agriculture accounted for 380,000 sq. Km in Nigeria, which covered above 40 per cent of its national area. This figure indicates a 20 per cent increase compared to 1975. Indeed, from 1975 up to the year 2000, the new agricultural land cultivated was 130,000 sq. Km, with an addition of 110,000 sq. Km from the year 2000 up to 2013 (Ajayi, 2015). Interestingly, Nigeria is the only country in Africa where agriculture has taken over places in the savanna, and doubled its area in 38 years, making it the most significant land cover type (World Wildlife Fund, 2016; Ogbanga, 2018). Furthermore, the growth of agriculture was seen among all eco-regions reaching from the forest zone of southern Nigeria (dominated by root and tree crops) to the forest-savanna development of the centre of the country (mostly dominated by root crops), up to the grain belt of semi-arid northern Nigeria (Nwocha, 2016). The Niger and Benue Basins were endorsed as the leading agricultural expansion area and future breadbasket as far back as the 1970s and they have witnessed the most outstanding infringement of agriculture into the savanna, sharpening the outlines of the protected regions that are left. Even though the conversion from savanna region to agricultural area constituted the major land cover variations, some alterations in the lesser land cover groups also show as vital (WWF, 2016; Nwocha, 2016).

Over the same period there was an increased rate of alteration for settlements, agriculture under irrigation, plantation agriculture and open excavations, with expansion accelerating from 1 to 2 per cent per year between 1975 to 2000 and up to 2–4 per cent per year during the period 2000–2013 (Nwocha, 2016). With a fast-growing population and economy, we see forests, gallery forests and woodlands, added to the savanna land cover types, all declined in area, with the amount of damage growing to more than 2 per cent per year during the 2000–2013 period. Forest regions have decreased by 45 per cent from 1975 to 2013 (CBN, 2003; Nwocha, 2016).

The area of mangroves and swamp forests found along the coast and particularly in the Niger Delta region, (which is a significant hotspot of biodiversity), has reduced when compared to that of some other land cover types. Added to this, the well-being of these environments has been seriously jeopardised by persistent oil spillage which is as a result of accidents, mismanagement, and disruption of the large-scale oil extraction structure in the Delta regions (NBS, 2017). Additionally, environmental rules are considered inadequate and are hardly obligatory, coupled with ineffective protection of the Delta regions, whose forest and animal populace are faced with severe risk (FAO, 2014; WWF, 2016; NBS, 2017).

2.5.1 Nigerian relief and soil types according to zones

Nigeria has two major relief regions which are: the high plateau that ranges between 300m and greater than 900m above sea level, and the lowlands, which are usually lower than 300m. The high plateau comprises of the North Central Plateau, the Eastern and North-eastern Highlands and the Western Uplands. In contrast, the lowlands consist of the Sokoto Plains, the Niger-Benue Trough, the Chad Basin, the interior coastal valleys of Western Nigeria, the swamps and scarp lands of South-eastern Nigeria and coastlands. The majority of the rivers in the country have their sources coming from four major hydrological basins which are the North Central Plateau, mainly comprising of Sokoto-Rima, Hadejia, Gongola, and Kaduna rivers ; the Western Uplands mainly consisting of the Moshi, Awun, Ogun, Osun, Osse rivers; the Eastern Highlands consisting primarily of the Katsina-Ala an, Donga rivers,; and the Uri Plateau made up of Anambra, Imo and Cross rivers (Federal Govrnment of Nigeria- FGoN, 2017; FGoN, 2019).

According to FAO (2014), the categorisation of Nigerian soil is from low to medium infertility. Nevertheless, they concluded that the more substantial part of the soil in the country would probably have medium to good productivity value if this resource had appropriate management. Nigeria's soil types are affected by the climatic and vegetational zones that are present in the country and so are broadly classified accordingly. The influence of the vegetational zones on the soil is possible since the volume of moisture that is present in the soil is an essential factor that brings about soil reactions, its richness and productivity (Oyegun, Lawal & Ogoro, 2016). Notably, the type soils present in the humid tropical forests relatively differ from those found in the arid forests and the drier savanna zone, and therefore turns out to be unlike that of the Sahel savanna zone.

The map of Nigeria showing the different types of soil available in their respective locations is presented in figure 2.2.

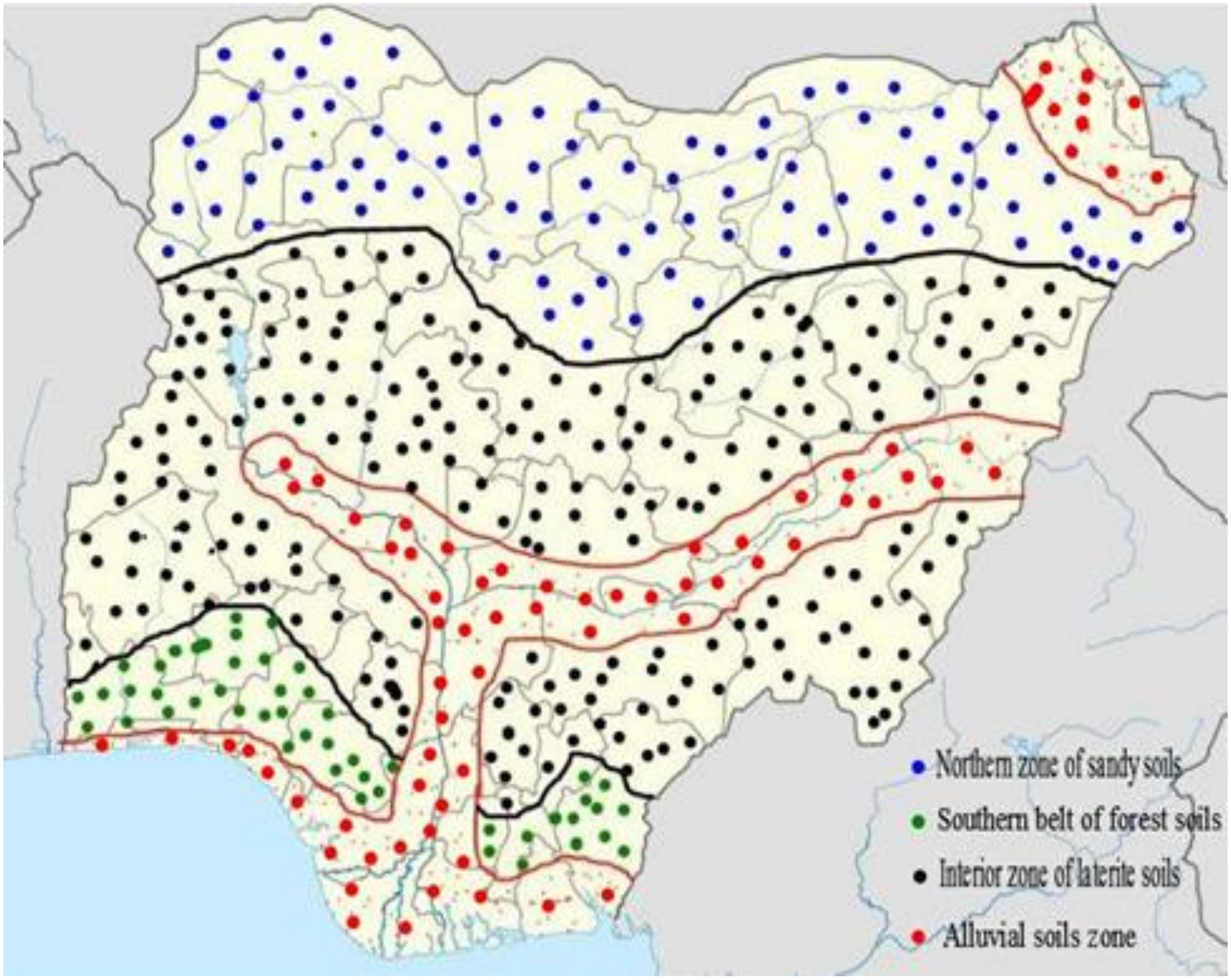


Figure 2.2: Map of Nigeria showing soil types

Source: Adapted from Oyegun, Lawal & Ogoro (2016)

2.5.2 General categorization of the soils found in Nigeria

The different types of soils present in Nigeria are grouped into classes which comprise of four (climatic) zones that are soil related (Nwocha, 2016; Oyegun et al., 2016; FGoN, 2019). The classes are:

(i) Northern zone of sandy soils

(ii) Southern belt of forest soils

(iii) Interior zone of laterite soils; and

(iv) Alluvial soil zone.

i) Northern zone of sandy soils

The Northern region of sandy soils is in the parts of the north of the country. In a few places such as the Sahel savanna belt, these soil's are formation is under aridity, occurring through the help of the wind as it deposits sand in the area (Oyegun et al., 2016). The formation of these types of soils may perhaps be as a result of wind-sorted desert sands that had accrued for an extended period when the Sahara Desert infringed many kilometres to the south of its limit at the time. The soils found in this zone are abundant in the production of some crops such as groundnut, some species of sorghum, cowpeas and a considerable quantity of millet. For example, in states like Kano, Northern Kaduna, Zamfara and Sokoto, a fine sandy loam is present here, it is friable, and cultivation of the soil is quite easy.

This type of soil is slightly leached and still perfect for use in cultivating groundnut. However, in the southern part of Kaduna state, what is there is a combination of soils with fragments from local granite, and also the loose soils which were taken away by winds from the northern area. Nevertheless, this type of soil is not said to be sandy. They are also known as the Zaria loam that supports the cultivation of the highest output of cotton in Nigeria (Nwocha, 2016).

ii) Southern belt of forest soils

The soils found in this zone are largely represented by those of the humid, tropical forest climate zones of the south (area with long wet season), the short harmattan season and a densely covered forest (Nwocha, 2016). The types of soil found in a specific location is usually depending mostly on the parent rock. More so, the soils are typically a rich clayey loam in places where the underlying rocks are either granite or clay. The forest soils present in this zone is suitable for the cultivation of crops such as cocoa, oil palm and rubber which are of substantial importance in Nigerian agriculture (Oyegun et al., 2016, FGoN, 2019)

iii) Interior zone of laterite soils

The central zone of laterite soils comprises of sands and clays. These soils are grey to black clays in colour, not well-drained and seasonally flooded giving rise to the "fadama". When the green vegetation on these soils is cleared, the outcome is an additional loss in fertility, consequently, making the existing soil to have little or no agricultural worth. As soon as the soil is uncovered, and is exposed to the surface, it turns out to be so hard like bricks, and because of this, the soil in this location is most appropriate for road paving and wall construction, and not suitable for cultivation (Oyegun et al., 2016)

Additionally, it is essential to note that there exist other types of soil in this zone apart from the laterite soils; nevertheless, they are not present in high quantities. The Biu Plateau, which is in this zone, owns a highly fertile soil, rich in plant nutrients, and it supports productivity. This soil, therefore, provides an opportunity for the increase in the area of farm size of cotton production as it encourages cotton growth (Oyegun et al., 2016; FGoN, 2019).

iv) Zone of alluvial soils

The soils in this zone are seen on the flooded plains of rivers or deltas or found along the coastal flats. This zone extends explicitly from the coast inland to the valleys of the river Niger and the river Benue, and further cuts across the vegetation areas (FGoN, 2019). These soils that are present in this zone are highly independent on climate and vegetation for their buildup. However, the underlying parent rock considered to be the most significant factor in the accumulation of the soil. Soils found here in the zone are mostly of freshwater soil of grey to white sand type, grey clay type and sandy clay having humus topsoil (Nwocha, 2016; FGoN, 2019)

2.6 Nigeria agro-ecological zones

Nigeria is in the tropics, a place where the climate is seasonally damp and very humid. The natural vegetative zones that are present in the country are ruled by the collective impacts of temperature, humidity, precipitation and mainly, the changes that arise in the rain. This builds a significant impact on the nature of native plants that grow fruitfully in various areas in the country. The entire land area of Nigeria is separated into eight wide agro-ecological zones (Nwocha, 2016; FGoN, 2019). The classification is dependent on the likeness of climate and vegetation cover in addition to the kind of crops that are cultivated to each land area. In this classification, no state of the country can claim to have one agro-ecological zone. A state may possess as much as three agro-ecological zones (FGoN, 2019). Nevertheless, in some areas of the East and some other places near the coast, increased precipitation had given rise to severely leached soils and severe erosion in some parts (Oyegun et al., 2016).

The Northern part of the country which represents about 80 per cent of the vegetative regions has less rain and a briefer rainy season; these are the Savannah lands. The Savannah land makes up an outstanding natural habitation for a large number of grazing animals which include cattle, goats, horses, sheep, camels, and donkeys. The natural vegetative zones came up as a result of the interaction amongst the climate, humidity, rainfall and soils. These elements have been altered by human events and man's system of land use (Oyegun et al., 2016).

Consequently, the agro-ecological zones of Nigeria can be categorized into nine zones as shown in Figure 2.3, and are explained as follows based on Onyeka *et al.,* (2008) and FGoN (2019).

i) Mangrove swamp forest and coastal ecological zone:

This zone is seen in areas near the coast that is under the effect of salty water usually seen in the Niger Delta. It is also seen in low swampy land connected with rivers and Lagoon near the coast and under the effect of the sea. Soils in the mangrove area are poorly aerated with waterlogged mud and is high in salt content because of the continual flooding by the sea (Oyegun et al., 2016).

The following species are found in the Mangroves; *Rhizophora racemosa, R. mangle, R. harrisonii, Avicennia africana* and *Laguncularia racemosa.* In Cross River State, the mangroves are endangered by the exotic Nypa Palm, *Nypa fruticans,* that was brought into Calabar and Oron between 1906 and 1912, and has extended other states in Nigeria like Rivers, Delta and Bayelsa. Moreover, the coastal swamp area is not extensively used for farming, apart from the cultivation of swamp rice in places where the locations are stabilised and non-saline. This zone is identified by an entangled dense growth of stems and aerial roots. It, however, supports swamp rice and consists of blends of trees such as palm and raffia. The better-drained areas support oil palm trees and Iroko. Fishing and fiber-making are important products of the zone (Oyegun et al., 2016; FGoN, 2019).

ii) Freshwater Swamp Forest Ecological Zone

This forms an extended belt inland beyond the mangrove swamp forest and coastal zone. This area possesses many open canopies, that may get to 45m tall, are densely tangled, and with nearly impermeable undergrowth (Nwocha, 2016). It is typically flooded throughout the wet season and dries out all through the dry season and further leaves sections of dry forest floor scattered with lasting pools of water. However, many of this kind of vegetation have been changed into agricultural and urban lands, and the initial swamp forest stays typically on alluvial sites along the main rivers (Oyegun et al., 2016).

In the freshwater swamp forest ecological zone, climbing palms with hooked spines are predominant. Large aroids like *Cyrtospernia senegalense* are also found here. Additionally, large trees like *Mitragyna ciliata, Spondianthus preussii, Lophira alata, Anthostema aubryanum* and *Alstonia congensis* are predominant (Nwocha, 2016; Oyegun et al., 2016).

iii) Lowland rain forest ecological zone

This area is situated in the north of the freshwater swamp forest and south of the derived savanna ecological zone. It is a region covered with a thick evergreen forest of tall trees with dense underbrush that consists of three layers of trees which are; the emergent layer with trees more than 36m in height; the middle layer between 15-30m; and the lowermost layer is usually below 15m. The understory is a shrub stratum made up of single-stemmed shrubs. The forest in the Northern parts of the area is identified by several species that belong to the *Sterculiaceae* family, but the *Ulmaceae* and *Moraceae* families are also common (Nwocha, 2016; Oyegun et al., 2016).

In some places, tropical rain forests are restricted to forest reserves, national parks and game reserves, and are also infringed.

iv) Derived savanna Ecological Zone

The Derived savanna is made up of an east-west band between the lowland rain forest and Guinea savanna ecological zones. The characteristic feature of this zone is that it is densely populated. The aspects and conformation of derived savanna are mostly similar to that of the southern areas of the guinea savanna, exception of the relics of lowland rainforest. Nevertheless, in some places particularly where human influence on the forests have been on the increase, there will probably be a substantial decrease of vegetation and plant species (Nwocha, 2016)

The influence of humans has been so severe in this zone that places which are untouched in order to grow back incline to grow savanna type grasses, hence, resulting in a "derived savanna". Fragments of the high forest could possibly show up in upland or rocky places that are not proper for agriculture (Nwocha, 2016; Oyegun et al., 2016).

In addition, this area is comprised of dispersed trees and tall grasses. The main food crops cultivated here are maize, cassava, yam and rice. Overall, the savannah zone has a great possibility for producing food in the country; however, the burning of bush and erosion resulting from over grazing of animal particularly cattle is considered to be the main threat to agriculture in the zone (Nwocha, 2016)

v) Guinea savanna ecological zone

The Guinea savanna otherwise known as the savanna woodland/wooded savanna, is the widest vegetation of Nigeria and it covers nearly half of its area. It spreads from Ondo, Edo, Anambra and Enugu States in the South, extends into Oyo State and goes further to Zaria in Kaduna State. It constitutes a combination of trees and grass (Nwocha, 2016; Oyegun et al., 2016).

It experiences an annual rainfall of 1000 – 1500 mm that lasts for about 6-8 months. It comprises of parkland savanna, gallery forests and derived savanna. It is characterized by a vegetation of an open woodland with tall grasses between 1 to 3m tall in open areas and trees as tall as 15m in height typically with short boles and broad leaves. (Nwocha, 2016; FGoN, 2019).

vi) Sudan savanna ecological zone

This zone is located in the Northern parts of Nigeria and extends from the Sokoto Plains goes beyond the Northern areas of the High Plains of Nigeria up to the Chad Basin (FGoN, 2019). It comprises places near Sokoto, Kaduna, Kano and Borno States of Nigeria, including a section more than a quarter of the country. Rainfall varies from around 600-1000mm and the relative humidity is usually below 40 per cent, exception of some months during the rainy season when this can increase upto 60 per cent or higher Nwocha, 2016; Oyegun et al., 2016).

The vegetation receives a dry season of around 4-6 months. Due to this, the zone has accordingly been affected greatly by the influence from man and livestock. The landscape has fewer vegetation than the Guinea savanna. Present vegetation consists mostly of short grasses, of around 1-2 tall, and some stunted tree species which include

Acacia species, the silk cotton *Ceiba pentandra* (silk cotton) and the *Adansonia digitata* (baobab) (FGoN, 2019).

vii) Jos plateau ecological zone

This area is based on the difference in the vegetation of the plateau with altitude of around 1200 m which relies on two reasons. Firstly, the high plateau has been affected extensively with degradation by human in such a way that only remnants of Guinea woodland persist (Nwocha, 2016; Oyegun et al., 2016).

Currently, the plateau is nearly lacking trees. Secondly, the flora on the zone has a peculiarity to numerous species of woody and herbaceous plants not seen elsewhere in West Africa, together with several usual Guinea Savanna species (Oyegun et al., 2016).

viii) Montane region ecological zone

This zone is distinguished by grassland vegetation at the base, forest vegetation on the windward slope and grassland vegetation on the Plateau (Nwocha, 2016; FGoN, 2019).

The lower slopes of mountains situated in the forest belt like the Bamenda Highlands (in Cameroon) and the Obudu Hills are protected with forest vegetation. In contrast, the upper slopes and the plateau tops have grassland vegetation, which encourages cattle population typically (Nwocha, 2016; Oyegun et al., 2016).

This vegetation is seen along the South Eastern border of Nigeria in the Cameroon mountains. Forest vegetation spreads as much as 1600 to 2400 m and meets with mountain grassland. There are two major types of montane forest. The first is from around 1000 to 1800 m altitudes, and the forest is covered in mist for an extended period and is known as Mist Forest. The second type of montane is the lower grasslands where the majority of the grasses are tussock, have flat leaves, and reach 0.6 m in height, or slightly more. The family *Compositae* is mostly seen in this grassland (Nwocha, 2016; Oyegun et al., 2016; FGoN, 2019).

At about 3000m there is a noticeable difference, the flat-leaved tussock grasses, like *Andropogon distachvus* are substituted by grasses that are of shorter tussocks of narrow rolled leaves, like *Festuca abyssinica.* Trees are not present from this upper grassland, with the presence of some bushy plants like *Blaeria mannii, Senecio clarenceanus* and *Helichrysum mannii* (FGoN, 2019).

However, the region has a high probability of producing maize, wheat, carrot, cabbage and other exotic vegetables but then the mountainous nature of the zone stops commercial farming (Nwocha, 2016).

ix) Sahel savanna ecological zone

The Sahel savanna is situated to the far Northwest and Northeast of the country, whereby the annual rainfall is lower than 600 mm and with dry seasons going beyond eight months. Usually, the zone is made up of grasses, open thorn shrub savanna with scattered trees, of about 4 to 9m high, mostly thorny, and widespread sparse grasses (Nwocha, 2016; Oyegun et al., 2016).

Table 2.4: Summary of Nigerian Agro-ecological zones

Agro-ecological zone	**Description**
i) Mangrove swamp forest and coastal ecological zone	This zone is seen in areas near the coast in the Niger Delta. Soils are poorly aerated with waterlogged mud and is high in salt content. This area is not extensively used for farming, apart from the cultivation of swamp rice in places where the locations are stabilised and non-saline
ii) Freshwater Swamp Forest Ecological Zone	This area is typically flooded throughout the wet season and dries out all through the dry season and further leaves sections of dry forest floor scattered with lasting pools of water. In the freshwater swamp forest ecological zone, climbing palms with hooked spines are predominant.
iii) Lowland rain forest ecological zone	It is a region covered with a thick evergreen forest of tall trees with dense underbrush that consists of three layers of trees which are; the emergent layer with trees more than 36m in height; the middle layer between 15-30m; and the lowermost layer is usually below 15m.

iv) Derived savanna Ecological Zone	The characteristic feature of this zone is that it is densely populated, and its conformation is mostly similar to that of the southern areas of the guinea savanna, exception of the relics of lowland rainforest. The main food crops cultivated here are maize, cassava, yam and rice.
v) Guinea savanna ecological zone	This area is the widest vegetation of Nigeria, and it covers nearly half of its area. It is characterized by a vegetation of an open woodland with tall grasses between 1 to 3m tall in open areas and trees as tall as 15m in height.
vi) Sudan savanna ecological zone	This zone is located in the Northern parts of Nigeria and consists mostly of short grasses, of around 1-2 tall, and some stunted tree species. The landscape has fewer vegetation than the Guinea savanna.
vii) Jos plateau ecological zone	This area is based on the difference in the vegetation of the plateau with altitude of around 1200 m. The high plateau has been affected extensively with degradation by human in such a way that only remnants of Guinea woodland persist.
viii) Montane region ecological zone	This vegetation is seen along the South-eastern border of Nigeria in the Cameroon mountains. There are two major types of montane forest. The first is around 1000 to 1800m altitudes, and the second is the lower grasslands where the majority of the grasses are tussock, have flat leaves, and reach 0.6 m in height.
ix) Sahel savanna ecological zone	The Sahel savanna is situated to the far Northwest and Northeast of the country and made up of grasses, open thorn shrub savanna with scattered trees, of about 4 to 9m high.

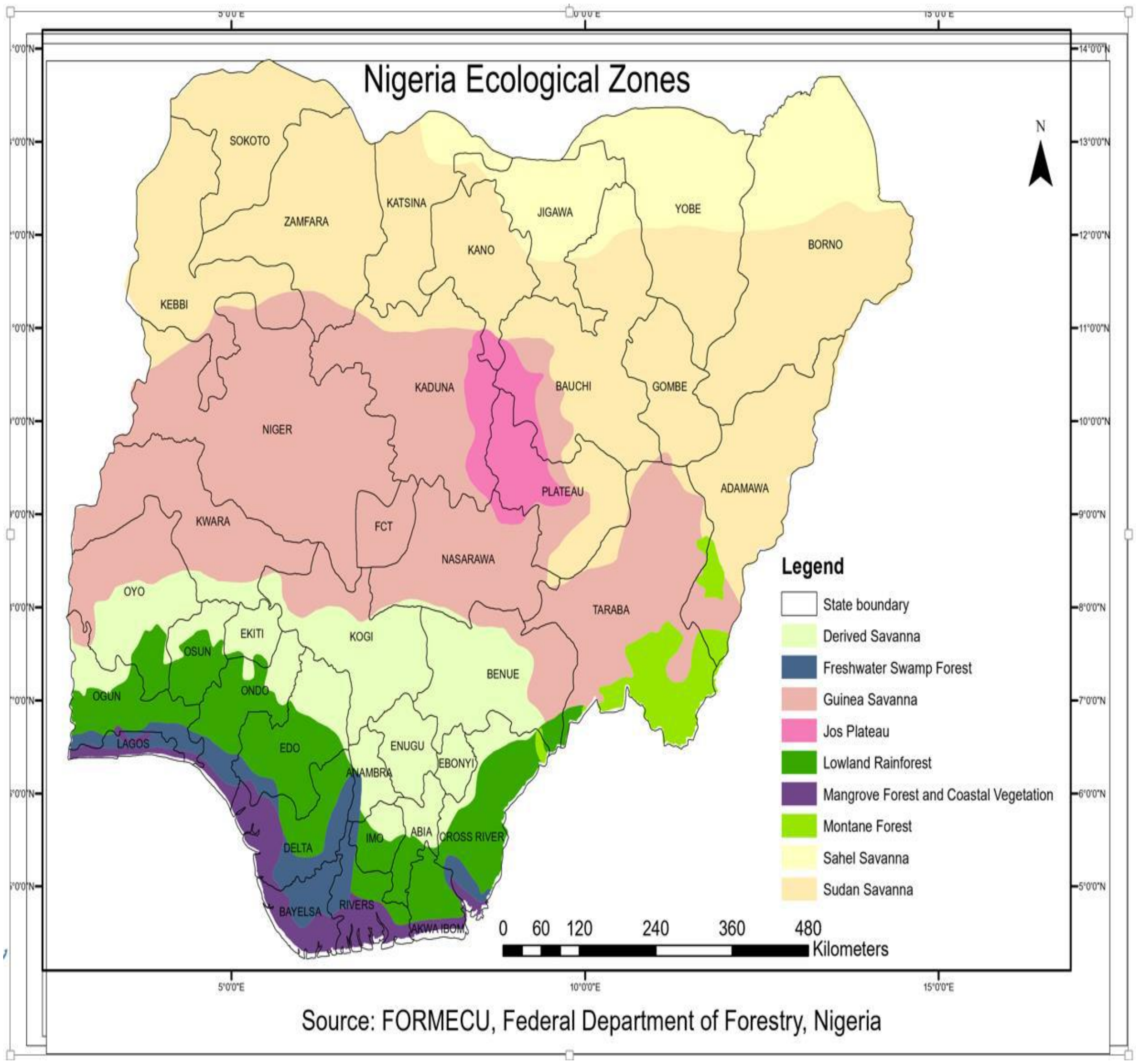


Figure 2.3: Map of Nigeria showing the agro-ecological zones

In summary, the different types of ecological zones influence the crops that are prevalent in each zone. These zones cross multiple States and some States may contain multiple ecological zones. The yam crop, the focus of this study thrives well in the derived savanna ecological zone.

2.7 Food staples in the different ecological zones in Nigeria and the need for adaptation strategy

Nigeria is prominent for the diversity of its ecosystems, a benefit for cultivating a wide variety of crops. The rainfall measure in the country varies from 500mm in the North to nearly 3,000mm in the South (FMARD, 2016). The forests in the subtropical climate of the South where rain is substantial profit from excessive rainfall and quite short dry seasons. This, however, allows for a wide range of crops to thrive in Nigeria. The staples are root crops, including yams, cassava, taro (coco-yams), and sweet potatoes. Tree crops--cocoa, oil palm, and rubber--comprise the region's critical saleable commodities. Cacao, from which cocoa is made, is planted typically in the southwest. Oil palms (whose kernels can be made into palm wine) dominate in the southeast and are abundant in the south-central area. Rubber stands are prevalent in south-central and south-eastern Nigeria (Agbor, 2007; FMARD, 2009).

The area between the arid north and the moist south lies the Guinea savanna region which is occasionally called the middle belt. This region grows food staples which include yams, sorghum, millet, cassava, cowpeas, and corn, with rice a significant crop in some areas. The middle belt's southern side signifies the minor bounds of the northern grain-dominated economy. The most significant substantial saleable crop of the central belt is sesame (or benniseed). Also, mechanised farming is on the rise in this area (Agbor, 2007; Agom, Ohen, Itam, & Inyang, 2012).

Furthermore, the dry zone in the North is typically dedicated to cultivating grains such as rainfed sorghum and millet, irrigated and/ or rainfed rice, legumes, onions and groundnuts. The northern third of Nigeria, which faces a dry season of five to seven months, is located majorly in the Sudan savanna and the arid Sahel zone. There, the staples are millet, cowpeas, and a drought-resistant variety of sorghum known as guinea corn. Corn is also cultivated here in the area. The north's primary salable crops are cotton and groundnuts. As already mentioned, the majority of Nigerians consume grains, but the cultivation and demand of sorghum (guinea corn) and millet are highly focused in the savanna north (Agbor, 2007; Agom et al., 2012).

Importantly, climate change affects staple food production in Nigeria. Specifically, results from the Environmental Policy Integrated Climate (EPIC) model show an increase in yields of staple food crops such as maize, sorghum, rice, millet, and cassava across all lowland ecological zones as the predicted climate changes are calculated towards 2050. However, near the end of the 21st century, the amount of production increment is predicted to be likely to be slow (Adejuwon, 2006).

Using output from 14 CMIP3 General Circulation Models (GCMs) and applying the crop model DSSAT, Thornton *et al.,* (2011) estimate mean yield losses of 24 per cent for maize and 71 per cent for beans under warming beyond 4^0C. Regarding non-cereal crops, there is a lower decisive indication of the effects of climate variation on productivity. Productivity in cassava is likely to rise into the 2030s, if there is a CO fertilization as a consequence of climate change, nonetheless, by mid-century adverse effects from climate variations are likely to arise (Schlenker & Lobell, 2010; Lobell et al., 2008). Cassava crops appear to be more resilient to increase in temperatures and inconsistent rainfall than cereal crops (Niang et al., 2014). Added to this, tuber development in potatoes is severely inadequate at temperatures less than 10°C and more than 30°C (FAO, 2016). Therefore, the negative effect of climate variation on agriculture calls for the need to apply adaptation strategies in Nigeria. The yam crop is now considered specifically.

2.7.1 The yam crop

Yam is chosen as the indicator crop for this study as it is a staple food in the Nigerian and West African diet. It is a tropical crop in the genus *Dioscorea* and has as many as 600 species out of which six are economically important staple species. The *Dioscorea rotundata* (white yam) and *Dioscorea alata* (water yam) are the most common species in Nigeria (Agboola, 1979; Ike & Inoni, 2006; Awoniyi & Omonona, 2007). However, *Dioscorea rotundata* (white yam) will be considered in this study as it is the most common and essential species in Cross River State.

The use of yam as an industrial starch is recognised as some of the species provide excellent quality that can be processed into much starch (Ike & Inoni, 2006). The cultivation of yam is carried out in three major ecological zones in Nigeria: the northern section of the rainforest (Cross River State inclusive), southern Guinea or derived savanna, and the south portion of the north of Guinea savanna (Zakari et al., 2014). Yams are primarily a tropical crop, and require good fertile soil, adequate and well-distributed rainfall, for agronomic operations such as land preparation, planting, staking, and weeding. Since they require 6-9 months to mature on the field, the wet season must last for this period, (except where there is provision for supplementary irrigation) with a sharply demarcated dry season of 2-5 months. Yams do not tolerate waterlogging (Onwueme & Sinha, 1991).

Importantly, the distribution of rainfall is more important than the volume. Yams grow better in areas that have 1,000-1,500 mm of rain well distributed over their maturity period in the cropping season. They require a temperature of between 25^0C and 30^0C for excellent performance. Yams do not tolerate frost and require sunshine at their growth stage (Onwueme & Sinha, 1991). Yams need moisture through the dynamic growth period for vine and leaf development, tuber initiation and bulking; the most critical stages are at tuber initiation and bulking (Zakari et al., 2014). Yam output and harvest patterns are important economically to the income of an average Cross River State farmer, the location for this study, because they contribute to food sufficiency in rural areas in the state.

2.7.2 Factors that influence yam productivity and profitability in Nigeria

Yams are the fifth most extensively harvested crop in Nigeria (after cassava, maize, guinea corn/sorghum, and beans/cowpeas); and, the most frequently harvested tuber crop after cassava (NBS, 2012).

Despite how vital Yam is to people, the attention given to its production is still limited. However, some scholars empirically examined the influences on the level of yam production in Nigeria and elsewhere in the world (Verter & Bečvařova, 2015). Some of these studies, including that of Bamire and Amujoyegbe (2005) reveal a positive relationship between net returns (profitability) in yams output and land improvement techniques in Nigeria. Added to this, lack of access to inputs, finance, reduced producer prices, inadequate of storage facilities, incidences of pests and diseases have negatively affected yam production in Nigeria (Tanko, 2013). Similarly, in other studies by Ike and

Inoni (2006); Maikasuwa and Ala (2013, they assess some determinants of yam production in different regions in Nigeria. The findings of their study revealed that factors of production such as labour, finance and inputs like fertiliser have influenced yam production in Nigeria. Arguably, one of the costliest crops to produce is yam because the process of sowing and harvesting needs substantial labour input; yam seeds are expensive, and limited in supply (Verter & Bečvařova, 2015).

Moreover, the Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) data showed that only 43 per cent of farm families that harvest yam retail any portion of the produce. In contrast, it was found out that farm families are much more likely to sell harvested cassava, maize, and beans/cowpeas in the proportion 66, 57, and 69 per cent, respectively (NBS, 2011). The LSMS-ISA data indicated that nearly 45 per cent of harvested yam seed is preserved for the subsequent planting season. This is different from other staple crops, for which almost 20 per cent of produce collected is preserved (NBS, 2011). Although farm families are expected to prefer to preserve their yam seed to selling the produce, yams, however, signify a valued element of farmers' source of income (NBS, 2011).

2.7.3 Trends in yam production

According to FAO (2018), the area of yam harvested in the world has increased from 1.15 million (Ha) in 1961 to 5.04 million (Ha) in 2017. Yield (Kg/Ha) in the world has also improved from 72.35 thousand metric tons in 1961 to 116.65 thousand metric tons in 2017. Over 60.75 million tons of yams were produced in the world in 2017, out of which 92.2 per cent were from West Africa. However, Table 2.4 presents data available from FAO (2018), which reveals the trends in annual yam production in Nigeria, between the period 1961 and 2017.

Table 2.5: Annual yam production in Nigeria (1961-2017)

Yam element	***1961***	***1980***	***1985***	***1990***	***1995***	***2000***	***2010***	***2015***	***2017***
Area harvested (Ha, 1000)	450	498	840	1276	1218	2647	2869	5390	5925
Production (MT Million)	3.30	5.25	4.74	13.62	22.82	26.21	34.16	45.68	47.94
Yield (Kg/Ha)	77,778	105,382	56,405	106,771	107,734	98,984	119,073	84,748	80,917
Yield (MT/Ha)	7.80	10.50	5.60	10.70	10.8	9.80	11.90	84.70	80.90
Production (% of the world)	42	44	39	63	69	66	64	65	67

Source: FAOSTAT, 2018

The table shows that Nigeria, particularly, accounts for over 67 per cent of the world yam harvest and grew about 5.9 million hectares of land in 2017. Also, Figure 2.4 illustrates the output of yam production during the period 1961-2017 especially that yam output was on a steady increase from 1980-2017 potentially as a result of the increase in area of land cultivated throughout the period.

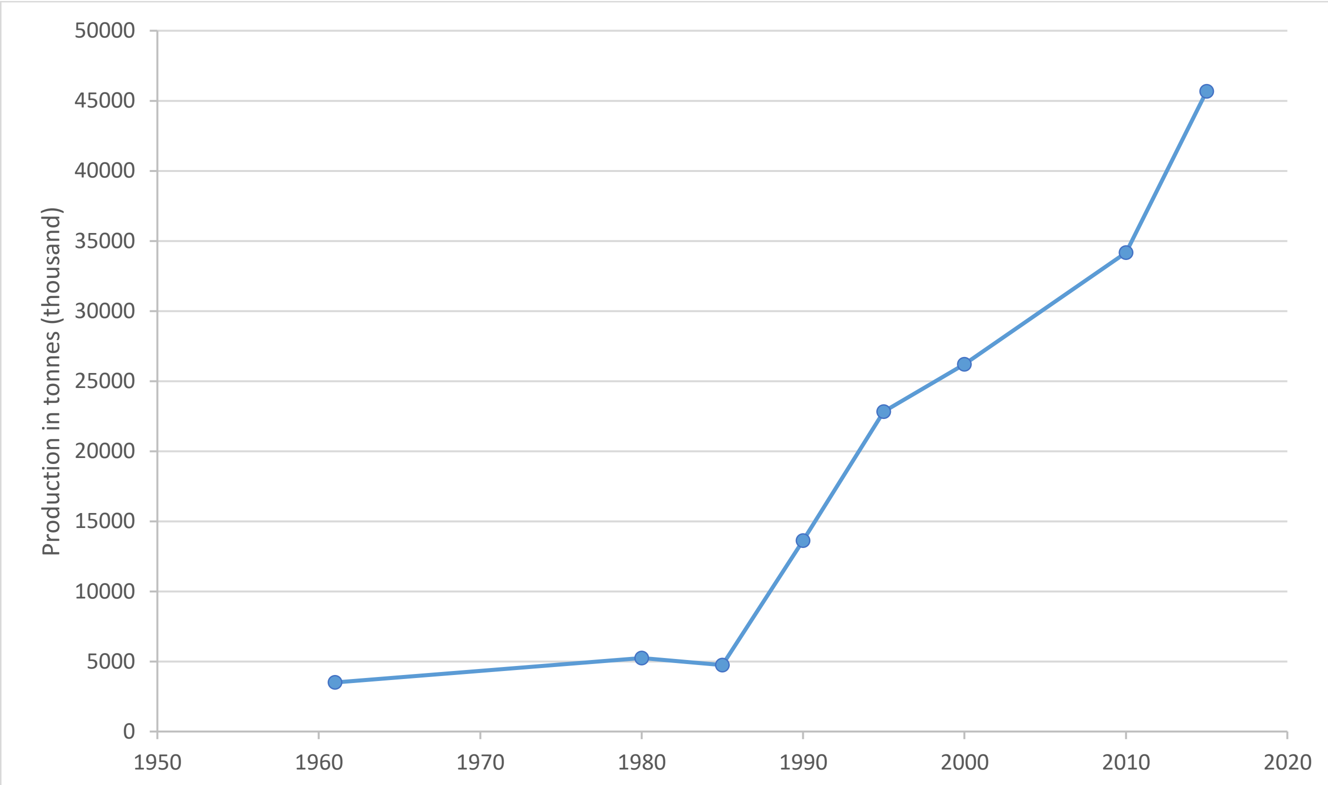


Figure 2.4: Trends in yam production in Nigeria (1961-2017)

Source: Author's analysis with data from FAOSTAT 2018

2.7.4 Economic and socio-cultural importance of yam

Yams have a wide range of uses. Yams are part of the most eaten food crops in West Africa, including Nigeria (NBS, 2012). Yam farming is very lucrative despite its high costs of production and price variations in the markets (Izekor & Olumese, 2010; IITA, 2013). According to IITA (2013), after the harvest and storage of yam in Nigeria, an average return per yam seed was estimated to be above US$13,000 per hectare harvested.

Additionally, the demand for yam by households for consumption is high in Sub-Saharan Africa and in terms of nutrition, yam is a staple food. For years, even before maize and other good crops became diffused across farms, yam has been the primary staple food for the Nigerian population (Zakari, Mohammed, Medugu & Sandra, 2014). In terms of food security, people in West Africa rely on yam (Verter & Bečvářová, 2015). Yams are rich in carbohydrates, vitamin C, potassium, manganese and other essential minerals with more than 21 per cent dietary fibre (IITA, 2009). In many areas where yam is produced in Nigeria, it is said that yam is food and food is yam. Nevertheless, yam production in Nigeria is considerably limited and not able to meet the increasing demand at the level it is consumed presently (Awoniyi & Omonona, 2007). More so, the place of this edible crop in the diet of smallholder farmers cannot be disregarded. This is because it produces more than 200 dietary calories per capita per day for more than 150 million individuals in West Africa (Babaleye, 2003). Added to this, some families in the rural areas where yams are cultivated consume it daily, perhaps due to yams being the only available food, particularly during the harvest periods (Verter & Bečvářová, 2015). Furthermore, yam contributes to the essential roles in the social-cultural events in Nigeria. For example, some people use it on occasions like marriage and birth ceremonies. Moreover, the yam festival occurs annually to celebrate its yield, and other social rites in most yam farming communities (Aidoo, 2009; Izekor & Olumese, 2010; IITA, 2013).

2.8 Role of government and extension in agriculture

The government and extension services carry out some vital roles in agriculture in Nigeria, these roles are discussed in the following sub-sections.

2.8.1 Role of government in Nigerian agriculture

The effective execution and administration of the whole agricultural policy board of Nigeria depend critically on the national, state and local organisations, which are built and instituted for agricultural progress. It will, therefore, be the duty of the board to make sure that the goal of the government in agricultural development are satisfied in accord with the set aims.

To lessen the overlap and repetition that occurs during operations in certain areas amongst the three tiers of government (federal, state and local government) in Nigeria, the roles of the Federal, State and Local Governments are distinctively considered in this sub-section following Federal Ministry of Agriculture, Water Resources and Rural Development (2018).

Table 2.5 presents the differentiated role of federal government, state government and local government in agriculture in Nigeria. The Local Government establishments was anticipated to take over gradually the duties of the State government.

Table 2.6: The role of role of federal government, state government and local government in Nigerian agriculture.

Role of Federal Government	Role of State Government	Role of Local Government
i) To provide the overall policy framework to develop agriculture, and supervision to state and other public interventions on areas of importance for investment; ii) To lead research into all areas of agriculture, including the provision of breeding stock and finding seeds of improved varieties, brood stock and improved fast-growing hybrid species; iii) To control pests and diseases of national and international significance; iv) To develop water resources, which includes the building and care of small, medium and large dams for irrigation, aquaculture (fish farming), rural water supplies and other uses and the construction of boreholes; maintaining strategic grains and animal product reserves for food security;	i) Promoting of the primary production of all items of agricultural produce via the maintaining of active extension service. ii) Ensure land accessibility to people interested in farming; iii) Education for agricultural development iv) Inhibit plant and animal pests and diseases v) establishing suitable organizations to administer credit to small scale farmers, pastoralists, fishers and fish farmers vi) maintaining buffer stocks of agricultural commodities to deal with price fluctuations	i) Providing an operative agricultural extension service; ii) Providing the rural infrastructure; iii) The organisation of farmers for quicker agricultural and rural development through cooperative groups and the communities; iv) Providing land for new farmers in agreement with the provisions of the Land Use Decree; and v) The organisation of data collection at the primary levels

v) Guidance on agricultural commodity tariff and pricing policy via depictions in suitable policy design committees; vi) The promotion of the sale of exportable agricultural produce outside the country; vii) Maintaining a realistic flow of resources into agriculture and rural development by way of matching grants, subventions and investments in Federal, joint Federal and State, State and other specialised projects and by creating conditions which facilitate resources flow from other sources; viii) The education of human resources for agricultural development; and the formation of an Agricultural Insurance Scheme.	vii) Investing in rural development, which involves rural roads and water supply to improve the living standards of living of rural inhabitants; viii) Tenure status, management and control of forest estates held in trust for the local communities;	

2.8.2 Role of extension in agriculture in Nigeria

The extension process involves the transfer of technology or innovation on agriculture to farm families with the view to improve their economic conditions. Hence extension in agriculture means providing information to farmers on the adoption of the new technologies and improved practices in various subsectors like crop production, livestock rearing, fodder production, sericulture, beekeeping, horticulture etc. Extension, whether knowledge transfer or knowledge exchange activities, seeks to change the attitude and views of the farming community in general and also finds ways to improve the farm operations and the farmer's family life. (Agbarevo, 2014). In order to improve, farmers require direct access to developing agricultural technology. For a group of farmers to be educated in current methods and practices, there has to be a sustainable process to keep pace with rapidly changing agrarian technology (Agbarevo, 2014; Ajayi, 2015).

Extension effectiveness serves as an indicator which aids in assessing the success of extension personnel (Ajayi, 2015). Hence, to determine extension effectiveness, the following factors are considered: the level of awareness of the farmers about extension services, the village extension worker's number of visits, the percentage of meetings that occur between farmers and extension workers, the number of field meetings that have taken place, whether village extension worker's regular meetings are held, the number and frequency of scheduled field days by village extension worker, monthly or quarterly, etc., the demonstrations scheduled by the village extension worker within a given time (monthly, quarterly, annually), the number of supervisory visits, and the number and regularity of research-extension linkage workshops and the farmer training sessions/farmers trained (Agbarevo, 2013; Ajayi, 2015). Effectiveness, however, stresses what the extension personnel achieved in terms of the events being organised and how resources, such as capital, manpower, goods and services, training and technologies are required for execution of the programme have been applied (Williams, 1984).

As a way of assessing the extension programme, the extension effectiveness model was developed by Ajayi (2015). This model evaluates the extension programme based on the achievement of project involvement delivery system. The model stresses the purpose of effectiveness by way of the suitability of input supply, delivery of machinery and their accessibility, among other variables. Amalu (1998) and Agbarevo (2014) noted that extension delivery shows unsatisfactory result concerning extension effectiveness factors, specifically with regards to farming systems research and farmer training programmes, which are recognised as a weak connection in the agricultural extension delivery in Nigeria. This poor performance in extension delivery is as a result of:

- the researcher's insufficient attention of externalities and the extensive resources that would be required for it to be on track with the dynamics of farming systems;
- inadequate preparation of scientist for a face-to-face discussion with farm households, and
- the propensity of researchers to control the strategy, content, conduct and assessment of the on-farm test (Amalu, 1998; Uza, Avibodo, Abubakar & Ahmed, 1999).

Similarly, the principal goal of agricultural extension delivery is to get farm households to accept the recommendations on how to improve agricultural technology to increase the harvest. Thus, the achievement of the Millennium Development Goal on food security would neccessitate that efficient extension recommendations are offered to show the felt needs of farmers and how well they are distributed among other variables (Agbarevo, 2013).

Additionally, the Cross-River State extension service, as part of their role, made the following production recommendations for agriculture growth according to Agbarevo (2014):

1. Small Plot Adoption Technique (SPAT) -Yam based interplanted with melon and maize;
2. Planting yam, groundnut, maize as a course at specific spacing and time;
3. Crop rotation;
4. Planting legumes in rotation;
5. Early planting;
6. Use of melon as a cover crop;
7. Use of Neem leaves as mulch/surface cover;
8. Use of yam bean for pest control;

9. Compost making;
10. Fertiliser types, timing and methods of application;
11. Herbicide use;
12. Chemical pest/disease; and
13. Keeping proper records.

2.9 Summary of Nigerian agricultural policy

The making of agricultural policy in Nigeria has passed through evaluation several times. All through each phase of the review by the fedreal government, the features of the plan have echoed the duties that the sector is likely to perform and the relative available resources. This is mainly because petroleum turned out to be a significant source of income used to fund the programme. With regards to this, agricultural policy is considered to be dynamic (FMARD, 2016).

2.9.1 Different agricultural sector programmes and policies in Nigeria

The Federal Government of Nigeria introduced policies and programmes that were set to commence in 1986 to eliminate administrative bottlenecks in offices. These policies were also formulated with an intension to adopt a free-market-oriented economy that will support private businesses and encourage efficiency in the utilization of resources. An example of such a programme is the Structural Adjustment Programme (SAP) which had three objectives. These objectives were to; (i) raise the output of cash crops for exportation, and in so doing, diversify the export base of the country’s economy, (ii) increase the employment and income of rural dwellers (iii) raise the quantity of food produced locally, increase dietary status and standards. The federal government designed policy instruments of SAP that impacted on the agricultural sector directly or indirectly, and such policies included; (i) the fiscal policy, (ii) the monetary policy and (iii) the trade and foreign exchange rate policy (FMARD, 2016).

However, different agricultural policies and programmes were previously executed before SAP was launched in 1986 by the federal government. Some of these programmes were not implemented well and some were reorganized. Nonetheless, some are still in existence (Iwuchukwu & Igbokwe, 2012; Olomola, 2014; FMARD, 2016). These policies include (i) Farm Settlement Scheme (FSS), (ii) National Accelerated Food Production Programme (NAFPP), (iii) Agricultural Development Projects (ADPs), (iv) River Basin Development Authorities (RBDAs) (v) Nigerian Agricultural, cooperation and Rural Development Bank (NACRDB), (vi) Operation Feed the Nation (OFN), (vii) Green Revolution Programme (viii) Directorate of Foods, Roads and Rural Infrastructures (DFFRI) (ix) Agricultural Credit Guarantee Scheme Fund (ACGSF) (FMARD, 2016).

Again, in the year 2004, the Federal Government of Nigeria introduced additional economic transformation programme which was referred to as the National Empowerment and Development Strategies (NEEDS). The programme aimed to promote growth and development, and also alleviate poverty via a participatory process which involves a partnership between the civil society and development bodies. Added to this, the NEEDS programme in the agricultural sector was intended to promote and improve output, support distribution of goods and the processing of agricultural products (Izuchukwu, 2011; Iwuchukwu & Igbokwe, 2012; Olomola, 2014; FMARD, 2016).

Regardless of these policies and programmes mentioned, it has been reported earlier in this chapter that the performance of the agricultural sector has been unimpressive compared to what was anticipated when the policies and programmes were initiated in an attempt to contribute to the economic development of the country (Izuchukwu, 2011; Iwuchukwu & Igbokwe, 2012; FMARD, 2016).

2.9.2 Policy to support agriculture

The policies to support agriculture in Nigeria are discussed under the next sub-headings based on the work of Iwuchukwu and Igbokwe (2012), Olomola, (2014) and FMARD (2016).

(1) Agricultural extension, technology development and transfer policy

The main objective of the policy on agricultural extension, technology development and transfer of the government was to make rural people acquire knowledge on how to increase their standard of living using their determinations. By this, the government was interested in the spreading of meaningful and practical knowledge that relates to agriculture, how to practically apply such information and how to mobilize the resources of farmers for the aim of bettering their wellbeing (Iwuchukwu and Igbokwe 2012; FMARD, 2016).

Although it is known that the agricultural extension system in Nigeria is influenced by administrative, human resource and financial problems, the government was devoted to addressing these matters in an attempt to assist smallholder farmers. However, the state government who is responsible for the mobilisation of farmers was to be supported via the following policy strategies (FMARD, 2016).

(a) Providing suitable facilities and infrastructure to aid in training for efficient extension services;

(b) Establishing an effectual communication network amongst researchers, extension agents and the farmers to assist in linkages;

(c) The efficient use of extension services as go-betweens for technology and innovation transfer from researchers to the farmers;

(d) Establishing of demonstration farms and rural processing demonstration centers for crops, livestock, fisheries and forestry; and

(e) Supporting to the private sector for investment in agricultural information dissemination

(2) Agricultural credit policy

The aim of the agricultural credit policy was to make sure enough investment funds are accessible to the agricultural sector at the appropriate time and at a given rate that will improve agricultural incomes (FMARD, 2016).

The strategy the federal government intended to approach this in two ways. The first approach is a structural adjustment in fiscal and monetary policies as these policies have a significant impact on the agricultural sector. The second approach encompasses a change in the activities of the existing institutions that are put in place to make available agricultural loans.

The first approach to modify fiscal and monetary policy was to involve:

(a) A rise in the allocation of loans to different sub-sectors and advance to agriculture from 15 percent to around 25 per cent;

(b) The scrapping of grace periods and suspension on agricultural loans in line with the development periods of the projects;

(c) Reconsideration of interest rates to aid the Nigerian Agricultural and Cooperative Bank (NACB) to get funds from financial sources outside the Central Bank;

(d) A government rule which makes it compulsory for financial institutions to give loans of as much as 50 per cent in communities under rural banking scheme to borrowers in the rural centres; and

(e) A system monitored by the government to be sure that credit procedures are accomplished (Olomola, 2014).

Likewise, the second approach which involves changes in the process of loaning institutions was to comprise of;

(a) A rise in the number of divisions and share capital of the Nigerian Agricultural and Cooperative Banks to allow penetration to the rural centres and mobilisation of rural savings;

(b) The annulment of the condition of perceptible collaterals such as the Certificate of Occupancy and survey plan and the replacement of Customary Occupancy Rights as securities for obtaining an agricultural loan by smallholder farmers; and

(c) Establishing of a rural socialised financial institution with the NACB, cooperatives and farmers' organisations taking most of the equity shares while the state governments obtains minor shareholding. These banks, however, will function as an on-lending institutions for directing NACB and other bank credits to the rural farmers (Iwuchukwu & Igbokwe, 2012; Olomola, 2014; FMARD, 2016).

(3) Agricultural Insurance Policy

In the year 1984, the federal government of Nigeria recognised the failure of the small-scale farmers to afford the obligatory securities as a key issue in loan administration to small-scale farmers which under the Agricultural Credit Guarantee Scheme, are covered only as much as 75 per cent of accruable bad debts. In an attempt to prevent this problem of lack of loan collaterals on the part of smallholder farmers, the government would launch an agricultural insurance scheme for the advantage of the small-scale farmers specifically (Iwuchukwu & Igbokwe, 2012; Olomola, 2014).

Moreover, the main aim of agriculture insurance policy will be to protect the small-scale farmers in Nigeria against the impacts of natural dangers via a process or a technique that provides fast protection (compensation) adequate to sustain these farmers in their occupation and also as offer required back-up to government policies on the growth and development of agriculture. It was also envisioned to aid in the availability of loans to farmers and in improving the recovery of the loan. Furthermore, the federal government intends to apply the following measures (Olomola, 2014; FMARD, 2016).

(i) It will be made obligatory for farmers who benefit from an agricultural loan to have insurance even though self-financed farmers will also be beneficiaries of the organisation. Even so, small to medium and large-scale farmers will have eligibility via involvement or registration in farmers' cooperatives and other groups of the farming organisation;

(ii) Primary attention and consideration will be given to the whole parts of crop and livestock production in all the ecological zones of the country with consequent expansion to fisheries, forestry and other agricultural activities;

(iii) The formation and early provision of funds to the agricultural insurance scheme will be in control of the Federal Government, even though the state governments and well-organized private sectors will take part in the subsidy and carry out corresponding activities in the execution; and

(iv) The expectation of insurance companies to organize coffers to invest in agriculture, which will help in supporting agricultural output.

(4) Agricultural products marketing policy

The purposes of the agricultural produce marketing policy was to efficiently distribute the produce from the agricultural sector in a way that seasonal changes are kept to the barest minimum and agricultural goods are uniform and consistent all over the country and produced so they can be sold at reasonable prices; and secondly, to encourage the exportation of all agricultural produce that can be exported (Olomola, 2014; FMARD, 2016).

Moreover, since product marketing boards and the controlled pricing of arranged agricultural goods are no longer in existence, the government was to, therefore, implement proper planning to encourage a fire, fair and competitive marketing administration for agricultural produce. The government was to adopt the subsequent approaches in the agricultural products marketing policy (Olomola, 2014; FMARD, 2016);

(i) People, processors, cooperatives, associations and limited liability companies will have the freedom to export agricultural produce;

(ii) The whole produce considered will be exposed to sorting and authorisation by the State and Federal Produce Inspection Services to ensure a suitable quality standard. Added to this, the produce will be exposed to regular customs inspection before they are exported;

(iii) Give a variety of striking incentives to producers of commodities and those who transport goods;

(iv) Ensure an overall investigation that covers the free produce market activities via the present Technical Committee on Agricultural Produce and the Export Commodities Coordinating Committee and both of will be controlled for improved efficiencies. More so, robust strategies was to be put in place to ban any control to the national drive of goods in Nigeria;

(v) Activate a buffer stock scheme where agricultural produce will be bought and kept in the times of fair supply excess for re-sale at the time of virtual scarcity so that the prices of agricultural commodities can be stabilised;

(vi) Offer help to the development of mainlymarketing cooperatives and commodity exchange market, and this will be primarily private sector enterprises;

(vii) Offer a suitable framework for marketing research and the distribution of market information that concerns overall agricultural commodities;

(viii) Thoroughly check and legalise every agricultural marketing operations especially the marketing activities of the general market groups to lessen the unpleasant actionsby some of the associations; and

(ix) The government will, at all stages keep on providing enough structures to aid in the speedy expansion of agricultural marketing. Regarding this, operations will be increased to make available additional rural centres via the building and care of rural roads. Additionally, the state and local governments will be supported to build other agricultural markets and make improvements to storage amenities in these markets (Olomola, 2014; FMARD, 2016).

(5) The agricultural commodity storage policy

The aims of this policy were, firstly, to improve food price stability during inter-season and inter-yearly; and secondly, to make sure there is increased food security for the country via competent food storage programmes (Iwuchukwu & Igbokwe, 2012; FMARD, 2016).

The strategies the government was to adopt under this policy are;

(i) Access the entire existing ways and skills to encourage and assist small-scale farmers in taking the on-farm storage of agricultural produce. Simultaneously, the private sector will also be supported to gather and store excess agricultural produce;

(ii) Deposit around 10 per cent of the overall grain production in their respective area of consideration which will be utilised as a buffer stock to stabilise the price. Further, the Federal Government will also accumulate at most 5 per cent of the overall grain production in the nation precisely to serve as a strategic grain reserve; and

(iii) Support will be offered for the instant processing and handling of perishable agricultural produce whereas suitable skills will be established for them to be stored in fresh forms.

(6) Agricultural commodity processing policy

The objectives of this policy were as follows; (Iwuchukwu & Igbokwe, 2012; FMARD, 2016);

(i) To increase the demand base for agricultural commodities and hereafter, hasten the amount of growth and development of the agricultural sector;

(ii) To support the preservation of fresh agricultural produce to lessen the amount of waste and the rate of their price variations during the season; and

(iii) To encourage diversification of job prospects in rural centres via the formation of rural-based small-scale agricultural produce processing industries.

The strategies, government will undertake include;

(i) The government will encourage investing in agro-processing, particularly in rural centres, via credit facilities, infrastructural amenities and other incentives to investors;

(ii) Research interest in the proper agro-processing skill that is mostly undertaken by the small-scale Nigerian system of agricultural production will be encouraged;

(iii) Producers in agriculture will be supported to join the farm agro-processing cooperatives to assist them in cooperatively processing their agricultural products; and

(iv) Programmes to enlighten farmers will be planned by the government to inform small stakeholders with the economic prospects which are hidden in simple, cottage agro-processing operations in Nigeria.

(7) Agricultural Research

The purposes of the research policy regarding agricultural growth and development will comprise of

(i) The growth of better-quality and more significant yield production materials which include seeds, stems, seedlings, fingerlings, etc.

(ii) The growth of suitable skills in the part of preparing the land, planting, harvesting, processing and storage of farm products which are not just practical and economical but is also able to reduce the everyday drudgery in agriculture;

(iii) The growth of suitable skills for the best application of farm input like fertilizers, herbicides, pesticides, etc., to intensify production abilities; and

(iv) Providing proper skills and packaging of activities for optimal output and the overall enhancement of the standard of living of the farmers in the rural areas (Iwuchukwu & Igbokwe, 2012; FMARD, 2016);

The strategies government intends to adopt include;

(i) The government will make sure that research institutes and other bodies that partake in agricultural research carry out research and progress technologies which are essential to the needs of the farmers in Nigeria. These research institutes will, therefore, make sure that the outcomes of their studies are forwarded to get to the end-users;

(ii) The government will make sure research institutes are effectively sponsored over a continued period to confirm the accomplishment of outcomes. Research sponsorships will be made possible to apply to respective projects with specific and realistic goals. Regarding this, the federal government will assign up to 3 per cent of its annual budget to research. In contrast, the private sector will be assisted via tax relief to encourage problem-solving research;

(iii) A built-in mechanism built to organise, and check research operations will be put in place. This mechanism will take required knowledge of research importance and also emphasise farming system research and the progress of proper technologies for land preparation, cultural operations, crop harvesting, processing and storage;

(iv) The administration of these research institutions will be undertaken by a combined organising committee that involves the Federal Ministry of Agriculture to bringing together the research and development workers; and

(v) The Government will support a good relationship between research institutions and extension agencies to make sure that the transfer of research outcomes reaches end-users. To accomplish this, a technical committee of research and extension workers will be established (Iwuchukwu & Igbokwe, 2012; FMARD, 2016).

(8) Agricultural Cooperative policy

Cooperatives, in general, are well-developed and have adequately functioned in Nigeria since 1935. Agricultural cooperative could be regarded as a cooperative whose members are agricultural producers or are involved in related activities. (Iwuchukwu & Igbokwe, 2012; FMARD, 2016).

The primary purposes of the government with agricultural cooperatives are as follows:

(i) To build a system that will simplify their operations and practice in agriculture as an efficient channel for social and economic growth at the grass-root level all over the nation; and

(ii) to utilise agricultural cooperatives as a channel for rural transformation and growth that will affect the different parts of rural life.

The strategies envisioned that could be adopted are:

a) The strengthening of cooperative agricultural teaching, training and public information at all stages to bring about improved partaking and contribution by farmers and other rural individuals in the cooperative programme and enhance the decision-making process of rural people to improve their overall well-being.

b) The utilisation of agricultural cooperatives to attain improved local production of food and fibre, industrial raw materials and manufactured products and the unbiased distribution of inputs, farm products and other goods;
c) The utilisation of agricultural cooperatives to expand the democratic base in the local communities via cooperative involvement and operations intended to enhance personal attainment and fulfilment; and
d) To implement a systematic and steady withdrawal of government's direct participation in the daily administration of these cooperatives to the disadvantageous level of prying with involvement and being in control of their normal private operations. Regarding this, the government's part in cooperative progress will be to generate and sustain a favourable social-economic framework and surrounding within which the members can assist themselves (Nnadozie, 2016; FMARD, 2016).

(9) Land resource policy

Land resources policy aims to naturalise the locations of the nation that are presently under the effect of drought, desert encroachment, soil erosion and flood and to avert the expansion of these natural catastrophes to other places via an efficient protective strategy (Olomola, 2014; FMARD, 2016). This aim will be achieved via the following strategies:

(i) In the interest of the farmers in general, the government will make sure that no individual or group will be permitted to obtain greater than 2,000 hectares of land
(ii) To accompany the present government activities in arid zone, afforestation, soil survey and land assessment, erosion control, soil fertility survey and evaluation and the formation of an earth resources data centre will be put in place. The government will recruit the support of private companies and international groups to fight the severe operations of these natural catastrophes;
(iii) Proper actions will be in place to assemble and teach the public about the general control of land degradation;
(iv) The government will make sure that unceasing inventory and evaluation of land resources is undertaken to put them into their optimal use and check deviations in their abilities for agriculture use;

(v) The government will endorse the legislature to take charge of the standard and quantity of agro-chemicals including fertilisers and physical factors added to land so that it will guard it against degradation and pollution;

(vi) The government will support education in land protection and preservation in all post-primary educational institutes to meet the labour needs in land resources and sciences;

(vii) Land protection committees will be built in every State to give a guide on the use of agricultural land; and

(viii) The federal and state governments will generate area land use maps that will aid in offering property to people, commercial farmers and other businesspersons in a way that will also benefit peasant farmers (Nnadozie, 2016; FMARD, 2016).

(10) Pest control policy

The aims of pest control policy are given as follows (Iwuchukwu & Igbokwe, 2012; FMARD, 2016): too control, and eliminate and uphold good observation of the main economic pests whereby their occurrences are accountable for extensive damage or loss to agricultural output, and to offer safety to man and animals against deadly disease-causing creatures. For the government to achieve these aims, the following strategies will be adopted;

(i) To continually check the incidence of crop and animal pests and diseases nationally, which cuts across States and international boundaries so that an early warning system can be used to attract consideration to any outbreak;

(ii) Developing the effort required to control outbreaks as soon as possible, and further establish and oversee control activities through the use of required and obtainable resources;

(iii) Develop training programmes to ensure farmers realise the needs for initial warning of pest or disease occurrences and further include the farmers in the undertaking of basic control techniques;

(iv) Support farmers in defining and measuring losses instigated by pests;

(v) Sign contracts with neighbouring countries to manage and sustain good observation along the shared borders, and further pursue international support or collaboration to control pests of economic importance without jeopardising our national security;

(vi) Undertake surveys in partnership with research institutes and Universities on the biology and ecology of commercial pests in any terrestrial zone and identify the top approaches of control;

(vii) Strengthen human resource growth to offer pest control workers a high amount of skill and specialized knowledge that will help to accomplish the aims;

(viii) Support state governments to build pest control units for themselves which will be complementary to federal government operations; and

(ix) Check the form and usage of chemicals imported or produced domestically and employ all needed methods to make sure they are safe for use (Nnadozie, 2016; FMARD, 2016).

Table 2.6 gives a summary of the agricultural policies and programmes/projects in Nigeria with respect to the past and current policies ‐ colonial era [time frame], post-colonial era [time frame], military era [time frame] and democracy era [time frame]. The table also includes the outcomes of the policies.

Table 2.7: Nigerian agricultural policy from colonial era (pre-independence) till date.

Year	Policies/Programmes	Description	Efficacy/Outcomes
Colonial era			
1937	Forest Policy	Addressed the issue of depreciating forest capital as a result of unregulated misuse (Ayoola, 2001).	The plan for these years were unreliable (Ladan, 2013). Policy failed as a result of poor institutional planning, aims, goals and no precise objectives towards realization of the policies (Iwuchukwu & Igbokwe, 2012).
1945	Forest Policy	Revision of previous (1937) policy and also reflected the position of government that agriculture takes precedence over forestry (Ayoola, 2001).	
1946	Agricultural Policy	First all-embracing policy statement concerning agriculture. Five agricultural areas were created in Nigeria; the Northern provinces pastoral or livestock production area, Northern provinces Export crop production area, Middle belt food production area, Southern provinces Export crop and Southwest food export area (Ayoola, 2001).	
1948	Policy for the marketing of oils, seeds and cotton	Policy specific to commodity and was directed at stabilisation of post-second world war prices in Britain (Ayoola, 2001).	
1952	Forest Policy for Western Region	Regional policy focused on forest matters	
1952	Agricultural Policy	Plan to bring together several policies of federal government in Agriculture by the federal Department of Agriculture (Iwuchukwu & Igbokwe, 2012).	

1959	Western Nigeria Policy of Agriculture and Natural Resources	The critical element was the farm settlement scheme (Amalu, 1998; Iwuchukwu & Igbokwe, 2012).	
1959	Farm settlement scheme (FSS)	Introduced in old western Region and intended to settle young school leavers by making farming their career. This idea was to prevent them from moving to the town areas in search of white-collar jobs. Policy instruments include agricultural extension cooperative societies, credit facilities (Iwuchukwu & Igbokwe, 2012).	The FSS policy failed because of inappropriate institutional planning and misunderstanding of the young school levers (Iwuchukwu & Igbokwe, 2012).
Post-Colonial era			
1960-1966	New agricultural policy	Policy aimed at actualising continuous growth in agricultural output; plan for export-led growth which led to the separation of the country into the Western Region (cocoa), Northern Region (groundnut) and Eastern Region (oil palm). Also, there was an import substitution policy (Pearce, 1986; Ayoola, 2001; Iwuchukwu & Igbokwe, 2012).	The plan to achieve these policies were unclear which led to a let-down (Iwuchukwu & Igbokwe, 2012).
Military era			
1972	National Accelerated food production programme	Designed to enhance the technical efficiency of farmers in the production of grains. Policy instruments included subsidy, credit and research (Ayoola, 2001).	In 1973, the Agricultural Credit Bank (NACB) was established by the Nigerian Government

			as part of the programme (Rogers, 1999; Ayoola, 2001).
1974	Agricultural Development projects	Aimed to improve the technical efficiency of smallholders by providing rural infrastructure development and modern input (Manyong et al., 2005; Iwuchukwu & Igbokwe, 2012).	The reduction in oil prices affected the project leading to decline in agriculture growth (Manyong et al., 2005). Also, it became less efficient because of the World Bank fund withdrawal (Philip et al., 2009).
1976	Operation Feed the Nation	A mass mobilisation and awareness programme to increase food supply via mass media, centralized input procurement, massive fertilizer subsidy and imports (Rogers, 1999; Iwuchukwu & Igbokwe, 2012).	This was a campaign to increase food production and did not exist for a long time because of poor vision and improper indicators (Manyong et al., 2005).
1976	River Basin-Development Authorities	Aimed at improving irrigation services, fishery development, flood and erosion control through distribution of inputs, credit services, infrastructure development and manpower development (Ladan, 2013; Iwuchukwu & Igbokwe, 2012).	This was capital-intensive, and also led to salinity and high degradation of land (Ladan, 2013).
1980	Green Revolution	Aimed to achieve the goals of the agricultural sector. Food production plan, input supply and subsidy, special commodity development programme, and review of agricultural credit	This policy failed as a result of its emphasis on mechanisation and large-

		guarantee scheme, were the policy instrument (Manyong et al., 2005; Iwuchukwu & Igbokwe, 2012).	scale agriculture with little attention to smallholders (Manyong et al., 2005).
1986	Directorate of food, Roads and Rural Infrastructure (DFRRI)	Established to provide roads and to facilitate rural infrastructure programmes (Ayoola, 2001; Iwuchukwu & Igbokwe, 2012).	The infrastructure built by the DFRRI were of sub-standard with poor maintenance because of the exploitation by programme directors (Iwuchukwu & Igbokwe, 2012; Ladan, 2013).
1988	Agricultural Policy of Nigeria	Aimed to achieve food self-sufficiency and provide agricultural raw materials (Iwuchukwu and Igbokwe, 2012).	Policy did not have a well-defined vision/mission with poor policy aims (Iwuchukwu & Igbokwe, 2012).
1989	Agricultural Development Projects (Replication of 1974)	See 1974. Replication to reach the entire state in the country.	Replication to reach the entire state, then 19 states (Iwuchukwu & Igbokwe, 2012), and now 36 states (still in place).
Democracy till date			
1999	New agricultural policy - National Economic	Aimed to achieve poverty reduction, create wealth, generate employment, increase export, attain food self-sufficiency,	Policy inconsistency which led to food insecurity in spite of

	Empowerment & Development Strategies (NEEDS) & for State (SEEDS) & also Local governments (LEEDS) components	sustainable agricultural resources use & food security (Okoro and Ujah, 2009; Manyong et al., 2005).	the food security programmse put in place (Manyong et al., 2005).
2002	National Special Programme for Food Security	To improve food production, eliminate rural poverty, strengthen research, training and extension.	
2003	Root and Tuber Expansion Programme	Aimed to achieve economic growth, improve access to social services, and address food production difficulties in the rural areas (Iwuchukwu & Igbokwe, 2012	
2007	The 7-point Agenda of President Umar Yar'Adua	Aims similar to NEEDS and modified into the Agricultural Transformation Agenda (ATA) (Okoro & Ujah, 2009).	
2012	Agricultural Transformation Agenda (ATA)	Aimed at making agriculture a business, to integrate the agricultural value chain, and job creation (3.5 million by 2015), enhance food security, increase domestic food production by 20 million metric tonnes; enhance rice production, deregulate the input sectors, & reform markets (FMARD, 2016).	Policy could not attain all the objectives as the country's importation is still about $3-5 billion worth of food annually (FMARD, 2016)
2016	The Agriculture Promotion Policy (2016-2020)	Established to continue from the achievements of the ATA, to build agri-business to meet domestic food security, to create	The Policy assesses the successes & failures of the

		exports & make foreign exchange, and to facilitate government capacity to attain food security in the country (FMARD, 2016).	ATA & provides a new path for the Nigerian Agricultural Sector at a time where food import bill increases with low exports (FMARD, 2016).

2.10 Summary

Agriculture is an important sector in Nigeria as it contributes 21.9 per cent of GDP and employs about 70 per cent of the working population in Nigeria (Ogbanga, 2018). The government of Nigeria had paid farmers low prices over the years on food for the local market to satisfy urban demands for cheap necessary food products (FMARD, 2016). This strategy turned out to make agricultural work gradually unattractive and boosted the interest of farmworkers' movement to the cities. These developments jointly worsened the low productivity, both per unit of land and per worker, because of some factors: inadequate technology, acts of nature such as drought, poor transportation and infrastructure, and trade restrictions (FMARD, 2016).

Consequently, the government of Nigeria developed some policies to support agriculture over time (see Table 2.6). However, these policies ought to have an absolute start time and a precise lifespan for which the specified aims and associated metrics have to be delivered. The growth of agriculture is also influenced by other external factors such as climate change which is explored in the next chapter.

Chapter 3 Climate change and its impact on food staple production

This chapter examines the causes and outcome of climate change, its future projection and implications for agriculture in Nigeria. The chapter starts by addressing the causes and effects of climate change on agricultural, by looking at rainfall, temperature, elevated carbon dioxide, increase in water demand, pest and disease and finally soil fertility and erosion. The chapter then goes on to develop these themes with regard to Africa and particularly Nigeria. Theimpact of rainfall and temperature are considered, as well as future projections in Africa. The chapter also identifies the different climates and the different seasons found in Nigeria along with the situation of climate change in the country. The chapter then moves on to investigate the consequences of climate change on staple food production and food security. This is considered through the lenses of food availability, food accessibility, food utilisation and food stability. Finally, an overview, including the strengths and weaknesses of the principal models used in determining the impact of climate variability on agriculture are given in this chapter.

3.1 Causes and effects of climate change

Climate change has affected and will keep affecting global temperatures, water resources, ecosystems, agriculture and health, among others (Odjugo, 2011; Deressa, Hassan, & Ringler, 2011; IPCC, 2018). Scientists and researchers believe that greenhouse gas emissions contribute majorly to climate change (Umar & Ozohu, 2015). The increased concentration of greenhouse gases (GHGs) in the atmosphere gives rise to a warming effect which leads to climate change (also known as global warming). This effect now causes further heatwaves, drought and flooding along with the threat of supplying food and water in many parts of the world (Osuafor & Nnorom, 2014). The emissions from these GHGs continue to linger in the atmosphere over time; the concentration of these gases rising steadily (IPCC, 2007). Ocean warming too brings about a longstanding change in climate (Mendelsohn & Dinar, 2009). Flooding and changes in precipitation patterns then occurs which harms agricultural production. The GHGs of interest here are water vapour, carbon dioxide, methane and nitrous oxide, and they cause ozone layer depletion (IPPC, 2007; Umar & Ozohu, 2015). According to IPPC (2007), global rise in carbon(iv)oxide concentrations are due principally to the use of fossil fuel. Furthermore, there is the possibility that the observed rise in methane concentration is primarily as a result of agriculture and use of fossil fuel, with a change in land-use which provides another substantial but then lesser contribution. Therefore, the factors responsible for the emission of the GHGs that lead to climate change can be categorised into two groups: the natural occurring factors and human activity factors (Umar & Ozohu, 2015; Atteridge & Remling, 2018).

A natural occurrence such as the eruption of volcanos, ocean current, the earth's orbital changes and any solar variation practically influence a shift in climate (IPPC, 2007; Umar & Ozohu, 2015). Even so, when a volcanic eruption occurs, volumes of sulphur(iv)oxide, water vapour, dust, ash and aerosols are released into the atmosphere in high quantities. Consequently, enormous amounts of this emission can stimulate climate patterns for an extended time (Umar & Ozohu, 2015).

Estimates reveal that the activities from human have caused approximately 1.0°C of global warming more than pre-industrial levels, with a possible range of 0.8°C to 1.2°C. Global warming has the possibility of reaching 1.5°C between 2030 and 2052 if it keeps rising at the current rate (IPCC, 2007; IPCC, 2014; IPCC, 2018).

Moreover, GHG emissions globally as a result of the activities from humans have increased since pre-industrial periods, with an increase of 70 per cent between 1970 and 2004 (IPPC, 2007). The principal influence on climate change is said to be from the burning of fossil fuels used in vehicles, generating power for industries and households which emits carbon(iv)oxide, Nitrous oxide to the atmosphere (Umar & Ozohu (2015). Also, deforestation and land clearing release a high volume of carbon(iv)oxide into the atmosphere. In contrast, trees absorb the released carbon(iv)oxide from the atmosphere which helps to normalise the climate.

Added to this, cutting down of trees hinders the advantage of the trees in absorbing carbon dioxide and the carbon previously sequestered within the trees gets released into the atmosphere which adds to the impact of GHG emissions (Rosenzweig & Hillel, 1998; Umar & Ozohu, 2015). Another cause of human activity increasing GHG emissions is the application of nitrogen in excess on farms, which is in fertiliser use leads to nitrous-oxide release into the atmosphere.

Human activities like mining and industrial activities have given rise to dust which is an aerosol in the atmosphere. More so, the course of oil drilling, coal mining, landfills and dumping of waste releases methane (Deressa & Hassan, 2009). Concentration in halocarbon gas has arisen mainly as a result of human activities (chlorofluorocarbons) which have been used widely in refrigerators, including some industrial activities (IPPC, 2007; Umar & Ozohu, 2015).

Therefore, the effects of climate change include higher temperature, elevated carbon dioxide, water demand, pest and diseases, soil fertility and erosion, are now explored in turn.

3.1.1 Higher temperature

Higher temperatures affect the natural state in the soil. For example, once temperatures go beyond the ideal level for plant growth, crops often show a negative response with a steep drop in net growth and production (Obiora, 2013). Heat stress disturbs cultivation of crops during the biological processes, development and lastly output (Obiora & Madukwe, 2011; Obiora, 2013). Also, increased temperature causes crop yield to reduce by affecting a range of biological, to biochemical and then molecular processes (Wheeler *et al*., 2000).

The yield of cereals and fruits could be lowered by just some days of temperature change either by being more than or less than a specific optimum threshold (FAO, 2007). More so, fish stocks are going to be explicitly affected because of the variations in sea temperatures. This effect can lead to a decline in trends in output by 50 to 60 per cent (Laurence & Williamson, 2001). Rise in temperature (1°C-3°C mean temperature) is predicted to be beneficial to crop production in temperate regions. However, it will affect the tropical and dry areas negatively, especially for cereal crops (Adams, Benzie, Croft & Sadowski, 2021).

3.1.2 Elevated carbon dioxide

Secondly, atmospheric carbon(iv)oxide at an increased level can bring forth photosynthesis and growth of crops, a process known as the carbon(iv)oxide fertilisation effect (Enete, 2014). This fertilisation effect leads to an increase in the output of some crops (Johnston *et al.,* 2009). Also, a rise in carbon(iv)oxide concentration in the atmosphere raises the absorption level of carbon(iv)oxide in the plant via the stomata (tiny openings in the leaf). This is done during the process of photosynthesis which releases carbohydrates for plant development (Paudel, Acharya, Ghimire, Dahal & Bista, 2014). Atmospheric carbon(iv)oxide at an increased level further allows the closure of the stomata by plants. However, in the presence of carbon(iv)oxide, crops will likely use a lesser amount of water although they may have more carbohydrates (Khanal, 2009; Paudel *et al.,* 2014).

3.1.3 Water Demand

A further consequence of climate change is drought which is most likely to have a severe effect on plant and livestock production (Johnston *et al.,* 2009). The danger of fire can be increased by drought, with resulting damage of the vegetative cover, which is desirable for grazing (Eze, Ikeogu, Iwuh, & Nwakama, 2014). The desire for moisture by plants and animal will also increase (Johnston *et al.,* 2009). An assessment on the effect of climate change on the output of food from a 2020 viewpoint reveals that around two-thirds of arable land will be lost by 2025 in Africa as a result of reduced precipitation (Zewdie, 2014). There is also an estimate that yields of food crops will decline by 50 per cent in some Sub-Saharan countries where 96 per cent of the arable land is dependent on rainfall (Liliana, 2005; FAO, 2007; Zewdie, 2014). This reduction in the amount of water available for food crop production in such regions could be critical to crop production (Enete, 2014).

3.1.4 Pest and disease

Climate change can also affect the prevalence of pest and diseases. Warmer climates conditions are conducive for the proliferation of insect pests (Zewdie, 2014). Changes in wind pattern are likely to bring about the outburst of wind-borne parasites, fungi and bacteria which promotes crop disease. Higher temperatures favour the population of the pests that cause destruction. Also, increased temperatures offer a favourable environment for widespread pests, thus, encouraging the possibilities of upsetting plant production. Added to this, higher temperatures can favour livestock diseases (Johnston *et al.,* 2009; Khanal, 2009).

3.1.5 Soil fertility and erosion

The final effect of climate change considered here is that of soil fertility and erosion. Bacteria found in the soil can influence the availability of nitrogen to plants in an organically usable state (Umar & Ozohu, 2015). This process of nitrogen fixation, which is associated with better development of the root of crops, is also expected to rise in hotter situations (Singh & Dobo, 2007; Johnston *et al.,* 2009). This is possible with higher carbon(iv)oxide, and if there is no limit in soil moisture. A predictable rise in convective rainwater which is due to a higher increase in temperature and pressure and high atmospheric humidity could give rise to extreme precipitation. Such heavier rainfall occurrences could lead to the incidence of soil erosion (Singh & Dobo, 2007); like in the case of soil erosion in the South eastern region of Nigeria (Okorafor, Akinbile & Adeyemo, 2017).

3.2 Climate change global projection

Climate models forecast substantial differences in regional climate features to be 1.5°C between present-day and global warming (IPCC, 2018). The effects of these projected differences can be in a rise in mean temperature in several lands and ocean regions, an increase in precipitation in many areas and the chances of drought and reduced rainwater in some areas too (IPCC, 2018). Altogether, there will be an experience of heavier rains in a warmer climate due to climate change (Berg, Moseley & Haerter, 2013). According to Ajetombi and Abiodun (2010), the problem of climate change which results in extreme temperature, recurrent flood and drought is now a persistent issue driving global discussion.

The strength of the debate on climate change is on the increase as a result of the dangers it poses particularly to the developing countries (Jalloh et al., 2013). This discussion with regards to Sub-Saharan Africa is due to the prevailing poverty situation, the predominant practice of farm residue and bush burning, GHG release and soil erosion hazards that frame third-world economies (Ajetombi & Abiodun, 2010; Jalloh et al., 2013).

Nevertheless, IPCC, 2007 identified the possible ranges and best estimates (which is the change in magnitude between the lower and upper limit values of the likely range) for universal average surface air warming. These estimates differ for the various Special Report on Emission Scenarios (SRES) of the IPCC, as shown in Table 3.1. The increase in sea-level, according to the prediction, also varies. The lowest carbon dioxide emission scenario (B2 scenario) has the least rise of 18.0-38.1 cm, while the maximum emission scenario (A1F1) shows the highest increase of 25.9-58.9 cm over the period 2090-2099, comparative to the 1980-1999 period. The basis for the IPCC SRES scenarios is the future greenhouse gas emissions predictions, primarily carbon dioxide, which is in turn propelled by factors associated with social, economic and technological changes. Therefore, social, economic and technological changes define the degree of vulnerability to climate change (IPCC, 2007c, IPCC, 2018). In addition, some susceptible regions, including small Islands and Least Developed Countries, are predicted to experience high multiple interrelated climate hazards even at a global warming level of 1.5°C (IPCC, 2018).

Table 3.1: Projected global averaged surface warming and sea-level rise at the end of the 21st century.

	Temperature Change (°C at 2090-2099 relative to 1980-1999)		**Sea-Level Rise (cm at 2090-2099 relative to 1980-1999)**
Case	Best Estimate	Likely Range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations	0.6	0.3 - 0.9	NA
B1 scenario	1.8	1.1 - 2.9	18.0 - 38.1
A1T scenario	2.4	1.4 - 3.8	20.1 - 45.0
B2 scenario	2.4	1.4 - 3.8	20.1 - 42.9
A1B scenario	2.8	1.7 - 4.4	21.1 - 48.0
A2 scenario	3.4	2.0 - 5.4	23.1 - 51.1
A1F1 scenario	4.0	2.4 - 6.4	25.9 - 58.9

Source: (IPCC, 2007b)

3.3 Climate change impact and future projection in Africa

The African continent is vast and diverse, second only to Asia in size and population. This feature makes Africa's regional climate change trends and impacts more relevant for decision-making (Ajetombi & Abiodun, 2010). Agriculture is an important sector of the African economy. Economically, several African countries depend primarily on agricultural produce and fisheries for food, fibre, and income. Besides the provision of variable food crops that grow in Africa, the livestock reared, and seafood produced, agriculture also employs the majority of the populace (60 per cent) (Umar & Ozohu, 2015).

Consequently, Table 3.2 below illustrates the possible future impacts of climate change owing to changes in extreme weather and climate events. This projection is based on the mid- to late 21st century scenarios provided by IPPC, 2007. It shows the examples of the significant future impacts projected by sector.

Table 3.2: Impacts of climate change as a result of changes in extreme weather and climatic conditions, based on forecasts to the mid- to late 21st century.

Phenomena and direction of trend	Possibility of future trends	Agriculture, forestry and ecosystems	Water resources	Industry, settlement and Society
Over several land areas, hotter and fewer cold days and nights, hotter and more frequent hot days and nights	Almost certain	Rise in output in colder areas; reduction output in hotter areas; rise in insect occurrences	impact on water resources depending on snowmelt; impact on some water provisions	Reduction in energy needs for heating; Rise in need for cooling; reducing air quality in towns; reduction in disrupting transportation as a result of snow, ice; impacts on winter tourism
Hot spells/heatwaves. Frequency rises over many land areas	Very possible	Reduced yields in warmer regions due to heat stress; The rise in danger of wildfire	Increase in the need for water; water quality difficulties, e.g., algal blooms	Reduced quality of life for people in hot areas without proper housing; effects on the aged, very young and underprivileged

Excessive rainfall occurrence. Frequency rises over many areas	Very possible	Crop damages; soil erosion, unable to cultivate land as a result of waterlogging in soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Interruption of settlements, trade, transportation and societies due to flood; pressures on urban and rural infrastructures; damage of properties
Area covered by drought rises	Possible	Land degradation; low yields/crop damage and disaster; Rise in livestock deaths; Rise in the risk of wildfire	Major water stress	Water scarcities for settlements, industry and societies; reduction in hydropower generation potentials; potential for populace migration
Intense tropical cyclone activity rises	Expected	Damages to crops; windthrow (uprooting) of trees; damages to coral reefs	Power outages causing interruption of the public supply of water	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers, the potential for population migrations, loss of property

A rise in the occurrence of extreme high sea level (except tsunamis)	Expected	Salinization of irrigation water, estuaries and freshwater systems	Reduced freshwater accessibility as a result of the saltwater disturbance	Costs of coastal protection versus costs of land-use relocation; potential for movement of people and infrastructure

Source: IPPC, 2007

Climate change will give rise to more unpredictable rainfall, and recurrent and severe droughts in drylands and savanna areas. It will bring about alterations in weather patterns that will change the time and period of cropping seasons (Niang *et al.,* 2014; Hassan & De Leeuw*,* 2015). In all seasons in Africa, there is an expectation that warming will be higher than that of the global mean values (IPCC, 2007b).

Eriksen *et al.* (2008) reported that in the latter part of the 21st century, the average temperature rise would be between 3°C and 4°C, which is about 1.5 times that of the global mean. Africa is susceptible to changes in the weather pattern, not only because of its high exposure to these changes but also because many African communities cannot adapt to the effects of the changes. Throughout Southern Africa, there is a prediction that drought will be experienced (especially in regions with winter rainfall). Whereas, over parts of eastern Africa, a rise in precipitation is projected (IPCC, 2007b).

Moreover, warming trends have already become evident across the continent, and the continent's 2000 likely mean annual temperature change is predicted to exceed +2°C by 2100 (Tesfaye & Seifu, 2016). Amid the warming expectations, there should be a consideration for the impact of changes in rainfall patterns. In general, increased temperatures and changes in rainfall patterns have the possibility of reducing crop yields, and there have been recent indications that perennial crops will also be affected negatively by this increase in temperatures (Tesfaye & Seifu, 2016). There is an expectation that the resultant effects, which are the increased spread of insects, weeds, and diseases will cause harmful impact on crop productivity and livestock.

Additionally, since Africa is reported to have the highest percentage of malnourished populations in the world, it is frequently said to be one of the most susceptible regions to these climate change effects (Slingo *et al*., 2005; Jalloh *et al.,* 2013). More than 60 percent of the population of sub-Saharan Africa is smallholder farmers, and agriculture contributes about 23 percent to the gross domestic product (GDP) of sub-Saharan Africa (Knox, Hess, Daccache & Wheeler, 2012; Goedde, Ooko-Ombaka & Pais, (2019). Climate change has a significant effect on agricultural systems as it affects both plant growth and animal health. A rise in temperature and changes in rainfall pattern is the critical climatic factors that affect agriculture in the African region. Even though some uncertainty exists in terms of the direction of climatic changes that

Africa will face, especially concerning precipitation projections, assurance on the likely impacts of the change in climate on agricultural systems has risen significantly since the first Intergovernmental Panel on Climate Change (IPCC) reports (Tesfaye & Seifu, 2016). The vulnerability of Africa's agriculture arises from the dependence of the agricultural system on rainfall i.e., smallholders rely on rain-fed farming methods. The majority of African farmers are smallholders with insufficient financial resources, lacking informational and institutional accessibility (Pereira, 2017). This impacts on their ability to effectively utilise water storage and irrigation systems. However, the state of poverty is aggravated in the rural areas whose livelihood is dependent on agriculture (Ajmi, Aye, Balcilar & Gupta 2015).

Climate change has made a precarious situation worse in Africa. This situation is so because, in sub-Saharan Africa in general, there is a case of low agricultural yields, comparative to the population growth of the region (Niang *et al.,* 2014). It is worthy of note that African women are especially susceptible to the effects of the change in the climate. This is because they bear a considerable burden of being responsible for subsistence agriculture, where production could likely be unfavourably affected by the change in climate and infertile soil (Viatte, Graaf, Demeke, Takahatake & de Arce, 2009; IPCC, 2014). This adds to climate change making a bad situation worse.

Although agricultural production improved during the period 2000–2010 in Africa, the majority of this development was because of the recovery from the unfortunate situation of the 1980s and 1990s, coupled with the high domestic prices (Nin-Pratt & Yu, 2012; IPCC, 2014). Also, climate change adds a layer of complexity to this challenge. Following the trends in demography and the economy of Africa, it is predicted that climate change impacts will be intensified. More so, the lengthy extreme events such as droughts will put further pressure on the limited water resources available, which will lead to a reduction in crop yields (Picot & Moss, 2014).

Furthermore, limiting temperature to 1.5°C in comparison with 2°C is projected to lead to lesser net reductions in the productivity of maize, rice, wheat, and possibly other cereal crops, mainly in sub-Saharan Africa (Zhai et al., 2018).

3.3.1 Temperature impacts and future projections

Irregularities in air temperature, closer to the surface areas in Africa, were higher during the year 1995–2010 compared to the year 1979–1994 (IPCC, 2014). According to Niang et al. (2014), warming across Africa over the last century has risen by 0.5°C or more, having the minimum temperatures increasing faster than the maximum temperatures. Higher temperatures result in reduced crop productivity by upsetting a range of biological, biochemical and molecular developments (Umar & Ozohu, 2015). Most African regions, where there is the availability of information, have a large number of temperature extremes recorded (Seneviratne *et al.,* 2012). Also, there is a suggestion that there will be longer duration heatwaves, which will lead to more hot days in future putting crops at risk of pests and diseases (Niang et al., 2014).

In most parts of West Africa and the Sahel, temperatures close to the surface have risen in the past 50 years (IPCC, 2014). Employing the indices developed by the Expert Team on Climate Change Detection and Indices (ETCCDI), many of the climatic trends are statistically significant at the 90 per cent level. There were similar trends found in extreme temperature indices (IPCC, 2014). In Africa, for the period 1970-2010, warming between 0.5°C and 0.8°C was statistically significant with the use of a remote sensed data, and having a high degree of change in the latter 20 years of the period when compared to the previous years (IPCC, 2014).

There is an expectation that temperature irregularities toward the last part of the century will exceed 6°C across broad areas of the African subtropics, with overall temperature rises as much as 4°C. Added to this prediction, temperatures over African region will increase faster than that of the average world rise throughout the 21st century (Sanderson et al., 2011). Furthermore, global average air temperature close to the land surface area will exceed the 20th century estimated variability by 2069 based on the Representative Concentration Pathway 4.5 (RCP4.5) and by 2047 based on RCP8.5 (IPCC, 2014; Zhai et al., 2018).

Nevertheless, in the tropics, mainly tropical West Africa, these extraordinary climatic events are expected to take place one to two years earlier than the predicted global average time (IPCC, 2014). This is so because the reasonably small natural climatic inconsistency in this region produces thin climatic limits that can be easily surpassed by a relatively small climatic change (IPCC, 2014; Zhai et al., 2018). Temperature predictions across West Africa for the end of 21st century based on the SRES A2 and A1B scenarios, and RCP4.5 and RCP8.5 shows between 3°C and 6°C which is above the late 20th-century baseline (Diallo, Sylla, Camara & Gaye, 2012; Monerie, Fontaine & Roucou, 2012; IPCC, 2014). The Sahel and tropical West Africa are recognised as the hotspots of climate change based on the RCP4.5 and RCP8.5 pathways, and extraordinary climate events are predicted to take place earliest in the late 2030s to early 2040s, in these regions (Diallo *et al.,* 2012; IPCC, 2014).

In summary, higher temperatures will ultimately lead to a reduction in the yields of important crops and tend to support weed and pest growth (Pender & Gebremedhin, 2008; Jalloh *et al.,* 2013). Agriculture, as it relates to crop and livestock production, is profoundly dependent on the climate. The rise in temperature reduces the phonological stages of crops - for example, planting, flowering and harvesting (Diallo *et al.,* 2012; Sarker et al., 2013). Also, changes in precipitation patterns affect the maturity in the field of crops (Onwueme & Sinha, 1991).

Moreover, the variations and incidence of extreme climates lead to a significant decrease in yields of the crop, mainly at critical crop growth and development stages (Sarkar et al., 2012). Food crop production is primarily sensitive to changes in climatic events because crop productivity depends directly on climatic conditions such as temperature and precipitation patterns (Thomas-Hope, 2017; Benzie, & Persson, 2019). In tropical regions, (Nigeria inclusive) warming will result in a decline in the number of crops harvested (Thomas-Hope, 2017). Also, high temperatures add to the stress of plants. In practice, however, higher temperatures hasten evaporation in plants and soils; therefore, the amount of any given rainfall is minimal (Toulmin, 2009).

Additionally, unless there is substantial mitigation of climate change, there is a prediction that the heatwave experienced near the last part of the 20th century will return. For the African region, a mitigation situation might lessen the likelihood of speedy regional temperature rises and its resulting impacts (Zhai et al., 2018). Mitigation opportunities are considered in the next chapter (chapter 4), section 4.6.

3.3.2 Rainfall impacts and future projections in Africa

As for rainfall, future predictions are more uncertain than temperature predictions (Monerie et al., 2012) as they present a higher spatial and seasonal dependence than temperature projections (Orlowsky & Seneviratne, 2012; IPCC, 2014). Added to this, precipitation projections for Africa are less precise than the corresponding temperature futures. Most areas in the African continent have insufficient observational data to make conclusions regarding the trends in annual rainfall in the last century (IPCC, 2014). This is primarily because of a lack of observed data and inconsistencies between different monitored precipitation datasets (Niang et al., 2014). Generally, rainfall predictions in Africa indicate a trend toward wetter tropical regions and drier subtropical regions (Monerie et al., 2012). However, a mixed signal of rainfall increases, and decreases appears in the predictions for western Africa and the Sahel; that is, significant uncertainties are around the estimated rainfall prospects in this area (Niang et al., 2014).

As for severe events, research based on regional models proposes a rise in the number of intense precipitation days (days experiencing rainfall near the upper end of observed values) over western Africa and the Sahel during May and July, and a more intense and more recurrent incidence of extreme precipitation over the Guinea Highlands and Cameroon Mountains (Vizy & Cook, 2012; Niang et al., 2014; IPCC, 2014). Longer duration of rainfall leads to waterlogging on farms as well as flooding when in the extreme. Besides, flooding will lead to a reduction in the expanse of land available for cultivation (Udoimok et al., 2014). Extreme rainfall of longer duration is detrimental to crop production as it results in higher yield losses through flooding and waterlogging (Onwume & Sinha, 1991; Elzebroek & Wind, 2008). Also, an increase in the duration of rainfall leads to the probability of increased crop failure and decline in crop yield. Subsequently, there is a challenge in food sufficiency (Cairns et al., 2013).

Across West Africa, there is between little to an average level of confidence in the predicted change in extreme rainfall by the end of the 21st century using the CMIP3 GCMs (Seneviratne et al., 2012; IPCC, 2014). Africa, and particularly the southwestern territories, are exposed to the risk of extreme droughts and a higher frequency of dry spells which is detrimental to the developmental stage of crops (Shongwe et al., 2011; Niang et al., 2014). West African rainfall predictions based on CMIP3 and CMIP5 records reveals inter-model disparity in both the amplitude and direction of change that is partially attributed to the inability of GCMs to resolve convective precipitation (Roehrig, Bouniol, Guichard, Hourdin & Redelsperger, 2013; IPCC, 2014).

3.4 Nigerian climate and different seasons

The Nigerian climatic condition is classified into three different types, and the seasons in a year are divided into two distinct seasons. These are explored in the following sub-sections.

3.4.1 The climatic conditions in Nigeria

The climatic condition in Nigeria is generally classified into four different types as follows: tropical rainforest climate, tropical savanna climate, highland climate or montane climate. The map showing the different climatic zones are presented in figure 3.1 below.

i. The tropical rainforest climate or the equatorial monsoon

The tropical monsoon climate can be found in the southern part of Nigeria and is represented as "Am" by the Köppen climate classification (Figure 3.1). The monsoon is a factor that influences this climate, and it originates from the South Atlantic Ocean. This monsoon finds its way into the country through the maritime tropical (MT) air mass, which is a warm sea to the seasonal land wind with moisture content. The warmth and high humidity feature it holds gives it a strong propensity to rise and form plentiful rain (Akande, Costa, Mateu, & Henriques, 2017). The abundant precipitation it produces is because of the condensation of water vapour in the fast-ascending air in the atmosphere. In addition, the range in temperature found in the tropical rainforest monsoon climate is minimal, and these temperature ranges are nearly constant through the year. For instance, Calabar city, which is in the southern part of Nigeria, records a maximum of 28°C (82.4°F) for its hottest month while its minimum temperature is 26°C (78.8°F) in its coldest month. Therefore, the temperature difference of Calabar city is not more significant than 2°C (5°F) (Eludoyin, Adelekan, Webster & Eludoyin, 2014).

More so, the southern part of Nigeria experiences substantial and plentiful rainfall. The amount of annual precipitation attained by this region is usually very high. This is typically above the 2,000mm precipitation totals which are given to the tropical rainforest climates globally. As for the coastal area of Nigeria which is the Niger Delta region, it obtains more than 4,000mm (157.5in) of annual precipitation (Akande et al., 2017). Bonny, a city which is in the coastal area of the Niger Delta, receives more than 4,000mm (157.5in) of annual rainfall. The other part, the southeast region, gains yearly rainfall of between 2,000mm and 3,000mm (118.1in) (Eludoyin et al., 2014).

ii. Tropical savanna climate or tropical wet and dry climate

The tropical savanna climate or tropical wet and dry climate is widespread in the area covering the whole of western Nigeria up to the central part of the country. It begins from the borderline of the tropical rainforest climate in the southern part of Nigeria (Akande et al., 2017). It extends to the central region, where it exerts a vast influence on the area. This climate displays a remarkable wet period and a dry period. It has a single peak which is referred to as the summer extreme as a result of the distance it has away from the equator. Temperatures in the tropical savanna climate are well above 18°C (64°F) throughout the year (Eludoyin et al., 2014). Abuja, Nigeria's capital city in the central part of Nigeria, has a temperature range of 18.45°C (65.21°F) to 36.9°C (98.4°F). The amount of precipitation is about 1,500mm (59.1in) throughout the year with a single peak rain in September (Adejuwon, 2006; Eludoyin et al., 2014).

Besides, the dry period in this climate is warm, which begins in December and ends in March. This climate has the Harmattan wind, a continental tropical (CT) airmass laden which comes with dust from the Sahara Desert predominant all over this season. During April, substantial rainfall comes from pre-monsoonal convective clouds mostly in the squall lines form which is also called the north easterlies (Akande et al., 2017). This significant rainfall is formed mainly due to the connections between the two central air masses in Nigeria recognised as the Maritime tropical (south westerlies) and the Continental tropical (north easterlies). The rainfall begins in the central part of Nigeria. At the same time, the Monsoons from the southern Atlantic Ocean reaches central Nigeria in July and accompanying it is high humidity, substantial cloud cover and ample precipitation. All these features that it brings with it could occur daily and lasts until September, at the time the monsoons slowly begin to retreat southward to the southern part of the country (Eludoyin et al., 2014).

iii. The Sahel climate

The Sahel climate or tropical dry climate is the primary climate type found in the northern part of Nigeria. The yearly precipitation entireties are lesser compared to the southern and central parts of the country. The wet period in the north part of the country lasts for barely three to four months (about June to September). The other part of the year in the north of Nigeria is warm and dry having temperatures rising to 40°C (104.0°F) (Eludoyin et al., 2014).

iv. Alpine climate or highland climate

Alpine climate or highland climate or mountain climate are on the highland areas in Nigeria. Highland regions in Nigeria having the alpine climate are beyond 1,520m (4,987ft) above sea level. Since they have a high position in the tropics, the elevation brings about the closeness to the temperate climate line in the tropics, thus, giving the plateaus, mountains and the upland regions found above this altitude a cool mountain climate (Adejuwon, 2006; Eludoyin et al., 2014).

However, figure 3.1 below shows the Nigerian map of Koppen climate classification.

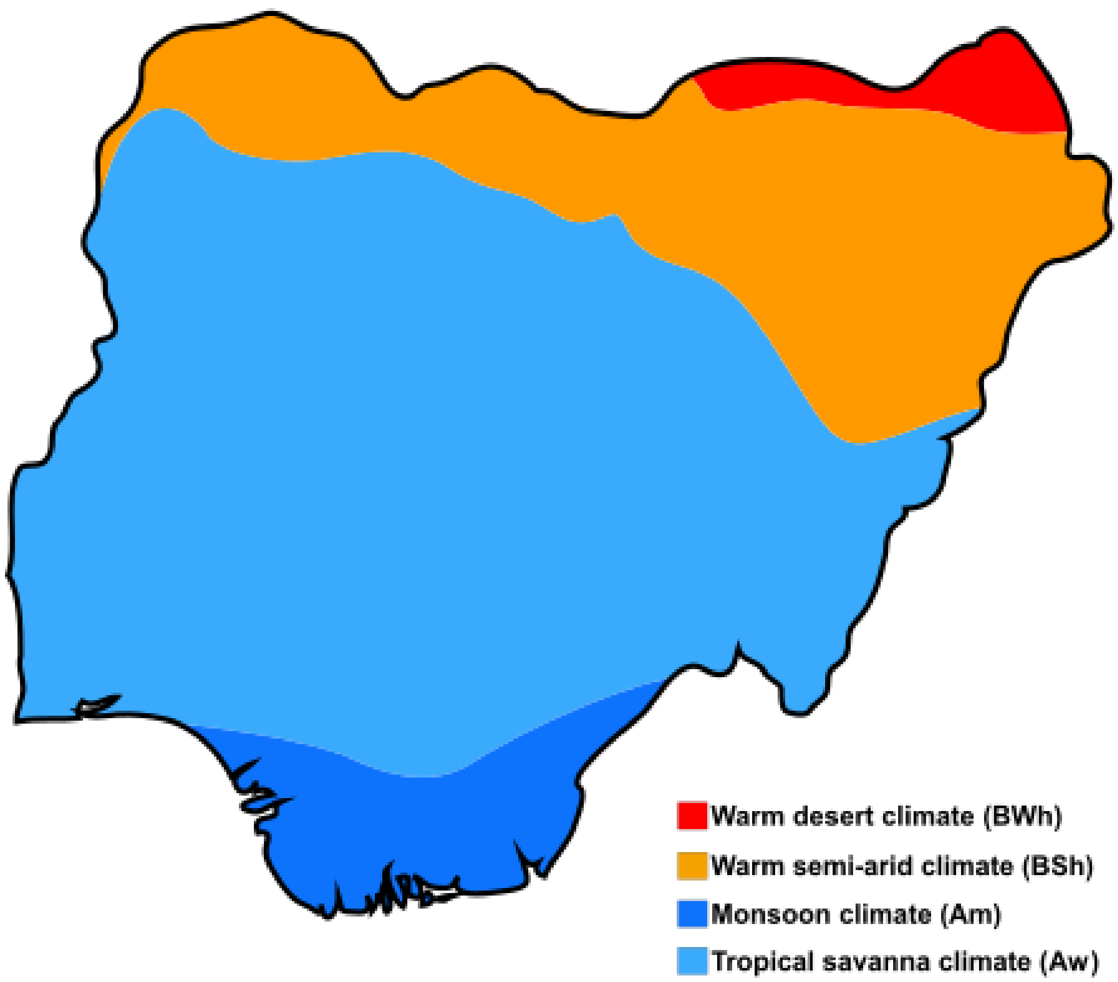


Figure 3.1: Map of Nigeria showing climate classification

Source: Eludoyin *et al.*, 2014.

3.4.2 The different seasons in Nigeria

As for the different seasons in Nigeria**,** the seasons in a year are divided into two (2); the dry season and the rainy (wet) season. Following the dry period is a dust-laden airmass which comes from the Sahara Desert and referred to as Harmattan, or by its common name, The Tropical Continental (CT) airmass. Whereas the wet period is severely inclined by an airmass which originates from the south Atlantic Ocean, often called the southwestern wind, or by its common name, The Tropical Maritime (MT) airmass. These two main wind patterns in Nigeria are known as the trade winds (Adejuwon, 2006; Eludoyin et al., 2014).

Furthermore, the region of Nigeria experiences a dual precipitation extreme characterised by two high precipitation peaks. These peaks have a short warm period and a lengthier warm period falling in between and after each peak. The first wet period starts about March and persists until the end of July with the highest rainfall in June (Eludoyin et al., 2014; Akande et al., 2017). Accompanying this wet period is a brief dry interruption in August which is called the August break. This interruption in August month is a short dry period which lasts for about two to three weeks. The break is interrupted by the short-wet period which begins about early September and continues till mid-October with the highest period at the later part of September. Accompanying the end of the short-wet period in October a lengthy dry period. This dry season begins from late October and persists until early March with the highest dry situations between early December and late February (Eludoyin et al., 2014; Akande et al., 2017)

3.4.3 Climate change in Nigeria and future projections

In summary, the climate future for Nigeria in terms of the average annual temperature is projected to rise between 1.1°C and 2.5°C by the 2060s and 1.4°C and 4.6°C by the 2090s (World Bank, 2018). Projections indicate that warming will be higher in the northern part of Nigeria. Mean annual temperatures over West Africa are expected to rise by 3°C to 6°C by the end of the 21st century which could be unfavourable to crop growth (IPCC, 2014; Zhai, 2018).

In addition, most projections indicate small increases in mean annual precipitation over Nigeria but show wide variations across the country. Also, predictions indicate a rise in the number of days with severe rainfall. There is from little to average confidence in GCM predictions for extreme rainfall over West Africa by the end of the 21st Century, but RCMs indicate a rise in the number of days with extreme rainfall in May and July over West Africa (World Bank, 2018).

Furthermore, in Nigeria, hot days per year are expected to rise by 18-49 per cent by the 2060s and 23-73 per cent by the 2090s. These warm days are projected to increase most quickly in June-August. The annual number of hot nights is also expected to increase as well. Projections indicate an increase of 32-60 per cent by the 2060s and 37-74 per cent of nights by the 2090s, with hot nights increasing most rapidly in June-August. On the other hand, cold days and nights per year are projected to decrease, with most models projecting that these events do not occur by the 2090s. As for heatwave duration, it is projected to increase under B1, A1B, and A2 emissions scenarios by middle (2046-2065) and late 21st century (2081-2100). The most substantial increase in the length of heat waves is projected for northern Nigeria. Finally, sea level is expected to rise during the 21st century and rise by 0.4m (low emissions scenario, RCP2.6) to 0.7m (high emissions scenario, RCP8.5) by 2100 which can cause destructive erosion, wetland flooding, and agricultural soil contamination with salt (Wiebe et al., 2015).

Notably, given the complications and vagueness inherent in the basic methods involved, it is imperative to note that projections vary widely, and it depends on the exact models and postulations used (Wiebe et al., 2015). Figure 3.2 below shows the average total (May-October) rainfall in Nigeria based on the 1981-2015 historical record in millimetres (mm).

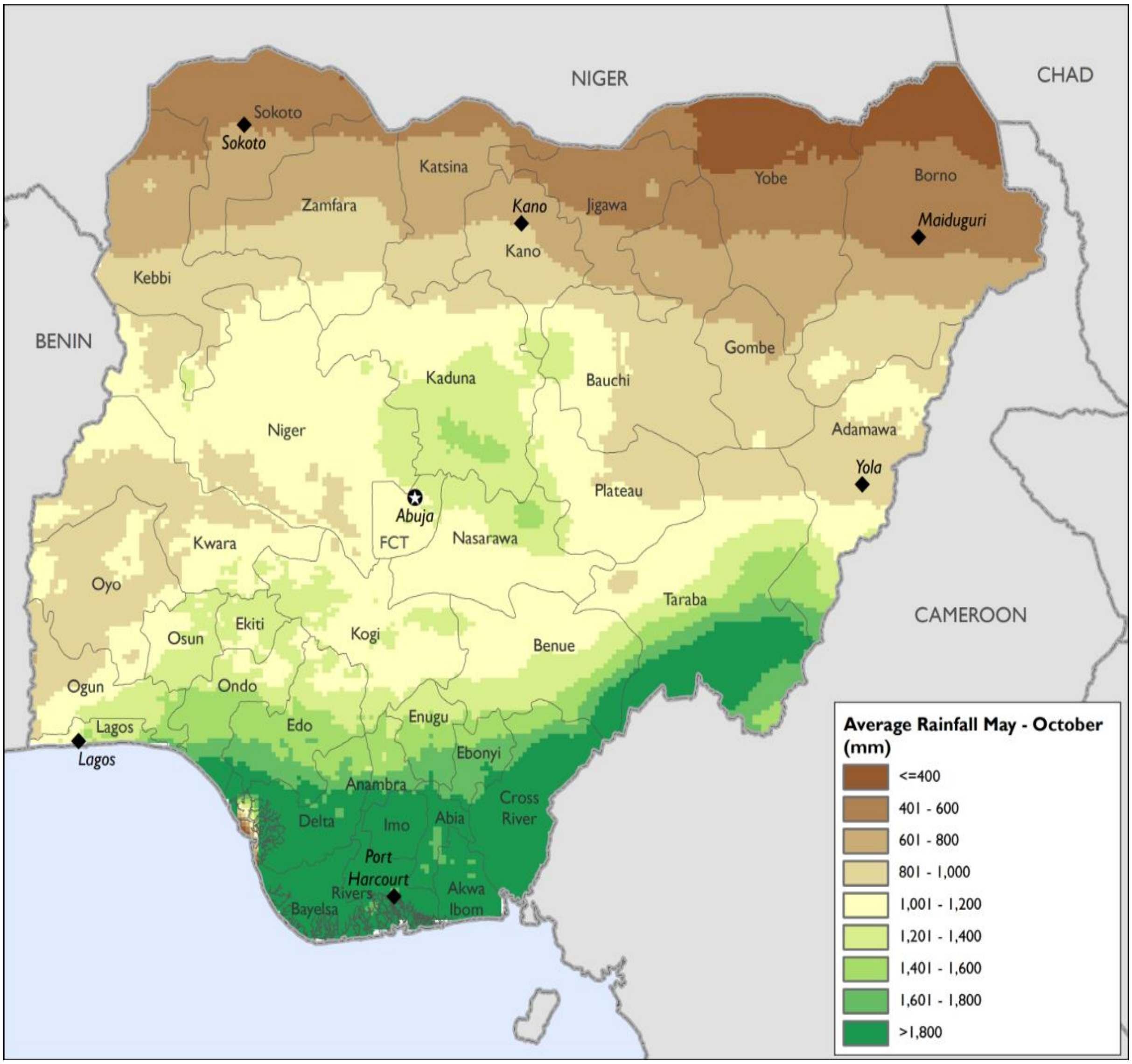


Figure 3. 2: Average total rainfall in Nigeria based on the 1981-2015 historical record (mm) for the month of May-October

Source: Semire, Adekunle & Adegbola, 2019

Typical May-October rainfall in Nigeria ranges widely across the country. Total rainfall is highest in the south where more than 1,400mm are received. A wide central band (middle belt) of Nigeria receives 800mm-1,200mm between May-October. The south-south and some part of the south-east received more than 1800mm for the period. Northern areas received less than 800mm during this same period (Semire, Adekunle & Adegbola, 2019).

3.5 Impact of climate change on agriculture and food production in Africa

Climate, however, is considered in relation to agriculture as a result of its impacts and outcome on crop productivity. Climate contributes to what is cultivated, where it is grown, how it can be cultivated and when it's cultivated (Zakari, Mohammed, Medugu & Sandra, 2014). The impacts that are likely to occur are reduction in yields and lower farm incomes (Jalloh et al., 2013). Evidence has revealed that crop productivity is already affected by changes in climate in many countries (IPCC, 2007; Dinar et al., 2008; Meldelsohn & Dinar, 2009; Jalloh et al., 2013; Obayelu, Adepoju & Idowu, 2014). Agricultural productivity in Sub-Saharan Africa is mainly susceptible to the impacts of the change in climate, with the agriculture relying on rainfall accounting for about 96 per cent of the total crop production (Obayelu et al., 2014; Serdeczny et al., 2017). Specifically, the rainfed agricultural systems on which the region's inhabitants' livelihoods currently depend is susceptible to these climatic changes (Serdeczny et al., 2017). More disparities in rainfall give rise to the possibility of short-term crop failures and long-term yield declines (Jalloh et al., 2013).

Climate, however, is not the only determinant of agricultural productivity, others include soil fertility. The fertility of the soil is imperative to plant development, nonetheless, no matter the fertility or richness of the soil, without a favourable climatic state, the anticipated yield output would become poor (Zakari et al., 2014). In addition, higher temperatures and changes in precipitation patterns are predicted to have impacts on crop production through higher pest and disease pressure, soil fertility, drought, floods, and increased water erosion (Dinar, Hassan, Mendelsohn & Benhin, 2008; Thomas-Hope, 2017).

In developing countries, it is revealed that production in agriculture will decline from 9 to 21 per cent by 2080 as a result of changes in climate (IPPC, 2007; Masson-Delmotte et al., 2018). Added to this, increase in temperature and inconsistency in rainfall are likely to lessen the yield of staple foods such as grains by up to 50 per cent (Nelson, 2009;

Umar & Ozohu, 2015). Evidence shows that more recurrent and more concentrated extreme climatic events (such as drought, heat waves, heavy storms), rising sea levels and increasing variability in seasonal precipitation patterns (including flooding) are presently having an abrupt effect on food production, food distribution, incidence of food emergencies, livelihood assets and health in the urban and rural centres in Nigeria (Umar & Ozohu, 2015). As livelihoods in agriculture is becoming more threatened, the amount of rural–urban relocation may likely grow, in addition to the already substantial urbanisation trend in the region (Serdeczny et al., 2017; Adams et al., 2021).

The entire effect of the change in climate on the productivity of the most important cereal crops in the African region stated with high levels of confidence and is expected to be negative, with strong regional disparity (IPCC, 2014; Serdeczny et al., 2017). It is also indicated that the worst-case estimates (5th percentile) showed losses of 27 to 32 per cent for maize, sorghum, millet and groundnut for a warming of around 2°C above pre-industrial levels by mid-century (Serdeczny et al., 2017). Nevertheless, in western Africa, the optimistic effects on millet and sorghum from rise in rainfall are expected to be offset by temperature increases above 2°C (Niang et al., 2014; IPCC, 2014).

More so, findings on increased-temperature sensitivity thresholds for important crops such as maize, wheat and sorghum have been made, with a high decrease in productivity predicted once the threshold is surpassed (Cairns et al., 2013). Maize, which is known to be one of the most valuable crops in Sub-Saharan Africa, has been observed to have a specific high sensitivity to temperatures over 30°C during the growing season (Serdeczny et al., 2017). Moreover, yields of beans are estimated to decrease by the mid-21st century (Thornton, Jones, Ericksen & Challinor, 2011; Jarvis, Ramirez-Villegas, Campo & Navarro-Racines, 2012). While for peanuts, some literature shows a positive effect from the change in climate on the yield especially in rain-fed systems (Thornton *et al.,* 2011; IPCC, 2014) and a negative effect in other studies (Schlenker & Lobell, 2010; Lobell et al., 2008). Additionally, in western Africa and the lowlands of eastern Africa, banana and plantain production could decline, but in the highlands of East Africa it is expected to increase due to higher temperatures, but many more studies are required to better establish the impact of changes in climate on these two crops (Niang et al., 2014;

IPCC, 2014). Despite this, many contrary effects on crop productivity are not yet signified in modelling studies (Serdeczny et al., 2017).

It is imperative to note, though, that these model estimates are based on a diversity of assumptions about GHGs emissions. They are based on how these emissions will have influence on the climate, how the change in weather pattern overtime will affect crops, and then, finally, the financial consequences if they are included in the model. Even within a single area, these models are likely to provide contradictory evidence (Alvaro, Tingju, Katrin, Richard & Claudia, 2009; Masson-Delmotte et al., 2018).

3.6 Impact of climate change on food security

The World Health Organisation (WHO) reveals that there are three-pointers that determine food security, and they are: food availability, food accessibility, and food utilisation (Gachene, Karuma & Baaru, 2015). However, the FAO added a fourth pointer which is the stability of the other three dimensions of food security. Climate change is presently causing an impact and will have a more considerable influence on all three dimensions of food security and nutrition in future (Zewdie, 2014; Gachene, et al., 2015; FAO, 2016). Climate change distorts food production directly by via variations in agro-ecological conditions and, thus, changes general food supply (Molua 2002; Masson-Delmotte et al., 2018). More so, extreme climatic events such as cyclones, floods and droughts distort food supplies significantly and therefore, food security (Sarkar et al., 2013; Janssens et al., 2020).

Sub-Saharan Africa is more susceptible to the impacts of changes in weather pattern than many other developing regions (Masson-Delmotte et al., 2018). These effects are because of the over-dependence on rainfed agriculture which leads to high inconsistency in productivity, inadequate and small producers, recurring food shortages and net importers, low institutional ability to adapt, lack of insurance and safety networks and fragile environments (Serdeczny et al., 2017).

Some studies have tried to categorise climate change effect on food security in four ways (Zewdie, 2014; Serdeczny et al., 2017): Firstly, changes in temperatures and rainfall have the possibility of altering the distribution of agro-ecological zones which distorts irrigation accessibility and demand. Secondly, carbon(iv)oxide effects are likely to have a positive effect as a result of better water use efficacy and better rate of photosynthesis. Thirdly, availability of water which is very sensitive to change in climate can distort food availability. Finally, reduction in agricultural products can be due to climate inconsistency and the higher frequency of extreme events such as droughts and floods or changes in rainfall and temperature pattern (Zewdie, 2014; Serdeczny et al., 2017).

3.7 Climate change impact on the four dimensions of food security and modelling of the impact of climate change on food security

Accordingly, this section summarises the climate change impact on the four dimensions of food security and introduces modelling of the impact of predicted climate change on food security.

3.7.1 Food availability

The Australian International Food Security Research Centre (AIFSRC) in 2015 opined that food supply and trade are essential in food availability and not just the amount of food, but also the quality and variety of food. Food availability relates to the supply of food using production, delivery and exchange. It denotes the presence of enough quantities of food with suitable quality and is driven by utilising domestic production or importation (FAO, 2016). Food availability in Sub Saharan Africa is directly influenced by many features of change in the climate such as rise in temperature, change in the amount of precipitation and patterns, increasing atmospheric concentrations of carbon(iv)oxide, changes in climatic inconsistency, extreme events and rise in seawater levels (Gachene et al., 2015).

It is worthy of note that predictions differ given the scenario applied, the model used and time measure. There is, nevertheless, reliability on the fundamental orientations, which is that productivity is mainly affected in tropical regions than at higher latitudes and the effects are more severe with high warming (FAO, 2016). Significantly, most of the places where crop productivity is projected to decline, are also places that have presently experienced food insecurity, such as Nigeria (FAO, 2016). Availability of marine foods will differ, both in the positive and negative direction, through changes in habitats, stocks and species distribution (Barange & Perry, 2009; FAO, 2016). Universal temperatures of 4°C or above, accompanied by a rise in food demand, will pose a substantial risk to food security universally and locally (Gitz, Meybeck, Lipper, Young & Braatz, 2016; FAO, 2016).

3.7.2 Food accessibility

Households in sub-Sahara regions are unable to have access to food for several reasons such as increased food price, lack of access to markets, high level of poverty, poor employment condition, reduced educational level and property rights (Zewdie, 2014; Gitz et al., 2016). It is predicted that as much as it depends on the changes in climate situation, 200-600 (million) additional inhabitants of this region could be suffering from lack of food by 2080 (IPCC, 2007; FAO, 2016).

More so, 15 scenarios for change in climate were developed (FAO, 2016). Five climate change situations showed that up to the year 2050, economic growth has a more significant positive impact on universal food security than changes in climate, even though changes in environment do enhance adverse effects (FAO, 2016). Hertel, Burke and Lobell (2010) used a quantifiable general equilibrium model to examine food security effects of changes in climate, concentrating on the ends of the distribution of expected changes in climate effects on productivity up to the year 2030. The outcomes show the significance of revenue sources on food security. The finding shows the situations with significant effects on productivity also created rises in food prices, which profited net exporters and sellers. On the contrary, increased yield growth situations brought about the decline in food prices, which gave rise to differential effects on sellers and consumers (FAO, 2016).

According to Gitz et al., (2016), 836 million people are living in extreme poverty globally, that is on less than USD1.25/day. In addition to this, more than 70 per cent of the very underprivileged reside in the rural parts in Africa, and many of these poor people depend partially or wholly on agriculture for their survival. Apart from taking into consideration the impacts of carbon(iv)oxide, variations in temperature and rainfall will lead to a rise in universal food prices by 2050 (Nelson et al., 2014; FAO, 2016).

3.7.3 Food utilisation

The next pillar of food security is food use, which is the breakdown of food by individuals (Luther, 1999). Food utilisation hinges on the way how food is used i.e., if food has adequate nutrients, and if the diet can be sustained (Zewdie, 2014). However, as soon as a household acquires the food, different determinants influence the amount and quality of food that gets to the individual inhabitants of that household (Zewdie, 2014). To achieve food security, the food consumed has to be safe and should be sufficient to meet the physiological necessities of every individual (Ecker & Breisinger, 2012). Food safety, which is likely affected by the processing, handling, packaging and cooking in public and the household, can be detrimental to food utilisation (Gregory, Ingram & Brklacich, 2005).

Nutritional standards of the household is a factor of food choice (Gregory et al., 2005), and food meeting cultural preferences is essential to food utilisation in terms of psychological and social well-being of those individuals (Loring, Gerlach and Craig, 2009). Having access to healthcare is also a factor in food utilisation. For instance, abdominal micro-organisms and parasites can absorb nutrients from the body, causing a reduction in food utilisation (FAO, 1999). To reduce the incidence and spread of diseases that can distort food utilisation, sanitation can be put in place. Also, individuals can be educated on nutrition and food handling to minimise the harmful effects on food utilisation, thereby improving this pillar of food security (FAO, 1999; Ecker & Breisinger, 2012).

Zewdie (2014) opined those changes in climate disturb food utilisation dimensions through diverse mechanisms. Amongst these mechanisms is that changes in weather pattern disrupt the amount of output and forms of various food items within the diet. More so, this disturbance poses a threat to the nutritional requirements of the populace. Added to this, climate change can affect the revenue and ability of the people to obtain a variety of food to achieve a balanced diet. The increase in price harms many of the communities in Sub-Saharan Africa countries. This is so because these countries are net food importers and also more susceptible to changes in weather patterns than developed countries (Zewdie, 2014). As a result of this increased food price, households will probably be compelled to lessen both the amount and/or quality of food they purchase. They may be forced to purchase a reduced amount of ideal food and allot these foods only to some particular household members (Chijioke, Haile & Waschkeit, 2011).

3.7.4 Food stability

Food stability could be referred to as the capacity to acquire food for an extended period of time (FAO, 2016). Increases in climate erraticism, i.e., increase in the occurrence and concentration of extreme events, as well as the slow impact of continuing changes, will likely disturb the stability of food supply, food access and food utilisation (FAO, 2016). Security of food supply will be affected by the variations in the weather pattern, rise in alteration of the ecological productivity, rise in supply risks and reduction in food supply certainty – problems that may also have substantial effects on supply chain costs and retail prices (FAO, 2008; IPCC, 2019).

According to FAO (2016), the difference in the revenue of individuals who depend on agriculture for their livings will rise, as well as food prices, and instability will impend economic access to food. This issue will be further complicated in some areas, mainly in non-coastal countries and small island states with lesser physical access to food. It will be extensibility aggravated in the situation of extreme climate events (FAO, 2016). However, to meet food security and nutrition necessities for a growing populace on the African continent, as well as achieve the targets of the Sustainable Development Goals (SDGs), refining the economic performance of the agricultural sector is of strategic importance (Niang et al., 2014).

Even now, the region is suffering from recurrent threats to food production. If appropriate actions to adapt are lacking, these threats could develop to more severe ones under climate change. For example, for the situations approaching 4°C warming, the danger to food security in Africa would be high, with inadequate potential for lessening the risk through adaptation (Niang et al., 2014).

3.7.5 Principal models employed in analysing climate change impact on crop

Due to the impracticality of performing controlled experiments to observe interactions between the climatic and human factors, models are widely used to estimate climate change effects on agriculture (Dinar & Mendelsohn, 2011). Various models can be employed to estimate the effects of climate change on agriculture. These models vary in scope, approach, variables considered, data needs, the scale of analysis and outcomes produced. In addition, these models can be used either alone or in combination when the outcome of one tool is used as an input for another or to compare results (Dinar & Mendelsohn, 2011; De Salvo, Begalli & Signorello, 2013). Each model is unique with strengths and weaknesses and presents different levels of complexity and completeness concerning the specific aspects considered in its analysis (De Salvo et al., 2013).

3.7.5.1 Integrated Assessment Model (IAM): This theoretical model begins with predictions of future GHG emissions to climate sensitivity and ends with damages or benefits of the GHG on crops. Secondary data is used in the model (Muller, Mendelsohn & Nordhaus, 2011; De Salvo et al., 2013).

3.7.5.2 Ricardian Model: This theoretical model examines how climate affects the net revenue of farmers. The model uses both primary and secondary data (Mendelsohn & Dinar, 2009; Sarker et al., 2012). The model, however, has been explained briefly in Table 3.4 below.

3.7.5.3 Production Function Model: This model evaluates the impacts of climate change by altering some climate variables. The climate change effects are determined by the variation in output (Sarkar et al., 2012; De Salvo et al., 2013). Based on the link between climate and output, the crop modelling approach evaluates the effects climate change has on agricultural production. The procedure uses survey or experimental data for its measurement. This agronomic-economic technique begins calibrating crop model from controlled agronomic experiments. Both primary and secondary data are used in the model (Rosenzweig & Parry 1994; Adams *et al.,* 1998; Easterling et al., 2007). Similarly, the agronomic modelling assesses the reaction of the crop to the varying environmental conditions (Sarkar et al., 2012).

3.7.5.4 Crop Simulation Model: The crop simulation model focuses on the biological and ecological effects of climate change on crops and soil (Mendelsohn & Dinar, 2009; De Salvo et al., 2013). Crop simulation models developed globally include CERES (Hawaii), CROPSYST (Washington), CROPWAT and CROP Yield Forecasting (Sarkar *et al.,* 2012). These models, however, have been effectively used in some studies (Rosenzweig *et al.,* 1995; Tubiello et al., 2000; Easterling et al., 2007). This method presents a thorough application of controlled and randomized environmental conditions. On the other hand, the laboratory-style results may not include the adaptation behaviour of farmers (Sarkar et al., 2012). Although some adaptations are in the model here, it is unclear how well this agrees to the real behaviour of farmers (Guiteras, 2009). Moreover, this approach will likely give estimations with an undesirable outcome (Sarkar et al., 2012). Also, these estimations can be too high if the supposed adaptation does not reflect adjustment mechanisms (Guiteras, 2009). Most agronomic models have a poor outcome of including adaptation in this model in developing countries (Sarkar et al., 2012). Hence, including new technologies is usually disregarded in agronomic models (Mendelsohn & Tiwari, 2000).

3.7.5.5 Mathematical Programming Model (MPM): To obtain this model's estimation, a mathematical-optimisation problem is solved with farm data. The model employs secondary data. It is also an economic management model. (Dinar & Mendelsohn, 2011; De Salvo *et al.,* 2013).

3.7.5.6 General Equilibrium Model (GEM): This model sees the economy as a complicated interdependent component (Mendelsohn & Dinar, 2009; De Salvo et al., 2013). GEMs have the advantage of capturing common variations, and to quantify the effects climate change has concerning other economic areas. However, they have limitations because of the combination of the different regions characterized by definite economic and spatial proportions, in a sole unit. For instance, agriculture is usually measured as a common area at the national level, and its local specifics are not considered. Likewise, the factors of production (e.g., irrigation water) are applied in the model as homogenous goods (De Salvo et al*.,* 2013). Additionally, the consideration of farmer's adaptation to climate variations, or techniques, and competencies which should be incorporated in the analysis are not captured. This model uses secondary data (Mendelsohn & Dinar, 2009).

3.7.5.7 Panel data approach: This method undermines the issue of omitted variables. It uses the technique of panel data to evaluate the effects of climate variation on crop yield mean and variability using secondary data (Barnwal & Kotani, 2010). The application of the panel data method to the study of economic effects of yearly differences in weather variables on agricultural production and returns is as a result of the omitted variables' bias in the cross-sectional approach (Schlenker & Roberts, 2006; Deschenes & Greenstone, 2007; Sarkar et al., 2012).

Thus, the peculiarities of each model are discussed below, and the summary of their strengths and weaknesses are presented in Table 3.3 below. The production function model, however, was employed in the study. The details of choosing the production function model over other models are presented in chapter 5 under the theoretical framework of the study.

Table 3.3: Summary of models that are used to analyse the impact of climate change

Model	***Description***	***Merit***	***Demerit***	***Reference***
Integrated Assessment Model	The model begins with predictions of future greenhouse gas emissions to climate sensitivity and ends with damages/benefits. It is built on the application of General Circulation Model, crop growing, soil usage, and economic models cooperatively.	It is a simultaneous analysis that considers all agricultural dimensions. It follows the casual change of events from greenhouse gas emission to final effects.	It is difficult to estimate. In some cases, the required data are not available. Interaction between agriculture and the use of land is partly remediable with the climate. Productivity is treated as an exogenous variable.	Mendelsohn (2000); Dinar and Mendelsohn (2011); De Salvo et al. *(*2013)
Ricardian method	This is a cross-sectional approach that examines farm performance across climate zones. It values the contribution environmental measures make to farm income.	It has the ability to incorporate adaptation response by farmers to the local climate. It is easy to estimate. It is cost-effective	The experiment is not carefully controlled across farms. It does not take into the account water supply.	Mendelsohn (2000); Mendelsohn and Dinar (2009); De Salvo et al. *(*2013)
Production Function	This model estimates the impacts by altering one or more variables. Yields sensitivity to climate is determined by assessing an empirical production function that links water, soil, climate and economic input to yields for specific crops.	It considers historical farm-level data and its possible to estimate the impact of weather on yields over time.	It is specific to crop and location. It does not capture farmers' adaptation strategies in response to climate change. It cannot sufficiently capture future plant-climate reactions.	Rosenzweig et al. (1993); Sarker et al. (2013); De Salvo et al. (2013)

Crop Simulation	This model is focused on the biological and ecological consequences of climate change on crops and soil.	It is suitable to evaluate the fertilisation effects of carbon dioxide concentration. It simulates and compares crop productivity for different climatic conditions.	Adaptation response by farmers is not considered, and the farmer's management practice is considered fixed. It is specific to crop and site. The analysis is limited to the biological and ecological costs of climate change on crops and soil	Mendelsohn and Dinar (2009); De Salvo et al. (2013)
Mathematical Programming Model	It represents a suite of optimisation models, including both linear and non-linear programming that have been used to assess resource allocation and related economic decisions, including farm management analysis.	It assesses the economic effects of climate change, especially in the simulation of irrigation-farmer adaptation options and water policies, including water markets and irrigation efficiency improvement	It is difficult to estimate. It is difficult to find data on technical coefficients and limiting production factors. It assumes simulated farmer strategies not obtained from observed choices in specific climatic scenarios.	Dinar and Mendelsohn (2011); De Salvo et al. (2013)
General Equilibrium Economic	This model views the economy as a complex system composed of interdependent components (e.g. industry, production factors, institutions).	It considers all economic sectors and measures the impact of climate variations on other economic areas. It incorporates and world-wide fluctuations like those related linked to the prices of input and output.	It is difficult to estimate. It aggregates into one single entity sectors that are different in economic and spatial characteristics. It does not consider farmers' adaptation	Mendelsohn and Dinar (2009); De Salvo et al. (2013)

		It gives evidence on the impact of climate variations in different areas.	strategies to climate change.	
Panel data approach	This approach overcomes the problem of omitted variables. The panel data approach is used to estimate the effects of climate variation on average crop output (Barnwal & Kotani, 2010).	It controls for time-invariant, district level and unobservable effects of omitted variables such as local soil condition, labour and fertiliser availability, infrastructure, access to markets and farmers' skills.	It is difficult to estimate. This method undermines the issue of omitted variables and uses only secondary data.	(Schlenker and Roberts (2006); Deschenes and Greenstone (2007); Baltagi (2008); Barnwal and Kotani, (2010); Semykina and Wooldridge (2010).

3.8 Chapter summary

GHG can be said to be a significant contributor to climate variability. The influence of GHG emissions that give rise to changes in weather pattern can be grouped into two aspects; the naturally occurring elements such as volcanic eruption, and secondly, human activity factors, for example, the burning of fossil fuels and deforestation.

Overall, climate variation is expected to see a rise in average temperature in several land and ocean regions. An increase in precipitation in many areas in Africa is also projected, the chances of drought and reduced rainwater in some regions is a concern, which could be harmful to crop growth, leading to a reduction in food crop output.

In Nigeria, the average yearly temperature is projected to rise between 1.1°C and 2.5°C by the 2060s and between 1.4°C and 4.6°C by the 2090s (IPCC, 2018) and this level of climate variation has been shown to have an adverse effect on agriculture. This chapter sets the scene on the projected impact of climate change in Nigeria and leads into the next chapter on the adaptation, barriers to and determinants of adaptation by farmers in the face of climate change.

Chapter 4 Climate change adaptation, barriers to and determinants of adaptation

4.1 Introduction

This chapter addresses adaptation strategies to climate change, the factors that affect farmers' adaptation and barriers to adaptation. The adaptation measures that could be employed by farmers to address the dangers of climate variability are identified. The chapter also discusses that Nigerian farmers are faced with some constraints which hinder them in adopting the different adaptation strategies that are available, and such restrictions are highlighted. Furthermore, the determinants of farmers' choice of adaptation options are considered in this chapter. Also, the role of government, the role of extension in agriculture, and the proffered solutions to the impact of climate change on agriculture, are captured in this chapter. Finally, empirical results from other studies on climate change and adaptation studies are presented, and the gaps identified in the literature are revealed.

4.2 Agricultural adaptation strategies to climate change

Table 4.1 shows a summary of climate change adaptation strategies in agriculture. These adaptation measures are classified into different groups namely; technological development, government programmes and insurance, farm production practices and farm financial management.

Adaptation refers both to the process of adapting and to the condition of being adapted (IPCC, 2001; Zhai et al., 2018). Mendelsohn and Dinar (2008) identified three essential adaptation terms: efficient adaptation, private adaptation and public adaption. Accordingly, efficient adaptations are activities that make actors better off. It implies a change in behaviour in response to climate change that makes society better off. For example, to avoid running in hot weather, to buy air conditioning, to change crops, adjust water management, and control disease causing pests. Whereas private or individual adaptations are such where only one person benefits (the actor) (Mendelsohn, 2000; Benzie, & Persson, 2019). For instance, a farmer can change type of crop or alter planting dates to increase profitability, and this is a private or individual adaption. In the case of agriculture, specific farmers are the key actors in adaptation (Konrad & Thum, 2014). Alternatively, public adaptations are where many people benefit, for example, the construction of dams and canals to improve water management infrastructure, because there are many beneficiaries to this decision. Adaptation is one of the best mechanisms that can be employed to combat the threats linked with climate variation. Due to the nature of climate variations in Africa, farmers are expected to take proper adaptive measures to climate change in order to continue with production (Babatunde, Ayobami & Mark, 2011; IPCC, 2018). Some authors revealed that there is a high possibility for food output to rise under climate change in many areas of the world provided adaptive measures are taken into consideration (Rosnzweig & Parry, 1994; Dinar et al., 2008; Mendelsohn & Dinar, 2009; Thomas-Hope, 2017). According to IPCC (2018), most adaptation needs will be lower for delivering global warming of 1.5°C compared to 2°C. Also, there is a wide range of adaptation options that can reduce the risks associated with climate change outlined in the previous chapter. There are, however, limits to adaptation for some human and natural systems at global warming of 1.5°C, with associated losses. More so, the number and availability of adaptation options vary by sector (IPCC,2018; Masson-Delmotte *et al.,* 2018). Adjustment of planting dates and crop variety, crop relocation, improved land management, e.g., erosion control and soil protection through tree planting are the likely adaptation option/strategies for farmers in Nigeria, while technological and financial constraints, access to new varieties and markets are various barriers to their adaptation (IPPC, 2007). The most common adaptation strategies in agriculture include changing crop varieties, adopting irrigation techniques, planting trees, crop and livestock diversification, soil conservation, early and late planting, increasing plant spacing, use of clay soil, and adjusting the level and timing of applying fertiliser (Bradshaw et al., 2004; Kabubo-Mariara & Karanja, 2007; Nhemachena & Hassan 2007; Deressa, Hassan & Ringler, 2008; Kurukulasuriya & Mendelshon, 2008; Bryan et al., 2009; Deressa, Hassan, Ringler, Alemu & Yesuf, 2009; Molua, 2009; Sarker et al., 2013). Likewise, multiple-cropping systems seem to lessen the danger of crop failure compared to single-cropping systems (Waha *et al.*, 2012). A wide array of adaptation strategies is available, but a more extensive adaptation is adopting a single adaptive measure to implement a set of actions to reduce climate change effects (IPPC, 2007; Sarker, Alam & Gow, 2014).

Moreover, a variety of adaptation measures are available to offset the dangers to natural and managed ecosystems (e.g. ecosystem-based adaptation, ecosystem restoration and avoid degradation and deforestation, biodiversity management, sustainable aquaculture, and local knowledge (indigenous knowledge), the risks of sea-level rise (e.g., coastal defence and hardening), and the risks to health, livelihoods, food, water, and economic growth, especially in rural landscapes (e.g., efficient irrigation, social safety nets, disaster risk management, risk spreading and sharing, and community-based adaptation) and urban areas, e.g., green infrastructure, sustainable land use and planning, and sustainable water management (IPCC, 2018; Masson-Delmotte et al., 2018)).

Agricultural adaptation to climate change includes a change in the management practice in agriculture in line with the change in climate situations. It involves a mixture of several separate responses at the farm-level with the assumption that there is access to different practices and technologies (Nhemachena & Hassan, 2007). Since the amount and time of climate fluctuations are unknown, it is essential to shape groups that can deal with unexpected variations.

Being capable of adapting to climate variations is associated with socioeconomic factors, like poverty, diversified income sources, educational level, and access to infrastructure and technologies. Babatunde et al. (2011), stated that promoting a wide-based advancement in agriculture to take rural areas away from poverty is perhaps the real adaptive measure that is available. Nevertheless, the technical level has useful information on how to make agricultural systems support production (Nhemachena & Hassan, 2007). Farmers have always experienced climate fluctuations, and they have several ways to cope with droughts and floods, which gives the basis for adjusting to climate variations. Most of these adaptative strategies are 'no-regrets' responses, and they also give benefits (Johnston et al., 2009; Babatunde et al., 2011; Sarker et al., 2014).

Table 4. 1: Summary of climate change adaptation strategies in agriculture

S/N	Adaptation strategies
1.	**<u>TECHNOLOGICAL DEVELOPMENT</u>** **Crop Development**

	• Developing improved crop varieties, which includes mixtures, to raise the resistance and appropriateness of crops to temperature, moisture and other important climatic situations. **Weather and Climate Information Systems** • Developing a system that gives early warning of day-to-day weather forecasts and seasonal predictions. **Resource Management Innovations** • Developing management technology for water, that includes irrigation, to assess the danger of water shortages and growing occurrence of droughts. • Developing resource management technologies at farm-level to check the hazard related to varying temperature, water and other applicable climatic situations.
2.	**<u>GOVERNMENT PROGRAMMES AND INSURANCE</u>** **Agricultural Subsidy and Support Programmes** • Adjust crop insurance programmes to impact on the farm-level hazard measures regarding the loss of crop production related to climate. • Adjust the investments in recognized revenue maintenance programmes to impact on hazard management measures at the farm-level. **Private Insurance** • Build private insurance to lessen the dangers related to climate on output, infrastructure and revenue at the farm-level. **Resource Management Programmes** • Build and execute policies and programmes to impact on farm-level land and water resource utilisation and management activities considering varying climatic situations.
3.	**<u>FARM PRODUCTION PRACTICES</u>** **Farm Production** • Diversification of crops, as well as crop replacement, to check the ecological changes and economic dangers connected with climate variations.

	• Diversification of livestock types and varieties to check the environmental changes and economic hazards connected with climate variations. • Changing the growth of production to assess the ecological changes related to climate on the loss in income. • Adjust the programmes on subsidy, support and incentive to impact on production activities and monetary management at the farm-level. • Alter the programmes on unplanned reimbursement and support to partake on the dangers of revenue loss connected with extreme events at the farm-level. **Land Use** • Modify the site of crop and livestock production to check the ecological changes and economic hazards related with climate variability. • Apply alternate uncultivated and tillage operations to check climate change-associated water and nutrient insufficiencies. **Land Topography** Modify land structure to check the water shortages that are linked with climate variations and lessen the dangers of damaging farmland. **Irrigation** • Implement irrigation measures to check the moisture shortages related to climate variations and lessen the threats to loss in revenue due to frequent drought. **Timing of Operations** • Adjust the time of farming practices to check the varying period of planting seasons and related alterations in temperature and water.
4.	**FARM FINANCIAL MANAGEMENT** **Crop Insurance** • Buy crop insurance to lessen the dangers associated with climate on revenue loss. **Crop Shares and Futures**

	• Finance crop shares and stocks to decrease the financial threats associated with climate change on the loss in revenue. **Income Stabilization Programmes** • Take part in programmes that stabilize revenue to lessen the threat of income loss as a result of the varying climatic situations. **Household Income** • Diversify the source of revenue of farmers so as to mitigate the dangers associated with climate change on revenue loss.

Source: Smit and Skinner, 2002

According to Johnston et al., (2009), autonomous farm-level adaptation may be adequate (in the short-run), but after a long time, adaptive measures like technological and structural changes will become essential. This will need planned approaches that relies on analysing local and regional circumstances. Moreover, Johnston et al., (2009)'s research revealed a number of adaptive measures taken by farmers to cope with the changes in climate and is shown in Table 4.2 below. The timescale (type of response) is the time needed for the adaptive measure to be implemented.

Table 4. 2: Adaptation responses and issues

Type of response	Autonomous	Policy-driven
Short-run	• Choice of crop, portion of crop, time of planting.	• Better weather forecast • Investigation for better knowledge of climate threat
Long-run	• Private venture investment (for instance, on-farm irrigation) • Private crop research	• Large-scale public venture (for example, water, storage, roads) • Investigation on crop
Issues	• Expensive to the poor social safety networks • Trade-offs with incorporation	• Undefined returns on investment • Expenses

Source: Rosegrants et al., 2008

The adaptation strategies/measures, the underlying policy framework for the adaptation strategy, the key constraints to adaptation as well as the opportunities for implementing the adaptation strategies are illustrated in Table 4.3 (IPCC 2018), The policy framework which supports agriculture and consequently yam production in Nigeria was provided in detail in chapter 2 section 2.9.2.

Table 4. 3: The adaptation strategies/measures, underlying policy framework, key constraints to adaptation as well as the opportunities to implementation

Adaptation strategy	***Underlying policy framework***	***Key constraints/barrier***	***Opportunities for implementation***
• Modification of cultivation times and crop change; • crop rearrangement; • better land management, e.g. erosion control and soil conservation by the planting of trees	• Research and Development (R&D) policies; • institutional reform; • land tenure and land reform; • education; • capacity development; • crop insurance; • financial incentives, e.g. subsidies and tax credits	• Technological and economic barriers; • Accessing improved varieties; • Markets	• Lengthy planting season in higher latitudes; • Income generated from 'new' crops

Source: IPCC, 2007; IPCC, 2018

4.3 Barriers to climate change adaptation

There are constraints, limitations and costs to climate change adaptation which inhibit many farmers from making alterations to their farming activities. The constraints to the adaptation of climate change faced by farmers are insufficient information, lack of access to credit and land, and shortage of water (Deressa et al., 2009; Sarkar et al., 2012; Ndamani & Watanabe, 2015). Also, poverty and socioeconomic variation, underdevelopment, inadequate economic capacity and challenges in governance contribute to Africa's limited ability to respond to climate variation (Shackleton, Ziervogel, Sallu, Gill & Tschakert, 2015).

In addition, literature has identified numerous constraints to climate change adaptation. According to Gbetibouo, Hassan, and Ringler (2010)'s research of the

Limpopo basin in South Africa, 60 per cent of the farmers that did not adopt any adaptive measures identified monetary constraints as a significant cause for no adaptation. Similarly, Maddison (2006) also reported that lack of access to credit facilities was a major constraint. Likewise, Nhemachena and Hassan (2007) in a study in South Africa; and Bryan *et al.,* (2009); in another study in Ethiopia, discovered that the main constraint to adaptation was lack of credit facilities.

Moreover, besides the lack of access to financial resources, the inability to access information on adaptation measures and lack of access to weather information is additionally reported to be a significant constraint to adaptation in previous studies (Nhemachena & Hassan, 2007; Bryan et al., 2009; Deressa et al., 2009; Sarker et al., 2013; Alauddin & Sarker, 2014). Nevertheless, these studies emphasize the essentials of adaptation policy and support by the government in offering information on adaptation strategies, information on weather and credit accessibility for effective climate adaptation in agriculture.

Other barriers faced by farmers when responding to the impacts of climate variations are: limitations of land, poor knowledge of the changes in climate, limited agricultural extension service delivery, expensive farm inputs and processing services, poor access to valuable irrigation services, the limited response from government on climate change risk management, credit limitations, labour constraints, and income constraints (Ozor, Madukwe, Enete, Amaechina & Onokala, 2010; Arimi, 2014).

Hence, multiple barriers, singularly or in combination depending on the situation, can impact on farmers and their ability to adapt to climate change.

4.4 Determinants of climate change adaptation practices

Literature has recognised numerous factors that determine the choice of an adaptation strategy and its influence. Looking further into the determinants of farmers' choice of adaptation, certain factors are identified that influence the option to adaptation strategies, and it is the farm household or the individual farmer that will take the adaptation decision (Mendelsohn, 2012). Several factors guide farmers' choices of adaptations such as household characteristics, institutional factors and social capital (Kurukulasuriya & Mendelshon, 2008; Arimi, 2014; Ndamani & Watanabe, 2015; Belay, Recha, Woldeamanuel & Morton, 2017) and can broadly be classified into four categories, and they consist of the following:

i) Socio-economic characteristics:

The socio-economic characteristics include the age of household head, gender, farming experience, educational level of the household head, family size and family income (Bryan et al., 2009; Sarker et al., 2013; Belay et al.,2017). However, the empirical findings of the influence of these factors are not precisely similar in all the studies. Some studies reported that the age of the household head is an important factor and has a positive influence on the choice of adaptation (Nhemachena & Hassan, 2007; Bryan et al., 2009; Deressa et al., 2009; Gbetibouo et al., 2010; Acquah & Onumah, 2011; Sarker et al., 2013), while some other studies had a contrary finding (Nyangena, 2008; Ndamani & Watanabe, 2016). The disagreement is that older farmers have more experience and so can make judgements in their state of affairs, and therefore have greater possibilities to undertaking new technologies; on the contrary, due to risk aversion and the possibility of being rigid, older farmers may be less likely to take up new practices.

In the same way, some studies discovered that male household heads have a higher potential to undertake adaptation strategies than female-headed households (Bryan et al., 2009; Deressa et al., 2009; Sarker et al., 2013; Belay et al.,2017) while some other studies found a contrary situation (Nhemachena & Hassan, 2007; Tesfaye & Seifu (2016) which could be as a result of different study areas where the research work was undertaken. Besides the determinants described above, other issues that may influence adaptation choices are income and educational level.

ii) Farm Characteristics:

The farm characteristics consist of farm size and the fertility of the farm plot (Gbetibouo et al., 2010; Sarker et al., 2013). The size of farmland is reported to positively affects the adaptation decision of farmers (Nhemachena & Hassan, 2007; Deressa et al., 2009; Sarker et al., 2013; Belay et al., 2017). On the other hand, the fertility of farmland is identified to be a significant factor that determines farmers' adaptation choice (Di Falco and Veronesi, 2014). Added to this, Gbetibouo et al., (2010) reported that the size of farmland and the perception of farmers that their farmland is very fertile was significant and positively related to the choice of adaptation options.

iii) Institutional Accessibility:

The institutional factors comprise access to extension service, access to credit facilities, access to market, access to weather information, off-farm job opportunities and tenure status which are considered to be the most significant determinants identified in previous studies (Bryan et al., 2009; Deressa & Hassan, 2011; Gbetibouo, 2009; Deressa et al., 2011; Di Falco, Veronesi & Yesuf, 2011; Di Falco, Kohlin & Yesuf, 2012; Sarker et al., 2013; Tesfaye & Seifu, 2016; Belay et al.*,*2017). However, Ito & Kurosaki (2009) and Gbetibouo (2009) argued that among the determinants above, off-farm job opportunities act as a means to diversify risk and encourage farmers to participate in farming practices, which will, therefore, raise the chances of adaptation. Although some studies reported that tenure status positively affects adaptation decision, some authors had a contrary finding that there is no significant impact of land ownership by farmers on the tendency to undertake adaptation (Maddison, 2007; Gbetibouo, 2009; Acquah & Onumah, 2011; Yegbemey, Yabi, Tovignan, Gantoli, & Haroll Kokoye, 2013; Di Falco *et al.,* 2012; Sarker et al., 2013; Kpadonou *et al.,* 2017; Senanayake & Rathnayaka, 2017).

iv) Access to Information and Other factors:

Other determinants affect farmers' adaptation choice such as factors associated with social education, for example, farmer-to-farmer extension and the number of family and friends in the vicinity (Deressa *et al.,* 2009; Sarker, *et al.,* 2013; Ndamani & Watanabe, 2015). According to White & Selfa (2013), the prevailing social systems influence farmers' capacity to acquire knowledge about adaptation and affects choices of undertaking a new measure. Bandiera & Rasul (2006) earlier reported that social education might enable farmers to decide to initiate a new practice. Regarding this, family and friends affect the choice of adaptation strategies. Furthermore, Ozor et al. (2012) revealed that the number of farmer associations and participation in them has a significant influence on farmers' decision to adapt to climate variations.

v) Farmer perceptions of climate change

The strategies adopted by farmers may depend on the information they receive, and the available resources, which includes funding. Other factors influencing the adoption of adaptation strategies include the farmers' personal experience and knowledge on climate prediction. Importantly, reliable predictions on climate can encourage the activities of farmers, whereas unreliable information on climate predictions can cause harm to poor farm households (Acquah & Onumah, 2011; Arimi, 2014). The perception of climate change by farmers is discussed more in chapter 7.

vi) Technology adoption

Technology can be applied to the entire agri-food value chain. When focusing on the farm, and the different aspects of agriculture, it can be applied for example, to the application of herbicide, pesticide, fertiliser, and improved seed (Alexander, Greenhalgh, Moglia, et al., 2020). Technology adoption in agriculture is the key to the success of the Green Revolution and is a key factor in understanding how farm households operate and remain viable or competitive (McFadden & Gorman, 2016; Clarke et al., 2018). This can be achieved with the help of Extension services or peer-to peer interaction. Extension service, whether knowledge transfer or knowledge exchange activities, brings technology or innovation to farm families.

Some of the economic factors that determine the rate of agricultural technology adoption include the size of land, cost and benefits of technology (Morris, Henley & Dowell, 2017; Alexander, Greenhalgh, Moglia, et al., 2020). Also, farmers' education level, age, social groupings, and gender are some of the social factors that influence the probability of a farmer to adopt modern agricultural technologies (Douthwaite & Hoffecker, 2017). Small scale farmers, however, face both internal and external barriers to the adoption of modern agricultural technologies. This challenge results in the slowing of the rate at which such technologies are adopted (Clarke et al., 2018). Some of the aspects of technology to be considered include how to apply and organise fertiliser, irrigation, intensive tillage, monoculture, and the application of other resources. However, in order to achieve these goals, farmers need to understand the concept of modern farming and the use of technology (Clarke et al., 2018).

However, farmers take various types of strategies to adapt to the changes in climate. Their approaches vary depending on their perceptions, knowledge, locations, availability of resources, cropping patterns, nature, and degree of vulnerability (Alam et al., 2010). According to Alam, Alverson, Siwar & Murad (2013), adaptation approaches need to be considered at the technological level, government level, and farm level.

Technological development needs to be adapted in the following different ways to help farmers cope with climate vulnerability:

- Resource Management Innovations: In order to address the threat of moisture deficiencies, increasing frequency of droughts, and improvement of irrigation, water management innovations need to be developed. Farm-level resource management innovations need to be created to deal with the effects related to changes in temperature, rainfall and other relevant climatic conditions (Alam et al., 2013; Clarke et al., 2018).
- Crop Development: To increase the tolerance and suitability of plants under different temperature, rainfall and other unfavorable climatic conditions, technological advancements related to crop variation, hybrids, new crops, and alternative crops development are very important (Alexander et al., 2020).
- Weather and Climate Information Systems: Technological improvement for reliable weather forecast system, early warning system and ensuring delivery of adequate information to the farmers is also very important for adaptation at the farm level (Clarke et al., 2018; Alexander et al., 2020).

The technological usage for climate change adaptation by yam farmers in Cross River State is shown in detail in chapter 7, section 7.6 of this thesis.

vii) Off-farm income generation and on-farm diversification

The main reason for this strategy by farmers is that farm income is not adequate and many farming households cannot entirely depend on the outputs of the farming enterprise to sustain their families in the rural areas. Also, the cost of agricultural production is rising. For example, the cost of fertilisers and other inputs are increasing and the earnings from farm sales cannot meet the cost of inputs (Nwaogwugwu, 2017). Therefore, farmers have to seek other sources of income to meet the cost of purchasing agricultural inputs (Recha et al., 2017), especially where they do not have access to credit. Moreover, many farmers now ensure their children are enrolled in local schools as the need for education cannot be overemphasized. Many farm families engage in other small-scale enterprises like trading, shear butter and other pomades for the skin, tailoring and sewing (Sennuga, et al., 2020).

Dependence on an off-farm income generating occupation is also a main strategy adopted by farm families to cope with the impacts of climate change (Recha et al., 2017). Most farm families obtain a fraction of their total income by depending on off-farm sources (Morris et al., 2017). Income from off-farm activity is that portion of household income obtained from activities not based on any form of on-farm production or diversification.

Vii Farm decision-making

An adaptation pathway is a farm decision-making strategy (Robert, Thomas & Bergez, 2016). This approach helps to deal with the deep uncertainty associated with climate variability (Jain et al., 2015; Robert et al., 2016). A decision-making strategy provides structure and guidance to help incorporate flexibility into adaptation planning. It can reduce unnecessary expenditure, preventing farms from being locked into actions that may not be the best solutions for what is a long-term problem (Wise et al., 2014; Robert et al., 2016). Under the decision-making approach, rather than determining an outcome or decision at an early stage, farmers can build a strategy that will follow changing circumstances over time (Jain et al., 2015).

The approach acknowledges that while not all decisions can be made now, they can be planned, prioritised and prepared for. It is a useful approach for dealing with uncertainty, especially in cases where the uncertainty may reduce over time, for example with improvements in estimates of future local sea-level rise (Robert et al., 2016). This is considered in more depth in Chapter 9 in the context of the research findings.

However, female-led families were reported to have a higher chance of adopting crop diversification as a choice of adaptation (Tesfaye & Seifu, 2016). This might be because women are likely to get involved in peer-to-peer knowledge exchange on several agricultural practices while carrying out agricultural activities as they tend to interact better than the men (Tesfaye & Seifu, 2016). Thus, they can engage effortlessly in decision-making to cope with climate variability based on the available information on adaptation strategies and other factors (Hassan & Nhemachena, 2008; Akhtar et al., 2018).

4.5 Conceptual model for farm-level adaptation to climate change

A farmer's response to climate variations entails choosing from a set of adaptive measures. For an adaptive action to be successful to lessen the harmful effect of climate variation, particularly in developing countries, it is vital to consider the development of adaptation choice, constraints and drivers that will influence farmers (Mendelsohn, 2012). Arising from the empirical discussions made in the previous sections, a simplified model for farm-level adaptation to climate variability is presented at this juncture from the viewpoint of an individual farmer (Figure 4.1). This model has been informed by the literature referred to in this chapter. It is the decision of a single farmer whether to adopt an adaptation strategy or not. The choice of adaption method is affected by his or her personal, social and demographic characteristics, farm characteristics, access to information and institutional supports and perception of changes in the weather pattern. Therefore, to construct a simple model for farmer's adaptation and government policies, all changes are considered to be constant. However, there could be an argument that government policy would perhaps be reflected indirectly to an extent in the aforementioned characteristics.

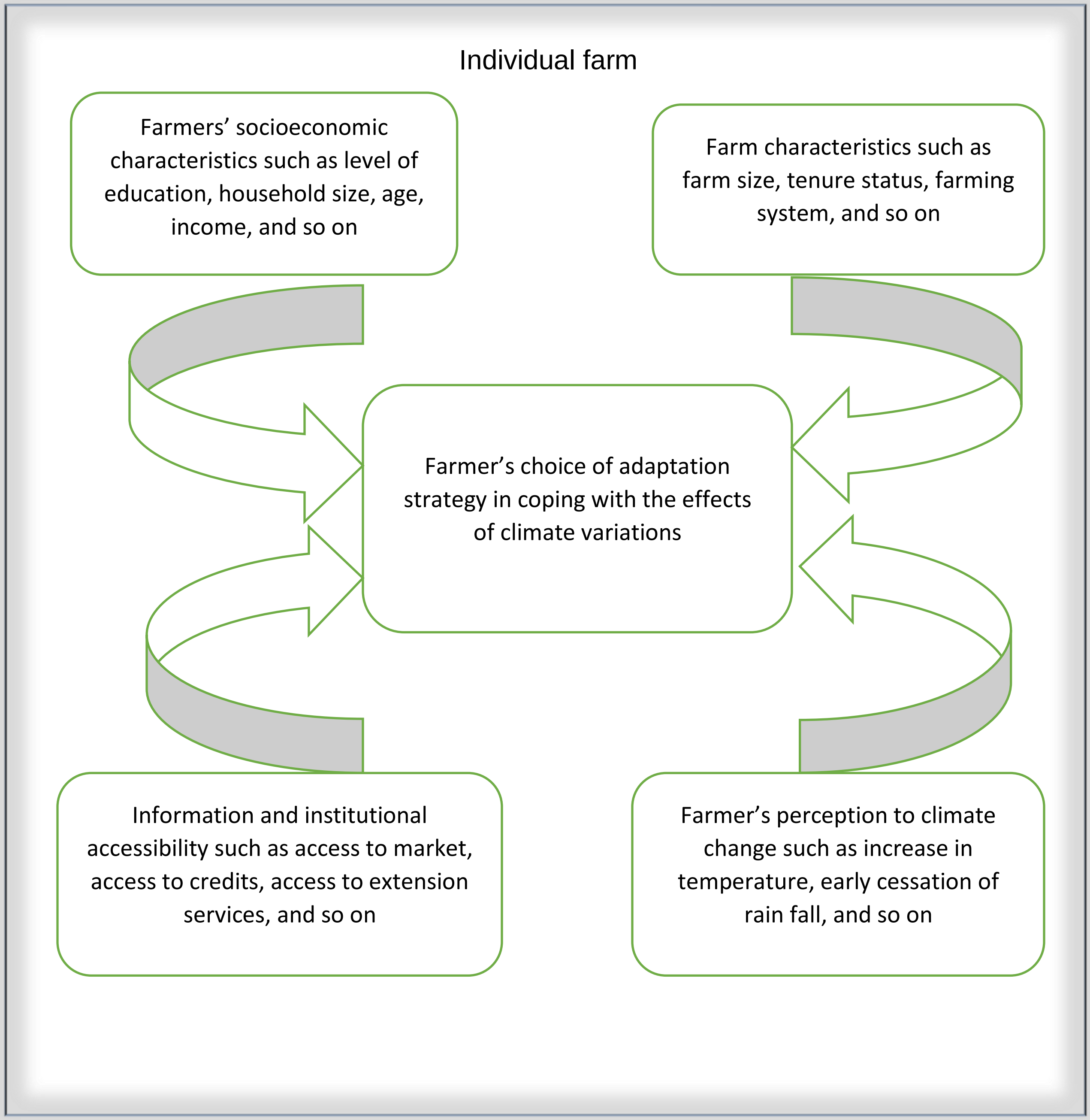


Figure 4.1: Farm level adaptation to climate change model

Source: Author, 2019

Generally, from the above literature, it can be deduced that even though there are descriptions of a considerable large number of factors that affect the choice of adaptation, there is no clear direction from the literature as to what comprises the key elements of influence. The influence of the factors, singularly or in combination, differs from research study to research study and location to location. In addition, looking at the developing countries' viewpoint, most of the previous studies have been carried out in African countries. Consequently, one cannot generalise these outcomes to all developing countries. Therefore, country-specific research is essential to recognise the factors that determine farmers' adaptation decisions in specific locations.

4.6 Difference between adaptation and mitigation of climate change

Adaptation is important in addressing the dangers of climate fluctuations; however, with only the application of adaptation strategies, the achievement of climate goals will be limited (IPPC, 2014). There are restrictions to adaptation, because some dangers will persist; therefore, adaptation alone cannot be relied upon (Arbuckle, Morton & Hobbs, 2015). Mitigation too, has a critical part to play in shaping the risks of climate variations. The government supports climate change mitigation. Mitigation, however, is a human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs). Changes in climate that are not mitigated present a high risk to the health of humans, food security around the globe, and economic development (IPPC, 2014; Niles, Brown & Dynes, 2016). Therefore, it is crucial to take active measures to lessen emissions to evade the dangers of climate variation.

Importantly, the combination of adaptation and mitigation will lessen the level of risks of climate change, although some risks will be unavoidable (Niles et al., 2016). According to IPPC (2014), early actions and choices being adopted will take some time to see an impact response. Also, the extent of adaptation needed depends on the amount of mitigation undertaken (IPPC, 2014). It is also worthy of note that the policies govern agricultural activities, forest protection and management are more efficient when it involves both adaptation and mitigation (IPPC, 2014; Arbuckle et al., 2015).

Consequently, if proper, preventive measures are not considered, and adaptive strategies are not employed at the right time, the effects in the state and country at large could be catastrophic (Del Prado, Crosson, Olesen & Rotz, 2013). Still, in the light of solutions to mitigating climate change, IPPC (2014), opined that decarbonisation of electricity, through renewable, nuclear and carbon capture and storage (CCS), will need to happen readily, with the majority of power being provided by low-carbon sources. Measures for mitigating climate change include improving energy efficiency and opting for renewable energy over fossil fuels (Tol, 2005; IPCC, 2018). Mitigation options also include encouraging public transportation by increasing journeys within cities by bicycle, discouraging flights and taking more trips by train or in shared cars where possible (IPCC, 2001; IPCC, 2018). Promotion of responsible consumption in the agricultural industry, fish and livestock farming, food sustainability, and the 3Rs rule (reduce, reuse, recycle) are also mitigation options, as well as placing a tax on the use of fossil fuels and CO_2 emissions markets (Tol, 2005; IPCC, 2018).

Table 4.4 presents the difference between adaptation and mitigation. The main difference between climate change mitigation strategies and climate change adaptation is that mitigation is aimed at tackling the causes and minimising the possible impacts of climate change, whereas adaptation looks at how to reduce the negative effects it has and how to take advantage of any opportunities that may arise. Adaptation and mitigation differ in terms of spatial scales too: although climate change is a global issue, adaptation benefits are local and mitigation benefits are international. Adaptation and mitigation also differ in terms of timescale and economic sectors (Tol 2005; IPCC, 2001; IPPC, 2014).

Table 4.4: Difference between mitigation and adaptation

Mitigation	**Adaptation**
Mainly an international issue, as mitigation offers global advantages	Mainly a local issue, as adaptation primarily offers local benefits
Mitigation has a lasting result because of the inertia property the climatic system has	Adaptation can give a temporary result of decreasing the susceptibility of agriculture to climate change
Mitigation is important in the energy, transportation, industrial and waste management sectors	Adaptation is important in the water and health sectors and in lowland regions

Source: (Tol 2005; IPCC, 2001; IPPC, 2014)

In this regard, Cross River State government aims to have a transition to a low-carbon and climate-resilient economy, developing pathways of decarbonisation of the production and consumption economy as a mitigation option (Ministry of Climate Change and Forestry- MCCF, 2017). However, certain factors may affect the climate change adaptation strategies used by farmers specifically. These factors can be analysed using different models. The different models used in investigating the determinants of adaptation strategies are discussed in the following sub-section.

4.7 Models for analysing the determinants of adaptation strategies

The agro-economic and Ricardian cross-sectional models can include some adaptive measures, but these two models cannot address the factors that influence farmers' choice of adaptation (Gbetibouo & Hassan, 2005; Deressa & Hassan, 2009; Sarker et al., 2013). Agro-economic models are tools which help to analyse possible developments in the future and alternative strategies to influence these developments (Sarker et al., 2013; Nehrey, Kaminskyi & Komar, 2019). They give an understanding of the diversity of interrelations and factors and substantiate causal relationships. The model also studies the long-term effects of making decisions, systematically examines trade processes at the regional and international levels, and assess scenarios and their consequences (Nehrey et al., 2019). Whereas the Ricardian model observes farms across the landscape to expose the variances in agricultural productivities in the different climate zones (Mendelsohn, 2000). This model investigates how climate disrupts the net revenue of farmers (Mendelsohn & Dinar, 2009). Therefore, the Logit and Probit models are mostly chosen to examine the acceptance of agricultural technology (Sarker et al., 2013; Belay et al., 2017). Binary Logit and Probit models are employed when the number of adoptions practiced by farmers is no more than two options, that is, dichotomous. On the contrary, if the adaptation options are not limited to two choices, the multinomial logit (MNL) and multinomial Probit (MNP) models, which are an extension of the Logit and Probit models, are employed. Given that several adaptive measures are examined, the appropriate econometric model for analysing the determinants of adaptation strategies is likely to be an MNL or an MNP. Equally, these models investigate the influence of the explanatory variables on a dependent variable (adaptation option) and provide various options in a way that is not ordered (Sarker et al., 2013). The two models (Logit and Probit) identified here are employed in several types of research on climate change adaptation (see Nhemachena & Hassan, 2007; Seo & Mendelsohn 2008; Deressa et al., 2009; Hisali, Birungi & Buyinza, 2011; Sarker et al., 2013).

Consequently, Nhemachena and Hassan (2007), used the MNP model to address the factors that affect farmers' adaptation options in southern Africa. Seo and Mendelsohn (2008), used the MNL model to determine the choice of crops South American farmers make. Deressa et al., (2009) similarly employed the MNL model to evaluate the determinants of farmers' choice of adaptation strategy in the Nile Basin of Ethiopia. Hisali et al., (2011)'s research also used the MNL model to investigate what determines the adaptation option of the farmers in Uganda. Similarly, Sarker et al., (2012) employed the MNL model to investigate the factors that influence the adaptation options farmers take in the face of perceived climate change in Bangladesh. Nevertheless, all these authors had remarkable success in using the MNL model.

Additionally, the MNL model is commonly employed since in comparison with the MNP model it is simple to compute (Sarker et al., 2013; Belay et al., 2017). The MNL model expressively entails the assumption of independence of irrelevant alternatives (IIA) should hold to attain unbiased and reliable parameter estimates. The IIA assumption signifies that the likelihood of accepting specific adaptive measure by a particular farmer needs independence from the possibility of choosing alternative adaptive action (Greene 2003; Tesfaye & Seifu, 2016). Similarly, the likelihood of selecting a particular adaptive measure is equal to the possibility of that specific option being greater than or equal to the values of all other options in the group of alternatives (Tesfaye & Seifu, 2016). Added to this, the parameters of this model can be calculated by employing the maximum likelihood approach. Nevertheless, the parameter estimates of the MNL model gives the level of the effect the independent variables have on the dependent variable (Greene, 2003; Tesfaye & Seifu, 2016).

4.8 Empirical results of climate variation on agricultural production and adaptation strategies

In line with the available literature, the comparison of the related studies will be organised methodologically and grouped into two sections: the modelling type studies and the mainly descriptive type studies (Table 4.5). The method of analysis and key findings are included.

Table 4.5: Summary of literature review

Name of study	Method of analysis used	Key findings	Reference	Comment
The modelling type studies				
Climate Change and Crop Production in Nigeria: An Error Correction Modelling Approach	Co-integration analysis	The effect of climatic variables on crop production varies depending on the type of crop and seasonal properties and length of days of the crop.	Eregha, Babatolu and Akinnubi (2014)	
Effect of Climate Change on Agricultural Productivity in Nigeria: A Co-integration Model Approach	Co-integration analysis	Temperature change was revealed to exert negative effect while rainfall change exerts positive effect on agricultural productivity.	Ayindea, Muchiea and Olatunji (2011)	The co-integration method of analysis used here gave a clear result of the impact of climate variables on agriculture.
Effect of climate change on food crop production in southeast, nigeria:	Co-integration analysis	Unsteady climatic pattern with peak points across the period under review. Also,	Chikezie et al. (2015)	

a co-integration model approach		climate change impacted on yam and maize output.		
The effect of arbitrary year-to-year variations in temperature and rainfall on agricultural revenues in United States	Co-integration analysis	A positive impact of temperature and rainfall changes on the United States agriculture.	Deschenes and Greenstone (2007)	
Perception of climate change in the Niger Delta region of Nigeria.	Correlation analysis	The majority of Nigerians within the Niger Delta have very poor knowledge of the causes and effects of climate change.	Odjugo (2011)	The method of analysis used here (correlation analysis) only showed the relationship that exists among the variables and not the cause and effect.
Impacts of Climate Change on Agricultural Production in Enugu State, Nigeria	Correlation analysis	The traditional crops with the exception of cassava and pepper had a significant output decrease as rainfall continued to be more erratic.	Enete (2014)	

Impact of climate change on the productivity of cassava in Nigeria	Multiple regression analysis	Precipitation posted as positive coefficient in the short run but imposed a negative effect on cassava productivity over a long period of time while temperature influenced cassava productivity negatively both in the short and long run.	Mbanasor et al. (2015)	The method of analysis used here (regression analysis) revealed the effects of the explanatory variable on the dependent variable. The method also allows inferences to be made from the data in the studies.
Effect of climate variability on output of cassava in Abia State, Nigeria.	Multiple regression analysis	The coefficients for farm size, quantity of fertiliser, labour cost and rain were determinants of cassava production in the study area.	Nwaobiala and Nottidge (2015)	
Analysis of Coping Strategies Adopted against Climate Change by	Ordinary Least Square regression analysis	Over 83 percent of the farmers adopted alteration of the planting date while more than 95 percent of them adopted mixed farming as well as a mixed	Ike and Ezeafulukwe (2015)	

Small Scale Farmers in Delta State, Nigeria		cropping system to cope with the probable failure of one of the major crops planted.		
Effects of climate change on the production and profitability of cassava in the Niger Delta Region of Nigeria	Ordinary Least Squares (OLS) estimation procedure	Results showed high effects of climate change on cassava production. Also coping strategies to climate change by farmers were either highly or averagely adopted with none being poorly adopted.	Ajayi (2015)	
Impact of climate change on the composition of agricultural output in Nigeria for the period 1981- 2011	Ordinary Least Squares (OLS) regression	Climate change had a significant and positive impact on the composition of agricultural output in Nigeria.	Akinbobola, Adedokun and Nwosa (2015)	
Climate Variability: Relative Effect on Nigeria's Cassava	Ordinary Least Squares (OLS) regression	Climate variables had no significant effect on the output of cassava within the period under study.	Agwu, Nwachukwu and Anyanwu (2012)	

Productive Capacity				
Impact of climate change on agricultural production and Sustainability in Nigeria.	Regression analysis	The impact of agricultural inputs is significantly reduced by climate change, indicating that beside the direct negative impact of climate change itself on agriculture, it can also have an indirect negative effect by reducing the beneficial impact of other agricultural production inputs.	Iheoma (2015)	
Effects of climate change on cassava productivity in Ilesha – East Local Government Area of Osun State, Nigeria	Regression analysis	There is no significant relationship between the recent effects of climatic variability and the cassava yield in the study area.	Ezekiel et al. (2012)	
Rural farmers' perception of	Regression analysis	Farmers were aware of climate change. Also, many	Ofuoku (2011)	

climate change in central agricultural zone of Delta State, Nigeria.		of the farmers adapted to climate change by planting trees, carrying out soil conservation practice, changing planting dates, using different crop varieties, installing fans in livestock pens, and applying irrigation.		
Impact of climate change on yam production in Abuja, Nigeria.	Pearson product-moment correlation	14 per cent of the proportion variation of yam yield is explained by rain and temperature. The association between precipitation and the productivity of yam and between temperature and yam productivity were positively related.	Zakari et al. (2014)	
Farmers adaptation strategies to the effect of climate	Chi-square and Pearson Product Moment Correlation	A significant relationship was shown between secondary occupation ($\chi 2$ =	Oluwasusi (2013)	

variation on yam production in Ekiti State, Nigeria		14.068), farm size ($\chi 2$ = 99.597) and the level of production of yam farmers.		
Analysis of Impact of Climate Change on Growth and Yield of Yam and Cassava and Adaptation Strategies by Farmers in Southern Nigeria	Probit model and Multinomial Logit Model	The main outcomes of climate change were flooding (71.29 per cent), decline in crop yields (65.1 per cent), food price increases (62.87 per cent), and food shortages/insecurity (57.92 per cent). Also, the average amount of loss to climate change was N164,318.8 naira per farm.	Chukwuone (2015)	
Analysis of Climate Change Perception and Adaptation among Arable Food Crop Farmers in South Western Nigeria.	Logit regression analysis	There were low outputs from farms, as a result of low rainfall and increased temperature.	Apata, Samuel and Adeola (2009)	

Impact of climate change on agricultural production of Odisha (India): a Ricardian analysis	Ricardian analysis	Climate change has significant influence on the agricultural production of Odisha.	Mishra, Sahu and Sahoo (2016)	The Ricardian analysis incorporates farmers' adaptation strategy to the model in the studies unlike other methods. The method also allows predictions of the data.
Economic impact of climate change on Nigerian maize sector: a Ricardian analysis	Ricardian analysis	Net maize revenue per hectare is sensitive to climate change.	Ater and Aye (2012)	
Economic impact of climate change on maize production in Nothern Nigeria	Ricardian analysis	There was a significant correlation between climate change variables and net revenue from maize production.	Ibrahim et al. (2014)	
A Ricardian analysis of the impact of climate change on African cropland	Ricardian analysis	African farms are sensitive to climate and especially temperature. Also the study revealed that farm net revenues are lower in	Kurukulasuriya and Mendelsohn (2008)	

		places with higher temperatures.		
Impacts of climate change on rice agriculture in Nigeria	Ricardian analysis	Increase in temperature will reduce net revenue for dry land rice farms while net revenue rises with increase in temperature for irrigated rice farms. Precipitation had similar effects on rice net revenue.	Ajetomobi, Abiodun and Hassan (2011)	
The Economic Impact of Climate Change on Plantation Agriculture in Nigeria: Implication for Enhanced Productivity	Ricardian analysis	On the average, annual increases in temperature and decreasing precipitations are associated with net revenue losses for rain fed farms, whereas it increases for irrigated cocoa farms.	Fonta, Ichoku and Urama (2011)	
The significance of climate variables on the net revenue per hectare (NRh) of	Ricardian analysis	NRh is highly sensitive to climate variability in Nigeria, and depends on whether cocoa farms	Fonta et al. (2018)	

Nigerian cocoa farms		undergo supplementary irrigation or not. A rise in temperature and decrease in rainfall are related to NRh loss in farms that are dependent on rainfall, while it rises for cocoa farms under irrigation.		
Climate change impact on United States agriculture	Ricardian analysis	With the exception of autumn, increased temperatures in all seasons led to a reduction of average farm income, while increased rainfall (except in autumn) led to high farm income.	Mendelsohn, Nordhaus and Shaw (1994)	
The impacts of climate change on agriculture across the region in China	Ricardian analysis	Increase in temperature had an adverse effect on agriculture. In contrast, an increase in rainfall has a beneficial impact on crop growth.	Wang, Huang, Zhang and Li (2014)	

Reinsborough (2003), employed the Ricardian method proposed by Mendelsohn *et al.,* (1994) and found a positive impact of climate change on agriculture in Canada. Furthermore, similar outcomes were produced by Nhemachena and Mano (2007), who followed the same approach in Zimbabwe, and by Deressa and Hassan (2009) in a study in Ethiopia. Nevertheless, Wood and Mendelsohn (2015) discovered that increased temperatures and rainfall reduce agricultural profits in the peak of the rainy season but raise earnings in the dry season in the areas of northern Guinea and southern Senegal. However, a few studies estimated the impact climate change has on agriculture by concentrating mainly on livestock. Kabubo-Mariara (2009) assessed the net revenues of livestock in Kenya using a Ricardian model based on a sample size of 722 respondents. From the study, the marginal impact suggested profits as a result of an increase in temperatures and losses from the rise in rainfall. In another study, by Seo and Mendelsohn (2008) carried out in Africa, the result of the study based on a survey of about 5,000 livestock farmers across ten countries revealed that the net revenues of the livestock of large farms are more sensitive to temperature than those of small farms in the study area. Employing the Ricardian approach, this research further estimated that the net revenues of small farms would rise as much as 120 per cent (+USD6 billion) but then those of large farms would fall by 20 per cent (USD12 billion) by 2060. According to Seo, Mendelsohn and Munasinghe (2005), it is worthy of note that agronomic studies opine that a specific range of temperature and rainfall is essential for optimum crop production and aberration from that particular range would lead to a reduction in the crop productivity.

Moreover, Schlenker and Roberts (2009) discovered that temperature and crop yield are highly non-linear and asymmetrically related. In general, the influence of climate on agricultural production is anticipated to be non-linear because firstly, productivity rises and after that declines with higher temperature and rainfall, implying that it inclines to a hill-shaped relationship (Mendelsohn, 2012). As a result of this, climate-related studies use the non-linear specification of climate variables; which are temperature and precipitation in their empirical model (Kumar & Parikh, 2001; Seo et al., 2005; Kurukulasuriya & Mendelsohn, 2008; Wang et al., 2014; Wood & Mendelsohn, 2015; Belay et al.,2017; Elijah, Osuafor & Anarah, 2018). In the United States, Roberts, Schlenker and Eyer (2012) discovered the relationship between climate variation and corn production using time series data of corn output from 1950-2010. In the end they discovered that changing 24 hours of temperature from 29^0C to 39^0C reduces corn output by nearly 6.2 per cent. Even though this research revealed a positive relationship between rainfall and corn output, the outcome indicated that increased temperature could be detrimental to corn output even when rainfall is more than or lesser than the average value. On the contrary, a similar study previously carried out in the United States by Schlenker and Roberts (2009), argued that there exists a strong negative relationship between extreme heat and corn output.

Wei et al., (2014) examined how climate change impacts on some food crop output in China, namely; wheat, rice and maize. The study considered provincial panel data for the period 1980 to 2008. The result of the survey revealed that rise in temperature positively impacted on the output of wheat and rice by 1.3 per cent and 0.4 per cent respectively. In contrast, the reverse was the case for maize with 12 per cent negative impact on output. The research further concluded that in China, even though the influence of rainfall is positive, the critical effect of climate change on crop output is from temperature rise. In the same way, the possible impact of climate variation on the agricultural sector in Taiwan was conducted by Chang (2002). The study considered yields of 60 crops harvested from 15 sub-regions in Taiwan from 1977-1996. The research discovered that the impacts of climate change variables have a significant influence on crop output, but they differ according to the crops. Further, the estimates from the result implied that generally, rise in temperature would not be harmful to the agricultural sector of Taiwan, instead, there would be a severely damaging effect from the rise in the amount of rainfall. However, the conclusion drawn from this research is entirely contrary to that of the investigation by Wei, Cherry, Glomrød, and Zhang (2014). Considering the study by Wei et al. (2014), it was discovered that the influence of temperature and precipitation are positively related to the yield of rice. In addition, precipitation consequence is marginal on crop output in the same study while it is very harmful in the study by Chang (2002). This suggests that the impacts are very crop specific within a given location.

Likewise, Chen, McCarl, and Schimmelpfennig (2004) assessed the likely impacts of changes in climate on significant food crop output in United States' agriculture. The study used the panel data procedure developed following a stochastic production function method. The findings of the study indicated that though temperature and precipitation increase had a positive effect on the output of sorghum, they show the opposite influence separately on corn output. Furthermore, in studies conducted in India by Guiteras (2009), and Barnwal and Kotani (2010), the influence of climate alteration on Indian agriculture was examined by both studies. By applying a similar methodology, the former surveyed the whole nation while the latter researched just one state, Andra Pradesh. By employing the panel data, both studies ran a regression on the yearly district-level output of the leading food crops (rice, wheat, sorghum, and maize) on yearly weather (temperature and rainfall) data and district fixed effect. Consequently, both studies concluded that a rise in mean temperature has a negative impact on food crop output in India.

However, Table 4.6 presents a further review of related studies which adopted primarily descriptive analysis such as using means, frequencies, standard deviation and percentages.

Table 4.6: Studies that employed the descriptive statistics in data analysis

The mainly descriptive type of study				
Adaptation of root crop farming system to climate change in Ikwerre Local Government Area of Rivers state, Nigeria.	Percentages, mean and standard deviation	There was an increase in both rainfall and temperature during the period under study. Also, farmers identified crop failure, reduced crop yield, increased incidence of pest and diseases and delay in planting period as the direct effects of climate change.	Weli and Bajie (2017)	The method used in these studies only describes the data and does not allow for predictions (inferences) from that data.
Challenges of adaptation to climate change and variability for cassava farming in Musoma, Rural District in Tanzania.	Means, percentages and standard deviation	Several challenges such as poor implementation of policies and lack of adequate climate change policies to combat drought led to decreased cassava yields.	Kanyama and John (2016)	

Rural Peoples' Perception to Climate Variability/Change in Cross River State-Nigeria	Means and percentages	Effects of climate in rural areas include poor crop yields (56.7 per cent response); reduced soil fertility (66.7 per cent response); increase flood (56.7 per cent), poverty and food shortage (50 per cent response).	Egbe et al. (2014)	
Impacts of climate change on sustainable livelihood Of rural dwellers in Southeast Nigeria.	A 4-point Likert- type scale and descriptive statistics	Of the thirty variables used to assess climate change impact on sustainable livelihood of rural dwellers in the study area, they strongly agree that eight variables were evident in their environment namely; onset of rain is now delayed, increase in earth's surface temperature, unusual rainfall, general undefined weather, planting	Ifeanyi-obi and Asiabaka (2014)	

		time of crops is now unpredictable, increase heat stress on crops, increase heat stress on livestock and reduction in length and quality of milk in lactating animals.		
Cassava farmers' adaptation to climate change in Oron agricultural zone of Akwa Ibom State, Nigeria	A 4-point Likert- type scale	The result of the analysis identified seven major adaptation options used by the cassava farmers which were; use of improved and resistant species and farm chemicals, use of improved farming practices and information from agricultural extension agent, diversification, water conservation practices, soil fertility and land policies/ practices, use of insurance	Ifeanyi-obi, Etuk and Uloh (2013)	

		and credit facilities, and use of weather forecast facilities.		
Perception and impact of climatic variations on crop production in Sapele Local Government Area of Delta State, Nigeria	Frequencies and percentages	Major climatic problems are water related; floods (88.3 per cent), windy rains (86.7 per cent) and heavy rainfalls (90.0 per cent). Also, root and tuber crops (cassava, yam, and cocoyam) are mostly affected by the climate problems.	Ajokporise (2011)	

4.9 Gaps in the existing literature

Different methods of analysis are used by different authors in examining the impact of climate of change. These methods have their strength and weaknesses. However, it is important to use a method of analysis that allows inferences to be drawn from the results. Consequently, Table 4.6 presents the six gaps identified in the literature as a result of undertaking the literature review.

Table 4.6: Gaps identified in the existing literature

1. Most of the economic studies identifying the influence of climate variation on agriculture have concentrated on agriculture by putting together most crops in one category. This means that they may have not looked at crop specific impacts. However, crop types are influenced heterogeneously by climate fluctuations (Deressa, Hassan, & Poonyth, 2005; Isik & Devadoss, 2006; Sarker *et al.,* 2012). Thus, it is essential to carry out enterprise (crop) specific analysis (Ater & Aye, 2012; Sarker et al., 2012).
2. The effect of climate variation differs between and within Agro-Ecological Zones of the same country (Gbetibouo & Hassan, 2005; Sarker et al., 2012). Therefore, there should be scope for further area or country-specific studies with a concentration on individual crops or livestock (Kabubo- Mariara & Karanja, 2007).
3. There is a lack of studies to date that consider the impact of climate change on essential root crops such as yam which is a staple food in Nigeria. In literature, there are too few studies to comment on whether there has been any significant impact of climate change on the output of yam in Nigeria and this presents a clear research gap.
4. Most of the past cross-sectional studies used state-level data. However, this research did not provide a detailed examination of socio-economic and demographic characteristics (livelihood) of farmers. The literature examined in this chapter has shown that livelihood characteristics are likely to affect their choice of adaptation and, thereby, to reduce or improve farm productivity. Even so, impact and adaptation studies on climate change that used detailed farm-level data are limited.
5. Previous studies using farm-level data have not focused on yam particularly. Moreover, the results from those studies were not robust because of insufficient statistical analysis tests.
6. In the case of Nigeria, there are some modelling studies, but very few empirical studies used standard econometric techniques in their analysis. Other studies used mainly descriptive analysis.

4.10 Chapter summary

This chapter captured the agricultural adaptation strategies adopted to cope with the changes in weather pattern experienced by farmers. The different adaptation options include changing of planting date, tree planting, expansion of farmland, crop diversification, among other possibilities. Nevertheless, certain socio-economic factors demographic characteristics, farm characteristics and access to information affect the choice of adaptation option taken by the farmers. Further, the farmers are said to encounter some barriers that discourage or prevent them from taking adaptation strategies. Some of the obstacles include financial constraints, lack of access to weather information, lack of access to extension services, and so on.

Moreover, the government of Cross River State have played a role in climate change adaptation and offered some possible solutions within the state such as moving to a low-carbon and climate-resilient economy. The models used in adaptation studies to analyse the factors that influence adaptation decision and choice have been explored, which include the Probit model and Logit model. Also, the review of related literature on climate change and adaptation in agriculture was presented in this chapter which has showed studies based on modelling and descriptive methodologies. This chapter however, provided the basis for the theories adopted by this PhD study which are presented in section 5.4 of the next chapter. Therefore, this chapter sets the context for the next chapter which outlines the methodology and theoretical framework employed in the study.

Chapter 5 Research methodology

5.1 Introduction

The focus of this chapter is on the philosophical and theoretical aspects and the research methods used to attain each of the research objectives. Importantly, a research methodology addresses the overall strategy of the research design that lies behind the selection of a specific method and links the use of these methods to deliver expected outcomes (Crotty, 1998). Accordingly, the chapter relates to research paradigms, research methods and the development of a theoretical framework.

5.2 Introduction to Research Paradigms

A paradigm is an established body of knowledge about specific epistemological and ontological foundations. It presents the opinion of the world and how it understands problems (Guba, 1990; Wong, 2014), and represents a theoretical framework guiding the approaches in conducting research (Easterby-Smith, Thorpe & Lowe, 2004))

Noor (2008) identified two significant paradigms, namely positivism and interpretivism. However, Johnson and Onwuegbuzie (2004) identified a movement in the direction of mixed methods (pragmatism) which synthesizes both the positivism and interpretivism philosophical views. The pragmatic philosophical view explains how to put research methods together to effectively become one method (Hoshmand, 2003). Moreover, the next sub-section presents a summary of the two fundamental paradigms as well as the pragmatic view.

5.2.1 Positivism

This paradigm is occasionally referred to as the systematic approach of research or can be said to be science research. It could equally be called positivist, post-positivist research or post-positivism (Creswell, 2014). The majority of quantitative and the qualitative research support this postulation (Creswell, 2014). Positivism, however, is a method of creating information through research which emphasizes the natural science model (Ticehurst & Veal, 2000). Also, quantitative procedures such as survey research, the use of well-structured questionnaires and official statistics are preferred in positivism-based research since if the method is designed appropriately, they can show excellent degrees of representativeness of the intended population and the researcher is working from a viewpoint of being objective (Charumbira, 2013). Positivists accept as true that there exists a sole reality, and that this reality is seen through observation, and that the researcher acts as an observer. Thus, the measurement of this reality is possible with the use of quantitative methods (Guba & Lincoln, 1994).

5.2.2 Interpretivism

Interpretivism focuses on subjectivism and constructivism that require the interpretation of elements of the study by scientists (Guba & Lincoln, 1994). It is said to be a qualitative research paradigm that tries to investigate the knowledge of the people that it intends to examine. Therefore, interpretivism assimilates human experience into research (Easterby-Smith et al., 2004). Interpretivism also shows that understanding the meaning humans give to reality of life is the aim of social science (Skinner & Edwards 2009). For an interpretivist researcher, it is essential to understand themes which do not allow for easy quantification that are potentially subjective and their status is dependent on time and situation (Hudson & Ozanne, 1988; Guba & Lincoln, 1994; Neuman, 2000). The use of interpretivism as a method in social science research is mostly qualitative as it uses unstructured interviews or member observation and interpretation technique to gain information (Neuman, 2000; Black, 2006). This requires the researcher to move from being an observer to instead act as an interpreter and identify meaning from the data collected.

5.2.3 Pragmatism

According to Dudovskiy (2016), positivism and interpretivism are two research paradigms that cannot occur at the same time. Although several studies generally settle in either of these two fundamental research paradigms, scientists occasionally adjust their philosophical view in the long run, to allow movement to a new place on the continuum between deductive (positivism) and inductive (interpretivism) approaches. These revised philosophical approaches are accepted by pragmatic scientists (Collis & Hussey, 2014). In a pragmatic research philosophy, the research focuses on one or a series of research questions rather than being based solely on testing positivist hypotheses. Even so, pragmatics often integrate the position of the positivist and interpretivism as methodological approaches within the methodology of a single study and how they are combined is dependent on the research questions presented in the research (Dudovskiy, 2016).

Therefore, to address the research question concerned, this study adopts the pragmatic philosophical approach.

5.3 Research methods and research design

Research methods are techniques or ways of proceeding in gathering evidence. They involve the techniques for collecting data, analysing the data and interpreting the data collected. According to Creswell (2014), there are three different research approaches; the qualitative research, the quantitative research and the mixed research approach. Qualitative research is a method that involves assessing and interpreting the description of a person or group of people to address a societal or human issue (Creswell, 2014). Qualitative methods are employed to provide answers to questions around experience, meaning and perspective, from the position of the respondents (Hammarberg, Kirkman & De Lacey, 2016), albeit that themes and meaning may be interpreted from the data by the researcher. Conversely, in quantitative research, observable and objective information is essential to test given hypotheses. It is useful in a positivist approach for variables to be aligned to form hypotheses before the data is collected (Creswell, 2014; Hammarberg et al., 2016). Another form of research is mixed methods research. This synthesizes quantitative and qualitative methods into a cohesive approach, although great attention should be given to the combination used to guarantee compatibility in the rationale behind the use of each technique (Hammarberg et al., 2016) The two methods can be used consecutively with the first being quantitative research followed by qualitative research or vice versa (Hammarberg et al., 2016). It is important to consider how one form of data collection informs the other as this will be rooted in the nature and quality of data and how it can be analysed.

It is, however, the research problems and research questions that determine the type of design one should use.

The different research approaches are aligned with the various paradigms as follows:

5.3.1 Quantitative approach

This approach has the post-positivist philosophical view, experimental design, and pre-test and post-test measures of attributes. In a situation like this, the investigator examines a theory by postulating narrow hypotheses that can be tested. Data collection takes place to accept or disprove the hypotheses. The data collection uses an instrument, e.g., an experiment or a structured questionnaire which measures attributes e.g., individual attitudes and allows for the evaluation of data with the use of descriptive and inferential statistical analysis and hypothesis testing (Johnson & Onwuegbuzie, 2004; Creswell, 2014).

5.3.2 Qualitative approach

This approach incorporates the interpretivist worldview, ethnographic design, and observation of behaviour. This approach also includes seeking to find a transformative worldview, and can be based on narrative design, and open-ended interviews, e.g. data can be collected as stories gathered on individual reflection about a given issue that relates to the research question. The data is then analysed using a narrative approach (Creswell, 2014).

5.3.3 Mixed methods approach

This approach considers the pragmatic worldview, gathering the quantitative and qualitative data consecutively in the design of the research. The investigator centres the investigation on the rationale that gathering different kinds of information best offers a more comprehensive understanding of a research problem than using either quantitative or qualitative data alone. This type of research can start with an extensive quantitative survey to take a broad view of outcomes to a populace and ends with an emphasis on qualitative, open-ended interviews to gather thorough opinions from respondents to aid in elucidating the preliminary quantitative survey (Cameron, 2011; Creswell, 2014).

Based on the above discussion of the different paradigms and research methods, and the research questions posed this study will adopt a mixed-method research approach.

Table 5.1 positions previous studies according to the research paradigms used. One-third of the related studies are from a pragmatic philosophical view which confirms the movement towards mixed-method research in the research discipline area. Specifically in this study, meeting the first four research objectives employed quantitative data from official statistics and a structured questionnaire (positivism), while the fifth research objective (research objectives are in chapter 1, section 1.3) employed qualitative data from relevant experts through a two-stage online survey (interpretivism). Therefore, the positioning of this research outlined in the thesis is from the pragmatic philosophical view. The inferential approaches used by these studies in Table 5.1 was revealed in Table 4.5 in the previous chapter.

Table 5.1: Summary of literature showing the philosophical viewpoints of related studies

Name of study	*Paradigm*	*Method used*	*Key findings*	*Reference*
Effects of climate change on the production and profitability of cassava in the Niger Delta Region of Nigeria	Pragmatism	Mixed method	Results showed high effects of climate change on cassava production. Also coping strategies to climate change by farmers were either highly or averagely adopted with none being poorly adopted.	Ajayi (2015)
Adaptation of root crop farming system to climate change in Ikwerre Local Government Area of Rivers state, Nigeria.	Pragmatism	Mixed method	There was an increase in both rainfall and temperature during the period under study. Also, farmers identified crop failure, reduced crop yield, increased incidence of pest and diseases and delay in planting period as the direct effects of climate change.	Weli and Bajie (2017)
Effects of climate change on cassava productivity in Ilesha – East Local Government	Pragmatism	Mixed method	There is no significant relationship between the recent effects of climatic variability and	Ezekiel, Olawuyi, Ganiyu, Ojedokun and Adeyemo (2012)

Area of Osun State, Nigeria			the cassava yield in the study area.	
Analysis of Climate Change Perception and Adaptation among Arable Food Crop Farmers in South Western Nigeria.	Pragmatism	Mixed method	There were low outputs from farms, as a result of low rainfall and increased temperature.	Apata et al. (2009)
Rural Peoples' Perception to Climate Variability/Change in Cross River State-Nigeria	Pragmatism	Mixed method	Effects of climate in rural areas include poor crop yields (56.7% response); reduced soil fertility (66.7% response); increase flood (56.7%), poverty and food shortage (50% response).	Egbe et al. (2014)
Challenges of adaptation to climate change and variability for cassava farming in Musoma, Rural District in Tanzania.	Pragmatism	Mixed method	Several challenges like poor implementation of policies and lack of adequate climate change policies to combat drought led to decreased cassava yields.	Kanyama and John (2016)
Analysis of Impact of Climate Change on	Pragmatism	Mixed method	The main outcomes of climate change were flooding (71.29%),	Chukwuone (2015)

Growth and Yield of Yam and Cassava and Adaptation Strategies by Farmers in Southern Nigeria			decline in crop yields (65.1%), food price increases (62.87%), and food shortages/ insecurity (57.92%). Also, the average amount of loss to climate change was N164,318.8 naira.	
Cassava farmers' adaptation to climate change in Oron agricultural zone of Akwa Ibom State, Nigeria	Pragmatism	Mixed method	The result of the factor analysis identified seven major adaptation options used by the cassava farmers.	Ifeanyi-obi, Etuk and Uloh (2013)
Rural farmers' perception of climate change in central agricultural zone of Delta State, Nigeria.	Pragmatism	Mixed method	Farmers were aware of climate change. Also, many of the farmers adapted to climate change by planting trees, carrying out soil conservation practice, changing planting dates, using different crop varieties, installing fans in livestock pens, and applying irrigation.	Ofuoku (2011)

Impacts of climate change on sustainable livelihood Of rural dwellers in Southeast Nigeria.	Pragmatism	Mixed method	Of the thirty variables used to assess climate change impact on the sustainable livelihood of rural dwellers in the study area, they strongly agree that eight were evident in their environment.	Ifeanyi-obi and Asiabaka (2014)
Effects of climate change on yam production in Cross River State, Nigeria.	Pragmatism	Mixed method	The effects of climate variability and change on yam production is statistically significant at $P<0.05$	Samuel et al. (2018)
Impact of climate change on China's rice production—An empirical estimation based on panel data (1979–2011) from China's main rice-producing areas	Pragmatism	Mixed method	Minimum temperatures (Tmin), maximum temperatures (Tmax), temperature difference (TD) and precipitation (RP) are the four key climate determinants of rice production in China. Among these, temperature difference was significant and all except maximum temperatures have positive effects.	Wang, Hao and Wang, (2018)

Impacts of climate change on net crop revenue in North and South China	Pragmatism	Mixed method	The rise in annual temperature affected farms both in the north or south of China. The impact on net farm revenues varies with farms. The north and the south were adversely affected by a rise in the temperature.	Wang, Huang, Zhang and Li (2014)
Productivity of Homestead based Yam Farmers: An Empirical Evidence from Southern Cross River State, Nigeria	Pragmatism	Mixed method	The maximum likelihood estimates of the specified models revealed an average technical efficiency of 70.41%. Farmer's education, experience; family size, level of farming involvement and farm size are significant factors affecting farm-level technical efficiency.	Akpan & Essien, (2019)
The Economic Impact of Climate Change on Plantation Agriculture in Nigeria: Implication for Enhanced Productivity	Pragmatism	Mixed method	Annual increases in temperature and decreasing precipitations are associated with net revenue losses for rain fed farms,	Fonta, Ichoku and Urama (2011)

			whereas it increases for irrigated cocoa farms.	
Effects of Climate Change on Yam Production in South-South Nigeria.	Positivism	Quantitative method	There exists a long-run equilibrium relationship between rainfall and temperature on agriculture in the study area.	Amuwah, Filho and Amos (2020)
Yam farmers' adaptation practices towards climate change disaster in Cross River State, Nigeria	Positivism	Quantitative method	Socio-economic variables such as age, number of years in school, access to extension facilities and size of farmland significantly influenced farmer's adoption of climate change adaptation strategies at $P<0.05$. Strategies adopted by farmers include multiple cropping, crop diversification, multiple planting dates, cover cropping, irrigation practices, and tree planting.	Elijah, Osuafor and Edeh (2020)
Impact of climate change on the composition of	Positivism	Quantitative method	Climate change had a significant and positive impact on the	Akinbobola et al. (2015)

agricultural output in Nigeria for the period 1981- 2011			composition of agricultural output in Nigeria.	
Climate Change and Crop Production in Nigeria: An Error Correction Modelling Approach	Positivism	Quantitative method	The effect of climatic variables on crop production varies depending on the type of crop and seasonal properties and length of days of the crop.	Eregha et al. (2014)
Climate Variability: Relative Effect on Nigeria's Cassava Productive Capacity	Positivism	Quantitative method	Climate variables had no significant effect on the output of cassava within the period under study.	Agwu et al. (2012)
Impact of climate change on agricultural production and Sustainability in Nigeria.	Positivism	Quantitative method	The impact of agricultural inputs is significantly reduced by climate change, indicating that beside the direct negative impact of climate change on agriculture, it can also have an indirect negative effect by reducing the impact of other agricultural production inputs.	Iheoma (2015)

Perception of climate change in the Niger Delta region of Nigeria.	Positivism	Quantitative method	Majority of Nigerians within the Niger Delta have very poor knowledge of the causes and effects of climate change.	Odjugo (2011)
Effect of Climate Change on Agricultural Productivity in Nigeria: A Co-integration Model Approach	Positivism	Quantitative method	Temperature and rainfall were statistically significant. Temperature change was revealed to exert a negative effect while rainfall change exerts a positive effect on agricultural productivity.	Ayindea, Muchiea and Olatunji (2011)
Impact of climate change on agricultural production of Odisha (India): a Ricardian analysis	Positivism	Quantitative method	Climate change had a significant influence on the agricultural production of Odisha.	Mishra, Sahu and Sahoo (2016)
Economic impact of climate change on Nigerian maize sector: a Ricardian analysis	Positivism	Quantitative method	Net maize revenue per hectare is sensitive to climate change.	Ater and Aye (2012)
Effect of climate change on food crop production	Positivism	Quantitative method	Unsteady climatic pattern with peak points across the period	Chikezie et al. (2015)

in southeast, Nigeria: a co-integration model approach			under review. Also, climate change impacted on yam and maize output	
Impact of climate change on the productivity of cassava in Nigeria	Positivism	Quantitative method	Precipitation had a positive coefficient in the short run but imposed a negative effect on cassava productivity over a long period of time while temperature influenced cassava productivity negatively both in the short and long run.	Mbanasor et al. (2015)
Impacts of Climate Change on Agricultural Production in Enugu State, Nigeria	Positivism	Quantitative method	The traditional crops with the exception of cassava and pepper had a significant output decrease as rainfall continued to be more erratic.	Enete (2014)
Economic impact of climate change on maize production in Northern Nigeria	Positivism	Quantitative method	There was a significant correlation between climate change variables and net revenue from maize production.	Ibrahim et al. (2014)
A Ricardian analysis of the impact of climate	Positivism	Quantitative method	African farms are sensitive to climate and especially	Kurukulasuriya and Mendelsohn (2008)

change on African cropland			temperature. Also the study revealed that farm net revenues are lower in places with higher temperatures.	
Impacts of climate change on rice agriculture in Nigeria	Positivism	Quantitative method	Increase in temperature will reduce net revenue for dry land rice farms while net revenue rises with increase in temperature for irrigated rice farms. Precipitation had similar effects on rice net revenue.	Ajetomobi, Abiodun and Hassan (2011)
Effect of climate variability on output of cassava in Abia State, Nigeria.	Positivism	Quantitative method	The coefficients for farm size, quantity of fertiliser, labour cost and rain were determinants of cassava production in the study area.	Nwaobiala and Nottidge (2015)
Analysis of Coping Strategies Adopted against Climate Change by Small Scale Farmers in Delta State, Nigeria	Positivism	Quantitative method	Over 83 percent of the farmers adopted an alteration of planting date while more than 95 percent of them adopted mixed farming as well as a mixed cropping system to cope with the	Ike and Ezeafulukwe (2015)

			probable failure of one of the major crops planted.	
Perception and impact of climatic variations on crop production in Sapele Local Government Area of Delta State, Nigeria	Positivism	Quantitative method	Major climatic problems are water related; floods (88.3%), windy rains (86.7%) and heavy rainfalls (90.0%). Also, root and tuber crops (cassava, yam, and cocoyam) are mostly affected by the climate problems.	Ajokporise (2011)
Impact of climate change on yam production in Abuja, Nigeria.	Positivism	Quantitative method	14% of the proportion variation of yam yield is explained by rain and temperature.	Zakari et al. (2014)
Farmers adaptation strategies to the effect of climate variation on yam production in Ekiti State, Nigeria	Positivism	Qualitative method	A significant relationship between secondary occupation ($\chi2$ = 14.068), farm size ($\chi2$ = 99.597) and the level of production of yam farmers was shown.	Oluwasusi (2013)

5.4 Theoretical framework

Two theories inform the research on climate change impact on agriculture, namely production theory (Chang, 2002; Sarker et al., 2012) and Ricardian theory (Kurukulasuriya & Mendelsohn, 2008; Sarker et al., 2012). These two approaches have been widely used in the literature to assess the impacts of climate change on agriculture.

5.4.1 Theory of production

From a theoretical perspective, the theory of production explains the transformation process of physical inputs (e.g., labour and capital) into outputs. In other words, the production function mirrors the level of technical efficiency in the production process by showing the ratio of observed output to the maximum level of output that a producer can produce, using given input (Agom, Ohen, Itam & Inyang, 2012).

Importantly in economics, the production transformation is expressed mathematically using the production function. Hence, this leads us to the production function presented in the next sub-section.

5.4.1.1 Production function

The production function is the mathematical expression, which indicates the maximum output that a producer can produce, given available physical input (Nwike & Ugwumba, 2015). Nevertheless, it is worthy of note that one of the approaches that are applied to evaluate the physical and economic impacts of changes in weather pattern on agriculture is the production function model. This model estimates the effects of climate change by varying one or more variables such as rainfall or temperature. Also, the basic idea of this method is that the development of production in agriculture relies on soil-related and climatic variables that are the independent variables in the model (Rahman, Mia, & Bhuiyan, 2012).

Similarly, a crop production function can be stated based on endogenous and exogenous variables; endogenous variables include labour, capital, fertilisers and other inputs while the exogenous variables are the climatic variables (Nwike & Ugwumba, 2015).

Mathematically, the expression of the crop production function is as follows:

$$Qt = f(Mt, Zt, Xt)$$

Where Q_t denotes agricultural productivity or yields per hectare of a specific crop, m_t represents farmers' characteristics, z_t represents climatic variables, x_t represents endogenous variables and the sub-index *t*, represents the time or the year observed.

More so, from an economic viewpoint, this approach relies on the fact that farmers attempt to maximise their profit and thus, they choose the number of inputs (X) that allow them to achieve this goal given the explanatory variables like weather factors. Climatic variables, considered as explanatory, however, play a significant role in determining crop yields. This is so because plant development depends on their exposure to rainfall and temperature in their growth stage.

In addition, to estimate the production function, the Cobb–Douglas production function is used. Usually, a functional quadratic formula is preferred to assess the production function to detect the temperature and rainfall levels that affect agricultural production positively or negatively. After the estimation, the production function, calculating the impact on the different variables (production or crop yield) is then possible given the variations in one or more factors like rainfall and temperature.

The production function approach estimates the effect of climate change on crop yields. Usually, the field of agricultural economics uses the production function approach to identify relevant variables and their impact on crop yields. In the case of estimating the impacts of climate change, this approach uses statistical regressions that relate yields to climate variables to capture the effects of climate on agricultural productivity. Climate change impact is estimated using this approach in the USA (Chen et al., 2004; Schlenker & Roberts, 2009; Roberts, Schlenker & Eyer, 2012), Nigeria (Ayindea et al., 2011; Eregha et al., 2014; Nwaobiala & Nottidge, 2015), Taiwan (Chang, 2002; Chen & Chang, 2005), India (Guiteras, 2009; Barnwal & Kotani, 2010) and China (Wei et al., 2014).

Chen et al., (2004) observed the potential effects of climate change on significant crop yield in U.S. agriculture using the panel data technique developed along the line of the stochastic production function approach. The estimated results implied that although temperature and rainfall increase have a positive impact on yield for sorghum, they have an opposite effect individually on corn yield. Also, Roberts et al., (2012) explored the link between climate change and corn yield in the U.S. using time series data from 1950-2010. They revealed that shifting 24 hours of temperature from 29^0C to 39^0C decreases corn yield by approximately 6.2 per cent. Though this study found a definite link between precipitation and corn yield, evidence suggested that high temperature can be damaging to corn yield even when precipitation is higher than or much less than the mean value. In a similar study conducted by Schlenker and Roberts (2009) in the U.S., they found a strong causal negative link between extreme heat and corn yield. A study by Samuel et al., (2018) in Cross River State, Nigeria reported that the effects of climate variability and change on yam production is statistically significant which is similar to the studies by Robert et al., (2012) and Schlenker & Roberts (2009). Another study conducted in south-south Nigeria by Amuwah et al., (2020) agrees with these studied and revealed that there exists a long-run equilibrium relationship between rainfall and temperature on agriculture in the study area.

Furthermore, Wei et al., (2014) in China assessed climate change impact on three crop yields, wheat, rice and maize, using panel data from 1980 to 2008. Their results disclosed that temperature increase had a positive effect on yield growth of wheat and rice by 1.3 per cent and 0.4 per cent respectively, but the opposite impact for maize by 12 per cent. Their study also concluded that although precipitation effect is positive, the key impact on crop yield is from temperature rise in China. Similarly, Chang (2002) estimated the potential impact of climate change on Taiwan's agricultural sector considering yield of 60 crops from 15 sub-regions in Taiwan for the years 1977-1996. This study found that the effects of climate variables are harmful to crop yield but differ on different crops. From the estimated results, Chang (2002), concluded that overall, Taiwan's agricultural sector would not suffer from temperature increase, but would see a severe deteriorative effect from any precipitation increase. The findings from this study differ from that of Wei et al., (2014).

Guiteras (2009), and Barnwal and Kotani (2010), estimated the impact of climate change on Indian agriculture using the same methodology. The former used data from the entire country, whereas the latter used data from just a state within the country. Both studies used the panel data to regress yearly district-level yield of major crops (rice, wheat, sorghum, and maize) on yearly weather (temperature and precipitation) data and the district fixed effect. These studies concluded that an increase in average temperature harms crop yield in India, which opposes the findings from Chen et al. (2004) in the U.S.

These studies show a complex set of findings that imply situational factors at country or state level also have a role.

5.4.2 Ricardian Theory

This approach is a cross-sectional method that observes farms across the landscape to expose the variances in agricultural productivities in the different climate zones (Mendelsohn et al., 1994). In other words, this model investigates how climate disrupts the net revenue of farmers (Mendelsohn, 2000; Mendelsohn & Dinar, 2009). The technique has been named the Ricardian method, named after David Ricardo (1772 – 1823) since it draws profoundly from his opinion that land value would reflect its net productivity. Following Dinar and Mendelsohn (2011), they assume that each farmer makes the most of his income subject to the exogenous situations of their farm.

Hence, the model is estimated by regressing net revenue per hectare on a set of exogenous variables such as climate, soils, socio-economic variables and prices; important factors affecting farm net revenue that the farmer cannot control or alter (Dinar, Hassan, Mendelsohn & Benhin, 2008). The Ricardian method explains how these variables influence land value in a regression analysis. Also, the Ricardian method implicitly captures adaptation (Mendelsohn & Dinar, 2009). The principle is expressed explicitly in the equation as follows:

$$LV = \sum PiQi(X, F, H, Z, G) - \sum PxX$$

Where LV represents the value of land,

Pi represents the market price of crop i,

Qi represents the output of crop i,

X represents the vector of purchased inputs (other than land),

F represents the vector of climate variables,

H represents the water flow,

Z represents the vector of soil variables,

G represents the vector of socio-economic variables and

Px represents the vector of input prices (Mendelsohn *et al.,* 1994).

Additionally, the Ricardian method is a cross-sectional analysis used in studying agricultural production. The most significant benefit of the Ricardian approach is its capacity to integrate efficient private adaptation. Investigations that do not incorporate useful adaptation (such as the early agronomic studies) misjudge the reparations related to any deviation from the best. Notably, adaptation is costly (Mendelsohn & Dinar, 2009). The Ricardian approach considers the expenses incurred in carrying out different alternatives.

In the past, cross-sectional studies have made use of the Ricardian approach as demonstrated in Kurukulasuriya and Mendelsohn 2008; Deressa and Hassan 2009; Ater and Aye 2012; Ibrahim et al., 2014; Fonta et al., 2016 and Mishra et al., 2016. Regardless of the extensive use of the Ricardian cross-sectional method, it presents some limitations. One of the shortcomings, with relevance to this present-day study, is that the Ricardian approach has the intrinsic assumption of long-run equilibrium of factor markets. Another limitation is that the Ricardian method does not quantify transition expenses. For instance, if a farmer experiences crop failure for a year or two during the introduction of the new crop, this transition or changeover cost is not shown in the analysis. Similarly, if the farmer takes a decision to change to a new crop abruptly, the method does not incorporate the cost of withdrawing capital equipment impulsively (Kurukulasuriya & Mendelsohn, 2008; Mendelsohn & Dinar, 2009).

Despite its significant limitations, the Ricardian approach has been widely used in both the developed and developing countries to estimate the damages from changes in climate change with remarkable success (Ater & Aye, 2012). The use of this method is more in studies involving the developing countries (Deressa 2007; Kabubo-Mariara & Karanja 2007; Kurukulasuriya & Mendelsohn 2008; Dinar et al., 2008; Jalloh et al., 2013; Mishra et al., 2015).

Therefore, since adaptations made by farmers play a crucial role in climate change impact analysis on agricultural productivity, the Ricardian method would have been appropriate in this present research. Nevertheless, another weakness of the Ricardian approach is that crops are not subject to controlled experiments across farms as farm may differ for various reasons in addition to climate. To be able to control this issue, the Ricardian research attempt to incorporate other important variables such as soil fertility and access to market. Another valid criticism that has been raised regarding the Ricardian approach is that it does not account for future changes in technology (Mendelsohn, 2000). Another significant criticism of the method is that the model assumes prices are constant.

Changes in price are ignored in the Ricardian studies because the approach depends on a cross-section within a country so there is minimal price disparity across farms. Another important limitation of the method is that it does not consider carbon(iv)oxide impacts on crop production. Carbon(iv)oxide concentrations are quite uniform across climate zones and the approach cannot detect the impact (Ater & Aye, 2012).

However, carrying out a study that entails gathering data across regions or within states in a country with different climatic zones (as recommended by Ricardian approach) is often impractical for an individual PhD researcher because of funding and time constraint. Hence, this study will not adopt the Ricardian approach. Consequently, this study will employ the production function model in determining the impact of climate change on crop production as this approach reflects farmers' behaviour, that is, they are solely profit maximisers.

5.4.3 Utility theory

Utility theory posits that individuals mostly decide on what they prefer, and what they do not, which can be described by random factors. The expression random, in this case, has an exact meaning; the variations in behaviour as a result of randomness must not be explainable (Olukosi & Erhabor, 2005). The choice of farmers who perceived climate change and decided to accept or not to accept a specific adaptation strategy (technology) relies on the utility associated with the decision. Utility is a term in economics that refers to the total satisfaction derived from a consumer for consuming a good or service. The adaptation decision taken by farmers to minimise the effects of climate change on agricultural output is characterised by certain socio-economic factors, farm characteristics, and climatic factors (Mabe, Sienso & Donkoh, 2014). Farmers' decisions on adaptation strategies are discrete and mutually exclusive. An individual farmer considers the likely utility he or she will obtain from an adaptation strategy before choosing or rejecting the option. There is an assumption that the choice of one of the available strategies is mutually exclusive and does not depend on the other strategy (Mabe et al., 2014). In practice this is clearly not the case.

Similarly, the random utility theory explains the theoretical perspective that supports the fact that a farmer chooses amongst a set of alternative strategies. Regarding this theory, the utility of the respective alternative strategy is modelled as a linear function of observed characteristics, added to an additive error term. More so, there is the assumption that farmers choose the alternative that gives maximum satisfaction (highest utility). Specifically, the utility of a farmer i from choosing alternatives j and k is expressed as;

$$Uij = Vij + \varepsilon ij$$

$$Uik = Vik + \varepsilon ik$$

respectively; where Vij and Vik suggest the efficient component of the utility, and εij and εik imply the stochastic part which signifies the uncertainty. Given the utility maximisation, farmer i will, therefore, only choose a particular alternative j if;

$$Uij > Uik \text{ for all } k \neq j.$$

5.4.4 Theory of cost

Cost refers to the economic value of the inputs used in production (Adegeye & Dittoh, 1985; Olukosi & Erhabor, 2005). Similarly, Ibrahim, Ayinde and Arowolo (2014), defined the cost of producing any good or services as the value of the resource used in producing them in their best alternative, since there are other alternative means of attaining these production goals. Production from a purely economic perspective naturally is aimed at either maximising output, maximising profit, maximising utility; minimising cost or a combination of or all these (Olayide & Heady, 1982).

Importantly, there exists a close economic relationship between production and cost. According to Iyoha, Oriakhi and Oyefusi (2003), the cost of production at a given time is dependent on the prices of the factor inputs, the quantity of output produced and the production period.

Mathematically, it is expressed as;

$$C = f(X, T, P, K))$$

Where; C = Total cost

X = Quantity of output

T = Technology

P = Prices of the factor input

K = Fixed factors

In addition, the cost of production that accrues to a business or firm consists of both explicit and implicit cost. Explicit cost is the cost of a resource or resources used in production such as payments for raw materials, firm's payroll or payment for a firm's overhead cost. On the other hand, the implicit cost is self-owned. It has to do with the firm's self-employed resources (Olukosi & Erhabor, 2005). In this model, there are two types of costs associated with production; Fixed cost (FC) and variable cost (VC). Fixed costs are costs that do not change as production is increased or decreased, e.g., rent, interest on loans, insurance, depreciation. Payment has to be made irrespective of the level of or efficiency of production. These costs exist even if the output is zero. Variable (direct) costs, on the other hand, are a cost(s) that varies with the level of output, e.g., direct labour, raw materials and components, packaging costs and heating (Iyoha et al., 2003).

5.5 Profit and Profitability

From an economic perspective, the guiding principle behind the activities and goal of any business enterprise, including yam farming, is profit maximisation. Farmers directly or indirectly seek an output level that will minimise cost and maximise profit. Profit is the financial value left after subtracting expenses in business from the revenue. The profit and loss statement of the business will highlight the profitability of a business in a given time period.

Conversely, Koutsoyianis (1979), defines profitability as the relationship between the profit of an investment and the returns on capital employed. Profitability is essential because it is one of the goals of a business. Profitability determines the survival of a business venture over time. Therefore, measuring present and previous profitability and estimating the forthcoming profitability is imperative. Measuring the income generated and the expenses incurred by the business aids in determining profit levels.

5.6 Revenue

The amount that a farmer receives from the sales of his goods is regarded as his/her revenue. Therefore, revenue is the total income earned by the farmer by selling his products.

Hence, ***Net revenue*** = Gross revenue – Selling Expenses

Where;

Gross revenue = sum of all income generated from the sale of goods and services

Selling expenses = sum of all costs incurred

Accordingly, the net revenue estimation in this study follows that of a previous study (Kurukulasuriya & Mendelsohn, 2008); which is gross revenue less the costs of transport, hired labour, light farm tools (such as files, axes and machetes), fertiliser and pesticide.

According to Kurukulasuriya and Mendelsohn (2008), the inclusion of household labour leads to several households recording negative net revenues. This situation is usually the case whether the expenses incurred by the respective family on labour were used, or whether market wage rates were assigned to the expenses. Therefore, the cost of household labour did not determine net revenue. Instead, the net revenue calculation included the number of household members as an independent variable to control for the cost effect.

Since markets in developing countries are imperfect, and factor mobility is restricted, which assumes fully integrated markets challenging (World Bank, 2003; Mishra et al., 2016), this study relies on net revenue, which is a more robust measure given the concern about market equilibrium. This is so because it estimates the farmer's current income without any considerations for expected returns, discounting capital or labour markets (World Bank, 2003; Mishra et al., 2016).

5.7 The online survey

The priorities when conducting an online survey is to determine the questionnaire design, the suitable rounds and the participants.

5.7.1 Questionnaire structure

The design chosen is the Likert scale choice which depends on the research purpose or aim of the study (Christie & Barela, 2005; Nerantzidis, 2012; Giannarou & Zervas, 2014). This decision implies that when a study wants to classify between three positions or investigate the level of importance, it uses a 3-point Likert scale, whereas when it tries to assess the degree of consensus, a 5 to 10-point Likert type rating (Christie and Barela, 2005). This view, however, contradicts with that of Giannarou and Zervas (2014), which states that when the investigation is on the level of importance, the study uses a 10-point scale whereas, when the survey is on the degree of agreement, it uses a 4 or 5-point scale.

Accordingly, Table 5.2 presents the number of rounds the survey used to reach a consensus. Also, this survey employed a 4-point Likert scale because of the aim, which sought to investigate the level of agreement among the participants. This position is in line with that of Green, Hunter and Moore, 1990; and Giannarou and Zervas (2014) but negates that of Christie and Barela (2005).

Table 5.2: Composition of the online survey rounds

Round I	**Experts' ranking of the study recommendations built from the study findings**
Round II	Response from evaluating the first round with suggestions given by the participants until it reaches a consensus

5.7.2 Selection of experts

When constructing the experts' panel, it is essential to consider that their knowhow or expertise determines the reliability and validity of the findings (Adler & Ziglio, 1996; Kittell-Limerick, 2005; Giannarou & Zervas, 2014). The number of experts required to reach a consensus in an online survey is, however, a subject of debate. This argument links closely to both the nature of the matter in question and methods of analysis. Therefore, if the topic in question is homogeneous or within a single discipline, then 10-15 panellists may be sufficient (Hsu & Sandford, 2007; Giannarou & Zervas, 2014). However, if the subject requires a more multi-disciplinary consideration, then more experts within the respective fields may be necessary (Delbecq, Van de Ven, & Gustafson, 1975; Hsu & Sandford, 2007).

5.8 Chapter summary

This study employs both the quantitative and qualitative methods and as such is mixed-method research which relies on the pragmatic theoretical perspective. The study adopted three theories to frame the quantitative analysis; production theory, utility theory and cost theory, while it adopted the online survey framework for the qualitative analysis.

In the production function approach, the consequence of climate alteration on crop production is assessed. Overall, in the area of agricultural economics, the production function approach is generally employed to find significant variables and their influence on agricultural production (Sarker et al., 2013; Osuafor & Anarah, 2018). Thus, the production function approach is adopted for this study.

The advantage of the Ricardian approach is that it uses the net revenue of the farm, so it incorporates all adaptations that the farm could take to use the land in response to climate change. However, this approach does not consider some other unobserved variables of cross-sectional units, does not give production information, ignores price differences and does not favour individual researcher. For these reasons, this approach was no adopted in this study.

Conversely, the advantage of the production function approach is that it analyses the crop-specific impacts from climate variables. However, this approach does not take into consideration the substitution, adaptation and new activities that farmer could take in response to climate change. Although the Ricardian method is suitable for this type of study based on literature, it does not apply to this research because the data collected were not across regions or within states in a country with different climatic zones.

From the empirical analysis done, the majority of the related study's employed the mixed method, hence, this present study will adopt the same. The method of the research and the philosophical viewpoint of the research, are the focus of this chapter, and this leads into the next chapter which constitutes information on the study area, data collection and specification of the models applied.

Chapter 6 Data collection method

6.1 Introduction

This chapter begins with the description of Cross River State, (the area of study) and its vegetation as a follow up from section 1.1.5 which provided a brief introduction to the study area. The chapter further outlines the survey process and the research methods employed in the study. The mixed method approach was adopted for this study as it provides a comprehensive understanding of the research, and this is in line with previous related studies reviewed in chapter 5. This chapter focuses on the method of data analysis employed in addressing the research objectives, the models used as well as the model specification employed in the study. The description of the study area, the sampling procedures which include the simple random sampling, the process of data collection and the type of data used for the study are also presented here. Typically, this chapter provides the details of the methodology applied in addressing each of the research objectives.

6.2 The study area

The study took place in Cross River State, Nigeria. A brief description of the study is presented in Chapter 1, section 1.1.5 of this thesis. The map of the study area is provided in Figure 6.1.

The State comprises of eighteen (18) Local Government Areas (LGAs). For administrative convenience, these LGAs are grouped into three agricultural zones as follows;

1. **Ogoja Agricultural Zone** which comprises of Ogoja, Yala, Bekwarra, Obudu and Obanliku, LGAs;
2. **Ikom Agricultural Zone** which consists of Ikom, Abi, Yakurr, Obubra, Etung, and Boki LGAs; and
3. **Calabar Agricultural Zone** which comprises of Calabar Municipal, Calabar South, Bakassi, Akampa, Odukpani, Akpabuyo, and Biase, LGAs.

The study focused on the Cross River State Agricultural Development Project (CRADP) yam farmers in the Ogoja and Ikom zone. Yam farming is economically essential to the livelihood of Cross River State people because it contributes to income and food sufficiency (see section 2.7.1 in Chapter 2). For many years, yams have been the staple food crop of the people. Therefore, high importance has been attached to the crop over time. Figure 6.1 presents the map of Cross River State showing the 18 LGAs.

Figure 6.1: Map of the study area

Source: Geospatial Analysis Mapping and Environmental Research Solutions (2018)

6.2.1 Vegetation of Cross River State

The agro-ecological regions that exist in Cross River State as recognised by Oyebo, Bisong, and Morakinyo (2010), consist of the lowland rainforest, freshwater swamp forest, the mangrove vegetation, coastal vegetation, montane vegetation, savanna-like vegetation, and wetlands. Figure 6.2 presents the vegetation map of the State, and the discussion on these zones are as follows:

The lowland rain forest spreads extensively to places in the centre, north and east of Cross River State, and is adjoining with the forests of South-West Cameroon. Even with the transformation of some areas into agricultural farms, and the natural forests being affected by deforestation and wood removal, the State remains home to the natural forest in Nigeria.

The mangrove forest in the State builds a thin belt along the coast and in the river mouth of Cross River. The mangrove areas comprise of different types of species as follows: *Rhizophora racemosa, R. mangle, Avicennia africana* and *Laguncularia racemosa.* Nevertheless, the mangroves are endangered by the Nypa Palm and *Nypa fruticans,* which had their introduction into Calabar and Oron between 1906 and 1912 from South East Asia. The palm tends to form stands and isolate the endemic mangrove trees.

The freshwater swamp forest builds a wide belt at the north of the mangrove vegetation area. It is typically covered with a flood during the wet season and dries out in the dry season creating areas of bare forest floor combined with lasting pools of water. Most of these vegetation areas are changed into farms, urban lands and the original swamp forest is still typically on alluvial sites along the main rivers; the Cross River, Calabar River and Great Kwa River.

The montane vegetation is principally in the north-eastern parts of the State on the Oshie Ridge of the Obudu Plateau close to the edge. The highest peak is near 1,819 m above sea level. This kind of vegetation comprises the lowland rain forest in the low- lying areas increasingly improved with montane elements. The common woody plant species consist of the *Xylopia Africana, Rauvolfia vomitoria, Tabernaemontana ventricosa,* and *Voacanga trouarsii.* The savanna-like vegetation may be weakened due to changes within the degraded rainforest that occurs in the central (Yakurr) and northern (Obudu) areas of the State. These formations are identified based on relic rain forest species which includes *Celtis zenkeri, Cola gigantea, Anthonotha macrophylla* and *Treculia africana*.

Finally, the wetlands in Cross River State are at the State River mouth, the Cross River Flood Plains at Obubra and also as disseminated swamps or flood plains. They consist of a combination of a seasonal flood riparian lowland forest area and tall grass swamps in the areas of Cross River and its Enyong creek stream. Some of the plant species that are dominant in the wetland regions include *Nymphaea lotus, Vossia cuspidata*, *Echinochloa pyramidalis, E. stagnina, Ragmites sp, Leersia hexandra, Ipomoea asarifolia* and *Mimosa pigra.*

However, the next section provides details of the survey carried out in the study area discussed above in addressing the research objectives 2, 3 and 4.

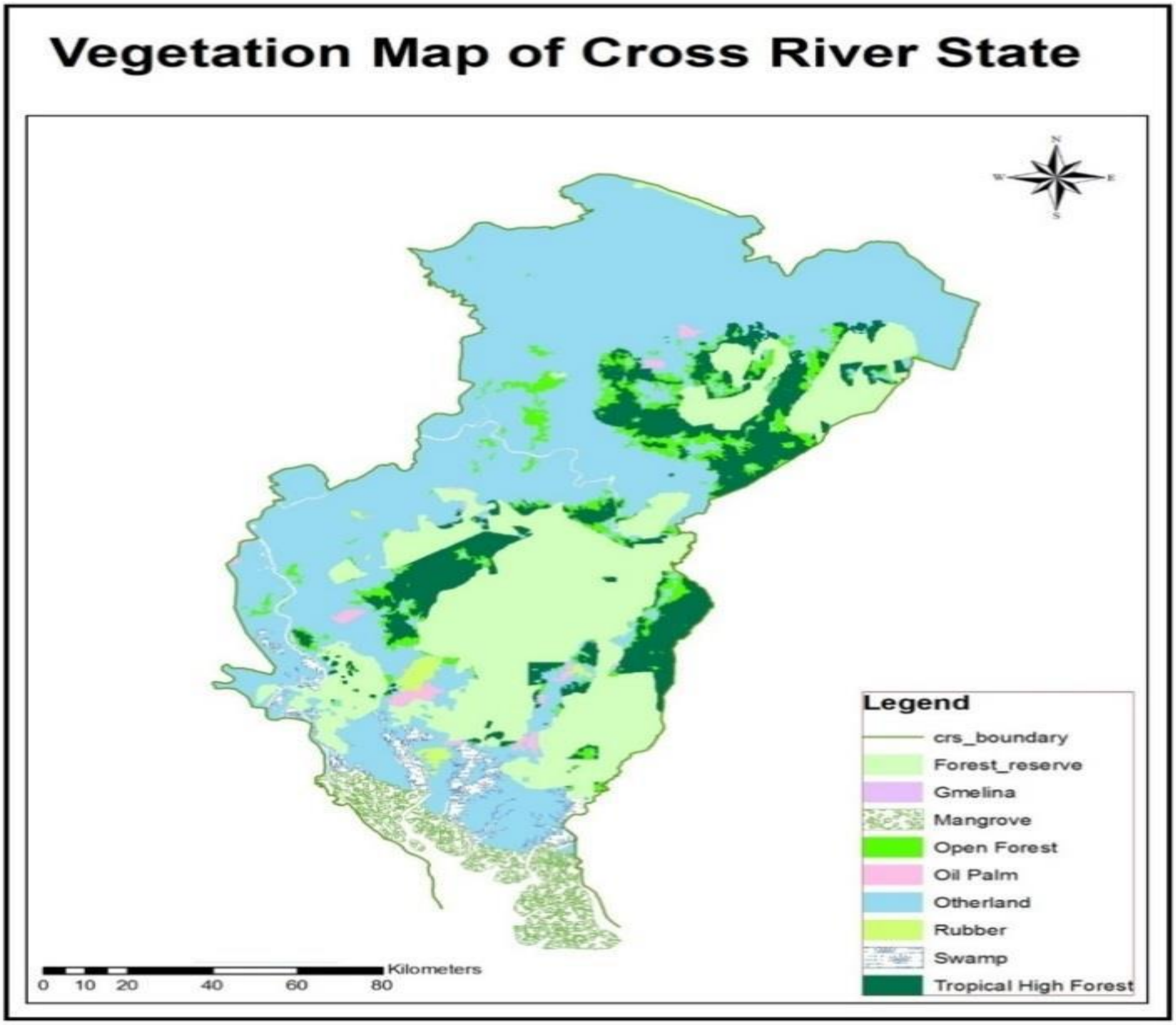


Figure 6.2: Vegetation map of Cross River State

Source: FGoN, 2018

6.3 Survey and instrument for data collection

The questionnaire design and the type of data collected for the study which was undertaken in the area described above are shown in the following sub-sections. Figure 6.3 shows a flow chart of the steps that were taken in conducting this research and the process of primary data collection. However, the investigation that used secondary data in this study area is shown in the next section.

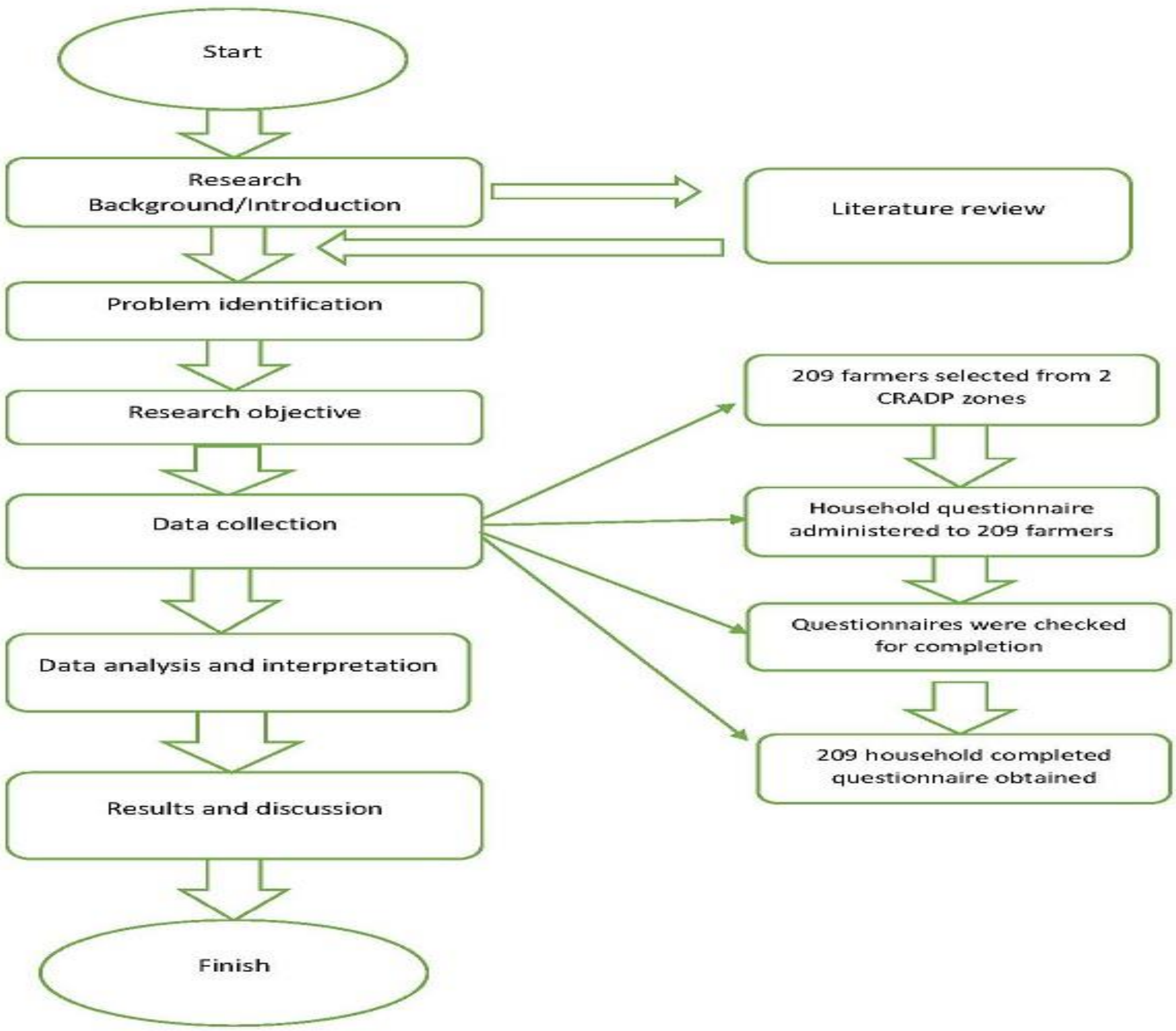


Figure 6.3: Flow chart of the research method and primary data collection process

6.3.1 The questionnaire design

A well-structured questionnaire (provided in appendix A) was designed for data collection about the livelihood and socio-economic characteristics of Yam farmers. This type of standardised questionnaire is advantageous because of its even distribution to every respondent, and it is appropriate for evaluation via computer (Casley & Kumar, 1990; Brace, 2008). The questions presented in the questionnaire were explicitly related to objectives 2, 3 and 4 of the study which were;

- To investigate the socio-economic factors that affect the net revenue of yam farmers at the farm level;
- To evaluate yam farmers' perceptions of, and adaptation strategies to changes in the weather patterns they are experiencing in the study area and any barriers to adaptation; and
- To determine the most important factors that affect farmers' choice of adaptation to climate change and build these into recommendations for improved state extension for yam farmers and their communities, respectively.

The questionnaire contained several sections to support the gathering of data vital for the study. The questionnaire had eight sections. The questions began with a section on socio-economic characteristics. It gathered questions that were related to the household head’s age, marital status, gender, educational level, household number, principal occupation, secondary occupation, household size and household assets. The following section had questions related to household head’s farm characteristics, such as the area of land cultivated, soil fertility, farming system, land ownership, livestock keeping and farm labour. The next section captured data relating to institutional accessibility such as access to extension services, credit and loans, weather information and access to the market. The following section focused on the costs and benefits on yam production for 2017-18 production year. Then the subsequent sections presented questions on perception of farmers about climate change, the adaptation strategies taken to cope with the changing climate, and the barriers to adaptation strategies.

6.3.2 Validity and reliability of the questionnaire

Validity and reliability are imperative in survey research (De Vaus, 2014). These two essential issues consider the representativeness and precision of measurement as they are not always flawless, especially in a situation of questionnaire responses. The answers provided in a questionnaire could be challenging to measure accurately and therefore produces a biased measurement (Singh 2007; Muijs 2010; De Vaus, 2014). The validity, however, refers to how accurately a method measures what it is intended to measure (Sarker et al., 2013).

To ground the questionnaire, the questions were constructed based on related literature (see Table 5.1 in the previous chapter) concerning the climate change impact and adaptation strategy. Furthermore, questionnaires from previous similar types of studies were taken into consideration while constructing the questionnaire for this research (see studies that employed mixed methods in Table 5.1, Chapter 5). These studies informed the choice of questions in the questionnaire used. In addition, the questions constructed were related to the research questions and objectives. That is to say, the variables and questions were derived from the related literature, research questions and objectives of this present study. Consequently, the rationality of the questions and procedure of data collection in this study can be supported, making the research questionnaire content valid.

On the other hand, reliability denotes how consistent the responses are with the actual situation being examined (De Vaus, 2014). Inconsistent responses to a question provided by the same respondent in different instances makes the question unreliable. Reliability also relates to bias. However, ambiguity or vagueness is primarily the reason for variable answers. This is so because the respondents may have a different understanding of a question at different times (De Vaus, 2014). In this study, the pilot survey carried out corrected such ambiguity or vagueness before administering the final questionnaire (see section 6.4.3).

Added to this, internal consistency helps to achieve a reliable questionnaire (Williams 2003; Sarker et al., 2013). This means that a respondent could be asked a question in different ways during the questionnaire administration. The consistency in the answers given by the respondent, in this case, was observed.

6.3.3 Pre-piloting the questionnaire or Preliminary Questionnaire

It is essential to check a draft questionnaire to become aware of any vagueness in the questions and also to recognise the possible answers that may be given to all questions. The pre-piloting test carried out is an essential part of the process of making sure the questionnaire is reliable; this involves an information gathering method (Williams, 2003). Hence, academics in the area of discipline at the Royal Agricultural University examined the questionnaire for this study (n=2). As the survey area was in Cross River State, the opinion of some experts in the study area (University lecturers) who are involved in agricultural research contributed to the development of the questionnaire (n=3). Draft copies were sent to them to make their contributions and input. Subsequently, there were adjustments in the questionnaire. The process, therefore, aims to ensure the questionnaire is unambiguous, appropriate and acceptable to respondents in the study.

6.3.4 Piloting the questionnaire or pilot survey

In survey research, piloting the questionnaire forms an important part of the methodology. It reveals if the questionnaire works appropriately and does what it intends to do (Czaja & Blair, 1996). Also, piloting the questionnaire is essential as it provides a better understanding of the survey instrument. A pilot survey identifies the difficulties the respondents would experience relating to the questions being misunderstood, not willing to answer, and the inability to answer the questions (Blair, Czaja & Blair, 2014). Another importance of a pilot survey is that it checks the respondents' ability to respond that ensures validity and reliability (Sarkar et al., 2012). However, Czaja and Blair (1996) reported that for responses to be valid, two things are required; Firstly, the questions should be able to measure the concept of interest and secondly, respondents should be able to interpret the questions as anticipated. Therefore, in conducting a pilot survey, errors in phrasing the draft questionnaire could be identified and amended before performing the final survey.

Nevertheless, it is essential to have the questionnaire tested with a group which is similar to the planned survey population to check how the respondents will provide answers to questions (Williams 2003; Greasley 2008; Muijs 2010). Considering the sample size to select in conducting a pilot survey, it is usually small when compared to the size of the final survey and often only a few respondents (Blair et al., 2014). According to Czaja and Blair (1996), a test on a sample size of ranging from twenty to thirty, is adequate to use in a pilot survey. In this case, there is no specific sampling technique used which is different from the final survey where it relies on random selection, as discussed in the sampling section below.

A face-to-face interview assisted in modifying the questionnaire tested during the pilot survey. This test involved a total of 20 farmers interviewed at two stages; 10 farmers at each stage. The two-stage interview employed permitted the first round of adjustments to be made on the questionnaire and thus tested at the second stage. Each of the steps involved an interview with ten farmers. The farmers were selected randomly from the two LGAs. Subsequently, there was an interview with ten selected respondents in the initial round and the questionnaire was modified afterwards. At this stage, the questions were re-worded for clarity and re-ordered to flow well. With the modified questionnaire, another session of the pilot survey was carried out on the other set of 10 farmers. This process demonstrated that the questionnaire worked adequately and was appropriate. Nevertheless, the pilot survey responses gathered were not part of the survey responses at the final stage.

The modification undertaken involved the re-wording of the questions for easy understanding, re-ordering questions to fit the flow of the different questionnaire sections and eliminating inappropriate questions. English language was used throughout the questionnaire.

6.3.5 The final questionnaire

The form of the questionnaire administered was a well-structured questionnaire (see Appendix A for the complete survey questionnaire).

6.4 Study population

Sampling represents the selection and observation of a section of a population to be able to make judgements on the entire populace. The population of this study consisted of all Yam farmers situated in the different ADP zones in Cross River State. Ideally, a survey should gather information on every individual in the target population, but this is only possible in a small population. Researchers, however, have to identify the subset of the entire population to conduct a survey (Garcia et al., 2018). This subset of the population is the sampling size. However, the resultant sample size provided by the standard statistical method for choosing a sample size is unrealistic for an individual researcher as the number is too large (Gilbert 2008; Blaikie 2010). This is due to constraints in funding and time. Instead, one should determine a practical sample size which within a specified time frame and available funds (Groves & Heeringa, 2006).

In addition, even though a sample size is small, the desired estimation can be achieved if a good sample design is applied (Leedy & Ormrod, 2014). As the farmers in the zones are faced with similar circumstances, they, therefore, constitute a homogeneous group. This, however, makes the use of small sample size validated as it can ensure a representative of the entire population (Gilbert 2008; Blaikie 2010). Likewise, a good sample design can attain the desired estimate, even with a smaller sample size (Leedy & Ormrod, 2014).

Thus, sample size can be obtained using other criteria different from the statistical formula. According to Perry (1998), three hundred and fifty is regarded as an ideal sample size when using a structured interview schedule in research. In addition, 5 per cent of the population of the study is considered to be a suitably large enough for sample size in survey research (Bartlett, Kotrlik, & Higgins, 2001; Sarkar et al., 2012). Similarly, the standardised tabulation recommends that at the level of precision ±7 per cent and for a population higher than 3,000 but less than 4,000, the sample size of about 200 should be used (Eboh, 2009; Angba, Eta & Angba, 2018).

Since the population of registered yam farmers in the chosen agricultural zones is 3,484 (State Bureau of Statistics, 2011; Angba, Eta & Angba, 2018), the study, therefore, used a sample size derived from the standardized tabulation of sample size. As a result of this, the study surveyed a sample of 209 randomly chosen Yam farming households, which is 6 per cent of the farm population in the selected zones (Angba, Baines & Butler, 2020a).

This study used a multi-stage sampling procedure (which is explained in the next section) because of the several stages that were involved in selecting respondents to ensure representativeness of the entire population. Cross River State was chosen for this study. This choice was because of the following reasons: the dominance of yam production in the area, the peculiarity of the research problem to the area and the familiarity of the researchers to the area. The population of the study comprised of all the yam farmers in Cross River State.

6.5 Sampling technique

A multi-stage sampling procedure was adopted for this study (Table 6.1). Firstly, there was a selection of two zones from the three Cross River State Agricultural Development Project (CRADP) zones. Random sampling technique assisted in selecting Ikom and Ogoja agricultural zones and interestingly, the cultivation of Yam in Cross River State is principal in these zones (FMARD, 2009). Secondly, simple random sampling was employed to select one (1) block each from the six (6) and five (5) blocks that constitute Ikom and Ogoja agricultural zones respectively giving a total of two (2) blocks. In the third stage, simple random sampling technique helped in selecting three (3) cells out of the eight (8) cells that make up each selected block giving a total of twelve (6) cells. In the final stage, a simple random sampling technique assisted in selecting two hundred and nine (209) Yam farmers from the selected cells. A list containing a registered number of yam farmers from the ADP office facilitated in the final selection of the farmers for the study. Hence, the sample size for this study was 209 (Angba, Baines & Butler, 2020a).

Table 6.1: Sampling procedure and sample size

CRADP zones selected	No of blocks	No of blocks selected	No of cells	No of cells selected	No of registered Yam farmers in selected zones	6% of farmers sampled
Ikom	6	1	8	3	1750	105
Ogoja	5	1	8	3	1734	104
Total	11	2	16	6	3,484	209

6.6 Model and model specification

The models and model specifications used to address research objectives 1, 2 and 4 (which are the objectives that involved testing of the hypothesis in the study) are specified in the sub-sections below and the objectives are as follows;

- Section 6.6.1; Research objective 1: To analyse the impact of climate variables on yam production at the state level for the period 1996-2017;
- Section 6.6.2; Research objective 2: To investigate the socio-economic factors that affect the net revenue of yam farmers at the farm level;
- section 6.6.3 and section 6.6.4; Research objective 4: To determine the most important factors that affect farmers' choice of adaptation to climate change and build these into recommendations for improved state extension for yam farmers and their communities.

6.6.1 Unit Root Test

The first step in the analysis of co-integration is to investigate the stationarity of the time series involved, i.e., the Integration order of a univariate time series. This step involves testing the order of integration of the individual series under consideration. The Augmented Dickey-Fuller (ADF), (1979) relies on rejecting a null hypothesis of a unit root (if the series are non-stationary) in favour of the alternative hypothesis.

6.6.1.1 The co-integration Test

If there is an establishment of a stable co-integration relationship established between variables, it can avoid spuriousness in a regression involving non-stationary variables. The concept of co-integration states that if there is a long-run relationship between two variables, then the deviation from the long-run equilibrium path should be bounded and if this is the case, then the variables are co-integrated (Masih & Masih, 1998). This study will adopt Engle and Granger (1987) two steps procedure approach. According to the procedure, if two or more time-series X_1 and Y_1 co-integrates, a linear combination of them must be stationary, i.e., $Y_1 = U_t$, where U_t is stationary.

6.6.1.2 Error correction model

If co-integration is proven to exist, then the third step requires the construction of an error correction mechanism to model dynamic relationships. The purpose of the error correction model is to indicate the speed of adjustment from short-run equilibrium to long-run equilibrium state. The greater the co-efficient of the parameter, the higher the speed of adjustment of the model from short-run to the long-run.

6.6.1.3 Multi-variate model specification

The multivariate regression analysis model is specified thus;

$$InQ = \beta_0 + \beta_1 InX_1 + \beta_2 InX_2 + u \qquad (6.1)$$

Where:

β = Regression Coefficient

Q = Output of Yam

X_1= Mean Annual Temperature (degree centigrade)

X_2= Mean Annual Rainfall (Millimetre)

U = Random Error Term

The co-integration model for the study is specified thus;

$$Y_t = f(X_1, X_2) \qquad (6.2)$$

Estimating equation (1) in an estimate form,

$$Y_t = a_0 + a_1 X_1 + a_2 X_2 \qquad (6.3)$$

The model is specified in log linear form as;

$$Log(Y_t) = a_0 + a_1 LogX_1 + a_2 LogX_2 + U_t \qquad (6.4)$$

Where:

Y_t = Output of yam (tonnes)

X_1 = Annual temperature (^0C)

X_2 = Annual rainfall (mm)

U_t = Stochastic error term

6.6.2 Production function model specification

In its most standard form for production of a single good with two factors, the function is thus:

$$Y = f(X_1, X_2) \tag{6.5}$$

Therefore, the statistical tool used to analyse the data collected to assess what influences the net revenue of Yam farmers in a climate change environment is the multiple regression analysis. This is so because multiple regression allows one to observe the relationship between multiple exogenous variables and a dependent variable. This relationship observed allows the researcher to predict why the outcome is what it is.

The model specification for the multiple regression is given as:

$$Y = a + b_1X_1 + b_2X_2 + \cdots b_{14}X_{14} + U \tag{6.6}$$

Where Y = the dependent variable (Net revenue from Yam farm)

a = intercept of Y (constant)

b = slope or coefficient of X

X_1 = Gender (male=1; female=0)

X_2 = Age (Years)

X_3 = Educational level (No formal education=0; Primary=1; Secondary=2; Tertiary=3)

X_4 = Household size (number)

X_5 = Farm size (hectares)

X_6 = Distance to market (km)

X_7 = Years of farming (Years)

X_8 = Marital status (Yes=1; No=0)

X_9 = Access to credit (Yes =1; No=0).

X_{10} = Access to extension services (Yes =1; No=0)

X_{11} = Information on weather forecast (Yes=1; No=0)

X_{12} = Livestock ownership (Yes=1; No=0)

X_{13} = Tenure status (Yes=1; No=0)

U = error term

6.6..3 Binary Logit model for choice of adaptation

The Binary model is suitable for studies on adaptation decision. According to Bryan et al., 2009; Deressa et al., 2011; Alauddin & Sarker, 2014, there is a rising interest in the study on climate change adaptation which is to describe the farmers' choice to take adaptation option. This study will adopt this model because the dependent variable is dichotomous, namely, adaptation and non-adaptation. Accordingly, farmers' decision to take adaptation is a binary variable A implied as one (1) if a farmer decides to take an adaptation strategy and zero (0) if he decides otherwise. Therefore, the expression is as follows:

A = 1 (with probability p); 0 (with probability 1−p).

However, to investigate the factors that affect the choice of adaptation, there must be a model for p, which controls the probability of having a positive result (which is to take adaptation decision). According to Cameron and Trivedi (2005), the model usually used for this form of the variable is a that of a single-index method with probability expressed as;

$$p_i = P_r\left[A_i = \frac{1}{x}\right] = F(xi\beta) \qquad (6.7)$$

where F = cumulative distribution function

The logit or probit model aids in obtaining estimates. In the situation that applies the logit model, F is the cumulative distribution function of standard logistic distribution, but in the case that uses the probit model, the cumulative distribution function is of a standard normal distribution. Alternatively, the notable difference amongst the logit model and the probit model is in the postulation of the distribution of the error term, ε (Bryan et al., 2009). Economists tend to prefer the Logit model because of the simplicity it presents during computation as opposed to the probit model (Sarker et al., 2012). Consequently, to determine the factors that influence farmers' adaptation decision, this study employed the Logit model.

6.6.4 Multinomial Logit model

In logistic regression analysis, the prediction of categorical outcomes within two or more groups is possible. One model can integrate explanatory variables of either categorical, continuous or have them mix. The model is widely used in adoption decision studies involving multiple choices and is easy to compute. The model is suitable for this type of analysis as it permits the decisions across two categories to be analysed. It allows the choice probabilities for different groups to be determined (Belay et al., 2017). Moreover, the choice of the logit model is used based on previous related studies.

The general framework of utility or profit maximisation describes the choice of adaptation (Gbetibouo, 2009; Gbetibouo et al., 2010; Belay et al., 2017). Moreover, from an economic viewpoint, a set of climate change adaptation strategies would be chosen by a rational household to maximise profit or net revenue given the available resources, technology and what they perceive about climate change (Gbetibouo et al., 2010; Di Falco *et al.,* 2012). According to Adesina and Zinnah, (1993), even though the utility function is disregarded, the satisfaction resulting from the use of an adaptation option is assumed to be a function of the vector of a practical farm. Given this postulation, the farm household adaptation decisions taken are;

$$A_{ij} = f(x_i) \tag{6.8}$$

where Aij = farmer's decision i, adaptation strategy j; xi = a vector of farmer's characteristics and perception of climate. A farmer, therefore, will practice an adaptation strategy if it supports net benefits, given the preference assumption, or he will not take the adaptation option (Gbetibouo et al., 2010; Greene, 2012).

And so, following Greene (2012), let A^* represent the latent variable that captures the satisfaction derived from taking an adaptation decision by a farm household, contrary to not taking adaptation. Therefore, the household's adaptation decision model, using the latent regression model as follows:

$$A_{ij} *= xi\beta + \varepsilon \tag{6.9}$$

$A_{ij} = 1, if\ A_{ij} *> 0$; and 0 if not

This expression implies that household i will adopt adaptation decision (Aij=1) by applying j option to reduce the impact of climate change. This situation is true if the utility derived is positive (Aij^*>0) and 0 if not. Likewise, farmer, i will take an adaptation option j, alternative to adaptation option k if the probable satisfaction gained from using j is more than the utility expected, E, to gain from using k;

$$[A_{ij} *] > E[A_{ik} *]$$

when $k \neq j$

The assumption is that $Aij*$ is the maximum satisfaction among all the utilities derived if a farmer i, decides to adopt a strategy j. Greene (2012), argued that the statistical model employed for a decision of this nature is as a result of the probability of preferring choice j over all other options available. The expression is as follows:

$$A_{ij} *> A_{ik} *$$

when $k \neq j$

According to Gbetibouo (2009), if farmer i choose an adaptation option j from a set of options, the probability that Aij equals 1 is;

$$P\left(A_{ij} = \frac{1}{x}\right) = (A_{ij} *> A_{ik} */x) \tag{6.10}$$

$$= (\beta jxi + \varepsilon j - \beta kxi - \varepsilon k > 0/x) \tag{6.11}$$

$$= (\beta jxi - \beta kxi + \varepsilon j - \varepsilon k > 0/x) \tag{6.12}$$

$$= \beta * xi + \varepsilon *> o/x) \tag{6.13}$$

$$= F(\beta * xi) \tag{6.14}$$

where ε* = random disturbance term

β* = vector of unknown parameters

($\beta * xi$) = cumulative distribution of ε*

In addition, the strength the MNL model specification has over the alternative multinomial Probit MNP model is that it is easier to apply it in computing the choice probabilities. The MNL model makes it easy to calculate the adaptation option situation, among other alternatives as it provides a suitable closed form for basic choice probabilities (Sarkar et al., 2013).

Therefore, the MNL model is employed in this study to determine the factors that influence farmers’ adaptation decisions in the study area.

6.7 Data required for the study and instrument for data collection

Secondary and primary sources assisted in generating the data needed for this study. Secondary data on the composition of Yam output, temperature and rainfall were sourced from government statistical database which included the National Programme for Agriculture and Food Security – NPAFS, (2010); FMA&WR, (2018); CBN, (2018) between 1996-2017. This information was used to address objective 1 of the study which was to analyse the impact of climate variables on yam production at the state level for the period 1996-2017. There was a challenge in collecting secondary data over a longer period in Cross River State, hence, this was the data available in the State’s database.

Conversely, the primary data was obtained using a well-structured questionnaire (gathered from yam farmers in the year 2017) explained in the previous sections, and an online survey. The online survey was used to address research objective 5 which was to validate the models used through the engagement of experts in relevant fields to get their opinions on the study recommendations for a new strategy for smallholders growing yam on their holdings. The information for the online survey on questionnaire design is found in chapter 5, section 5.7.

The weather (temperature and precipitation) conditions reported by the CBN (2018), over time gives the secondary climate data used in the study. From literature (Wang et al., 2018; Elijah et al., 2020; Amuwah et al., 2020), weather however, impacts on food crop production over time. Therefore, to cope with the negative effects of weather on food crop production, farmers adopt many of the adaptation strategies discussed in chapter 4 of this study

6.8 Data collection

During the investigation using the well-structured questionnaire and interview schedule to obtain data from the Yam farmers, efforts were put in place to ensure the quality and accuracy of data being collected. The quality control checks carried out to ensure consistency included publicity of the survey, recruitment of field staff, designing of data collection instruments, training of survey personnel, pre-test and pilot survey.

Field staff or investigators are the people collecting data on the field (Leedy and Ormrod, 2014). The field staff must know the quality and quantity of their work in advance. The six trained field staff carried out the field survey, which was monitored by the researcher. These field staff were former students of Agricultural Economics and Extension Department of the University of Calabar, (a university situated in the area of study) who have had experience in field data collection. The field staff were trained by the researcher both theoretically and practically in the field before conducting the survey. The researcher taught them about understanding the materials and questionnaire. The questionnaire was administered either at home of the farmer or on the farm through a face-to-face interview. This method allowed the investigators to elucidate the questions to the understanding of the farmers. The researcher fully participated in the fieldwork and closely monitored the execution of the survey. Personal interview was the most appropriate technique for this research to produce reliable data.

6.9 Likert-type rating scale technique

This technique was used to complement and further explain farmers' perception and effect of climate change. A four-point Likert scale was used for some statements to which the responses were rated 4 =strongly agree, 3 = agree, 2 = disagree, and 1 = strongly disagree. The responses were rated accordingly, and the cut-off mean score was determined by adding them up (4 + 3 + 2 + 1 = 10), then divide the sum by 4 to gives 2.50. Therefore, the cut-off mean score is 2.50 (Semie, Belay, Karippai & Bogale, 2009; Ali et al., 2020). The use of cut-off mean score to interpret the Likert scale analysis was also used in similar studies by Ifeanyi-obi, Etuk and Uloh (2013) and Ifeanyi-obi and Asiabaka (2014).

For instance, a statement like "Decline in crop yield is experienced" may have responses of strongly agree (f= 88); agree (f = 65); disagree (f = 40) and strongly disagree (f = 15); where f is the frequency. This will be expressed as 88 x 4 = 352, 65 x 3 = 195, 40 x 2 = 80 and 15 x 1 = 15. Then 352 + 195 + 80 + 15 =642. The sum is then divided by the total f. Thus, 642 /209 = 3.07. In this instance, 3.07 is the mean score which is greater than the value of the cut-off (2.50). Consequently, the ranking was done according to the mean values, with the highest mean ranking '1st'. Mean score values above or equal to

2.50 signified the principal effect experienced by the respondents while those with mean score values less than 2.50 were not observed as principal effects.

6.10 Independent sample t-test (the difference between means) of the study sample

The independent-samples t-test is one type of inferential statistics used to determine whether there is a significant difference between the means of the responses of two groups. The test procedure, which is called the two-sample t-test, was applied to compare the compare the responses for a given variable between the two populations of the Ikom and Ogoja sample. Specifically, this approach is suitable because the sampling method used in the study was simple random sampling. Also, the samples obtained were independent, and the sample size was much smaller than the population size.

The hypotheses are thus;

H_o: $\mu_1 - \mu_2 = 0$ (There is no significant difference between the means of the two samples).

H_a: $\mu_1 - \mu_2 \neq 0$ (There is a significant difference between the means of the two samples).

6.11 Chi-square statistics test

A chi-square (χ^2) statistic test measures how a model compares to actual observed data. There are two main kinds of chi-square tests; these are the test of independence, which asks a question of relationship, and the goodness-of-fit test. This study adopted the test of independence to determine the relationship between net revenue and various socio-economic characteristics. The chi-square test was used in testing the null hypothesis stated thus;

H_o: There is no relationship between net revenue and various socio-economic characteristics.

The coordination matrix in Table 6.2 presents the harmonisation of the research aim and objectives. It shows the research questions, data required in addressing the research questions, the sources of data and the methods of data analysis employed in the research. Both descriptive and inferential statistics facilitated the analysis of data.

Table 6.2: Harmonisation of the research aim and objectives

Research questions	Data required	Data sources	Methods of analysis
1) What is the impact of climate change on yam production in Cross River State?	Time series data on yam yields, time-series data on yearly maximum temperature, minimum temperature and total rainfall at the state level.	Secondary data from official statistics, Cross River State government statistical database, Central Bank of Nigeria (CBN) database and Nigeria Meteorological Agency	Co-integration analysis
2) How does socio-economic factors affect yam farmers' net revenue in Cross River State?	Relevant household socio-economic, demographic, farm and institutional characteristics.	Farm-level data from 209 farm households	Chi-square and Ordinary Least Square (OLS) regression analysis
3) How do yam farmers perceive and adapt to the impact of climate change on yam production?	Perception about production loss, total production costs, production revenue, household socio-economic, farm and institutional characteristics.	Primary data from 209 farm households	Likert scale, frequencies and percentages
4) What are the determinants of farmers' choices of adaptation in the face of perceived climate change?	Household socio-economic, farm and institutional characteristics.	Primary data from 209 farm households	Logit regression and Multinomial Logit (MNL) regression analysis

5) How are the models employed in the study refined and validated through experts?	Recommendations based on the findings of the study.	Primary data from 27 experts	A 2-stage online survey

6.12 Chapter summary

The study was conducted in Cross River State, Nigeria which lies partly in the tropical rain forest region. The data for the study was from both primary and secondary sources. Primary data was sourced from 209 yam farmers through the use of a structured questionnaire and a two-stage online survey from experts in relevant fields (12 experts participated in round 1 and 15 experts in round 2). While the secondary data was obtained from government publications and statistical database. Data analysis was achieved with the use of both descriptive statistics such as means, frequencies and percentages; and inferential statistics such as the multiple regression analysis.

This chapter, therefore, leads to the next on the study findings and discussions, as well as a detailed descriptive statistic of the yam famers in the study area.

Chapter 7 Findings and discussion

7.1 Introduction

This chapter presents the results of descriptive statistics and inferential statistics carried out in the study. It starts by explaining the basis for determining homogeneity of the study sample. It goes further to describe the socio-economic and demographic characteristics of the farmers in the study as well as their technical and behavioural factors as they relate to climate change and adaption. Moreover, this chapter and the subsequent ones seek to address each of the research objectives outlined in chapter one, giving details of the outcome of the analysis undertaken and developing discussions that compare and contrast the outcome with the arguments made by previous related studies.

The objectives are addressed as follows:

- Chapter 7 addresses research objective 3: To evaluate yam farmers' perceptions of, and adaptation strategies to changes in the weather patterns they are experiencing in the study area and any barriers to adaptation.
- Chapter 8 addresses research objective 1: To analyse the impact of climate variables on yam production at the state level for the period 1996-2017.
- Chapter 9 provides consideration on research objective 2: To investigate the socio-economic factors that affect the net revenue of farmers at the farm level; objective 4: To determine the most important technical and behavioural factors that affect farmers' choice of adaptation to climate change and build these into recommendations for improved state extension for yam farmers and their communities; and objective 5: To validate the models used through the engagement of experts in relevant fields to get their opinions on the study recommendations for a new strategy for smallholders growing yam on their holdings.

7.2 Independent sample t-test (the difference between means) of the study sample

A paired-samples t-test was conducted to compare some socio-economic characteristics of the farmers in the Ikom and Ogoja Local Government Areas (LGAs). The t-test was used to see if the two sets of farmers were in two discrete groups or could be considered as a single dataset. The findings revealed that there was no statistically significant difference in the ages of the farmers in Ikom (M=48, SD=6.97) and Ogoja (M=46, SD=8.35) conditions; t (207) =1.971, p=0.072. There was a trend for the farmers to be older in Ikom region, but this was not statistically significant. Also, for household family size, there were no statistically significant difference in Ikom (M=5, SD=2.44) and Ogoja (M=6, SD=7.28) although there was greater variation in family size in the sample set from Ogoja; t (207) =1.971, p=0.185. Similarly, for farm size, there was no statistically significant difference in Ikom (M=1.8, SD=0.82) or Ogoja (M=1.7, SD=0.75) conditions; t (207) =1.971, p=0.156.

The findings further showed that there was no statistically significant difference in the number of years of farming experience of the farmers in Ikom (M=28, SD=6.96) and Ogoja (M=26, SD=6.42) conditions; t (207) =1.971, p = 0.174. For the net revenue, the findings revealed there was no statistically significant difference in Ikom (M=86800, SD=3163.1) and Ogoja (M=89700, SD=3512.1) conditions; t (207) =1.971, p = 0.065, although there was a trend for net revenue to be higher for some farmers in the sample group in the Ogoja LGA.

These results suggest that the socio-economic characteristics among the farmers are not significantly different. Specifically, the results suggest that the Cross River State farmers that took part in this study can be considered to be a single homogenous dataset. For this reason, Ikom and Ogoja samples were not treated separately in the study. Rather, the study addressed the two groups as a single data set.

7.3 General characteristics of sample households

This section profiles and evaluates the Yam farmers within this study. This information will then provide the basis of understanding in developing the five research objectives of the study.

7.3.1 Socio-economic characteristics

The socio-economic characteristics determined of the respondents in the study area include their age, gender, marital status, educational level, access to credit and extension contact. Table 7.1 presents the results of the analysis.

Table 7.1: Distribution of respondents according to their socio-economic characteristics (n=209)

Socio-economic variables	Frequency	Percentage	Mean
Age			**47.2**
< 25	2	1.0	
26-40	39	18.7	
41-60	159	76	
> 60	9	4.3	
Gender			
Male	148	70.8	
Female	61	29.2	
Marital status			
Single	29	13.9	
Married	166	79.4	
Separated	11	5.3	
Widow/widower	3	1.4	
Level of education			
No formal education	16	7.7	
Primary	95	45.5	
Secondary	92	44.0	
Tertiary	6	2.9	
Household size			**8**
1-3	1	0.5	
4-6	71	34.0	
7-9	89	42.6	
10-12	44	21.0	
13-15	4	1.9	

Source: Field survey, 2018

7.3.1.1 Age of yam farmers

The majority (76.1 per cent) of the food crop farmers were between the ages of 41 and 60 years, with an average age of 47.2 years and a standard deviation (SD) of 7.78. This finding implies that most of the farmers interviewed in the study area were within the active and productive age range, and as such, could engage in agricultural activities effectively. That is to say, the ages of the respondents indicate a possibility for active labour participation in yam production (Arimi, 2014; Ozor, Umunakwe, Ani & Nnadi, 2015; Enimu, Edet & Ofem, 2016). The mean age of the farmers further implies that they are mature enough to have adequate knowledge relating to their environment which will enable them to provide useful information concerning their livelihood and the influence of climate change (Ozor et al., 2015).

7.3.1.2 Gender

Males head the majority (70.8 per cent) of the sample households while females led the rest. This outcome agrees with the study by Oluwasusi and Tijani (2013) and it suggests that males mostly practice yam farming because of the drudgery and vigorous agronomic activities that are involved in the production processes. In addition, the essential cultural norms which place most of the household responsibilities on the women rather than their men counterparts could be responsible for their low involvement in yam farming (Arimi, 2014). Although there is an indication that women were somewhat involved in yam farming, the gender balance of the sample set is biased towards the male voice. Whilst the men led the households, that does not mean that women were not involved in the farming activity across all enterprises, as women are said to constitute a bulk of the agricultural workforce (Arimi, 2014).

Table 7.2 shows a higher percentage of male led households (52.6%) between the ages of 41-60, than the female led households (23.4%) in the same category. The average age of the respondent in the study area (47.2 years) is in this category. This suggests that among the respondents in the study area, there are more males in their active age in farming than the females.

Table 7.2: Distribution of the household age according to their gender

Age	Gender		Total
	Female	Male	
< 25	0 (0)	2 (1.0)	2 (1.0)
26-40	12 (5.7)	27 (13)	39 (18.7)
41-60	49 (23.4)	110 (52.6)	159 (76)
>60	0 (0)	9 (4.3)	9 (4.3)
Total	61 (29.2)	148 (70.8)	209 (100)

Source: Field survey, 2018; Figures in parenthesis are percentages.

7.3.1.3 Marital status

The majority (79.4 per cent) of the respondents were married, while 13.9 per cent, 5.3 per cent and 1.4 per cent were single, separated, and widow/widower respectively. This finding implies that married people participate more in yam production in the study area and may gain support from their partners in carrying out some agricultural practices. This outcome agrees with the study by Oluwasusi and Tijani (2013), which reported that married people dominate yam farming. Marriage could provide farmers with the chances of receiving family labour which is readily available and cheap. According to Ozor et al., (2015), marriage encourages complementary efforts amongst farming families which could potentially promote adaptation strategies. In addition, decision-making regarding the adoption of climate change adaptation strategies could be cooperatively taken by members of the families because social relations are a considered to be a strong connecting factor amongst the farming communities (Arimi, 2014).

Additionally, Table 7.3 shows the frequency distribution and percentages of the household farmers according to their gender and marital status. The findings reveal that there are more married males (57.4% of the whole dataset) involved in yam farming than married females among the farmers considered in the study. But as a proportion of the gender subset, 81 per cent of the male were married and 75 per cent of the females were married.

Table 7.3: Distribution of the household marital status according to their gender

Marital status	Gender		Total
	Female	Male	
Single	12 (5.7)	17 (8.1)	29 (13.9)
Married	46 (22.0)	120 (57.4)	166 (79.4)
Separated	2 (1.0)	9 (4.3)	11 (5.3)
Widow/widower	1 (0.5)	2 (0.9)	3 (1.4)
Total	61 (29.2)	148 (70.8)	209 (100)

Source: Field survey, 2018; Figures in parenthesis are in percentages.

7.3.1.4 Level of education

In terms of literacy, the majority (92.4 %) of the sampled yam farmers had one form of education or another, either primary (45.5 %), secondary (44.0 %) or tertiary education (2.9 %). Respondents with no formal of education constitute 7.7 per cent of the sampled household (See Table 7.1). They can further be split down into male and female respondents, as shown in Table 7.4. The table shows that more males in the whole dataset had secondary education (33.0%) than their female counterpart (11%). And as a proportion of the gender subset, 47.0 per cent of the male had secondary education while 38 per cent of female had secondary education. Also, the tertiary education levels for both female and male led households was low with percentages; 1.9 per cent and 0.9 per cent for female and male respectively of the dataset although women were underrepresented.

Table 7.4: Frequency distribution of household gender according to their level of education

Level of education	Gender		Total
	Female	Male	
No Education	6 (2.9)	10 (4.8)	16 (7.7)
Primary	28 (13.4)	67 (32.1)	95 (45.5)
Secondary	23(11.0)	69 (33.0)	92 (44.0)
Tertiary	4(1.9)	2 (0.9)	6 (2.9)
Total	61 (29.2)	148 (70.8)	209 (100)

Source: Field survey, 2018; Figures in parenthesis are in percentages.

These levels of education are all formal and took place in a school environment. This infers that farmers with some education dominate the study area, but over half the dataset had no education or only education until eleven years of age. The level of literacy varied across the farmers interviewed. Education is a critical agent in addressing the issue of climate change. It can encourage people to change their attitudes and behavior and also helps them to make informed decisions. For example, education is an important factor in climate change adaptation decision (Unamma, Onwudike, Uwaegbute, Edeoga, & Nwosu, 2004; Nwaobiala & Nottidge (2015). In the classroom, young people can be taught the impact of global warming and learn how to adapt to climate change. This outcome aligns with the findings of Enimu et al., (2016) that reported that majority of the farmers in Cross River State were literate. According to Ozor et al., (2015), acquiring a formal education increases the level of adoption of enhanced agricultural technologies.

Consequently, yam producers' educational level in the study area may assist them in obtaining information in various sources to promote adaptation. Additionally, the level of education of the respondents was mapped with their primary choice of adaption as seen in table 7.5. Planting of different varieties had the highest response for adoption (28.2%) and the farmers who chose this option had primary (14%), secondary (11.5%) and tertiary (1.0%) education. Also, the use of inorganic fertiliser is the second most frequently reported adaptation option (20.1%) and the respondents who adopted this option had primary (7.7%), and secondary (10.5%) education. 14.4 per cent of the whole dataset were primary educated and planted different varieties, but nearly 30 per cent of primary educated (primary education subset) chose this option. Importantly, planting of different varieties involves planting of different types of crops such as yam, cassava, maize vegetables, etc. While the use of improved varieties entails the the use of crops which offer much higher yields, better quality, and more stable production. These improved crop varieties may be resistant to drought, heat, diseases and other stresses (IITA, 1990; Olagunju, 2020).

Table 7.5: Frequency distribution of the household according to their adaptation options and level of education

Adaptation strategies	Level of education				Total
	No formal education	Primary	Secondary	Tertiary	
No adaptation option	0 (0.0)	2 (1.0)	2 (1.0)	2 (1.0)	6 (2.9)
Use of improved variety	4 (1.9)	9 (4.3)	11 (5.3)	1 (0.5)	25 (12.0)
Change of planting date	1 (0.5)	10 (4.8)	10 (4.8)	0 (0.0)	21 (10.0)
Planting of trees	1 (0.5)	9 (4.3)	5 (2.4)	0 (0.0)	15 (7.2)
Use of inorganic fertiliser	4 (1.9)	16 (7.7)	22 (10.5)	0 (0).0)	42 (20.1)
Reduce bush burning	0 (0.0)	4 (1.9)	4 (1.9)	1 (0.5)	9 (4.3)
Expansion of farm size	0 (0.0)	3 (1.4)	2 (1.0)	0 (0.0)	5 (2.4)
Off-farm employment	3 (1.4)	12 (5.7)	12 (5.7)	0 (0.0)	27 (12.9)
Planting of different varieties	3 (1.4)	30 (14.4)	24 (11.5)	2 (1.0)	59 (28.2)
Total	16 (7.6)	95 (45.5)	92 (44.0)	6 (2.9)	209 (100)

Source: Field survey, 2018; Figures in parenthesis are in percentages.

7.3.1.5 Household size

Based on the number of household members, most (42.6 per cent) of the respondents had family sizes of between 7-9 members. Others were 34 per cent, 21 per cent, 1.9 per cent and 0.5 per cent for family sizes of 4-6, 10-12, 13-15 and 1-3 members respectively (Table 7.1). The mean household size was around 8, with an average number of two-income earners in the household. Table 7.6 shows the percentage of the different household sizes that were either female, or male led. The table showed that households in all categories had a higher percentage of being led by the males.

Table 7.6: Frequency distribution of respondents according to their gender and family size

	Gender	
Household size	**Female led**	**Male led**
1-3	0 (0)	1 (0.5)
4-6	19 (9.1)	52 (24.9)
7-9	30 (14.4)	59 (28.2)
10-12	12 (5.7)	32 (15.3)
13-15	0 (0)	4 (1.9)
Total	61 (29.2)	148 (70.8)

Source: Field survey, 2018; Figures in parenthesis are in percentages.

Also, the relationship between household size and level of education was assessed and presented in Table 7.7 using frequencies and percentages. The findings showed that household size of 7-9 members had equal number of respondents with primary (19.1%) and secondary level of education (19.1%), and these are the levels of education with the highest percentages. Also, household with the highest number of members with tertiary education (1.4%) had a size of 7-9 members.

Table 7.7: Distribution of respondents according to household size and level of education.

Household size	Level of education			
	No formal education	Primary	Secondary	Tertiary
1-3	0 (0)	0 (0)	1 (0.5)	0 (0)
4-6	5 (2.4)	32 (15.3)	33 (15.8)	1 (0.5)
7-9	6 (2.9)	40 (19.1)	40 (19.1)	3 (1.4)
10-12	5 (2.4)	21 (10.0)	16 (7.7)	2 (1.0)
13-15	0 (0)	2 (1.0)	2 (1.0)	0 (0)

Source: Field survey, 2018; Figures in parenthesis are in percentages.

Family labour is regarded as the primary source of labour supply in smallholder farming families (Enimu et al., 2016). The findings suggest that the family size of the respondents could supply them with a cheaper workforce (family labour) by enabling them to use their household members in farming activities. This includes the work from men, women and children in a family who make contributions of their intellectual and physical efforts to the household agricultural practices. A large family size would encourage the division of labour by farmers, thereby providing additional output and income (Ozor et al., 2015). Moreover, a study by Enimu et al., (2016) confirmed that farming families in Cross River State maintain a reasonably large household size which could be a boost to farm labour when carrying out farming activities.

Table 7.8 presents the distribution of the respondents according to their primary adaptation options and household size. The table shows that the highest adoption was in the use of planting of different varieties (28.2%). Of this 28.2 per cent of farmers, 12.0 per cent had a family size of 7-9 (category with the highest adoption). This indicates that the number of household members could help in decision making when considering the choice of adaptation as members of households come up with different suggestions. Also, the only adaptation option taken by the respondents with a family size between 1-3 is change of planting date. This group of farmers make up only 0.5% of the 10.0% of farmers who adopted this strategy. Hence, the larger the household, the more options available and also undertaken.

Table 7.8: Distribution of the household according to their adaptation options and household size

Adaptation strategies	Household size					Total
	1-3	4-6	7-9	10-12	13-15	
No adaptation option	0 (0.0)	1 (0.5)	3 (1.4)	2 (1.0)	0 (0.0)	6 (2.9)
Use of improved variety	0 (0.0)	6 (2.9)	11 (5.3)	8 (3.8)	0 (0.0)	25 (12.0)
Change of planting date	1 (0.5)	6 (2.9)	9 (4.3)	5 (2.4)	0 (0.0)	21 (10.0)
Planting of trees	0 (0.0)	6 (2.9)	3 (1.4)	4 (1.9)	2 (1.0)	15 (7.2)
Use of inorganic fertilizer	0 (0.0)	14 (6.7)	22 (10.5)	6 (2.9)	0 (0.0)	42 (20.1)
Reduce bush burning	0 (0.0)	4 (1.9)	4 (1.9)	1 (0.5)	0 (0.0)	9 (4.3)
Expansion of farm size	0 (0.0)	0 (0.0)	2 (1.0)	3 (1.4)	0 (0.0)	5 (2.4)
Off-farm employment	0 (0.0)	10 (4.8)	10 (4.8)	6 (2.9)	1 (0.5)	27 (12.9)
Planting of different varieties	0 (0.0)	24 (11.5)	25 (12.0)	9 (4.3)	1 (0.5)	59 (28.2)

Source: Field survey, 2018; Figures in parenthesis are in percentages.

7.3.2 Farm characteristics

The farm characteristics of the respondents considered in the study area include the size of farmland, tenure status (land ownership), the farming experience measured in the number of years in farming, livestock ownership and the types of crops cultivated. Table 7.9 displays the results of the analysis.

Table 7.9: Farm characteristics of yam farmers in Cross River State

Characteristics	Frequency	Percentage	Mean
Farm size (ha)			**1.71**
≤1.0	88	42.1	
1.1-1.5	93	44.5	
1.6-2.0	28	13.4	
Land ownership			
Owner	60	28.2	
Tenant	149	71.3	
Number of years of farming			**26.98**
11-20	38	18.4	
21-30	107	51	
>30	64	30.6	
Livestock production			
Yes	145	69.6	
No	64	30.6	
Major crops grown			**Proportion of yam**
Only yam	47	22.5	100%
Yam + Cassava	82	39.2	>50%
Yam + Maize	25	12	>50%
Yam + Cocoyam	35	16.8	>50%
Yam + combination of two or more other crops	20	9.6	>50%

Source: Field survey, 2018

7.3.2.1 Farm size

As for farm size, 42.1 per cent of farmers cultivated less than a hectare to 1 hectare of farmland, 44.5 per cent and 13.4 per cent of farmers had farm sizes of 1.1-1.5 and 1.6-

2.0 hectares respectively. This implies that the farmers are predominantly small-scale land holders which agrees with findings by Arimi, (2014) that most rural farmers in Nigeria are small scale land holders. The result further implies that the small-sized farmland cultivated by most of the farmers may be attributed to the type of land tenure system predominant in the study area, which supports smallholdings. Moreover, literature added that the tropical forest region, as well as the rangeland, are under threat from population pressure and system of land use (IPCC, 2007; Nwaobiala & Nottidge, 2015). The findings of this study also agree with the survey by Enimu et al., (2016) which reported that most food crop producers in the study area are subsistence farmers.

When the data was analysed using information on gender, and farm size, it shows that a higher percentage of male led households (70.7%) cultivated on the different categories of the farm sizes than the female led households (29.2%). However, among the female led households, majority of them (14.4%) had a farm size between 1.1-1.5ha. But as a proportion of the subset, 49 per cent of the females have farm size between 1.1-1.5ha.

Table 7.10: Distribution of respondents' farm size according to their gender

Farm size (ha)	Gender		Total
	Female	**Male**	
≤1.0	24 (11.5)	64 (30.6)	88 (42.1)
1.1-1.5	30 (14.4)	63 (30.1)	93 (44.5)
1.6-2.0	7 (3.3)	21 (10.0)	28 (13.4)
Total	61	148	209

Source: Field survey, 2018; Figures in parenthesis are in percentages.

7.3.2.2 Land ownership

In terms of the households' tenure status, the findings in Table 7.11 using the whole data set shows that 71.3 per cent of the respondents do not have title deeds to farmland, that is, they are tenant farmers. While the remaining 28.7 per cent were categorised as having title deeds to the farm, that is, they were owner farmers.

When this 28.7 per cent was analysed, the proportion of the subset showed that 75 per cent were male led households while 25 per cent household were female led. This implies that there were more male-led households who have title deeds than the female led households among the respondents. This profile of a land-owning yam farmer is important in developing long term planning for climate change action. It should also be noted that this group of farmers is the outcome of the various land tenure systems in Nigeria, which vary from communities, towns, or cities (Nwocha, 2016).

Table 7.11: Distribution of respondents according to land ownership and gender

Land ownership	Gender		Total
	Female	Male	
Ownership	15 (7.2)	45 (21.5)	60 (28.7)
No ownership	46 (22.0)	103 (49.3)	149 (71.3)
Total	61 (29.2)	148 (70.8)	209 (100)

Source: Field survey, 2018; Figures in parenthesis are in percentages.

Furthermore, Table 7.12 shows that among the 28.7 per cent of the respondent who have title deeds, 21 per cent of them kept livestock. However, a higher percentage of respondents who kept livestock (48.3%) had no land ownership. This implies that the farmers with no title deeds attempt to make the most of the piece of land available to them by cultivating crops and raising livestock on the same piece of land.

Table 7. 12: Distribution of respondents according to land ownership and raising of livestock

Land ownership	Livestock keeping		Total
	Yes	No	
Ownership	44 (21)	16 (7.7)	60 (28.7)
No ownership	101 (48.3)	48 (23)	149 (71.3)
Total	145	64	209 (100)

Source: Field survey, 2018; Figures in parenthesis are percentages.

7.3.2.3 Number of years in farming

Based on number of years in farming, a higher proportion (51 per cent) of the sample households had engaged in yam farming activities for 21-30 years. Also, 18.4 per cent and 30.6 per cent of the farmers have been cultivating yam for the period of 11-20 and above 30 years, respectively. The mean number of years in farming was 27 years, with a SD of 6.96. This implies that the respondents have been involved in farming activities for a long enough time to comment on the past changes they attribute to climate change. Any change in climate ought to be observed for a minimum of one decade (10 years) before it could be regarded as climate change (IPCC, 2007; Ozor, et al., 2015). Thus, the farmers in the study area have years of farming experience more than 10 years justifying that they have useful information on variation in climate and coping strategies as it affects their farming activities and production based on their experiences over the years.

7.3.2.4 Livestock production

More than half (69.9 per cent) of the households were involved in livestock production whereas the remaining (30.6 per cent) of them kept no livestock (Table 7.9). Even so, this livestock is not entirely raised in isolation, but usually in a mix with one or more types. The animals kept included poultry, goat, rabbit, pig and sheep. The farms which typically kept livestock had their profile presented in Table 7.13.

From the table, out of the 69.9 per cent of the respondent who kept livestock, 40.7 per cent had a farm size of ≤1.0, 46.9 per cent had a farm size of 1.1-1.5 while 12.4 had between 1.6-2 ha size of farmland. The average farm size was calculated to be 1.71 ha which is in the category of 1.6-2.0 with 13.4 per cent of respondents. The table further shows that among this 13.4 per cent, farmers who kept livestock constitute 64.3 per cent while those who do not keep livestock make up 35.7 per cent. This suggests that farm size also determines the choice of keeping livestock.

Table 7.13: Distribution of the respondents according to livestock ownership and farm size

Farm size (ha)	Livestock ownership		Total
	Yes	No	
≤1.0	59 [40.7]	29 [45.3]	88 [42.1]
1.1-1.5	68 [46.9]	25 [39.1]	93 [44.5]
1.6-2.0	18 [12.4]	10 [15.6]	28 [13.4]
Total	145 [100]	64 [100]	209 [100]

Source: Field survey, 2018; Figures in parenthesis are percentages of subset.

Table 7.14 presents the farmers' choice of livestock ownership according to their level of education. The profile of the 69.4 per cent of the farmer who own livestock are as follows: No formal education (5.7%), primary (32.5%), secondary (30.1%) and tertiary education (1.0). The table further shows that 7.6 per cent and 2.9 per cent of the respondents had no formal education and tertiary education respectively. Out of the 7.6 per cent farmers with no formal education, 5.7 per cent had livestock ownership, while 1.9 per cent do not. And out of the 2.9 per cent of farmers with tertiary education, 1.0 per cent had livestock ownership, while 1.9 per cent do not. These findings, however, suggest that level of education does not determine choice of keeping livestock.

Table 7.14: Distribution of household according to their level of education and livestock ownership

Level of education	Livestock ownership		Total
	Yes	No	
No formal education	12 (5.7)	4 (1.9)	16 (7.6)
Primary	68 (32.5)	27 (13.0)	95 (45.5)
Secondary	63 (30.1)	29 (13.9)	92 (44.0)
Tertiary	2 (1.0)	4(1.9)	6 (2.9)
Total	145 (69.4)	64 (30.6)	209

Source: Field survey, 2018; Figures in parenthesis are in percentages.

7.3.2.5 Crops grown

From the data collected, the yam crop is not planted by the farmers exclusively on the farmland, but usually in combination with one or more crops. Apart from 22.5 per cent of the farmers who plant only yam on their piece of land, the remaining 77.5 per cent grow yam mixed with other crops for consumption and partly for cash. However, yam is the most important crop grown as it is more than 50 per cent of the crops cultivated on each plot of land.

The major crops grown in combination with yam on the same piece of land are cassava, maize and cocoyam. The data collected shows that 39.2 per cent of the respondents cultivated a mixture of yam and cassava. This could be as a result of the ability of cassava to withstand adverse climatic conditions. Cassava is a crop that can tolerate unfavourable conditions like drought and low soil fertility (Manyong, Kling, Makinde, Ajala, & Menkir, 2000; Ozor et al., 2015). Moreover, the cultivation of yam and other crops on the same piece of land could be considered to be a coping measure against the risk and uncertainties caused by climate change in crop production.

7.3.3 Topography and soil

In terms of the landscape, all farmland is located above the average flood level in the study area. The entire sample (100 per cent) is categorised as lowlands as they are situated no more than 300m above sea level (Oyegun, Lawal & Ogoro, 2016).

On the other hand, the type of soil used in planting depends on the general soil type found in the area. This is an area where there is deep laterite basaltic soil (Akpan & Obang, 2012). However, the fertility of the soil was determined by the judgments of the farmers. According to Gray and Morant, (2003); Kelly and Anderson (2016); and Hansen (2019), farmers are in a good position to comment on how fertile their farmland is. A study on reconciling indigenous knowledge with a scientific assessment of soil fertility changes in southwestern Burkina Faso by Gray and Morant (2003) stated that farmers' observations of soil quality were in perfect agreement with the scientific investigations. Dawoe, Quashie-Sam, Isaac and Oppong's (2012) research, on exploring farmers' local knowledge and perceptions of soil fertility and management in the Ashanti Region of Ghana reported that the knowledge and observations of soil quality by farmers are based on some indicators related to plants and soil which include: colour of the soil, retaining capacity of soil water, rocky soil, difficult to plough soil, type and abundance of weeds, leaf colour and deficiency symptoms detected on crops, crop growth rate and the incidence and profusion of soil macro-fauna. The study further reports that although the indicators used by the farmers to evaluate and monitor their soil fertility were purely qualitative, it nonetheless was consistent with the scientific assessment of the soil quality in various respects.

Consequently, in obtaining information on soil fertility for the study, the respondents were asked two specific questions on the quality of their soil. Firstly, the question “how do you determine the quality (fertility) of your soil?” was asked. The response options were: “Scientifically tested” or “Personal experience.” From the results, the entire sample (100 per cent) of the respondents admitted that the quality (fertility) of their soil is determined through personal experience.

Secondly, the question “what is the soil quality (fertility) of your farmland?” was asked. The response options were; “Good,” “Average,” or “Poor.” The outcome shows that more than half of the farmers (53 per cent) reported good quality soil while the remaining 40 per cent and 7 per cent reported average quality soil and poor-quality soil, respectively. This finding is similar to that of Kelly and Anderson (2016), who researched the topic “comparing farmer and measured assessments of soil quality in Tanzania: Do they align?”. In their research, it was revealed that about 46 per cent of the respondents reported “Good” quality soil, while 48 per cent reported “Average” quality soil. Furthermore, a minority (less than 6 per cent) of the farmers reported having “Bad” quality soil.

7.3.4 Institutional accessibility of respondents in the study area

Farmers’ access to institutions plays a vital role in the growth and development of the agricultural sector of a nation (Sarker et al., 2013). Institutional accessibility indicates the farmers’ access to extension services, credits or loans, weather information, input subsidies and market and so on. Access or barriers to accessing these inputs contribute immensely to the efficiency of crop production. The result of the analysis of the data collected on institutional accessibility is presented in Table 7.15.

Table 7.15: Institutional and information accessibility of yam farmers in Cross River State

Variable	All sample (n = 209)	
Access to extension services	**Frequency**	**Percentage**
Yes	136	65.1
No	73	34.9
Access to credit		
Yes	117	56.0
No	92	44.0
Access to weather information		
Yes	137	65.9
No	72	34.1
Access to input subsidies		
Yes	50	23.6
No	159	76.4
Access to markets		
Yes	165	78.9
No	44	21.2

Source: Field survey, 2018

The majority (65.1 per cent) of the farmers had contact with extension agents. Extension contact is scheduled once a year to each LGA in Cross River State (Enimu et al., 2016). Whereas 34.9 per cents of the respondents reported to have had no contact with extension agents. Table 7.16 shows the adaptation strategies adopted by farmers who have access to extension services, and those who do not.

Table 7.16: Distribution of the household according to their adaptation options and access to extension services

Adaptation strategies	Access to extension services		Total
	Yes	No	
No adaptation option	4 (1.9)	2 (1.0)	6 (2.9)
Use of improved variety	14 (6.7)	11 (5.3)	25 (12.0)
Change of planting date	14 (6.7)	7 (3.3)	21 (10.0)
Planting of trees	9 (4.3)	6 (2.9)	15 (7.2)
Use of inorganic fertilizer	30 (14.4)	12 (5.7)	42 (20.1)
Reduce bush burning	6 (2.9)	3 (1.4)	9 (4.3)
Expansion of farm size	2 (1.0)	3 (1.4)	5 (2.4)
Off-farm employment	17 (8.1)	10 (4.8)	27 (12.9)
Planting of different varieties	40 (19.1)	19 (9.1)	59 (28.2)
Total	136 (65.1)	73 (34.9)	209 (100.0)

Source: Field survey, 2018; Figures in parenthesis are in percentages.

As for access to credits, 56 per cent admitted they had access to agricultural loans. The remaining 44 per cent of the farmers had no access to credit. Access to credit is also important in the choice of adaptation strategy. Therefore, Table 7.17 presents the adaptation strategies taken by the farmers according to their access to credit facilities. The use of inorganic fertilizer was adopted by 20.1 per cent of the respondents. This 20.1 per cent is made up of 12.4 per cent of farmers who had access to credit and 7.7 per cent of them who did not have access to credit. Also, for the adaptation option of using improved variety, 12 per cent of the farmers reported to have used this option. Among the 12.0 per cent, 9.1 per cent had access to credit facilities, whereas 2.9 per cent had no access.

These findings, therefore, indicate that access to credit is a determinant of these adaptation options.

Table 7.17: Distribution of the household according to their adaptation options and access to credit

Adaptation strategies	Access to credit		Total
	Yes	No	
No adaptation option	4 (1.9)	2 (1.0)	6 (2.9)
Use of improved variety	19 (9.1)	6 (2.9)	25 (12.0)
Change of planting date	12 (5.7)	9 (4.3)	21 (10.0)
Planting of trees	7 (3.3)	8 (3.8)	15 (7.2)
Use of inorganic fertilizer	26 (12.4)	16 (7.7)	42 (20.1)
Reduce bush burning	4 (1.9)	5 (2.4)	9 (4.3)
Expansion of farm size	3 (1.4)	2 (1.0)	5 (2.4)
Off-farm employment	13 (6.2)	14 (6.7)	27 (12.9)
Planting of different varieties	29 (13.9)	30 (14.4)	59 (28.2)
Total	117 (56.0)	92 (44.0)	209 (100.0)

Source: Field survey, 2018; Figures in parenthesis are in percentages.

Table 7.18 reveals that 7.7 per cent of the respondents did not have any form of formal education. Among this group of respondents, 5.3 per cent had access to credit facilities, while 2.4 did not have. This suggests that access to credit may not be a determinant of the next educational level for this category of respondents.

Table 7.18: Distribution of the household according to their level of education and access to credit

Level of education	Access to credit		Total
	Yes	No	
No formal education	11 (5.3)	5 (2.4)	16 (7.7)
Primary	43 (20.6)	52 (24.9)	95 (45.5)
Secondary	59 (28.2)	33 (15.8)	92 (44.0)
Tertiary	4 (1.9)	2 (1.0)	6 (2.9)
Total	117 (56.0)	92 (44.0)	209 (100.0)

Source: Field survey, 2018; Figures in parenthesis are in percentages.

More so, it is essential to note that precise weather forecasting and access to it for farmers plays a significant role in agricultural activities, particularly in determining sowing times and periods of the harvest of crops. Data from field survey shows that the majority (65.87 per cent) of the respondents in the study area have access to weather information; therefore, a third do not. Input subsidies, especially for smallholder farmers, are vital for progress in agricultural production (Sarker et al., 2013). However, the field survey data revealed that a smaller proportion of the respondents (21.15 per cent), receive subsidies in the form of agricultural inputs like fertiliser and planting materials from the government while 76.44 per cent of the farmers received no input subsidies.

Looking further to their access to markets, more than half (78.85 per cent) of the respondents have access to the major market in the study area. The remaining 21.15 per cent have no access to the major market but make use of the local (surrounding) markets.

7.3.5 Farming system

Agricultural farming systems are established cropping plans employed to make optimum use of the available resources to achieve economic and sustainable agricultural productivity that will meet the needs of the farm household (Okese, 2018). The dominant types of farming system used in the study area are mono-cropping, mixed cropping, and mixed farming.

Mixed farming is an agricultural practice whereby a farmer cultivates crops and rears animals simultaneously on the same piece of land (Okese, 2018). However, a variety of crops that differ in maturity periods are cultivated in the same period. There is also continuous cropping on the same piece of land throughout the season (this means there could be more than one harvest in a given year). Mixed farming allows use of farmyard manure; thus, the use of synthetic fertilizer is minimised. Mono-cropping is where only one crop is grown by the farmer. Farming practices are not done in isolation, but typically in combination with one or more enterprises. Therefore, the farmers were asked to identify the most significant kind of farming system they practice. As such, the options of the types of farming system adopted by the farmers in the questionnaire were mutually exclusive (that is, the farming systems cannot occur at the same time).

Table 7.19 illustrates the significant types of farming systems practiced by the respondents as well as the size of farm used for each practise. The majority (69.4 per cent) of the farmers practiced mixed farming in the study area. Most of the farmers in this group (32.5%) had a farm size between 1.1-1.5ha (Table 7.19). Also, mixed cropping was practiced by 18.6 percent of the farmers; the majority of these farms were of a size ≤1.0, whereas mono-cropping was practiced by 12 per cent of the farmers and the typical farms with this profile had a size of ≤1.0 (see Table 7.19).

This finding suggests that the farmers in the sample group diversify their enterprises and products, which could be because of the risks and uncertainties involved in agricultural production of a given crop (Adegeye & Dittoh, 1985; Ozor et al., 2015); and to produce for household consumption. As observed by Ozor et al., (2015), farmers in Imo State, Nigeria, assimilate crop and livestock production (mixed farming) as a strategy to cope with the changes in climate.

Table 7.19: Distribution of the household according to their farming system and size of farmland

Farm size	Farming system			Total
	Monocropping	Mixed cropping	Mixed farming	
≤1.0	12 (5.7)	19 (9.1)	57 (27.3)	88 (42.1)
1.1-1.5	10 (4.8)	15 (7.2)	68 (32.5)	93 (44.5)
1.6-2.0	3 (1.4)	5 (2.4)	20 (9.6)	28 (13.4)
Total	25 (12)	39 (18.6)	145 (69.4)	209 (100.0)

Source: Field data, 2018; figures in parenthesis represent percentages

7.4 Perception of climate change

In this section and the subsequent sections, the study addresses research objective 3: Evaluate yam farmers' perceptions of, and adaptation strategies to changes in the weather patterns they are experiencing in the study area and any barriers to adaptation.

There is an expectation that farmers should first observe that there is a change in a climate to adopt the required adaptive measures (Bryan et al., 2009; Sarker et al., 2013) i.e. they are reactive rather than proactive. In this regard, the survey carried out with the farm household heads enquired about their perceptions of the changes in selected climate variables for the previous 20 years. The key components of the inquiry were erratic rainfall pattern, hotter days, delayed onset of rainfall, increasing incidence of a flood, early cessation of rains, and long duration of rainfall.

The frequency distribution and results below, (Table 7.20), demonstrates for the sample group farmers' perception of climate change in Cross River State. The farmers reported they observed an increase in erratic rainfall patterns (66.5 per cent), increased temperatures (49.3 per cent), increase in long duration of rainfall (49.8 per cent), no change in heat wave/hot days (48.8 per cent) and increase in delayed onset of rainfall (44.5 per cent). This finding implies that the farmers in the study area have recognised the changes in some climate components. This indicates that the farmers are aware of climate change and have experienced these changes.

The outcome of this analysis is in agreement with Tambo and Abdoulaye, (2013), who ascertained in their research that most of the farmers in the Nigerian savanna region have observed changes in climate in the form of erratic rainfall pattern and have accordingly adjusted their farming activities to adapt. Deressa et al. (2009) reported a similar result in their study in the Nile basin of Ethiopia that the farmers claimed to have been observing variations in climatic factors for so many years. Another survey by Bryan et al. (2009) in Ethiopia also corresponds to these findings, and it revealed the farmers reporting an increase in temperature and decrease in rainfall. It is also in line with the study by Ofuoku (2011), who studied rural farmers' perception of climate change in the Central Agricultural zone of Delta State, Nigeria. In this study, farmers observed that afternoons were hotter, the delay in the onset of wet season was increased and the dry season had become shorter. Samuel et al. (2017); Ike and Ezeafulukwe (2015); Tambo and Abdoulaye, (2013) reported a similar result that farmers perceived long term changes in temperature and a decrease in precipitation.

The farmers in the study area perceived the effect of climate change to different degrees. However, the change perceived may depend on their years in farming because the climate change situation is dynamic. For example, farmers with more than 15 years of experience perceived an increase in temperature and farmers with more than 10 years in farming perceived erractic rainfall.

Table 7.20: Perception of climate change by farmers in Cross River State (n = 209)

Climate change component	***Increased***	***Decreased***	***No change***
Erratic rainfall pattern	139 (66.5)	16 (7.7)	54 (25.8)
Temperature	103 (49.3)	53 (25.4)	53 (25.4)
Duration of rainfall	104 (49.8)	72 (34.4)	33 (15.8)
Heat wave/hot days	97 (46.4)	10 (4.8)	102 (48.8)
Delay in onset of the wet season	93 (44.5)	80 (38.3)	36 (17.2)

Source: Field survey, 2018; figures in parenthesis represent percentages

7.5 Perceived effect of climate change

According to previous studies, changes in the weather pattern will have an undesirable impact on the output of some crops. That adverse effect ought to be perceived by the farmers as a driver to them adopting strategies to cope with such effects (Samuel, Shem, Daniel, & Silas, 2017).

Table 7.21 illustrates the observed effects of climate change by the farmers in the study area. The table shows the average agreement with the statement “state to what extent you agree to the following perceived effects of climate change on your yam farm” (1 = strongly disagree; 2 = disagree; 3 = agree; 4 = strongly agree). The findings from the analysis using a four-point Likert-type rating scale revealed that the perceived effects of climate change include a decline in crop output, late maturity of the crop, pest and disease proliferation, and the delay in planting period. These effects perceived by the farmers have severe implications for food security, particularly in the rural areas, which depend mostly on agriculture for food and other resources (Ofuoku, 2011; Tambo & Abdoulaye, 2013).

The outcome of this analysis coincides with that of Weli and Bajie (2017), who studied the adaptation of the root crop farming system to climate change in Ikwerre Local Government Area of Rivers State, Nigeria. It also corresponds with the result of the study by Ofuoku (2011), who assessed the rural farmers’ perception of climate change in the Central Agricultural Zone of Delta State in Nigeria. Another survey by Egbe et al., (2014) on Rural Peoples’ Perception of Climate Variability in Cross River State-Nigeria also agrees with the findings of this research. Furthermore, Wood and Mendelsohn (2015) reported in their study on the impact of climate change on net agricultural revenue: a case study in the Fouta Djallon, West Africa that based on farmers perceptions, higher temperatures, and precipitation lower incomes in agriculture during the wet season but increases revenues in the dry season.

Table 7.21: Average agreement on the statement of perceived effects of climate change (n = 209; 1 = strongly disagree; 4 = strongly agree)

Perceived Effect	*Total score*	*Mean score*	*Rank*
Decline in crop yield	595	2.85	1st
Delay in planting period	583	2.79	2nd
Pest and disease proliferation	564	2.70	3rd
Late maturity	532	2.55	4th
Poor tuberisation	470	2.25	5th
Erosion hazard	438	2.10	6th
Flooding of the farm	397	1.90	7th

Cut-off score = 2.50 (≥ 2.50 = important effect, < 2.50 = not important effect).

Source: Field survey, 2018

The rationale for the measurement of the perceived effects as "important effect" by the farmers was discussed in chapter 6 section 6.10.

7.6 Farmers' adaptation strategies to climate change in Cross River State

The adaptation strategies commonly practised by farmers are revealed in literature, and they include the use of improved varieties, changing planting date, planting of trees, use of inorganic fertiliser, reducing bush burning, expansion of farm size, off-farm employment and cultivation of different varieties of crop (Bryan et al., 2011; Juana, Kahaka & Okurut, 2013; Tesfaye & Seifu, 2016). This was discussed in more detail in section 4.2 of chapter 4. However, Table 7.22 presents the distribution of respondents' responses according to the adaptation strategies they stated they practised in Cross River State. The respondents were asked to select the most important adaptation option they use, although they may have adopted more than one adaptation option. The adaption strategies are discussed in more detail in this section.

Although farmers observed changes in climate, this study revealed that some farmers (2.9 per cent) in the sample group did not take any adaptation measures to cope with the changing climate. The profile of this group of farmers is as follows; Among the 2.9 per cent of farmers with no adoption, 1.9 had access to extension services while 1.0 per cent did not have access. Also, the 2.9 per cent (≈3.0%) of farmers with no adaptation option had one form of education or another (See Table 7.5; primary-1.0%, secondary-1.0% and tertiary-1.0%). This suggests that extension services and access to education may not be factors that determine the choice of adaptation for this group of farmers.

This finding is congruent with previous research (Ofuoku, 2011; Sarker et al., 2013; Tesfaye & Seifu, 2016; Ogallah, Wandiga, Olago & Oriaso, 2017). On the contrary, some studies found out that all farmers in the area of study adopted one form of adaptive measure or another. This is reported in a previous study in sub-Sahara Africa by Juana et al. (2013); and another study in Cross River State by Egbe et al. (2014).

Table 7.22: Adaptation strategies to cope with the effects of climate change in Cross River State.

Adaptation Strategies	Percentage of farmers reporting their adoption
Planting of different varieties of crop	28.2
Use of inorganic fertiliser	20.1
Off-farm employment	12.9
Use of an improved variety	12.0
Changing the planting date	10.0
Planting of trees	7.2
Reduce bush burning	4.3
No adaptation	2.9
Expansion of farm size	2.4
No response	0

Source: Field survey, 2018

7.6.1 Planting of different crop varieties

This is the most important adaptation strategy adopted by farmers in the study area. Farmers could cultivate different crop varieties as a response to changes in the weather pattern. One of the likely adaptation measures taken by farmers to cope with climate inconsistency is diversifying crops and planting that which is favourable to the existing climate as the climate changes.

This was reported by 28.2 per cent of farmers in the study population (Table 7.22). Crop diversification has been known to be a possible farm-level adaptation strategy used to cope with the change (Smit & Wandel, 2006; Juana et al., 2013; Sarker et al., 2015). Additionally, the highly inconsistent climates of most areas in Africa encourage farmers who are risk-averse to cultivate drought-resistant crops such as cassava to cope with climate change (Juan et al., 2013; Ogallah et al., 2017). In this study, 39.2 per cent of farmers grew cassava as well as yams.

Crop diversification is mostly used in the study area because farmers can grow crops that the changing climate is conducive for. This outcome is in line with findings by Ogalleh et al., (2012); Goshu, Kassa, & Ketema, (2012); Juana et al., (2013) and Tesfaye and Seifu (2016).

This 28.2 per cent of the farmers who adopted this strategy constitute 14.4 per cent who have access to credit facilities and 13.9 per cent who do not (see Table 7.17). Also, the 28.8 per cent of the farmers comprise of 19.1 per cent of farmers who have access to extension services and 9.1 per cent of farmers who do not (see Table 7.16). This suggests that access to credit may not be a major determinant of this choice of adaptation (planting of different crop varieties), while access to extension services determines this option of adaptation.

7.6.2 Use of inorganic fertiliser

From Table 7.22, the use of inorganic fertilizer was the second most important adaptation strategy reported by the farmers (20.1%). This group of farmers are made up of 14.4 per cent who have access to extension services and 5.7 per cent who do not have access (Table 7.16). Also, this 20.1 per cent of farmers comprise of 12.4 per cent who have access to credit and 7.7 per cent of farmers who do not (Table 7.17). These findings indicate that access to extension services and access to credit facilities determine the adoption of this strategy for this group of farmers, because more farmers with access to these services adopted this strategy.

7.6.3 Off farm employment

Background information on this adaption strategy was presented in section 4.4 of chapter 4. This is the third most important adaptation strategy adopted by the 12.9 per cent of the respondents (Table 7.22). The typical profile of these farmers are as follows; majority of these farmers have primary and secondary education (Table 7.5), family size between 7-9 (Table 7.8) and access to extension services (Table 7.16). This implies that education, large family size and access to extension education could improve the possibility of having off farm employment for this group of farmers.

In a study by Yang, Wan and Bi (2020) in China on off-farm employment and grain production change: new evidence from China, it was reported that there was a positive effect of off-farm employment on grain production. The positive effect was that off-farm employment increases household income and loosen the household's budget constraint on agricultural production i.e., they could afford to pay for more inputs such as fertiliser.

7.6.4 Use of an improved variety

This measure relates to technological adoption, which was discussed in chapter 4, section 4.4. Beyond off farm employment, farmers could change what types of crops they cultivate to an enhanced variety as the climate changes. Growing drought-resistant crop variety is a vital adaptation option chosen by farmers in developing countries (Legesse, Ayele, & Bewket, 2013; Tesfaye & Seifu, 2016). 12 per cent of farmers in the survey reported this strategy, albeit that it was the third most reported adaptation option practised. This outcome is in consonant with the results of Ogalleh, Vogl, Eitzinger, & Hauser, 2012; Tesfaye & Seifu, 2016). The reason for this is that improved varieties may be more susceptible than existing varieties to climate variation (Gandure, Walker & Botha, 2013; Tesfaye & Seifu, 2016).

After reviewing the profile of this 12 per cent of farmers, their characteristics were as follows; For access to credit, 9.1 per cent of these farmers had access to credit facility (Table 7.17). For education, 4.3 percent and 5.3 per cent had primary and secondary education respectively (Table 7.5). As for family size, 2.9 per cent, 5.3 per cent and 3.8 per cent of the farmers who adopted this adaptation strategy had household sizes of 4-6, 7-9 and 10-12 respectively (see Table 7.8). Moreover, 6.7 per cent of the group of farmers that adopted this adaptation option had access to extension services, while 5.3 per cent did not have access (Table 7.16). This implies that these factors could be a determinant of this adaptation option for this group of farmers.

In an area such as Cross River State where erratic rainfall pattern occurs, moisture stress is expected to be a constraint on plant growth. Therefore, a favourable adaptation option may be to plant fast-growing varieties to avoid drought or heat stress during sensitive stages of plant development. Moreover, provision of such type of crop variety in areas with erratic rainfall patterns should be a common goal for many government policies in Africa, and such an adaptation option would appear auspicious anywhere climate change is expected to shorten growing seasons (Legesse et al., 2013; Tesfaye & Seifu, 2016; Ogallah et al., 2017).

On the contrary, in areas where moisture is relatively constant, a movement to cultivating longer-maturing variety of crops may be preferred whereas, in areas with recurring droughts with higher temperatures, the optimum decision will be to take the option of a short duration crop variety to avoid considerable losses in arid periods or take a longer-maturing crop variety that will likely sustain average yields as the climate warmth (Tesfaye & Seifu, 2016). According to Tubiello, Rosenzweig, Goldberg, Jagtap, and Jones (2002), they reported in their study that substituting to longer-maturing winter wheat variety in areas with abundant moisture completely offsets the 15 per cent estimated yield decline under climate change.

7.6.5 Changing planting date

One of the most important on-farm climate change adaptation measures is the option of shifting planting date when the weather is not favourable. Farmers have previously demonstrated year-to-year alterations in planting dates in an attempt to cope with climate variability. Such farmers are mainly the ones who are in the areas where agriculture is rain-fed, and for that reason, they have to delay for the start of the rainy season before planting (Tesfaye & Seifu, 2016; Ogallah et al., 2017). Consequently, 10 per cent of the farmers in the study area reported to adopt this adaptation option in Cross River State by changing planting times to correspond with the change in the rainfall pattern (see Table 7.22).

Although this adoption is low, out of the 10 per cent, 5.7 per cent had access to credit facilities, while 4.3 per cent did not (Table 7.17). Also, this group of farmers include 6.7 per cent of respondents who had access to extension services and 3.3 per cent who did not (Table 7.16). This implies that access to credit facilities and access to extension services could improve the adoption of this strategy by this group of farmers. The low adoption of this strategy in the study area could be because of the lack of adequate knowledge of the opportunities as only 44 per cent of the respondents had access to secondary education (Table 7.1).

In most parts of Africa, farmers regularly change planting dates by one month or more from year to year in response to climate change (Tadross & Hewitson, 2005; Tesfaye & Seifu, 2016; Ogallah et al., 2017). Besides, empirical studies revealed that systematically altering of planting time by being two weeks earlier converts what would have been regarded as 20-25 per cent yield loss into a profit or breakeven (Tubiello & Rosenzweig, 2002; Gandure et al., 2013). This is due to cold temperatures restraining early planting in the present climate of the area, thereby exposing the crop to high temperature and drought stress during sensitive phases of plant growth. Also, hotter climates seem to support earlier planting and further reduces stress during critical growth stages (Gandure et al., 2013; Sarker, Biswas & Maniruzzaman, 2015).

The majority of the farmers in sub-Sahara Africa, particularly those in areas with low amount of rainfall have switched from planting high water-requirement crop to small water-requirement crops (Deressa et al., 2008; Gandure et al., 2012; Juana, et al., 2013; Ogallah et al., 2017). Whereas crop farmers in areas where floods are recurrent plant shorter-maturing crops and further altered the planting and harvesting dates to evade crops growing and being harvested during the intensive rainfall period (Acquah & Onumah, 2011; Juana et al., 2013). Changing planting times may perhaps be beneficial to farmers in places with recurrent temperature extremes in the present growing season (as the temperature increases) if irrigation measure is available for most of the time in the year (Tesfaye & Seifu, 2016). However, the result of this present shows that only 10 per cent respondents in the study area chose to change planting dates as one of the adaptation strategies in response to climate variability.

This strategy however needs to consider knowledge exchange and provision of information to the farmers and from the farmers to extension officers. Also, there is need for a reliable weather forecast system to help farmers in changing planting date in order to choose a favourable planting time.

7.6.6 Reducing bush burning (soil conservation)

Soil conservation practices have been associated with one of the ways to address climate variability because the techniques preserve the soil nutrient available for crops by having zero or minimal disturbance of soil structure, thereby reducing soil erosion (Dumanski & Peiretti, 2013; Tesfaye & Seifu, 2016). Reducing or stopping bush burning, as a soil conservation technique, reduces soil loss from farmland, preserves vital soil nutrients, and therefore increases crop yield (Tesfaye & Seifu, 2016; Ogallah et al., 2017).

As shown in Table 7.22, 4.3 per cent of the farmers in the study group indicated the option of reducing bush burning as a coping strategy in response to changes in climate in the study area. When the profile of these 4.3 per cent of farmers was analysed (see Table 7.5), the findings showed that all the respondents in this group had one form of education: primary (1.9), secondary (1.9) and tertiary (0.5). This indicates that education could determine the level of adoption for this adaptation strategy.

7.6.7 Other adaptation strategies

Food crop farmers have also practised planting of trees and expansion of farm size to cope with climate change (Deressa et al., 2008; Fosu-Mensah, Vlek, & Manschadi, 2010; Acquah & Onumah, 2011; Sofoluwe, Tijani, & Baruwa, 2011; Gandure et al., 2012; Juana et al., (2013) and Tesfaye and Seifu (2016). Accordingly, farmers in the study area at different proportions (Table 7.22) adopted these strategies to cope with the inconsistency in climate.

However, yam farmers in Cross River State in the study group reported they have adopted a variety of adaptation strategies. The uptake is low and so it is worth considering the barriers to adoption of such strategies and how they can be reduced.

7.7 Barriers to the adaptation to climate change by farmers in Cross River State

According to Ndamani and Watanabe (2016), determinants such as accessibility and utilisation of weather information, the institutional situation, and the socio-economic conditions of households may have effects on farmers' ability to adapt to changes in climate. Moreover, farmers' ability to cope or adjust has been challenged by numerous constraints in the study area. The study, however, observed the barriers to the adoption of various adaptation strategies to cope with climate change in the study area, and they are given in Table 7.23.

Table 7.23: Barriers to the adaptation to climate change by farmers (N=209)

Barriers to adaptation	Frequency	Percentage
Lack of credit facilities	53	25.4
High cost of improved varieties	47	22.5
Lack of adequate information about weather forecast	39	18.7
Illiteracy of farmers	29	13.9
Poor access to land	20	9.6
Farm labour shortage	17	8.0
Others	4	1.9

Source: Field survey, 2018

The data collected revealed that the most common barrier reported by the farmers is the lack of credit facilities (25.4 per cent). The profile of farmers in this group are mostly farmers who have off farm employment (see Table 7.24). Most of the farmers in this group also adopted the use of improved variety and planting of trees as strategies to cope with climate change (Table 7.25).

According to literature, adaptation is expensive. For example, if a farmer decides to introduce a new crop on his farmland as climate becomes hotter, that will mean the farmer will have to pay for new seeds and equipment (inputs) specific to the new crop (Dinar *et al.,* 2008; Sarker et al., 2013; Tesfaye & Seifu, 2016). The access to credits and loans could be a good way of overcoming this constraint. Thus, this suggests why a lack of credit facilities is a significant barrier to adaptation in the study area.

Table 7.24: Frequency distribution of the household according to barriers to adaptation and involvement in non-farm jobs

Barriers to adaptation	Off farm employment		Total
	Yes	No	
Lack of credit facilities	33	20	53
High cost of improved varieties	33	14	47
Lack of adequate information about weather forecast	20	19	39
Illiteracy of farmers	19	10	29
Poor access to land	15	5	20
Farm labour shortage	13	4	17
Others	3	1	4
Total	136	73	209

Source: Field survey, 2018

Another significant barrier to adaptation reported as being faced by the respondents are high cost of improved varieties (22.7 per cent). Majority of the farmers in this group have non-farm jobs (Table 7.24). A good number of the respondents in this category adopted planting of different varieties and the use of inorganic fertilizer as measures to cope with climate change (See Table 7.25).

Other barriers include lack of adequate information about weather forecasts (18.5 per cent), illiteracy of farmers (14 per cent), poor access to land (9.4 per cent) and farm labour shortage (8 per cent) as the least constraint affecting the farmers' adaptation. These barriers to adaptation by the respondents in the study area are also identified as constraints faced by the farmers in previous adaptation studies (Ofuoku, 2011; Sarker et al., 2013; Sarker et al., 2015; Ogallah et al., 2017).

Table 7.25: Frequency distribution of respondents according to barriers to adaptation and adaptation strategy

Adaption strategy	Barriers to adaptation							Total
	Lack of credit	High cost of improved variety	Lack of adequate weather information	Illiteracy of farmers	Poor access to land	Farm labour shortage	Others	
No adaptation option	0	6	0	0	0	0	0	6
Use of improved variety	2	12	7	4	0	0	0	25
Change of planting date	0	0	4	7	3	4	3	21
Planting of trees	1	10	4	0	0	0	0	15
Use of inorganic fertilizer	0	5	10	8	8	5	6	42
Reduce bush burning	1	3	3	1	1	0	0	9
Expansion of farm size	0	0	1	2	2	0	0	5
Off-farm employment	0	8	5	4	4	3	3	27
Planting of different varieties	0	9	13	13	11	8	5	59
Total	4	53	47	39	29	20	17	209

Source: Field survey, 2018

7.8 Chapter summary

This chapter developed a comprehensive profile of yam farms and their households within the study area. To validate the data across the two regions of Ikom and Ogoja in Cross River state and understand if this data can be used as one homogenous data set, a t-test was conducted, and it suggested that these two farming groups are not different.

The socio-economic characteristics of the farmers (such as age, farming experience, household size and farm size), their institutional accessibility (such as access to weather information and access to market) and farming systems were analysed in depth and a profile was provided to further support the research objectives of the study.

The chapter then went on to investigate research objective 3 and revealed that the perception of Cross River State Yam farmers to climate change effect includes erratic rainfall pattern, hotter days, increase in delay of onset of rainfall and long duration of rainfall. Added to this, the observed effect of climate change in the study area includes a decline in crop output, late maturity of crops, pests and disease outbreak and the delay in planting period.

Furthermore, the barriers to adaptation encountered by the farmers include lack of credit facilities, high cost of improved varieties, lack of adequate information about the weather forecast, illiteracy of farmers, poor access to and control of land and farm labour shortage (the least constraint affecting the farmers' adaptation). The findings of this research continue in the next chapter and report the impact of climate change on yam production.

The thesis now moves forward with this profile of the yam farms and their households to study the yam output as it responds to climate change.

Chapter 8 Yam output response to variability in climate in Cross River State

8.1 Introduction

According to literature, there are studies on the impact of climate change on agriculture in Nigeria using secondary time series data at state and national level (Agwu et al., 2012; Enete, 2014; Eregha et al., 2014; Akinbobola et al., 2015; Chikezie et al., 2015; Iheoma, 2015; Nwaobiala & Nottidge, 2015; Mbanasor et al., 2015; Elijah, Osuafor and Anarah, 2018). Nevertheless, very few of these studies using time series data determined the stationarity (level of integration) properties of the data which is a precondition for the estimation of time-series data that is for more than 20 years (Sarkar et al., 2012; Eregha et al., 2014; Chikezie et al., 2015; Verter & Bečvářová, 2015). For this reason, the high R-squared values estimated by these studies are spurious regression resulting in a biased estimate. Additionally, these studies did not address the problem of autocorrelation, heteroscedasticity, and multicollinearity. However, these issues need to be addressed to achieve an unbiased estimate (Sarkar et al., 2012; Tesso, Emana & Ketema, 2012; Mbanasor et al., 2015).

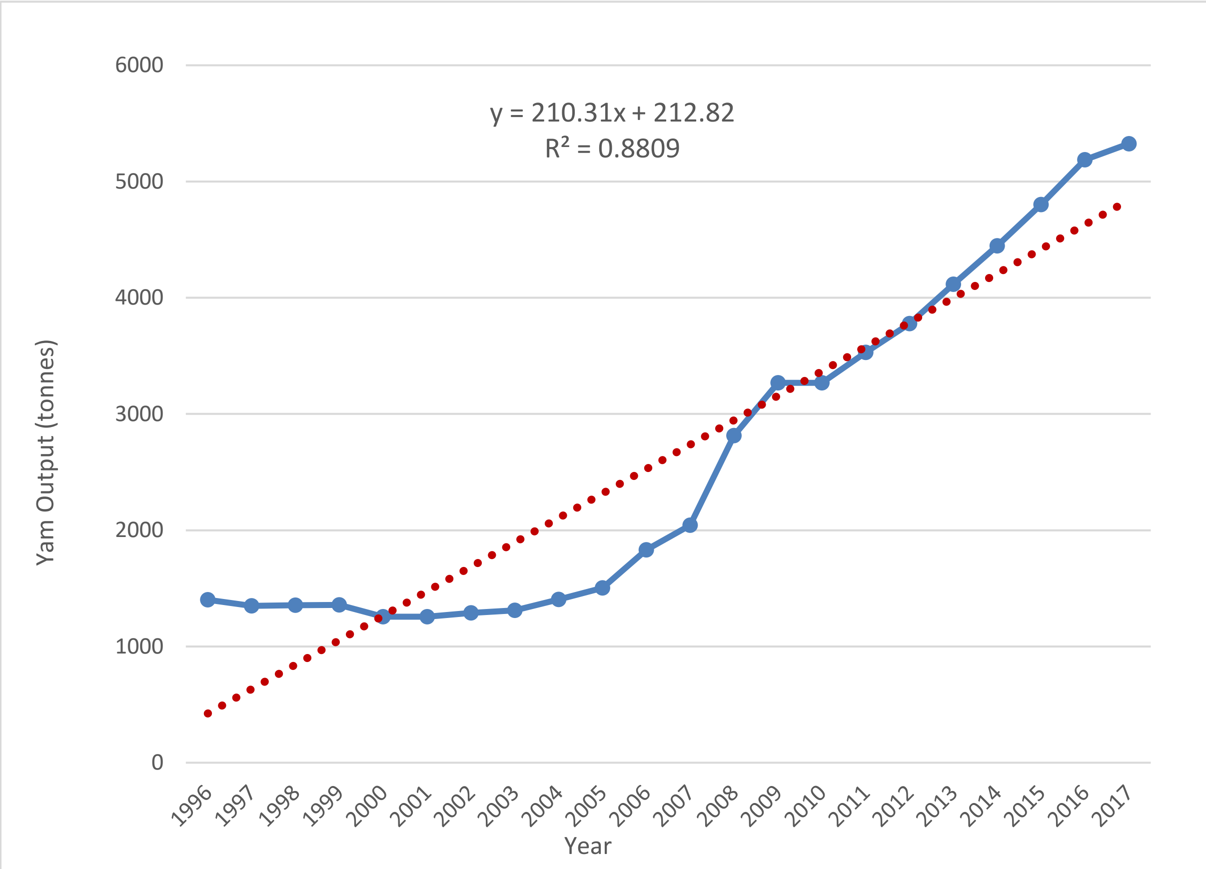
Consequently, this chapter attempts to fill this gap created in the literature while addressing the impact of climate change on yam production, which directly relates to research objective 1: Analyse the impact of climate variables on yam production at the state level for the period 1996-2017. The data was collected for 21 years because this was the available secondary data in the relevant database (NPAFS, 2018 and FMW&WR, 2018) at the time this study was conducted. This element of the study could only be undertaken using the secondary data available. This may be a limitation in the study. As a prerequisite for the estimation of time series data, a unit root test was carried out using the Augmented Dickey-Fuller (ADF) test to examine each of the study variables to detect the presence of a unit root. This estimate is carried out in this study to ensure that the results obtained are not spurious. However, the overall estimation was done in the following order; Unit root test, Johansen's cointegration test, trace test, the Error Correction Model test, and finally, the post regression test.

8.2 Trend analysis of yam production

Using data from NPAFS (2018) and FMW&WR (2018), Figure 8.1 below illustrates the trend analysis of yam production for the period under study (1996-2017). In this study we are looking at yam production as measured in terms of farm output in tonnes.

The trend analysis shows an upward trend in yam production for the entire period. Nevertheless, low output in yam was observed for the period 1996-2004. The low output of yam observed during this period may have been due to the decline in the total labour force in agriculture from 59 per cent in the 1981-1995 sub-period to 45 per cent in the 1996-2000 sub-period (Nwaobiala & Nottidge, 2015).

However, the trend analysis reveals that there has been a steady increase in the output of yam between the years 2005 and 2017 in the study area, as shown in figure 8.1. This persistent higher rates in yam output may be as a result of the implementation of the structural adjustment programme (SAP) in Nigeria, which was introduced around 1986. Furthermore, this increase was perhaps achieved through capital expenditure in agriculture having a higher growth rate than the growth rates found in other sectors of the economy in Nigeria (Ayindea, et al., 2011; Nwaobiala & Nottidge, 2015). More so, during the period under study, the maximum output was 5326 tonnes in the year 2017, whereas the minimum was 1256 tonnes in the year 2007. The mean output of yam was 2690 tonnes across the period under study (1996-2017). The findings of this analysis correspond to that of Verter and Bečvářová (2015) who worked on the analysis of yam production in Nigeria. Their study reported that the output of yam in Nigeria was on an upward trend from the period 1994-2012.



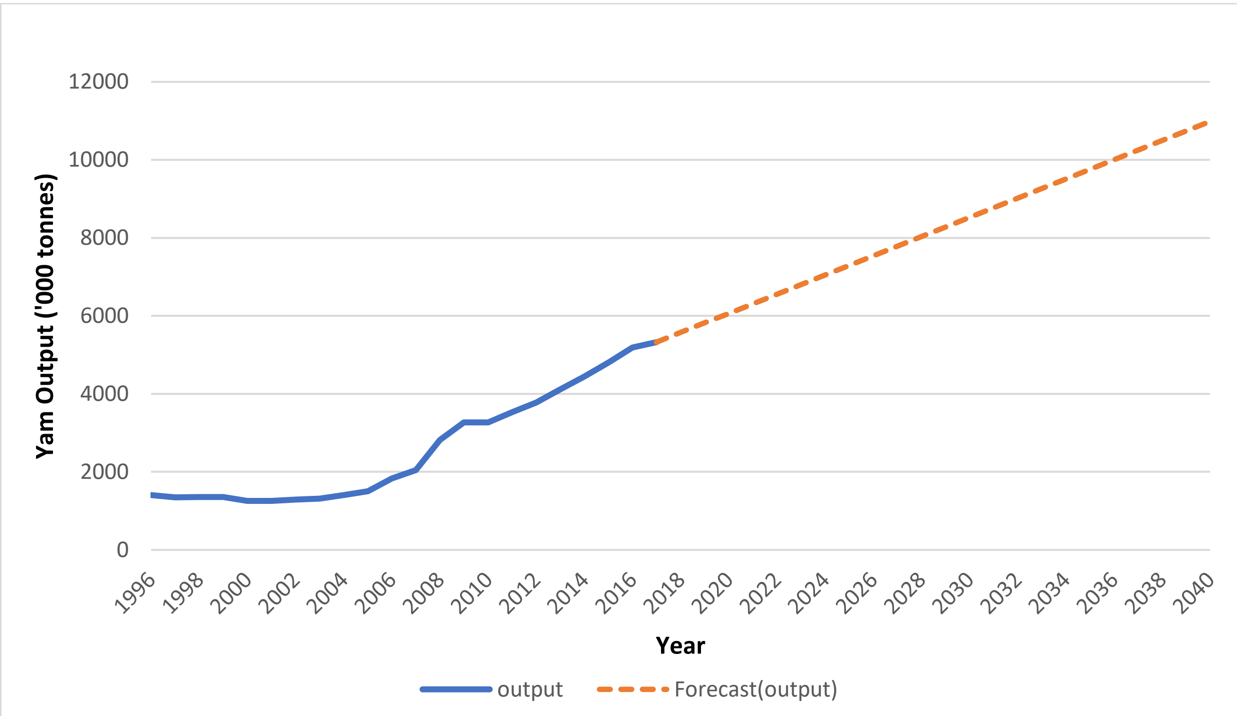
Source: Author's computation from data obtained from NPAFS (2018) and FMW&WR (2018)

Figure 8.1: Trend analysis plot for yam output in Cross River State ('000 tonnes)

This, however, contradicts a study by Chikezie et al. (2015), who examined the effect of climate change on selected food crop production in South-east, Nigeria. In their research, they found out that yam production was on the decline, moving in a downward trend from the year 1984-2012. This difference could be as a result of the different peculiarities of the regions covered by these studies.

In addition, the coefficient of variation (CV), also called relative variability, which is simply the measure of the dispersion of the variable was determined. The CV was estimated to be 54.43 per cent. This implies a high variability in the rate of yam output for the period under study. Also, the R squared in the trend analysis is 0.8809, which indicates that the trend line fits about 88 per cent of data values.

Furthermore, the yam production forecast in figure 8.2 suggests that there will be a rise in yam output for the next 20 years in the study area. The statistical package used for the forecast was the SPSS version 20. This prediction is, therefore, in agreement with research by Jalloh et al. (2013) on the topic of West African agriculture and climate change: a comprehensive analysis. The outcome of their study predicted that yam output in Nigeria would increase towards 2050.



Source: Author's computation from data obtained from NPAFS (2018) and FMW&WR (2018)

Figure 8.2: Distribution of yam production ('000 tonnes) and future projection

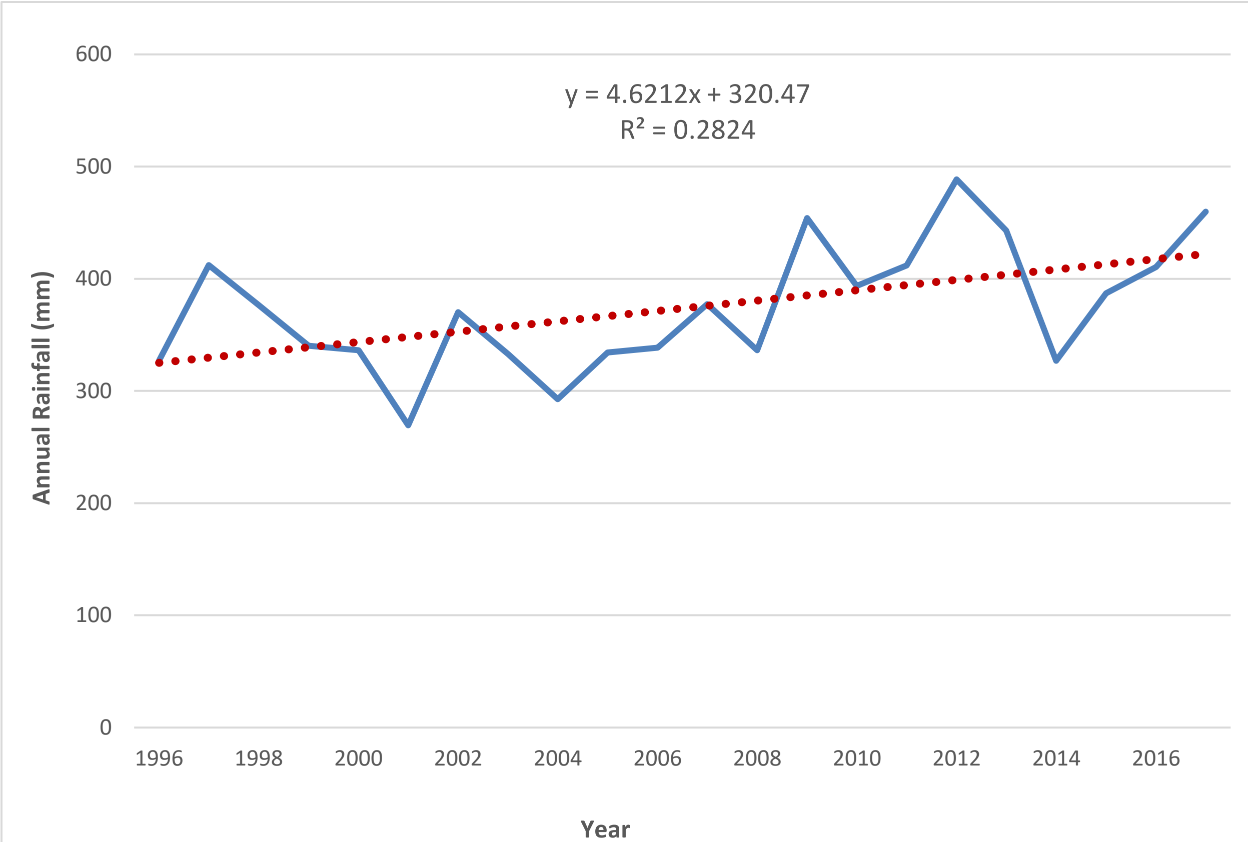
Even though yam output in predicted to increase over time, there will come a time where the law of diminishing returns will set in. This law implies that, as one input variable is increased, there is a point at which the marginal increase in output begins to decrease, holding all other inputs constant. At the point where the law sets in, the effectiveness of each additional unit of input decreases. Fixed cost is a factor that can lead to diminishing returns in the output of yam in figure 8.2. For example, yam farmers may choose to take an additional adaptation strategy like switching to a new crop to cope with the effects of climate change on yam. This will in turn lead to a reduction in the output of yam, therefore, creating diminishing returns. At this point, the graph in figure 8.2 will plateau.

8.3 Trend analysis of climate variables

8.3.1 The trend of annual rainfall

The figure below (figure 8.3), reveals the existence of rainfall variability and irregularity in the study area (Cross River State). The graph showed that rainfall was in an unstable movement from 1996-2017. The minimum annual rainfall was 269.40mm and experienced in the year 2004, while the maximum yearly rainfall was 488.60 mm experienced in the year 2012 during the period under study. The mean rainfall for the study period was estimated to be 373.61mm. However, the coefficient of variation was 55.11 per cent, which implies high variability in rainfall in the study area. This fluctuation in rainfall confirms the changes in weather patterns over time (Angba, Baines & Butler, 2020).

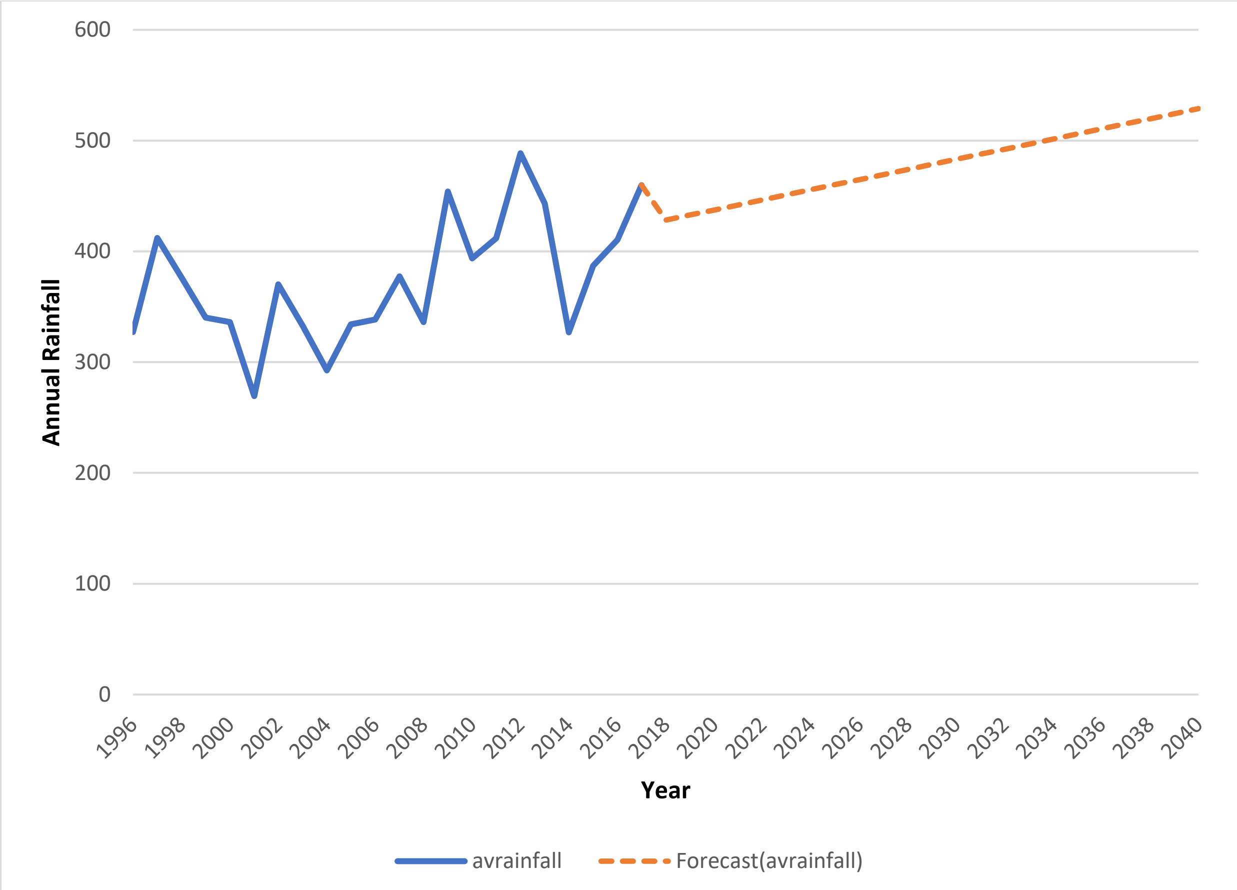
Further, the R-squared of 0.282, which signifies goodness of fit in the analysis, means that the trendline fits about 28 per cent of the data values. This means that the predictors (years) don't explain a large proportion of the variability of the dependent variable (rainfall) in the outcome. The result implies that 28 per cent of variability in annual rainfall is explained by the years considered (Angba, Baines & Butler, 2020).



Source: Author's computation from data obtained from CBN (2018)

Figure 8.3: Trend analysis plot for annual rainfall (mm) in Cross River State

Moreover, figure 8.4 shows the future predictions of annual rainfall in the study area using the SPSS statistical package. It reveals that annual rainfall is estimated to be on the increase in 20 years' time in the study area. This result is, however, not conclusive as it is challenging to predict so far into the future, particularly when there is so much seasonal variation.



Source: Author's computation from data obtained from CBN (2018).

Figure 8.4: Annual rainfall distribution in millimeters and future projection

8.3.2 The trend of annual temperature

Figure 8.5 shows the trend in annual temperature in Cross River State. The trend line shows an overall downward trend in movement. A decline in annual temperature was observed from 1996- 2005, and then a sharp increase between the years 2006 and 2008. It, however, continues to decline from 2008 to 2017 in an unsteady movement. During the period under study, the minimum annual temperature was 26.3^{0}C in the year 2015, while the maximum annual temperature was 28.9^{0}C in the year 1996. The mean temperature for the period under study was estimated to be 27.4^{0}C (Angba, Baines & Butler, 2020). Moreover, the relative variability was 24.1 per cent. This implies that variation in temperature in the study area for the period under study was not high. The R-

squared is estimated to be 0.8571, which is an indication that the trend line fits about 86 per cent of the data values. This also implies that 86 per cent variability of annual temperature is explained by the years considered (Angba, Baines & Butler, 2020).
Source: Author's computation from data obtained from CBN (2018)

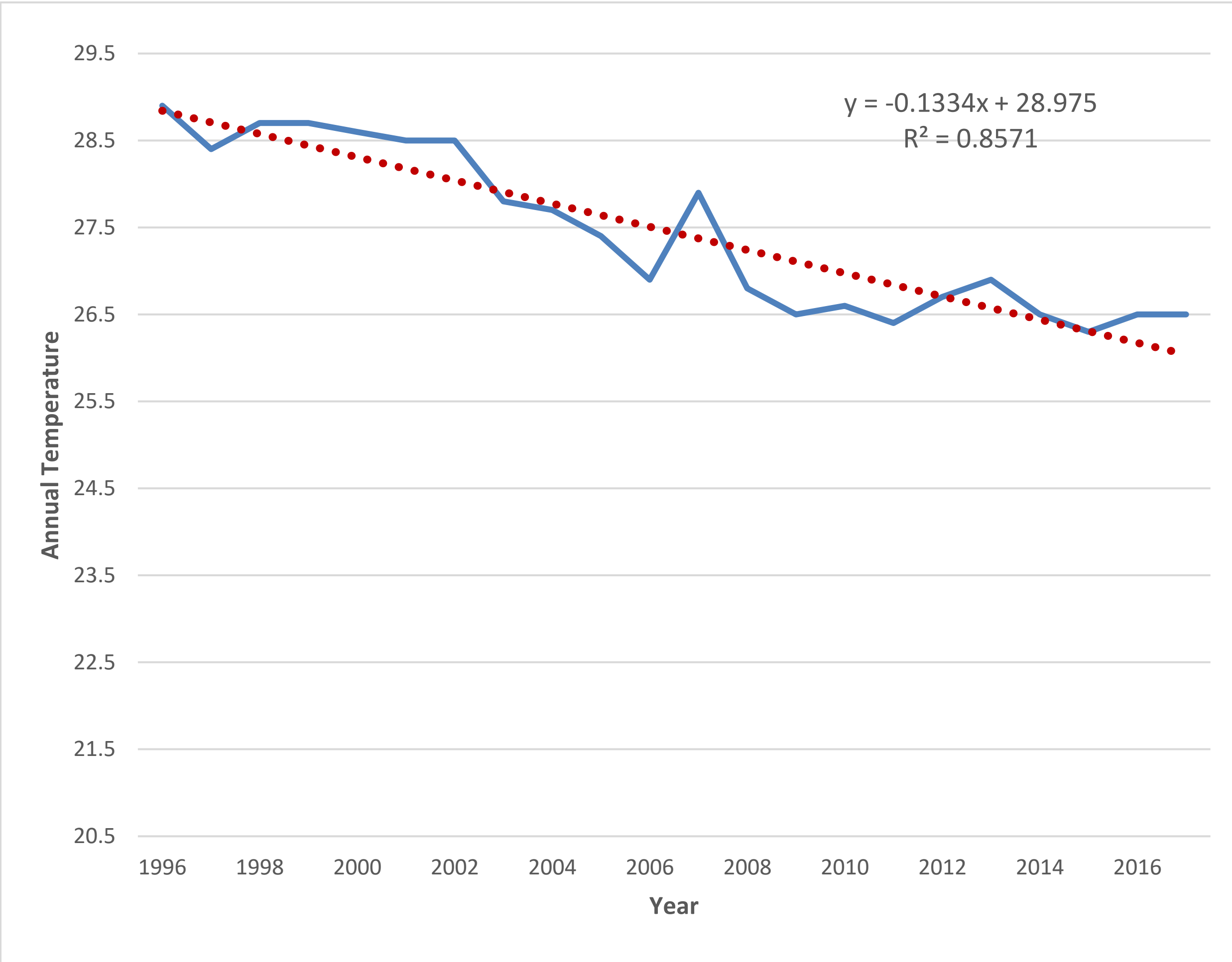
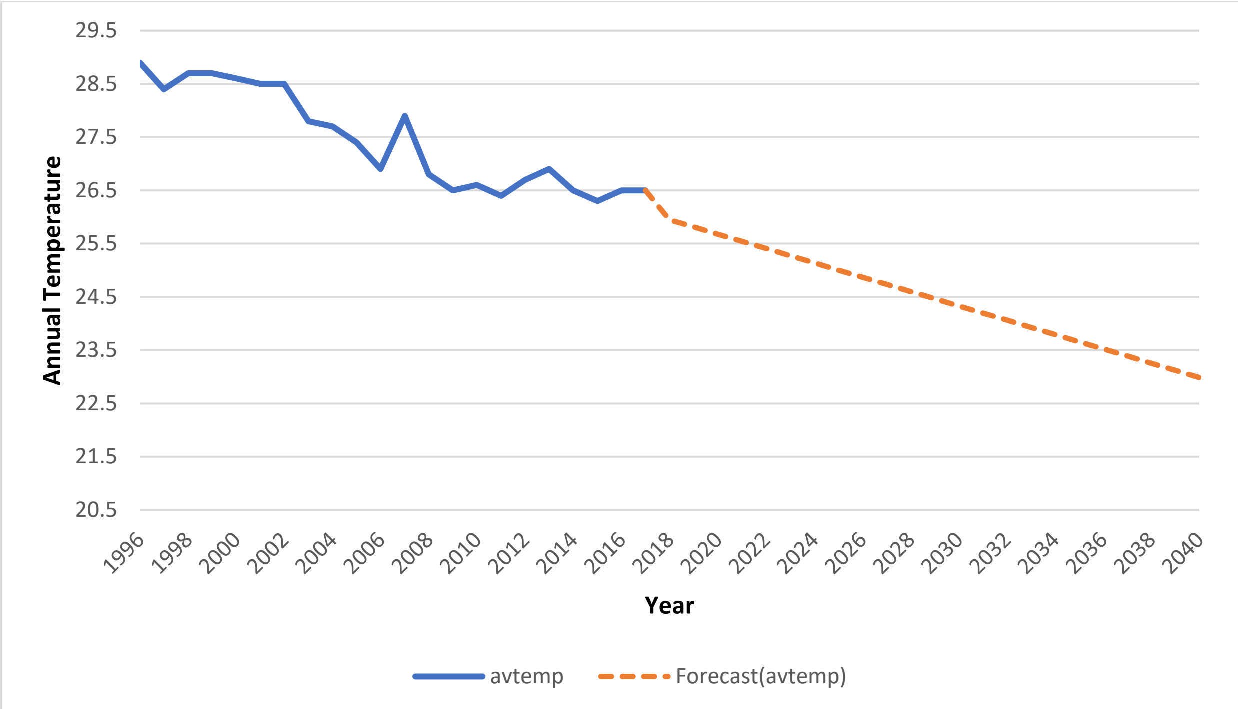


Figure 8.5: Trend analysis plot for annual temperature (^{0}C) in Cross River State

Additionally, figure 8.6 presents the temperature forecast for the next 20 years in Cross River State. The figure demonstrates that the annual temperature is predicted to continue to decrease over the next 20 years.



Source: Author's computation from data obtained from CBN (2018)

Figure 8.6: Annual temperature distribution in ^{0}C and future projection

8.4 Theoretical overview and evaluation of the climate change variables on yam production

Looking further forward, the yields of root and tuber crops including yam, which is presently on the decline, are predicted to increase in Nigeria towards 2050. As a result of the increase, exports are projected to grow indicating projected food surplus for the country (Jalloh *et al.,* 2013). Moreover, the impact of climate change will vary according to location, soil type, crop, and other local factors; consequently, so it is essential to conduct enterprise-specific analysis (Ater & Aye, 2012; Sarker et al., 2012). In a review by Knox, Hess, Daccache and Wheeler (2012), it was indicated that for yams, there were too few studies to comment on whether there has been any significant impact of climate change on the yield in West Africa. As a result, the next part of this section attempts to analyse the impact of climate change on yam production in Cross River State over the period of 21 years (1996-2017).

8.4.1 Stationarity and non-stationarity of time series

Time series data is made up of observations, which are considered as an understanding of random variables that can be described by some stochastic processes (da Cunha *et al.,* 2018). However, the notion of stationarity is associated with the properties of these stochastic processes. Following Zhang, Robinson and Yao (2019), this study will adopt the concept of weak stationarity, which implies that the data series are assumed to be stationary if the properties such as means, variances, covariances and autocorrelation of the series are independent of time (i.e., constant over time), rather than the whole distribution. On the other hand, non-stationarity in a time series arises when the properties such as the means or variances or both are not constant over time. The most important source the non-stationarity in time series originates is from sources of the unit root (Zhang et al., 2019).

8.4.2 Unit root (stationarity) test

Applying the Johansen's cointegration technique involves some preliminary testing of the time series to ensure the time series variables are integrated of order one, that is to say, testing for the presence of unit root. Given that time series data is susceptible to spurious regression outcomes, it is important to carry out a unit root test prior to estimating the econometric model (Verter & Bečvářová, 2015). In other words, the time series analysis starts by carrying out a unit root test to determine the stationarity or non-stationarity of the variables and to ascertain the suitability of the model specification. Accordingly, the Augmented Dicky Fuller (ADF) tests were employed to check if each of the variables possesses unit root (that is, to check the stationarity of the data series).

The ADF equation is provided as follows;

$$\Delta Y_t = \delta Y_{t-1} + \epsilon_t \qquad (1)$$

where Δ = the first difference operator, δ = (φ-1) and ϵt denotes a serially uncorrected white noise error term with a mean of zero and a constant variance.

The ADF test reduces autocorrelation in the error term because it involves the first difference in lags such that the error term is distributed as white noise (Gujarati, 2004; Eregha, Babatolu & Akinnubi, 2014). Table 8.1 shows the result of the ADF-test. It reveals that all the variables are integrated of order one [I(1)], (@ Level), indicating non-stationarity (presence of unit root) of the time series data. In this circumstance where the time-series variables under consideration are non-stationary, it, therefore, implies that the result produced by the regression using these variables in the classical framework will be a spurious regression result, except their linear combination provides a stationary residual (Gujarati, 2004; Tesso et al., 2012; Zhang et al., 2019).

Moreover, since most of the variables follow order one [I(1)] process (that is, are integrated at the same order), the next stage is to test if there exists a long-run relationship (cointegration) among the variables. Nevertheless, the variables of integrated order one [I(1)] need to undergo first difference before an estimation can be carried out (Gujrati 2004; Sarkar et al., 2012; da Cunha et al., 2018). However, the study variables became stationary after the first difference exception of the output of yam, which is confirmed by the ADF-test statistics in Table 8.1. Since the weather series are integrated of the same order, the cointegration technique was employed to ascertain if a stable long-run relationship exists between the time series. Consequently, the stationarity of the linear combination of the variables in integration order one [I(1)], were tested, and the outcome is presented in the next section using Johansen’s multivariate approach.

Table 8.1: Result of unit root test from Augmented Dickey-Fuller Test

Variables	@ Level				1stdifference			Decision
	ADF stat.	**P-value**	**Order of integration**	**Decision**	**ADF statistics**	**P-value**	**Order of integration**	
Yam output	-2.262	0.433	I (1)	Non-stationarity	-2.577	0.293	I (1)	Non-stationary
Rainfall	-3.526	0.062	I (1)	Non-stationarity	-4.725	0.007***	I (0)	Stationary
Temperature	-3.000	0.155	I (1)	Non-stationarity	-4.583	0.009***	I (0)	Stationary

Source: Author's computations from data obtained from CBN, NPAFS and FMW&WR
Note that *** indicates rejection of the null hypothesis (presence of a unit root) at a 5 per cent level of significance.

8.4.3 Cointegration test (Long term co-integrating relationship)

In a situation of non-stationary time-series, cointegration offers suitable statistical procedures to examine the presence of a long-term relationship between climate variables (Tesso et al., 2012). Thus, the weather series for stationarity in levels and the first difference are tested. In time series econometrics, the climate variable that is integrated of order one is represented by $C_t \sim I$ (1), and climate variable that is integrated of order zero is denoted by $\Delta C_t \sim I$ (0). In a case where time series are discovered to be non-stationary at levels, but stationary in first difference, cointegration procedures will probably be implemented (Natanelov, McKenzie & Van Huylenbroeck, 2013). Subsequent to the completion of unit root test on the time series, and with the assumption that the time series are integrated of the same order, a multivariate Johansen test was conducted on all the variables to investigate cointegration.

According to Zhang et al., (2019), the Johansen procedure is a maximum likelihood technique that verifies the number of cointegrating vectors in a non-stationary time series Vector Autoregression (VAR). The cointegration process is based on a Vector Autoregressive (VAR) model that is not restricted specified in an error-correction form (Johansen & Juselius, 1990; Johansen, 1988; Natanelov et al., 2013). The Johansen's estimation model is represented mathematically below;

$$\Delta X_t = \Pi X_{t-1} \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t\_i} + \Phi \mathcal{D}_t + \mathcal{V}_t$$

where X_t denotes all n variables of the model which are integrated of order one; Π, Γi, and φ denote the parameter matrices to be estimated; D_t represents a vector with deterministic elements (constant, trend and dummy) and V_t represents a vector of random errors which follow a Gaussian white noise process. The equation above indicates that there cannot be an existence of any relationship between a variable with a stochastic trend which is integrated of order 1, and a variable without a stochastic trend which is integrated of order 0.

Consequently, if $\Delta C_t \sim I$ (0), it means Π will be a matrix of zeros, unless when a linear combination of the variables in C_t is stationary. The Johansen test for cointegration, however, estimates the rank (r) of the matrix Π. Secondly, if r=0, then all variables are integrated of order one, and therefore not cointegrated. In the event 0 < r < N, it implies the existence of r cointegrating vectors. Thirdly, if r=N, then all the variables are integrated of order zero, hence stationary. And this means any combination of stationary variables will be stationary. Π signifies the long response matrix and is defined as the product of two matrices designated as α and β, of dimension (g x r) and (r x g), respectively. The β matrix comprises of the long-run coefficients of the cointegrating vectors. The α, on the contrary, is known as the adjustment parameter matrix, which is like an error correction term. In addition, the linear combinations βX_{t_k} of this matrix will be integrated of order zero, in the situation where the time series are cointegrated. That is to say, supposing, rank of Π=r=K, then the variables at levels are stationary, indicating that no integration occurs. In the case of rank Π=r=0, this signifies that all the elements in the adjustment matrix have zero value. Thus, none of the linear combinations is stationary.

Following the Granger representation theorem, when K > 0 and rank of Π (r) <K, it means there are r cointegrating vectors or r stationary linear combinations of the variables (Engle & Granger, 1987; Natanelov et al., 2013). The Johansen cointegration technique evaluates the Π matrix via an unrestricted Vector Autoregression and further tests if one can discard the restriction the reduced rank of Π implies. The two approaches for testing for reduced rank of Π are the trace test and the maximum eigenvalue which are expressed mathematically as follows;

$$\lambda_{trace} = -\mathrm{T} \sum_{i=r+1}^{n} (1 - \lambda^2)$$

$$\lambda_{max}(r, r+1) = -\mathrm{T}(\mathrm{I}n1 - \lambda_{r+1})$$

where λ_i represents the estimated values of the ordered Eigenvalues, whereas T denotes the number of observations after adjusting the lag. Additionally, the trace statistics test the null hypothesis that says the number of distinct cointegrating vectors (r) is less than or equal to 1, against the overall alternative hypothesis. The maximum Eigenvalue, however, tests the null hypothesis that states that the number of cointegrating vectors is r, against the alternative hypothesis of r+1 cointegrating vectors. Following similar previous studies, this present study employed the trace test approach (Eregha et al., 2014; Natanelov et al., 2013; Zhang et al., 2019).

8.4.4 Johansen cointegration test result

Table 8.2 below shows the results of the trace statistics from the Johansen cointegration test, which suggests a strong rejection of the null hypothesis. The results imply that the hypothesis of no cointegration among the variables can be rejected for the model used. The results further revealed that two cointegrating vectors exist among the study variables in the model. Hence, the rejection of the hypothesis of no co-integrating relationship among the variables (rainfall and temperature) under investigation. The result, however, infers that there exists a cointegrating long-run relationship among the time series at 0.05 per cent level of significance. Nevertheless, the trace test indicated that the hypothesis of one co-integrating equation could not be rejected (Angba, Baines & Butler, 2020).

As soon as cointegration between time series is recognised, it is important to investigate the causality of each cointegrating pair. The causality from the estimated Johansen Vector Error Correction Model (VECM) is evaluated via a likelihood ratio (LR) test by using a restricted disequilibrium error term (Natanelov et al., 2013; Zhang et al., 2019).

Table 8.2: Unrestricted Cointegration Rank Test (Trace)- shows cointegration between the variables

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.
None*	0.749	56.98	47.856	0.005
At most 1*	0.562	30.72	29.797	0.039
At most 2	0.444	15.04	15.495	0.068
At most 3*	0.184	3.881	3.841	0.048

Source: Author's estimation
Trace test indicates 2 cointegrating equations at the 0.05 level; *denotes rejection of the hypothesis at the 0.05% level. Note that None = (r≤0); At most 1 = (r≤1); At most 2 = (r≤2); At most 3 = (r≤3).

In view of the presence of long-term relationships recognised among the study variables, the analysis, therefore, undertook an error correction model (ECM) estimation approach. Consequently, the outcome of the ECM is made known in the following sub-section.

Alternatively, the long run cointegrating relationship was tested using the Engle and Granger technique. The results are shown in Table 8.3 below. It reveals that the R-squared value of 0.981 (98 per cent) is extremely high, but the Durbin-Watson statistics are low (1.188), implying that using the variables with an ordinary level regression (OLS) will lead to spuriousness. This means that if OLS is used, it will lead to a mathematical relationship in which two or more variables are associated but not causally related, (in this case rainfall and temperature) due to either coincidence or the presence of a certain third, unseen factor. This will in turn produce a fake or spurious result (Angba, Baines & Butler, 2020).

Table 8. 3: Long run relationship (OLS regression)

Variable	**Coefficient**	**Std. Error**	**t-Statistics**	**Prob.**
C	14.428	3.553	4.060	0.000
LOG(AVRAINFALL)	0.150	0.149	1.010	0.326
LOG(AVTEMP)	-3.420	0.991	-3.452	0.003
R-squared	0.981	Mean dependent var		7.730
Adjusted R-squared	0.979	S.D. dependent var		0.550
S.E. of regression	0.080	Akaike info criterion		-2.047
Sum squared residual	0.116	Schwarz criterion		-1.848
Log-likelihood	26.512	Hannan-Quinn criterion		-1.999
F-statistic	323.743	Durbin-Watson stat		1.188
Prob(F-statistic)	0.000			

Source: Author's estimation

Furthermore, in examining the residual, which is the Error Correction Model (ECM), the ADF was used to perform unit root on ECM. The result of the test is shown in Table

8.4. The outcome revealed that since the ADF test statistics of -3.372 is significant at 1 per cent level of significance, the null hypothesis of the presence of unit root in ECM was rejected. It, therefore, means that a linear combination of the three non-stationary series is stationary. In other words, the variables are cointegrated (Angba, Baines & Butler, 2020). Thus, the study proceeded to evaluate the error correction model in the next section.

Table 8.4: ADF unit root test on ECM

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECM(-1)	-0.779	0.231	-3.372	0.003
D(ECM(-1))	0.353	0.204	1.729	0.100
R-squared	0.386	Mean dependent var		0.003
Adjusted R-squared	0.352	S.D. dependent var		0.079
S.E. of regression	0.063	Akaike info criterion		-2.572
Sum squared residual	0.073	Schwarz criterion		-2.472
Log-likelihood	27.72	Hannan-Quinn criterion		-2.552

Source: Author's estimation

8.5 The outcome from the Error Correction Model

By employing a lag length of three as determined by the information criteria, Table 8.5 presents the error correction model result (parsimonious model), which was carefully chosen based on the Akaike information criterion and Schwarz information criterion.

The error correction model results presented in Table 8.5 specifies that the model is devoid of any critical econometric complications. This is so because the Durbin-Watson value of 1.186, which indicated the unit root test statistically addressed the existence of positive autocorrelation. Therefore, the Durbin-Watson statistics shows the non-appearance of serial correction. The F-statistics value of 2.718, however, approved the significant test. Simply put, the value of F-statistics suggests that there exists a significant similarity between each of the climate change variables in the model as the dependent variable, and the independent variables are placed together. This implies that the model was statistically fitted at 1 per cent level of probability, which confirms the general explanatory power of the model (Angba, Baines & Butler, 2020).

Furthermore, the value of the coefficient of determination of the model showed the goodness of fit as the explanatory variables explained 40 per cent of the variation in output of yam, which was used as the dependent variable in the model. In other words, the R-squared value of 0.405 implied that 40 per cent of the total variation in yam production (dependent variable) was explained by the climate variables (independent variables) included in the model, and the remaining 60 per cent are factors that were not analysed in the model. Thus, the results of the error correction model analysis are reliable and can be used to draw inferences (Angba, Baines & Butler, 2020).

Table 8. 5: Results from the Error Correction Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.012	0.023	0.552	0.588
DLOG(AVRAINFALL)	0.119	0.104	1.140	0.271
DLOG(AVTEMP)	-2.875	1.159	-2.479	0.025**
ECM(-1)	-0.477	0.269	-1.771466	0.0955*
R-squared	0.405	Mean dependent var		0.064
Adjusted R-squared	0.256	S.D. dependent var		0.085
S.E. of regression	0.073	Akaike info criterion		-2.181
Sum squared residual	0.086	Schwarz criterion		-1.933
Log-likelihood	27.909	Hannan-Quinn criterion		-2.128
F-statistic	2.718	Durbin-Watson statistics		1.287
Prob(F-statistic)	0.067			

Source: Author's computation
(Note that ** and * indicate that the test statistics are significant at 5% & 10% respectively)

Precisely, the deduction from the ECM results is in line with the theory that climate variables such as temperature played a significant role in the quantity of yam produced in the study area. Rainfall was seen to have a positive coefficient, but this was not statistically significant. This implies that there will be an impact on production as there is reduced moisture stress on the crop, yet analysis shows it is not statistically important, but it is a factor (Mbanasor et al., 2015; Nwaobiala & Nottidge, 2015; Wang et al., 2018). This finding however contradicts the findings of Weli & Bajie, 2017 who reported that rainfall was statistically significant, and reduced rainfall had a negative impact on yam output.

The temperature, on the other hand, was statistically significant and had a negative impact on yam production in the study area. This implies that a rise in the environmental temperature could result in a decline in yam output in Cross River State. The coefficient (-2.875) was statistically significant at a 5 per cent probability level meaning that a 1 per cent increase in temperature will lead to a 28 per cent decrease in yam production. This is true because an increase in temperature encourages the proliferation of pest and diseases, which could be a threat to yam production and yield at the growth and developmental stages. This finding corresponds with the *a priori* expectation since the temperature has shown a downward trend while yam output showed an upward trend during the period under study implying that as temperature decreases, the quantity of yam produced increases. Hence, the lower the temperature, the higher the quantity of yam produced and *vice versa*. This finding also corresponds with a study in North and South China on rice (Wang et al., 2014), in India on rice (Mishra, 2016), another study in China main producing area on rice (Wang et al., 2018) and in Nigeria on yam (Amuwah et al., 2020). These studies reported that temperature is statistically significant and has a negative impact on the output of these crops i.e., as temperature rises, crop output will fall.

However, the Error Correction Model (ECM-1) signifies the long-run adjustment of the model after disequilibrium was seen to be statistically significant. The coefficient (-0.477) of this term specified that annually, about 48 per cent of the deviation from the equilibrium was adjusted back to equilibrium. In other words, the result from the ECM implies that about 48 per cent of variation of yam production from its long-run value is corrected. This outcome demonstrates the presence of a strong co-integration, which in turn indicates that there is a long-run equilibrium relationship between the study variables (Angba, Baines & Butler, 2020).

Looking at previous studies, assessment of the impact of climate change on China's rice production was done using the Cobb–Douglas function by Wang and Wang (2017), in China. They utilised the daily weather information over the whole growing season for the period 1979-2011. The study, based on panel data (1979–2011) from China's main rice-producing areas reported that minimum temperatures (Tmin), maximum temperatures (Tmax), temperature difference (TD) and precipitation (RP) are the four key climate determinants of rice production in China. The study concluded that climate change had made a negative contribution to rice production in China. Similarly, another study was carried out by Samuel, Shem, Daniel and Silas (2017) in south-west Nigeria on the impacts of climate variability and climate change on agricultural productivity of smallholder farmers. The study discovered that crop yield had reduced tremendously as a result of erratic rainfall, an increase in the number of hours of sunshine, a rise in temperature and pest outbreak.

8.6 Post regression test

A post-estimation of the model was done, and the result is presented in Table 8.6. The post-regression analysis shows that the model employed in this present study is well specified. In the course of estimation, the Durbin Watson statistic was employed to detect the presence of autocorrelation in the model. Any Durbin Watson statistic outside the range of 1.5–2.5 indicates the presence of autocorrelation (Agwu, et al., 2012). Therefore, the Durbin-Watson statistics were estimated to be 1.762, meaning that there is no autocorrelation detected in the sample. Moreover, the sum squared residual, also known as the residual sum of square, is small; 0.045 (Angba, Baines & Butler, 2020). This, however, has fulfilled the least square principle that states that the coefficient of sum squared residual is selected such that this value is as small as possible (da Cunha et al., 2018). Thus, proving that the model specification of the study was robust.

Table 8.6: Post regression test result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.018701	0.019414	0.963238	0.3518
DLOG(AVRAINFALL)	-0.034880	0.081811	-0.426342	0.6763
DLOG(AVTEMP)	0.118822	0.900055	0.132016	0.8968
ECM(-1)	-1.274533	0.451685	-2.821732	0.0136
RESID(-1)	1.673803	0.482709	3.467521	0.0038
RESID(-2)	0.387120	0.312556	1.238562	0.2359
R-squared	0.476140	Mean dependent var		7.23×10^{-18}
Adjusted R-squared	0.251629	S.D. dependent var		0.065641
S.E. of regression	0.056785	Akaike info criterion		-2.637900
Sum squared residual	0.045143	Schwarz criterion		-2.289726
Log-likelihood	34.69795	Hannan-Quinn criterion		-2.562337
F-statistic	2.120784	Durbin-Watson stat		1.762265
Prob(F-statistic)	0.115641			

Source: Author's computation

Also, the residual graph plotted (Figure 8.7) tests the assumptions about whether the relationship between the variables is linear (i.e., tests linearity) and whether there is equal variance along the regression line (i.e., homoscedasticity). It further indicates the fitted values and shows that the distribution is free from autocorrelation (serial correlation) and heteroscedasticity. The random pattern indicates that a linear model provides a good fit for the data.

Figure 8.7: Residual graph to test the assumption of the relationship between variables

Source: Author's estimation

8.7 Chapter summary

The aim of the chapter was to analyse the impact of climate variables on yam production at the state level for the period 1996-2017, which is research objective 1 of this thesis. This was completed by developing a rigorous analysis, using secondary data, of the trends in yam production, annual precipitation, and annual temperature, and to analyse the impact of climate variables on yam production using time-series data from 1996 to 2017, the length of time the secondary data was available for.

Using the linear trend model, the outcome for yam production revealed an R-squared of 88 per cent. It further showed that there was a steady increase in yam quantity produced between the years 1996 and 2017. The trend in annual precipitation, reveals the presence of rainfall variability and irregularity in the study area. Concerning the trend in annual temperature, the trend line showed an overall downward trend in movement, indicating a decline in yearly temperature for the period under study (1996-2017).

Furthermore, the evidence of climate change variables on yam production in Cross River State was revealed using the co-integration model. The result of the ADF-test carried out showed that all the variables were integrated of order one [I(1)] at level, signifying the presence of unit root in the time series data. For this reason, a test for the presence of a long-run relationship (cointegration) among the variables was done. The outcome of this analysis suggested that there is the presence of cointegrating long-run relationship among these time series. It revealed a very high R-squared value of 98 per cent and a low Durbin-Watson statistic (1.188), which implies that using the variables with an ordinary level regression (the OLS) will lead to spuriousness. Therefore, the Error Correction Model (ECM) was employed. The result showed that temperature was statistically significant and negatively impacts on yam production in the study area. This implies that an increase in temperature, will result to a decrease in output of yam.

The following chapter presents more of the study findings, mainly reporting the impact of climate change on the net revenue of yam farmers and the determinants of farmers choice to adaptation.

Chapter 9 Socio-economic factors that affect the net revenue of farmers, determinants of famers' decision to adaptation and validation of study recommendations

9.1 Introduction

Following previous related studies (Sarker et al., 2013 and Elijah et al., 2018), the factors that affect the net revenue of farmers under climate change environment employed the use of Ordinary Least Square (OLS) analysis, a Chi-square test and an independent sample t-test. The regression analysis tool (OLS) was applied to investigate the influence of the socio-economic, institutional and farm characteristics to farm profit (which is defined as net revenue) under changing climatic conditions. The Chi-square test, however, was employed to show the relationship between the variables while the independent sample t-test was used to compare the means of net revenue between groups.

Importantly, the use of these statistical techniques can be said to be a methodological improvement upon the study carried out by Elijah et al. (2018) on the research on the effects of climate change on yam production in Cross River State, Nigeria. This present study extends to the use of symmetric (Phi) and directional measures (uncertainty coefficient) which show the strength and weakness of the existing relationship between the variables.

Also, in this chapter, the Multinomial logit was used to determine the most important factors that influence farmers' choice of adaptation to climate change. This chapter also highlights the need to engage with technology adoption and decision making in order to cope with the impact of climate change. Details on the use of technology adoption to help farmers in climate change situation was presented in chapter 4, section 4.4 and the various technologies adopted by farmers to cope with climate change were discussed in chapter 7, section 7.6. Furthermore, the findings from a two-stage online survey employed to gain experts' views on the study recommendation was presented.

9.2 Chi-square test to observe the association between net revenue and various socio-economic factors

In order to determine the existing relationship between net revenue and various socio-socioeconomic characteristics, a chi-square test was utilised. Table 9.1 presents the outcome of the analysis. The chi-square test was used to observe if there is an association between two categorical variables. However, the chi-square test is unable to demonstrate the strength of the relationship. Alternatively, Phi (symmetric measures) and the uncertainty coefficient (directional measures) can provide some information on the strength of the existing relationship. Based on the result of the Pearson chi-square analysis, four variables were discovered to be statistically significant. These are educational level (p-value=0.047), age (p-value=0.034), farming experience (p-value=0.061) and access to credit (p-value=0.088). Nonetheless, this existing relationship is merely indicative and not conclusive (Angba, Baines, & Butler, 2020a). Therefore, the null hypothesis tested by the chi-square; H_0: There is no relationship between net revenue and various socio-socioeconomic characteristics was rejected.

Furthermore, the significance values of Phi for the same variables found to be significant, suggest a statistically significant relationship. Moreover, the value of Phi ranges between 0.006 and 0.527, which implies that the link is from weak to strong. Notably, Phi values higher than 0.3 indicate a strong relationship, whereas the values lower than 0.3 signifies a weak correlation between two variables (Muijs 2004; Sarker et al., 2013). Therefore, the level of education and access to credit facility have Phi value of 0.098 and 0.010, respectively which show a weak relationship between these variables and net revenue. On the contrary, a strong relationship is observed between age and net revenue; farming experience and net revenue as the Phi value of these variables are 0.448 (age) and 0.420 (farming experience). As for the directional measures, otherwise known as the uncertainty coefficient, the p-values imply that most of the variables are not statistically significant (Angba, Baines, & Butler, 2020a).

However, the outcome of this analysis contradicts with that of Oluwasusi (2013) in Ekiti State, Nigeria on the adaptation strategies carried out by farmers to cope with the effect of climate variation on yam production. The research employed the Pearson’s chi-square analysis to show the relationship between demographic characteristics of the household and the level of yam production. The study found out that secondary occupation and farm size of the yam farmers were statistically significant. The study result implies that farmers with a large area of farmland usually have more economic resources, which includes land, and are better in the adoption of innovation on improved agricultural practices, and also better yam farmers with additional worthwhile income than farmers with a small area of farmland. The farm size and secondary occupation of yam farmers for this present study in Cross River State were not statistically significant (Angba, Baines, & Butler, 2020a).

Table 9.1: Chi-square result showing the relationship between net revenue and the characteristics of respondents in the study area

Variables	Pearson Chi-square test		Symmetric measures (Phi)		Directional measures (uncertainty coefficient)	
	Value	P-value	Value	P-value	Value	P-value
Gender	0.569	0.450	0.527	0.450	0.002	0.450
Educational level	1.994**	0.047	0.098**	0.043	0.006**	0.026
Household size	14.252	0.219	0.261	0.219	0.025	0.166
Farm size	0.500	0.919	0.049	0.919	0.001	0.919
Age	41.971**	0.034	0.448**	0.034	0.065	0.423
Years of Farming	36.805*	0.061	0.420*	0.061	0.054	0.778
Distance to market	1.967	0.161	0.097	0.161	0.007	0.160
Marital status	1.053	0.788	0.071	0.788	0.004	0.786
Access to credit	0.023*	0.088	0.010*	0.088	0.000*	0.070
Extension service	0.006	0.936	0.006	0.936	0.000	0.936
Access to weather information	0.492	0.483	0.049	0.483	0.002	0.482
Tenure status	1.501	0.220	0.085	0.220	0.006	0.220
Non-farm jobs	0.906	0.341	0.066	0.341	0.003	0.341
Livestock ownership	0.078	0.780	0.019	0.780	0.000	0.780

Note: *and **indicate significance level at 10% and 5 % respectively

Furthermore, another study conducted in Bangladesh (Sarker et al., 2013), found similar findings to that of this present study, the factors that determine net revenue of farmers using a chi-square analysis was investigated. The result of the investigation showed that most of the variables were statistically significant, which included the level of education, age, farming experience and access to credit. These findings agree with that of this present research, as these four variables mentioned were found to be statistically significant at $p<0.05$.

9.3 Independent sample t-test comparing the means of net revenue between groups

In order to compare the means of profit (net revenue) between groups in the study area, the two-sample t-test was used. The result of the analysis is presented in Table 9.2 below, using values for equal variances assumed as the Levene's test for equality (F) values were above 0.05. The findings show that only one variable produced a statistically significant difference ($p < 0.1$) in means, which is education (p-value=0.063). In making the comparison appropriate, the respondents were categorised into two clusters (which is consistent when the t-test is applied). The two groups were the educated farmers and uneducated farmers (Angba, Baines, & Butler, 2020a).

The outcome of the analysis further indicated that the mean of net revenue in Nigerian Naira (N) of the educated farmers (N89,409.32) is higher than that of illiterate farmers (N84,881.25), and the mean difference is statistically significant at 10 per cent level of significance. This implies that education is an important determinant of high net revenue of yam farmers. Ibrahim, Shamsudin, Yacob and Radam's (2014) research on the economic impact of climate change on the maize sector using a Ricardian approach also suggests that farmers with a higher level of education earned more profits than uneducated farmers (Angba, Baines, & Butler, 2020a).

The result of this analysis is thus, consistent with that of Sarker et al. (2013), who also found out that education produced a statistically significant difference in performance among rice farmers in Bangladesh.

Table 9.2: Independent sample t-test result

Variables	Two sample t-test (Equal variances assumed)	
	Value	P-value
Gender (male and female)	0.420	0.645
Access to credit (yes and no)	1.619	0.788
Education (educated and uneducated)	0.572*	0.063
Access to extension services (yes and no)	0.910	0.572
Use of improved variety (yes and no)	1.956	0.963
Tenure status (yes and no)	7.832	0.556
Non-farm job (yes and no)	0.928	0.412
Livestock ownership (yes and no)	0.321	0.145

Note: * indicates significance at 10 per cent level

9.4 Factors that affect net revenue of farmers using the ordinary least square (OLS)

Multiple regression analysis was employed to address the possible factors that influence farmers' net revenue in yam production. The relevant factors that were incorporated in the model were identified based on literature (Kurukulasuriya & Mendelson, 2008; Ibrahim et al., 2014; Chukwuone, 2015; Mishra et al., 2016; Elijah et al., 2018). Table 9.3 presents the result of the multiple regression analysis. The result presented shows evidence of a very highly significant estimation. This is because the general significance testing indices, designated as Prob>F, is not just less than 0.05, but it is 0.000. Additionally, the findings reveal that the R-square is 0.660, which infers that 66 per cent of the dependent variable (net revenue) is explained by the specified independent variables, with the remaining 34 per cent due to random error in the model (Angba, Baines & Butler, 2020a).

The result of the analysis shows that most of the explanatory variables are not statistically significant. However, the variables that have substantial effects on the net revenue of farmers are farming experience, household size, access to the weather forecast and tenure status. The result further shows that age, farm size, distance to market, access to credit, access to extension services and livestock ownership all have a negative relationship with the net revenue of farmers and are statistically not significant. In addition, the gender, educational level and marital status are positively related to the net revenue of farmers; however, they are not statistically significant. This implies that each of the insignificant variables has no influence on the net revenue of yam farmers in the presence of climate change in the study area. It further means that most of these variables are not relevant in the model.

Moreover, farming experience has a significant positive impact on the net revenue of the respondents. This indicates that farmers with many years of experience have a better capacity to use better agricultural practices in their enterprise based on their knowledge and skill over time than their counterpart with lesser years of experience. This outcome conforms with that of Elijah et al. (2018) in research on the effects of climate change on yam production in Cross River State, Nigeria. Ajayi's (2015), research is also in agreement with this result; the investigation on the effects of climate change on the production and profitability of cassava in the Niger Delta Region of Nigeria reported that farmers' years of experience in farming influenced the net farm income positively in the study area.

The second statistically significant variable that will be discussed is the number of household members which is positively related to the net revenue of farmers. This suggests that the farmers with larger household size save costs as they don't hire a lot of farm labour since they rely on household labour in the study area. This, in turn, promotes net revenue. Also, households with more members practice division of labour to increase efficiency in farming as opposed to farmers with smaller household size where the division of labour is a challenge with fewer members (Angba, Baines & Butler, 2020a).

This result corresponds with that of Elijah et al. (2018) who reported that the number of household members is significant in determining farmer's profit. The study added that it expects the farmers with higher household members should not hire much farm labour because they mostly make use of household labour which is available to them. On the contrary, research by Ezekiel, Olawuyi, Ganiyu, Ojedokun and Adeyemo, (2012), reported that household size and farming experience do not have a significant effect on the net revenue of cassava farmers in Osun State, Nigeria. Rather, an educational level and access to credit were statistically significant among the study variables considered (Angba, Baines & Butler, 2020a).

The next variable that showed a statistically significant association is access to weather information. Access to information on the weather forecast is negatively associated with the net revenue of farmers in the study area. This negative relationship could be as a result of the insufficient and inaccurate weather forecast information in Nigeria. Information on the weather forecast is often given on major cities in the country, and the minor towns and villages are left out. Sometimes, the predictions made do not come to reality (Angba, Baines & Butler, 2020a). Consequently, the farmers who rely on the weather forecast for agricultural activities are misinformed and thereby disadvantaged. A negative influence of weather forecast on net revenue of farmers was also revealed in a study in Bangladesh by Sarker et al. (2013). A similar result was reported in another study by Gbetibouo (2009), in South Africa.

Finally, the result of the analysis showed that tenure status was significant and positively related to the net revenue of farmers in Cross River State (Angba, Baines & Butler, 2020a). This finding suggests that land ownership reduces the uncertainty of obtaining the benefits of capital and labour investment in farming (Sarker et al., 2015). This positive influence of land ownership on the net revenue of farmers, is similar to the findings of Kurukulasuriya and Ajwad (2007) and Ajayi (2015).

Table 9.3: Parameter estimates of determinants of net revenue of farmer in Cross River State

Variables	Unstandardised Coefficients		t	P-value
	B	Std.Error		
Gender	169.222	943.757	0.179	0.858
Age	-36.346	82.404	-0.441	0.660
Educational level	5.957	652.661	0.009	0.993
Household size	182.408	215.292	2.247**	0.014
Farm size	-603.523	545.469	-1.106	0.270
Distance to market	-922.185	890.389	-1.036	0.302
Years of farming	177.307	91.234	1.943**	0.023
Marital status	534.454	885.103	0.604	0.547
Access to credit	-242.641	896.298	-0.271	0.787
Access to extension services	-766.255	906.005	-0.846	0.399
Information on weather forecast	-577.506	611.038	1.945**	0.036
Livestock ownership	-362.605	910.831	-0.398	0.691
Tenure status	-1911.414	939.108	-2.035**	0.043
Summary of model				
Constant	81735.689	4089.862	19.985	0.000
R-square	0.660			
Prob>F	0.000			

Note: ** signifies 5% level of significance

9.5 Determinants of farmers' decision to adaptation strategy

The independent variables for the determinants of farmers' choice to adapt were selected based on the existing literature. As previously described in the literature review, an adaptation pathway is a farm decision-making strategy (Robert, Thomas & Bergez, 2016) that can provide structure, guidance and flexibility, avoiding lock-in and addresses the deep uncertainty associated with climate variability (Jain et al., 2015; Robert et al., 2016). Under the decision-making approach, rather than determining an outcome or decision at an early stage, farmers can build a dynamic planning, prioritisation and delivery strategy that will follow changing circumstances over time (Jain et al., 2015).

Various factors are recognised to influence farmers' decision regarding adaptation strategies used to cope with the challenges of climate change (Arimi, 2014; Ndamani & Watanabe, 2015; Belay et al., 2017). These factors are discussed in detail in chapter 4, section 4.4. The variables include distance to market, access to credit, access to extension services, tenure status (land ownership), no of years in farming, livestock ownership, age of household head, household size, gender, farm size, household income, educational level and access to information on the weather forecast. The selected explanatory variables are summarised in Table 9.4 along with the *a priori* expectation.

Table 9.4: Independent variables hypothesized to influence adaptation decision

Explanatory variables	Measurement	*A priori* expectation of influence	References
Distance to market	Kilometres	+/-	Hassan and Nhemachena, 2008; Deressa, Hassan, Ringler, Alemu and Yesuf, 2009; Hisali et al. 2011; Belay, Recha, Woldeamanuel and Morton, 2017.
Access to credit	1=yes; 0=no	+	Hassan and Nhemachena, 2008; Bryan et al. 2009; Deressa et al. 2009; Hisali et al. 2011; Sarker et al. 2013; Ndamani and Watanabe, 2016
Access to extension services	1=yes; 0=no	+	Hassan and Nhemachena, 2008; Deressa et al. 2009; Belay et al. 2017.
Tenure status (land ownership)	1=yes; 0=no	+	Bryan et al. 2009; Sarker et al. 2013; Gbetibouo, 2009; Belay et al. 2017.
No of years in farming	Years	+/-	Hassan and Nhemachena, 2008; Gbetibouo, 2009; Ndamani and Watanabe, 2016
Livestock ownership	1=yes; 0=no	+/-	Deressa et al. 2009; Belay et al. 2017
Age	Years	+/-	Hassan and Nhemachena, 2008; Deressa et al., 2009; Hisali et al. 2011; Belay et al. 2017
Household size	Number	+	Seo and Mendelsohn 2008; Bryan et al. 2009; Deressa et al. 2009; Ndamani and Watanabe, 2016; Ogallah et al. 2017

Gender	1=male; 0=female	+/-	Hassan and Nhemachena, 2008; Deressa et al. 2009; Ndamani and Watanabe, 2016
Farm size	Hectare	+/-	Bryan et al. 2009; Deressa et al. 2009; Gbetibouo 2009; Ndamani and Watanabe, 2016
Household income	Naira	+	Nhemacha and Hassan 2007; Deressa et al. 2009; Ndamani and Watanabe, 2016; Ogallah et al. 2017
Educational level	1=educated, 0=uneducated	+	Seo and Mendelsohn 2008; Deressa et al. 2009; Sarker, Alam and Gow, 2013; Ndamani and Watanabe, 2016
Information on weather forecast	1=yes; 0=no	+	Bryan et al. 2009; Deressa et al. 2009; Gbetibouo, 2009; Ndamani and Watanabe, 2016

9.5.1 Factors influencing farmers' choice of adaptation: The binary Logit Model

The estimated result of the binary logit regression model for the determinants of farmers' adaptation decision to cope with the effects of climate change is provided in the following table (Table 9.5). The outcome shows that some factors determine farmers' choice to adapt in the study area. These factors are access to credit, educational level, farming experience, household size, and household income which are all statistically significant at 5 per cent level of significance.

Access to credit has a positive influence on farmers' choice of adaptation on yam production. This suggests that farmers with access to credit facilities have a higher possibility to adapt to changes in climate than farmers without access to credit facilities. This is particularly true because adaptation is expensive, and agricultural support in terms of credits and loans tend to alleviate the cost. This finding is similar to Hassan and Nhemachena (2008) who carried out a cross-sectional survey of over 8,000 farms from 11 African countries. Moreover, the findings of their study showed that the probability of adaptation to changes in climate increases with a rise in access to credit facilities. Farmers' access to credit is an indication that the availability of funds to the farm household is positively related to the level of adoption of climate change adaptation measures. This outcome is consistent with previous studies with the result that access to credit facilities is a significant variable which usually has a positive influence on adaptation decision (Fosu-Mensah, Vlek & MacCarthy, 2012; Sahu & Mishra, 2013; Ndamani & Watanabe, 2016; Tesfaye & Seifu, 2016).

Additionally, quality education improves knowledge and the degree of responsiveness of farmers to the potential benefits of adaption and increases their inclination to take part in local natural resource management and protection measures (Hassan & Nhemachena, 2008; Belay et al., 2017). The findings of this present study further revealed that the level of education was positively associated with farmers' choice to adapt to changes in the weather pattern. This indicates that farm household heads that are educated have more likelihood to adopt improved technologies to cope with the effects of climate change. This observation is particularly true since literate farmers are more well-informed than their counterparts due to their ability to access information that pertains to changes in the weather pattern and adaption options. Added to this, it was found out in previous research that there is a positive relationship between the level of education of farm household heads and adoption of adaptive measures (Igodan, Gwary, & Ekpere 1990; Ndamani & Watanabe, 2016). Moreover, several studies have revealed that to have improved education and to disseminate information is a vital policy strategy for motivating local involvement in various development and natural resource management opportunities (Hassan & Nhemachena, 2008; Belay et al., 2017).

Furthermore, the results showed that the probability of adaptation increases with a rise in number of years of yam farming. This is true given that number of years in farming is statistically significant and has a positive relationship with the decision of the adaptation strategies made by the farmers. Many years of farming, however, raises the consciousness of possible benefits to adaption and increases willingness to partake in the management and preservation of local natural resources (Hassan & Nhemachena, 2008; Belay et al., 2017). Farmers with many years of farming are, therefore, more well-informed about climate change than those with a smaller number of years in farming (Deressa *et al.,* 2009; Mishra et al., 2016). In Ghana, Ndamani and Watanabe's (2016) research on determinants of farmers' adaptation to climate change and the findings showed a negative relationship between the number of years of farming and adoption of adaptation strategy. It further reported that farmers that possess the highest number of years in farming are older individuals, which suggested that the probability of adopting a climate change adaptation measure reduces in older farmers. This outcome is congruent with the findings of previous research which discovered that older farmers with many years of experience usually lack willingness and motivation to adopt climate change adaptation strategies (Uddin, Bokelmann, & Entsminger 2014). These results, however, are not the case in this present PhD research because older farmers with many years of farming experience are observed to have the likelihood to adapt to changes in the weather pattern. There may however be other factors of influence in this present study that support this association but have not been observed in the primary research. However, this is still an interesting finding.

In addition, the study found out that household size positively influences the decision to adapt to climate change. According to Apata et al., (2009); Ndamani and Watanabe (2016), the larger the number of household members, the greater the probability of taking an adaptation option. In line with the outcome of this PhD study, previous research has shown that the propensity of a larger family size to adapt to climate change is perhaps due to their greater endowment of labour (Oyekale & Oladele, 2012; Ndamani & Watanabe, 2016).

The results of the study further show that household income has a positive relationship with the decision to adapt to climate change. This outcome is in agreement with the earlier investigation which found out that better-off farmers have a higher tendency to adopt to adaptation practices than their counterpart in response to changes in climate (Gbetibuou, 2009; Ndamani & Watanabe, 2016). Similarly, Sahua and Mishra's (2013) research on perception and adaptability strategies of the farmers to climate change in Odisha, India reported that annual income of farmers is one of the key factors that influence farmers' decision to adapt in response to changes in climate. Added to this, Hassan and Nhechema (2007), opined that per capita income on household has a positive effect on farmers' adaptation choices. This may be that capital is required to invest to adopt these adaption practices, therefore a lack of capital is a barrier to adoption.

The coefficient of distance to market, livestock ownership, access to extension services, information on weather forecast and land ownership are positively related to farmers' decision-making process but not statistically significant. Whereas the coefficient of age, gender and farm size have a negative influence on the adaptation choice of farmers but then, are not statistically significant.

The binary logit, however, only reveals the factors that influence the adaptation decision of farmers (i.e., whether to adapt or not to adapt), but it does not show which factor is responsible for a particular type of adaptation practice. For this reason, the multinomial logit (MNL) model was applied to complement it and the result is given in the subsequent section.

Table 9.5: Factors influencing adaptation decisions of farmers: Results of the logit model

Explanatory variables	Coefficients	P-value
Distance to market	0.127 (0.130)	0.281
Access to credit	1.402** (0.579)	0.037
Access to extension services	0.254 (0.158)	0.873
Tenure status (land ownership)	1.948 (0.523)	0.996
Farming experience	3.466** (1.740)	0.046
Livestock ownership	1.217 (0.443)	0.739
Age	-0.084 (0.074)	0.257
Household size	1.390** (0.234)	0.026
Gender	-0.475 (0.528)	0.368
Farm size	-1.219 (0.807)	0.103
Household income	0.257** (0.612)	0.016
Educational level	0.145** (0.949)	0.010
Information on weather forecast	0.325 (0.425)	0.241
Constant	-10.13 (0.663)	
Number of observations	209	
Pseudo R^2	0.476	

Note: standard error in parenthesis; ** denotes significance at 5% level

9.5.2 Determinants of farmers' choice of adaptation practices: The Multinomial Logit (MNL) Model

The requirement for the rationale for using the MNL model is for the Independence of Irrelevant Alternatives (IIA) assumption to be satisfied. To this end, the Hausman test can be applied to test for the IIA assumption (Cameron & Trivedi, 2005; Vijverberg, 2011; Belay et al., 2017). Consequently, the Hausman test was employed to check the validation of the IIA assumption. The estimates of the Hausman test are given in Table 9.6 below. In this case, the test accepted the null hypothesis of the IIA assumption. The p-values for all omitted adaptation options are not more than 1, signifying that the adaptation options are independent, and the model has fulfilled the assumption. Added to this, the probability of chi-square estimates is positive, which implies that the application of the MNL model for the dataset in the study is valid. It is important to note that supposing the chi-square value is less than 0.00, it, therefore, means that the estimated model does not meet the asymptotic assumptions of the test (Vijverberg, 2011; Belay et al., 2017).

Furthermore, negative test statistics are not unusual in empirical work (Cheng and Long 2007; Vijverberg, 2011; Sarker et al., 2013). This likelihood of negative statistics was noted by Hausman and McFadden (1984), and they concluded that a negative outcome was an indication that the assumption of IIA had not been debased. Thus, the result does not imply unsuitability for the use of the MNL model for the analysis. This means that the use of the MNL model for finding out the determinants of adaptation strategies is justified.

Table 9.6: Estimated results of Hausman tests of Independence of Irrelevant Alternatives assumption for MNL model

Omitted adaptation options	Chi-square	Df	P>chi-square	Evidence
Crop diversification	3.251	7	0.973	For H_0
Improved yam varieties	6.535	7	0.954	For H_0
Changing planting date	-2.139	7	0.865	For H_0
Planting of trees	-7.251	7	0.971	For H_0
Use of inorganic fertilizer	-9.314	7	0.857	For H_0
Reduce bush burning	4.219	7	0.962	For H_0
Expansion of farm size	-5.241	7	0.991	For H_0
Off-farm employment	-1.562	7	0.892	For H_0
No adaptation	2.913	7	0.957	For H_0

H_0: Odds (Outcome-J vs Outcome-K) do not depend on other alternatives.

Looking further, the result of the MNL model revealed which factor is responsible for a specific type of adaptation strategy among farmers in Cross River State. The outcome of the multinomial logit regression analysis shows the influence of additional factors that affect the adaptation choice of farmers apart from those discovered in the previous analysis (using the binary logit model in Table 9.5). The findings, however, do not differ significantly from the preliminary analysis, which confirms the robustness of the results.

However, eight adaptation options were incorporated in the MNL model, together with no adaptation and they are: use of the improved variety, changing planting date, planting of trees, use of inorganic fertiliser, reducing bush burning, expansion of farm size, off-farm employment, and planting of different varieties of the crop. Thus, the eight adaptation choices made up the dependent variable of the MNL model and were eventually categorised 0-8 with 0 = no adaptation.

Importantly, since the majority of the independent variables are dummies, the Relative Risk Ratio (RRR) could be explained as the relative probability of selecting alternative J (an adaptation strategy) to no adaptation which indicates the base category or reference category, i.e., the compared group (Hisali, Birungi & Buyinza, 2011). Therefore, following Yip, Wang, & Liu (1998), Hisali et al. (2011), Sarker et al. (2013) and Belay et al. (2017), Table 9.7 presents the RRR for each of the adaptation option considered (option J) given a specific characteristic (Xi) which are the factors that determine farm household decision to choose a particular adaptation strategy in the presence of climate variation. Based on the result, the probability value of the likelihood ratio (LR) chi-square suggests that most of the variables are together statistically significant, although some of the variables are not independently statistically significant. A similar result has been previously reported in the literature (Sarker et al., 2013; Belay et al.,2017). For this reason, only the statistically significant variables that affect adaptation options call for discussion in the following sub-sections which is in line with previous studies (Bryan et al., 2009; Sarker et al., 2013; Tesfaye & Seifu, 2016 and Belay et al., 2017)

9.5.2.1 Access to credit

The accessibility of credit by household implies that funds are available which has a positive relationship with the level of adoption of adaptive measures (Yirga & Hassan, 2010; Sarker et al., 2013). Access to credit by the farmers in the study area is statistically significantly associated and positively related to the use of a crop diversification strategy as an adaptation option to cope with the impact of climate change. This result could be because of the agricultural credit policy put in place to support agriculture by the Nigerian government. The positive influence of access to credit on the adaptation strategy used by farmers is consistent with the results of previous research (Deressa et al., 2009; Hisali et al., 2011; Sarker et al., 2013; and Tesfaye & Seifu, 2016). With more financial resources at farmers' disposal, they can make use of the available innovation to change their agricultural practices to cope with the varying climatic situations (Hassan & Nhemachena, 2007; Tesfaye & Seifu, 2016).

The result of the study further showed that access to credit facilities by farming households has a positive relationship with the use of inorganic fertiliser. Added to this, credit accessibility by the farmers enhances the adoption of improved varieties. A similar finding was found in previous studies by Kandlinkar and Risbey (2000) and Yirga and Hassan (2010).

9.5.2.2 Access to extension service

As reported by the previous researchers, access to extension services by the farmers increases the odds of taking different adaptation options (Sarker et al., 2013; Tesfaye & Seifu, 2016; Belay et al., 2017). From the results of the study, access to extension advice is statistically significant and has a positive association with the adaptation strategy (Table 9.7). The reason for this outcome could be because of the Nigerian policy on agricultural extension, technology development and transfer to support agricultural production in the country. Furthermore, farmers' access to extension services raises the chance of reducing bush burning thereby leading to soil conservation. Added to this, planting of trees is another adaptation option that is influenced by farmers' access to extension services.

According to Hassan and Nhemachena (2008) and Belay et al. (2017), improved access to extension advice on crops and livestock have a positive influence on climate change adaptation measures. These results correspond with the results of the research by Tazeze, Haji & Ketema (2012), in Ethiopia. Furthermore, farmers that have access to extension services have a greater probability to enhance their knowledge and understanding about several management practices (Gbetibouo et al., 2010). However, literature argued that although the extension service is more prejudiced in the direction of concerns for profitability than the risk of climate change (Tesfaye & Seifu, 2016), it improves farmer's ability to undertake climate change adaptation options (Yegbemey, Yabi, Tovignan, Gantoli & Haroll, 2013).

9.5.2.3 Number of years in farming

The result of analysis revealed that the number of years in farming is statistically significant and has a positive influence on climate change adaptation options chosen by farmers (Table 9.7). This indicates that as length of time in farming increases the probability of undertaking adaptation practices in response to the negative impacts of climate alteration on agriculture also increases. The reason for this is that farmers with many years in farming are presumed to have better awareness and understanding about weather conditions and its consequence on agricultural practices (Belay et al., 2017), or may recognise the subtle changes occurring on their farms.

Similar results have been reported in the literature. It was found out that the years of experience in farming by farmers raises the likelihood of adopting diverse adaptation practices, because experienced farming household heads have the knowledge and are well informed about climate variation (Hassan & Nhemachena, 2008; Deressa et al., 2009; Gbetibouo et al., 2010; Sarker et al., 2013). In addition, a study by Yegbemey *et al.,* (2013) on maize farming households in West Africa also revealed that farming experience influences the practice of adopting a land use adaptation strategy. The argument was that to alter land use, or to apportion the land among various crops, farmers ought to possess a high level of understanding in agriculture, and this only emanates from the number of years of farming.

Likewise, it is accepted in this present study that through farming experience, farmers acquire the skills in management and practice in agriculture, which in turn determines their choice of adaptation measures. The outcome of this study further implies that as the number of years in farming of the household head increases, the probability of changing planting date also increases as a strategy to cope with the effects of climate change. Added to this, another adaptation option that is determined by number of years in farming is planting of trees.

9.5.2.4 Tenure Status

Tenure status (land ownership) is usually assumed to enhance the acceptance of new agricultural technologies (Sarker et al., 2013; Kpadonou et al., 2017; Senanayake & Rathnayaka, 2017). The findings from this research showed that ownership of land positively raises the likelihoods of undertaking expansion of land, reducing bush burning and the application of inorganic fertiliser as adaptation strategies in response to climate variability (Table 9.7) This may perhaps be due to the belief that landowners undertake technologies which are associated with the improvement of land quality (Gbetibouo *et al.,* 2010). This optimistic impact of tenure status on adaptation options is similar to the studies carried out by Bryan et al. (2009), Hisali et al., (2011) and Sarker et al., (2013). Added to this, insecurity in land ownership gives rise to poor agricultural practices, where the utilisation of input is lesser than, or not as efficient as owned land (Gray & Kevane, 2001; Kpadonou et al., 2017). This may be that the lack of assets is a barrier to gaining loans to purchase such inputs. The marginal impact (Table 6.20) of this study showed that tenure status would probably lessen the adoption of tree planting as a measure to adapt to the changing climate by around 3.2 per cent.

9.5.2.5 Household size

The household number has a significant positive influence on climate change adaptation, increasing the chance of adopting changing of planting date and off-farm employment as a strategy to cope with the effects of climate change (Table 9.7). According to Kurukulasuriya and Mendelsohn (2008), Gbetibouo (2009) and Belay et al. (2017), the likely reason why family size is a significant determinant is that larger household size with a large number of productive household members raises agricultural production. This is because large household size is related to labour-intensive farming practices. Therefore, family size has a significant relationship with some of the adaptation practices as earlier mentioned. The result of study also revealed a higher chance of taking adaptation option by farm families with larger household sizes (Table 9.5). However, this greater possibility of implementing a successful adaptation strategy in larger families could also be as a result of having many family members to participate in the decision-making process and knowledge exchange. Decision-making is important in taking adaptation strategy to cope with climate variability (Robert et al., 2016). More information on decision making as it relates to taking adaptation measure was given in section 4.4.

9.5.2.6 Gender

The positive relationship between gender of household head and choice of adaptation strategy indicates that male-headed households enhance the probabilities of off-farm employment, as opposed to the base category which is taking no adaptation (Table 9.7). This perhaps may be due to male-headed families being well-informed about new technologies on agricultural practices than female-headed households (Asfaw & Admassie, 2004; Deressa et al., 2009; Sarker et al., 2013; Belay et al., 2017). In addition, the outcome of the study concerning the gender of the household head implies that male-led families had higher chances to take up adaptation practices as opposed to their counterpart (female-led families).

The findings are in line with the research by Deressa, Hassan and Ringler (2008), which was carried out in Ethiopia. The study assessed the farmers' choice of climate change adaptation strategies and found out that male-led households have higher chances to access new technologies and weather information than households headed by women. For this reason, male-headed families were in a better position to carry out various adaptation measures than female-led families (Demetriades & Esplen 2010). Belay et al., (2017) research conducted in the Central Rift Valley of Ethiopia show similar results. The study found that male-headed household increased the probability of tree planting, integrating crops with livestock, and soil and water conservation as adaptation strategies at 5 and 1 per cent significance levels compared to the base category (Belay et al., 2017). In addition, Sarker et al.'s (2013) research on assessing the determinants of rice farmers' adaptation strategies to climate change in Bangladesh revealed a similar result. Their findings showed that male-headed families increase the chances of practising irrigation, utilisation of short-duration rice and non-rice crops as an adaptation strategy compared to taking no adaptation. This study further reported that this outcome is likely because men have better knowledge about innovation than women in farming households.

The result of this present study is, however, contrary to that of Tesfaye and Seifu (2016), who carried out a survey on smallholder farmers on the adaptation of climate change in eastern Ethiopia. They reported that gender is negatively related to adaptation option. Their study added that the negative coefficient of the gender of the household head reveals that female-led families have a higher chance to adopt crop diversification as a choice of adaptation. This previous study added that the result might likely be because females are suitable to acquire more knowledge and information on several agricultural practices while carrying out agricultural activities as they tend to interact better than the male. Thus, they can effortlessly make adjustments on themselves to retort to climate change adaptation based on the available information on climatic situations and other factors. Similar findings were also reported in a study by Hassan and Nhemachena (2008).

9.5.2.7 Farm size

Size of farmland has a positive and significant relationship with up-take of crop diversification (that is, planting of different crop varieties) as an adaptation option (Table

9.7). This implies that farm size raises the likelihoods of adopting planting different crop varieties in contrast to the base category (no adaptation strategy) as a means to cope with climate variations. Particularly, farm size increases the relative risk of crop diversification relative to no adaptation by 5.5 times (Sarker et al., 2013). The reason for this is because farmers with large areas of farmland have a higher probability of taking up adaptation practices since they have greater assets and are exposed to more capital and are more furnished with other resources (Sarker et al., 2013).

The positive influence of the size of farmland on undertaking an adaptation strategy seen in this study corresponds with other previous studies (Bryan et al., 2009; Gbetibouo 2009; Sarker et al., 2013; Belay et al.,2017). According to Belay et al.'s (2017) report, the size of farmland increases the probability of planting different fodder trees as well as integrating crops with livestock production. Farm size has, therefore, positively and significantly increased the likelihood of adaptation to climate change. Furthermore, large farm sizes provide an opportunity for diversification of their crop and livestock enterprises, and it can help to distribute risks associated with unpredictable weather.

9.5.2.8 Household farm income

Household farm income is a pointer to the financial ability that reinforces the capacity to adopt agricultural technologies (Knowler & Bradshaw 2007; Sarker et al., 2015). Farm income is the most significant determinant for almost all the adaptation options in the study area (Table 9.7). The study showed that income from agriculture increases the likelihood of undertaking the choice of crop diversification, use of inorganic fertiliser, planting of trees, reducing bush burning (soil conservation practice), use of improved crop variety and expansion of farm size.

This outcome, therefore, corresponds with research by Olawepo (2010), who discovered that household income from agriculture is positively related to soil conservation practices, changing planting time and use of crop diversification as adaptation options. Furthermore, previous studies reported that household farm income is significant and has a positive impact on all adaptation options (Deressa *et al.,* 2009; Sarker et al., 2013; Chatzopoulos & Lippert, 2015; Ndamani & Watanabe, 2016; Belay et al.,2017).

9.5.2.9 Educational level

The results of the study (Table 9.7) showed that the level of education gives a positive impact on farmers' adaptation options; thus, it significantly enhances the potential for adopting adaptation strategies. The value of relative risk ratio implies that level of education of farming household head increases the probability of the farmers reporting they are changing planting date and using inorganic fertiliser. This is statistically significant at $p<0.05$ relative to the option of no adaptation. Educational level has a positive relationship with the adoption of improved technologies; farmers with many years of schooling, as previously described in this chapter, are likely to adapt better to climate variations and extreme conditions of climate. This expectation is based on the postulated increased knowledge of the possible benefits from the anticipated climate change adaptation strategies (Maddison, 2006; Hassan and Nhemachena, 2008; Deressa et al., 2009; Sarker et al., 2013; Sarker et al., 2015). However, the outcome of this analysis in the PhD study is in line with that of Sarker et al., (2013) and Belay *et al.,* (2017).

9.5.2.10 Access to weather information

Information on weather is another important variable that has effects on adaptation measures. The outcomes in Table 9.7 revealed as predicted in *a priori* that access to weather information influences adaptation to climate variation. A farmer who is exposed to better weather information (weather forecast) made a good choice of adaptation decision (Belay et al., 2017). The RRR value implies that having access to weather information takes smallholder farmers adaptation choice towards tree planting, changing of planting dates and expansion of farm size strategies at $p <0.05$. This positive influence may perhaps be due to weather information supporting farmers in the use of inputs such as fertilisers, herbicides and pesticides at the right time (Alauddin & Sarker, 2014; Melka, Kassa, Ketema, Abebaw & Schmiedel (2015). This result agrees with a previous related study. Belay et al. (2017) reported that farmers having a good knowledge about precipitation and temperature variability, the probability of adjusting planting time increased by 39 per cent. Furthermore, these results are in harmony with the findings found in other previous studies (Hassan & Nhemachena, 2008; Deressa et al., 2009; Tazeze, Haji, & Ketema, 2012; Di Falco & Veronesi, 2013; Alauddin & Sarker, 2014; Melka, et al., 2015).

Table 9.7: Estimated result of multinomial logit model for factors that influence farmers' selection of adaptation strategy

Explanatory Variable/Adaptation strategies	Relative Risk Ratio (RRR)							
	Crop diversification	Improved yam varieties	Changing planting date	Planting of trees	Use of inorganic fertilizer	Reduce bush burning	Expansion of farm size	Off-farm employment
Distance to market	3.534 (0.338)	1.917 (0.280)	0.737 (0.593)	0.887 (0.861)	1.568 (0.317)	8.092 (0.056)	0.211 (0.229)	2.183 (0.136)
Access to credit	5.090** (0.029)	5.121 (0.718)	1.413 (0.536)	1.421 (0.602)	1.524** (0.043)	0.385 (0.356)	3.003 (0.373)	0.846 (0.745)
Access to extension services	1.154 (0.927)	0.864 (0.792)	1.053 (0.931)	1.000* (0.023)	1.233 (0.655)	1.462** (0.019)	0.167 (0.161)	0.709 (0.516)
Tenure status	11.608 (0.079)	1.958 (0.271)	2.239 (0.178)	2.261 (0.238)	1.026 (0.959)	2.046 (0.433)	0.673 (0.772)	0.394 (0.161)
Farming experience	0.885 (0.425)	0.992 (0.891)	1.019** (0.012)	1.045 (0.498)	1.021 (0.659)	1.149 (0.167)	1.136 (0.202)	0.985 (0.767)
Livestock ownership	2.267 (0.564)	0.843 (0.775)	0.328 (0.053)	2.039 (0.423)	0.709* (0.078)	0.494 (0.450)	0.414* (0.088)	0.591 (0.327)
Age	1.096 (0.301)	1.049 (0.289)	0.979 (0.722)	1.023 (0.706)	0.992 (0.856)	0.948 (0.589)	1.012 (0.878)	1.029 (0.518)
Household	0.527	0.876	-0.996*	0.901	0.972	0.545	1.045	0.993**

size	(0.333)	(0.358)	(0.066)	(0.521)	(0.565)	(0.122)	(0.593)	(0.048)
Gender	1.561 (0.697)	0.746 (0.601)	0.837 (0.753)	1.219 (0.771)	1.484 (0.372)	2.015 (0.430)	0.448 (0.515)	1.390** (0.020)
Farm size	5.536** (0.028)	2.059 (0.036)	0.704 (0.389)	0.956 (0.917)	0.885 (0.680)	1.610 (0.360)	1.583 (0.545)	0.892 (0.731)
Household income	3.466** (0.012)	1.662 (0.735)	0.674 (0.254)	0.685 (0.713)	1.435** (0.033)	1.264 (0.546)	1.124 (0.045)	0.934 (0.236)
Educational level	3.467 (0.188)	0.838 (0.649)	0.779* (0.067)	0.558 (0.254)	0.948** (0.047)	3.452 (0.148)	1.389 (0.690)	0.820 (0.606)
Information on weather forecast	1.326 (0.632)	0.365 (0.385)	0.643** (0.012)	1.243** (0.017)	0.354 (0.161)	2.125 (0.031)	1.423** (0.031)	1.263 (0.381)
Model summary								
Base category	No adaptation							
LR chi-square	148.55							
Prob > chi-square	0.000							
Log likelihood	-332.13							
Pseudo R square	0.425							

Note: figures in parentheses signify p-value

**and * Significant at 5% and 10% probability level respectively

9.6 The online survey

This section seeks to address research objective 5: validate the models used through the engagement of experts in relevant fields to gain their opinions on the study recommendations for a new strategy for smallholders growing yam on their holdings. This section presents experts' views on the study implications and recommendations based on the findings of the research. These experts' views also help in validating the models used in the analysis which led to the research findings.

The validation of the study recommendations, however, reached a consensus between experts after employing a two-stage online survey process.

As stated in section 5.7**,** two rounds of expert evaluation used to reach a consensus as shown in Table 9.8.

Table 9.8: Composition of the online survey rounds

Round I	**Experts' ranking of the study recommendations built from the study findings**
Round II	Response from evaluating the first round with suggestions given by the participants until it reaches a consensus

9.6.1 Selection of experts (sampling)

The online survey invited a panel of 15 experts in the first round, and 18 in the second round to seek their opinion on the study recommendations and also to gain appropriate suggestions where applicable. The experts were selected from the academic and industry fields related to the study. Therefore, the basis for expert selection was to include the following personnel who are also stakeholders with experience in yam production:

A. Academia
B. Extension agents/Officer
C. Independent researcher
D. Agriculturist
E. Policymaker

Table 9.9 shows the number of experts and the percentage of response in each round. Out of the 15 experts in the first round, 12 responses were received. 6 more experts were recommended (snowball sampling), and they were added to the 12 earlier experts to make 18 participants for the second round. Of the 18 participants, responses were received from 15 of them. In both rounds, a total of 27 respondents took part. The use of convenience sampling in the selection of experts, means that sample representativeness cannot be guaranteed (Palinkas *et al.,* 2015). Most online surveys accept non-probability, convenience or snowball sampling to seek experts' views (Hasson, Keeney, & McKenna 2000; Powell, 2003).

Table 9.9: The online survey rounds

Survey rounds	Experts	Responded Experts	% Response
Round I	15	12	80.00
Round II	12+6 (recommended) =18	15	83.33

Table 9.10 shows the make-up of the various groups of experts that participated in the two rounds.

Table 9.10: Frequency distribution of participants in the two survey rounds

Expert	1st Round	2nd Round
Academia (in Agriculture)	6	8
Extension officer	2	2
Independent researcher (in Agriculture)	1	1
Agriculturist	2	3
Policymaker	1	1
Total	12	15

The statements used in the first and second round are presented in Table 9.11 and 9.12 respectively. The sample of the questionnaire used is presented in Appendix H. The statements on these tables are made up of the study findings and the recommendations that needs to be validated by the experts in relevant field. Each finding is provided with recommendations to be validated. Some statements in the first round did not make it to the second round.

Table 9.11: Statements used in round 1

No		Findings/statement
Finding 1		**Temperature has a negative effect on the output of yam and the following recommendations are given**
	1	Policymakers should make policies that support the formation of a reliable weather forecast system.
	2	The government should provide free pesticides to farmers
Finding 2		**Lack of education has the probability of reducing yam farmers' net revenue, and so the following policy implications should be applied**
	3	The government should emphasize the need for education to enhance the ability of farmers to adopt farming innovation and modern adaptation practices by conducting local workshops and seminars among others.
	4	Policymakers should revisit the existing policy on agricultural extension, technology development and transfer to confirm its efficiency and functionality so that uneducated farmers, especially younger farmers, can gain appropriate knowledge and understanding on the extension services and new technologies provided.
	5	Policymakers should consider revising the extension programme aspect of the agricultural policy to support farmers in Nigeria to concentrate more on the bottom-top participatory approach so that the existing and the developing adaptation practices and technologies could be focused on the farm level for a better farmer-education.
	6	Institutional transformations or innovation that can make farmers associate communally among themselves, particularly in the same locality should be supported by policymakers because the farmer-to-

		farmer extension model can encourage faster transfer of information which in turn enhances farmers' education.
Finding 3		**Farming experience, household size, access to weather forecast and tenure status have a statistically significant effect on the net revenue of farmers, and so, the following recommendation is given**
	7	Policymakers should lay emphasis on how to improve these factors by working with individuals and social groups in order to enhance farmers' net revenue to achieve increased self-sufficiency in food crop production.
Finding 4		**Lack of credit facilities (moss common barrier), high cost of improved varieties, lack of adequate information about weather forecast, illiteracy of farmers, and poor access to and control of land are the factors that hinder farmers' adaptation and so the study recommends that;**
	8	The government should create and make functional more credit facilities at the rural level to offer affordable credit services to smallholders help them in the area of climate change adaptation because adaptation is expensive
	9	Institutions should develop and provide free improved crop varieties to farmers.
	10	Government should provide free land for farming to farmers
	11	Government should encourage farmers to follow up weather report on weather stations

SA=Strongly Agree, A= Agree, D=Disagree, SD=Strongly Disagree

9.6.2 Round I

The first round of the online survey comprised of a 4-point-Likert scale type rating with statements from the findings of the study (Table 9.11). Since a possibility for bias could occur owing to the limited options available (Keeney, Hasson, & McKenna 2001), provisions were made for experts to make suggestions on recommendations in addition to other relevant comments (Scheibe, Skutsch & Schofer, 2002; Giannarou & Zervas, 2014). This round required sending statements to all the participants involved so that they could rate the recommendations preferred by the study and make any additional suggestions. Experts were required to choose and rank the study recommendations established from the study findings. A 4-point Likert scale facilitated the rating of the choices with value 1 denoting "Strongly Disagree", through to 4 "Strongly Agree" (Hackett, Masson, & Phillips, 2006; Giannarou & Zervas, 2014). These options provided gave no opportunity for the experts to make choices such as "Neutral".

Moreover, some of the participants gave feedback and further recommended more experts as requested, which enabled collation for further review and analysis.

9.6.3 Round II

Round II incorporated feedback from the first round (Table 9.12). It also included suggestions from participants to increase the level of consensus, reaction rate and strength of the statements. Statements that did not meet the criteria for consensus in round 1 were dropped. Then the suggestions and comments that were provided by the experts in the first round were modified and incorporated into the statements in the second round. The second round required experts to provide their opinion through selecting a value from 1 (strongly disagree) to 4 (strongly agree). However, the feedback rate at this round increased, though not substantially (from 80 per cent in the first stage to 83 per cent in the second stage). This round further built-in experts' suggestions. Statements with below 51 per cent of the experts choosing 'strongly agree' did not make it to the second round.Thus, by establishing experts' opinions into subsequent rounds, it assists in creating certainty in the study (Landeta, 2006; Giannarou & Zervas, 2014).

Table 9.12: Statements that make up round 2

No		Findings/statement
Finding 1		**Temperature has a negative effect on the output of yam and the following recommendations are given**
	1	The government should provide an effective weather forecast system that can get to local farmers to help them know when to expect temperature increase and thus take necessary adaptation action.
	2	The government need to create an enabling environment for independent researchers as well as institutes to develop pest- and disease-tolerant yam varieties.
Finding 2		**Lack of education has the probability of reducing yam farmers' net revenue, and so the following policy implications should be applied**
	3	The government should emphasize the need for education to enhance the ability of farmers to adopt farming innovation and modern adaptation practices by conducting local workshops and seminars among others
	4	Policymakers should revisit the existing policy on agricultural extension, technology development and transfer to confirm its efficiency and functionality so that uneducated farmers, especially younger farmers, can gain appropriate knowledge and understanding on the extension services and new technologies provided.
	5	Policymakers should consider revising the extension programme aspect of the agricultural policy to support farmers in Nigeria to concentrate more on the bottom-top participatory approach so that the existing and the developing adaptation practices and technologies could be focused on the farm level for a better farmer-education.
	6	Institutional transformations or innovation that can make farmers associate communally among themselves, particularly in the same locality should be supported by policymakers because farmer-to-farmer extension model can encourage faster transfer of information which in turn enhances farmers' education.

Finding 3		**Farming experience, household size, access to weather forecast and tenure status have a statistically significant effect on the net revenue of farmers, and so, the following recommendation is given**
	7	Policymakers should lay emphasis on how to improve these factors by working with individuals and social groups in order to enhance farmers' net revenue to achieve increased self-sufficiency in food crop production.
Finding 4		**Lack of credit facilities, high cost of improved varieties, lack of adequate information about weather forecast, illiteracy of farmers, and poor access to and control of land are the factors that hinder farmers' adaptation and so the study recommends that;**
	8	The government should create and make functional more credit facilities at the rural level to offer affordable credit services to smallholders help them in the area of climate change adaptation because adaptation is expensive
	9	The government should take appropriate measures to develop and provide improved varieties to farmers at subsidized rate.
	10	Governments should develop a reliable weather forecast system that can take weather information across to farmers to enable the farmers to plant at the appropriate time
	11	The government should put in place a proactive regulatory land-use acts that will enable the farmers to partake in a more tenable land ownership systems so that they can invest in and make use of sustainable adaptation practices whose benefits come in subsequent years
	12	Government should provide free education up to tertiary education to support farmers

SA=Strongly Agree, A= Agree, D=Disagree, SD=Strongly Disagree

9.6.4 Measuring consensus

Although, the primary purpose of the online survey, is to reach a consensus among the experts, nevertheless a standard method to determine it does not exist (Giannarou & Zervas, 2014). Therefore, some studies measure agreement through frequency distributions (Hasson et al., 2000), and others use the standard deviation (Hasson et al., 2000; Christie & Barela, 2005) or the interquartile range (Raskin, 1994; Rayens & Hahn, 2000; Giannarou & Zervas, 2014)

However, the definition of the percentage of response to any given category, according to McKenna (1989); Hackett et al. (2006) is determined to be 51 per cent of experts responding to the choice 'strongly agree', which is between values 4 and 5 on a 5-Likert scale. Another standard by Green et al. (1990) suggests that at least 70 per cent of the statements need to rate three or higher on a four-point Likert-type scale. Concerning the studies that employ the standard deviation or interquartile range to measure consensus, the former ought to be no more than 1.5 (Christie and Barela, 2005) and the latter no more than 2.5 (Kittell-Limerick, 2005) or 1 (Raskin, 1994; Rayens & Hahn, 2000). Additionally, each analysis should also include the calculation of mean and median, since using these measures help to describe the middle and most typical response, representing the central tendency (Kittell-Limerich, 2005; Hsu & Sandford, 2007), as well as the coefficient of variation, signifying the observations' consistency, and the mode, depicting the most frequently occurred value (Gupta & Waymire, 2008; Saunders & Lewis, 2012).

However, Giannarou and Zervas (2014) recommend a complimentary use of three methods to measure consensus, because each one on their own cannot be a good proxy for consensus. These methods are: (i) the interquartile range, (ii) the standard deviation and (iii) the 51 per cent percentage of respondents lying in the 'highly important' or 'strongly agree' category.

Consequently, the statements in the online survey for this study reached a consensus by employing the following three measures in combination:

I. the percentage of participants over 51 per cent responding to the category 'strongly agree', (Hackett, Masson & Phillips, 2006; Giannarou & Zervas, 2014), is at value 4 on a 4 point-Likert scale.

II. the interquartile range ≤ 1 (Raskin, 1994; Rayens & Hahn, 2000; Giannarou & Zervas (2014) and

III. the standard deviation below 1.5 (Christie & Barela, 2005; Giannarou & Zervas, 2014).

9.6.5 Results of the online survey

Table 9.13 shows the responses from 12 experts for the 1st round, and 15 experts for the 2nd round. The Table also proves the need for using the combination of three measures. As it is evident in the first round, there is a statement with a standard deviation below 1.5, while their interquartile range is above 1 and an above 51 per cent of the experts responding to the category 'strongly agree' (statement 11). More so, there may be a case where the percentage of experts' responses lying in the 'strongly agree' category is below 51 per cent, even when the standard deviation and or the interquartile range are below 1.5 and 1 respectively. The challenge of how one can ensure that these statements reach a consensus among the participants still exist.

Consequently, the mix of the above three methods was used to represent an overall agreement. In the first round, statements 3, 4, 5, 6, 7, and 8 reached an agreement. These statements were then built into round two with suggestions and comments from the experts. In the second round, there was an improvement in the level of agreement (Table 9.14). This is because the combination of the three measures of consensus produced an agreement among all the statements, except statement 12.

Indeed, the combination of these three measures ensured a reliable way of reaching consensus in the survey and provides an authentic approach to conclude on the experts' overall opinion on the study recommendation.

Table 9.13: Round 1 online survey result (N=12)

Statistics	Stm 1	Stm 2	Stm 3	Stm 4	Stm 5	Stm 6	Stm 7	Stm 8	Stm 9	Stm 10	Stm 11
Mean	2.17	2.42	3.92	3.83	3.67	3.92	3.75	3.92	2.42	2.92	3.75
Median	1.50	2	4	4	4	4	4	4	2	3	4
Mode	1	2	4	4	4	4	4	4	2	4	4
Standard Deviation	1.33	1.24	0.29	0.39	0.49	0.29	0.45	0.29	1.16	1.08	0.45
Per cent in category strongly agree	25.00*	33.33*	91.67	83.30	66.67	91.67	75.00	91.67	25.00*	41.70*	75.00
Inter quartile range	2.50*	2.50*	0.00	0.00	1.00	0.00	0.50	0.00	2.00*	2.0*	1.50*
Consensus for all three (Y/N)	N	N	Y	Y	Y	Y	Y	Y	N	N	N

Stm = Statement, Y=Yes, N=No

* value does not meet criteria: (i) the percentage of participants over 51 per cent responding to the category ‘strongly agree’, (Hackett, Masson & Phillips, 2006; Giannarou & Zervas, 2014), is at value 4 on a 4 point-Likert scale; (ii) the interquartile

range ≤ 1 (Raskin, 1994; Rayens & Hahn, 2000; Giannarou & Zervas (2014) and (iii) the standard deviation below 1.5 (Christie & Barela, 2005; Giannarou & Zervas, 2014).

Table 9.14: Round 2 online survey result (N=15)

Statistics	Stm 1	Stm 2	Stm 3	Stm 4	Stm 5	Stm 6	Stm 7	Stm 8	Stm 9	Stm 10	Stm 11	Stm 12
Mean	3.40	3.40	3.87	3.80	3.67	3.93	3.87	3.80	3.40	3.40	3.93	2.53
Median	4	4	4	4	4	4	4	4	4	4	4	2
Mode	4	4	4	4	4	4	4	4	4	4	4	2
Standard Deviation	0.99	0.83	0.35	0.41	0.49	0.26	0.35	0.41	0.99	0.83	0.26	1.06
Per cent in category strongly agree	66.67	60.00	86.67	80.00	66.67	93.33	86.67	80.00	66.67	60.00	93.33	26.67*
Inter quartile range	1.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	0.00	2.00*
Consensus for all three (Y/N)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N

Stm = Statement, Y=Yes, N=No

* value does not meet criteria: (i) the percentage of participants over 51 per cent responding to the category ‘strongly agree’, (Hackett, Masson & Phillips, 2006; Giannarou & Zervas, 2014), is at value 4 on a 4 point-Likert scale; (ii) the interquartile

range ≤ 1 (Raskin, 1994; Rayens & Hahn, 2000; Giannarou & Zervas (2014) and (iii) the standard deviation below 1.5 (Christie & Barela, 2005; Giannarou & Zervas, 2014).

9.7 Chapter summary

This chapter addressed the impact of climate change on net revenue and determinants of famers' decision to adaptation. The impact of climate change on farmers' net revenue was investigated using the Ordinary Least Square (OLS) regression analysis, the Chi-square test, and the independent sample t-test and the findings were presented. The findings of the OLS analysis showed that the variables that have statistically significant effects on the net revenue of farmers are number of years farming, household size, access to the weather forecast and tenure status. The results from the Chi-square test showed that educational level age, number of years farming and access to credit have an association with the net revenue of farmers. While the result of the analysis from independent sample t-test showed that only education produced a statistically significant difference in means; there was a significant difference between the net revenue of educated farmers and uneducated farmers. Educated farmers had higher net revenue.

Further in this chapter, the determinants of the farmers' adaptation strategy have been determined using the binary Logit Model and the Multinomial Logit Model. The binary logit, however, only revealed the factors that influence the adaptation decision of farmers (i.e., whether to adapt or not to adapt), but it does not reveal the factors responsible for a specific adaptation strategy. For this reason, the multinomial logit (MNL) model was applied to complement it. This chapter reveals the factors that affect the adaptation strategy used by the farmers in order to build a recommendation that will help farmers to cope with climate change.

The result of the binary Logit Model revealed that access to credit, educational level, farming experience, household size, and household income influenced farmers' adaptation decision. Whereas the result of the MNL was as follows:

- Access to credit influenced crop diversification;
- Access to extension services raised the chance of reducing bush burning;
- Number of years farming increased the probability of changing planting date;
- Ownership of land raised the likelihoods of land expansion, reducing bush burning and the use of inorganic fertiliser;
- The household size increased the likelihood of changing planting date and

off-farm employment;

- Size of farmland influenced crop diversification;
- Farm income increased the likelihood of crop diversification, use of inorganic fertiliser, planting of trees, reducing bush burning, use of improved crop variety and expansion of farm size;
- Level of education increased the potential for changing planting date and use of inorganic fertiliser;
- Access to weather information increased the likelihood of tree planting, changing planting dates and expansion of farm size.

In addition, the two-stage online survey employed in the study consisted of two rounds with statements from the findings of the study. The first round invited 15 experts but had 12 participants, whereas the second round invited 18 experts but received 15 responses. The statements that met the criteria for consensus in round 1 (5 statements out of 11) were built into round 2 along with comments and suggestions from the participants. In the second round, 11 statements out of 12 met the criteria which were then built into the study recommendation. Therefore, based on the agreement reached by the experts, the study offered the recommendations which are outlined in the next chapter.

This chapter, however, switches to the last chapter, which includes summary and conclusion of this research study.

Chapter 10 Summary, conclusion and policy implication for future research

10.1 Introduction

This research addressed the consequences of climate variations faced by farmers involved in yam production in Cross River State, Nigeria which is one of the most susceptible States to changes in climate variables in the country (UNICEF 2011). The findings and outcomes of the analysis performed in the study explored in this thesis were based on statistical evidence gathered from State-level time series data for the period 1996-2017, and farm-level survey data from 209 farmers in the study area and validation of recommendations by an expert panel. However, the goal of this chapter is to revisit each of the aims and objectives of the study (stated in Chapter 1), these being to;

1. Analyse the impact of climate variables on yam production at the state level for the period 1996-2017;
2. To investigate the socio-economic factors that affect the net revenue of yam farmers at the farm level;
3. Evaluate yam farmers' perceptions of, and adaptation strategies to changes in the weather patterns they are experiencing in the study area and any barriers to adaptation;
4. Determine the most important factors that affect farmers' choice of adaptation to climate change and build these into recommendations for improved State extension for yam farmers and their communities, and to,
5. Validate the models used through the engagement of experts in relevant fields to get their opinions on the study recommendations for a new strategy for smallholders growing yam on their holdings.

For each objective, the author will provide a linkage between them and the major outcomes of the research, and reconcile the discussions given in the different chapters to then draw appropriate study conclusions and enumerate the implications that may arise from the research findings in favour of the government, policymakers, farmers, non-governmental organisations (NGOs) and individuals. Added to this, recommendations are developed for more targeted extension support for smallholders, especially those involved in yam production. Furthermore, the limitations encountered during this study and prospects for future research are presented in this chapter.

The analytical aspect of this thesis comprised of three major parts; the impact of climate change on yam production, adaptation strategies to cope with climate change and a survey of experts. Thus, this chapter is organised as follows:

- Section 10.2 gives a summary of the key findings that addressed the five research objectives and test the null hypothesis stated in Chapter 1.
- Section 10.3 gives the conclusion of the research.
- Section 10.4 presents the validated policy implications and recommendations based on the findings of the study.
- Section 10.5 provides the contribution of the research to existing knowledge and finally,
- Section 10.6 gives the limitations of the study and provides direction for further research.

10.2 Summary of the key findings of the study

Using data from the Nigerian government statistical database, and data from a structured farmer questionnaire, an analysis was performed using SPSS and STATA statistical software. This section sets out the key findings from the analysis which addressed the five research objectives of the study.

10.2.1 Research objective one: to analyse the impact of climate variables on yam production at the state level for the period 1996-2017

The null hypothesis associated with this objective is as follows:

H_0 1: There is no significant impact of climate change on yam production in Cross River State for the period 1996-2017.

The findings produced for this research objective were concerned with the evidence of climate change variables on yam production in Cross River State using the co-integration model. Time series analysis starts by carrying out a unit root test to determine the stationarity or non-stationarity of the variables. The result of the ADF-test carried out showed that all the variables were integrated of order one [I(1)] at level, signifying the presence of unit root in the time series data. For this reason, a test for the presence of a long-run relationship (cointegration) among the variables was done. The outcome of the test suggested that there is the presence of cointegrating long-run relationship among the time series at 0.05 per cent level of significance. It revealed a very high R-squared value of 98 per cent and a low Durbin-Watson statistic (1.188), implying that using the variables with an ordinary level regression (OLS) will lead to spuriousness.

Therefore, the Error Correction Model (ECM) was employed. The ECM result was in harmony with the literature showing that climate variables such as temperature played a significant role in agricultural production. Rainfall was seen to have a positive coefficient but was not statistically significant. Temperature, on the other hand, was statistically significant at $p<0.05$ and had a negative impact on yam production in the study area. This implies that an increase in temperature reduces the quantity of yam produced (yam output) in the study area.

Hence, in testing the null hypothesis one, it can be deduced that the hypothesis which states that there is no significant impact of climate change on yam production in Cross River State for the period 1996-2017 was rejected based on these findings and that there was a statistically significant association between temperature and yam output.

10.2.2 Research objective two: To investigate the socio-economic factors that affect the net revenue of farmers at the farm level

The null hypothesis stated for this objective is as follows:

$H_0 2$: Socio-economic factors do not have a significant effect on yam farmers' net revenue.

The determinants of net revenue of farmers (for the planting season 2017/2018) employed the use of Ordinary Least Square (OLS) analysis, a Chi-square test and an independent sample t-test. The regression analysis tool (OLS) was applied to investigate the influence of the socio-economic, institutional and farm characteristics to farm profit (which is defined as net revenue) under changing climatic conditions. The Chi-square test, however, was employed to show the relationship between the variables while the independent sample t-test was used to compare the means of net revenue between groups.

Consequently, based on the results of the Pearson chi-square analysis, four variables were discovered to be statistically significant; educational level (p-value

=0.047) and age (p-value=0.034) at p<0.05, while farming experience (p-value=0.061) and access to credit (p-value=0.088) at p<0.10. Therefore, the findings implied that these variables are associated with the net revenue of farmers. Additionally, to compare the means of net revenue between groups in the study area, the two-sample t-test was used. The result of the analysis (which used values for equal variances assumed) showed that only one variable produced a statistically significant difference in means at p<0.10, which is education (p-value=0.063). Thus, the findings suggested that there is a significant difference between the means of net revenue of educated farmers and uneducated farmers. And it was revealed that the educated farmers had a higher net revenue.

Regarding the OLS, the multiple regression analysis was employed to address the possible factors that influence farmers' net revenue in yam production in the face of climate change. The findings showed evidence of a very high significant estimation because the estimated Prob>F was 0.000. Additionally, the findings revealed the R-square value of 0.660 which indicates that 66 per cent of the dependent variable (net revenue) is explained by the specified independent variables in the model. Furthermore, the findings of the analysis showed that most of the explanatory variables are not statistically significant. However, the variables that have statistically significant effects on the net revenue of farmers are number of years in farming, household size, access to the weather forecast and tenure status.

Therefore, in testing the null hypothesis two, these findings led to its rejection, which states that socio-economic factors do not have a significant effect on yam farmers' net revenue I.e., there is a statistically significant association between some scio-economic factors and yam farmers' net revenue.

10.2.3 Research objective three: To evaluate yam farmers' perceptions of, and adaptation strategies to changes in weather pattern they are experiencing in the study area and any barriers to adaptation

It is expected that farmers should first observe that there is a change in climate to undertake the required adaptive measure I.e., that they have had an attitudinal response to evidence of climate change that informs a behavioural response. The key components of the enquiry were to consider if farmers had been influenced by any of the following: erratic rainfall pattern, hotter days, delayed onset of rainfall, increasing incidence of a flood, early cessation of rains and long duration of rainfall. Using a four-point Likert-type rating scale farmers' perception of climate change in Cross River State was determined. The findings revealed that the farmers observed erratic rainfall pattern, hotter days, delayed onset of rainfall and long duration of rainfall. In addition, the perceived effects of climate change by the farmers in the study area were examined. The findings from the analysis revealed that the observed effects of climate change includes a decline in crop output, late maturity of the crop, pest and disease proliferation and the delay in planting period. These effects perceived by the farmers have severe implications for food security, particularly in the rural areas which depend mostly on agriculture for food and other resources.

Furthermore, the adaptation strategies commonly practiced by farmers which were revealed in the literature and the primary data gathered in this study include the use of improved variety, changing planting date, planting of trees, use of inorganic fertiliser, reducing bush burning, expansion of farm size, off-farm employment and cultivation of different varieties of crop. The research found out most farmers reported they observed changes in the weather pattern, and took adaptive measures, and only a very small minority of farmers in the study (2.6 per cent) did not take any adaptation measure to cope with the changing climate.

Nevertheless, farmers are faced with constraints that impede them from undertaking their choice of adaptation strategy. Added to this, literature argued that factors like accessibility and utilisation of weather information, the institutional situation and the socio-economic conditions of households might have effects on farmers' ability to adapt to changes in the weather pattern. This research revealed that the most common barrier to adaption to climate change stated by the farmers in the study group was the lack of credit facilities (25.4 per cent). Other significant barriers to adaptation experienced by the farmers are high cost of improved crop varieties (22.7 per cent), lack of adequate information about weather forecast (18.5 per cent), illiteracy of farmers (14 per cent), poor access to and control of land (9.4 per cent) and farm labour shortage (8 per cent) as the least constraint reported as affecting the farmers' adaptation practices.

10.2.4 Research objective four: To determine the most important socio-economic factors that affect farmers' choice of adaptation to climate change and build these into recommendations for improved state extension for yam farmers and their communities

This objective tested the null hypothesis 3 which was stated as follows:

$H_0 3$: Socio-economic factors do not influence the choice of adaptation strategies used by yam farmers in the study area.

The findings from this objective are in two parts; the binary logit model outcome and the Multinomial Logit (MNL) model result. Firstly, the outcome of the binary logit regression model for the factors that determine farmers' adaptation decision showed that farmers' choice to adapt in the study area is determined by access to credit, educational level, farming experience, household size, and household income at the 95 per cent confidence limit. The binary logit, however, only reveals the factors that influence the adaptation decision of farmers (i.e., whether to adapt or not to adapt), but it does not show which factor is responsible for a specific type of adaptation option. Based on this, the multinomial logit (MNL) model was employed to complement this result.

The prerequisite for the justification in using the MNL model is for the Independence of Irrelevant Alternatives (IIA) assumption to be satisfied. This is done by employing the Hausman test to test for the IIA assumption. This test was carried out and the result indicated that the use of MNL model is suitable for the analysis. That is to say, the use of the MNL model to find out the determinants of adaptation strategies was justified. The findings, however, did not vary greatly from the previous analysis, which confirms the robustness of the results. Moreover, eight adaptation options were incorporated in the MNL model, together with no adaptation and they were; use of improved crop variety, changing planting date, planting of trees, use of inorganic fertilizer, reducing bush burning, expansion of farm size, off-farm employment, and planting of different varieties of crop. Thus, the eight adaptation choices make up the dependent variable of the MNL model and were eventually categorized 0-8 with 0 = no adaptation. Based on the findings, the probability value of the likelihood ratio (LR) chi-square indicated that most of the variables are together statistically significant, although some of the variables are not independently statistically significant. For this reason, only the statistically significant variables that influence adaptation options were discussed (see Chapter 9, Table 9.7).

Thus, the null hypothesis three of the study, which states that socio-economic factors do not influence the choice of adaptation strategies used by yam farmers in the study area is rejected based on the study findings as there was a statistically significant association between the socio-economic factors and the choice of adaptation strategies.

10.2.5 Research objective five: The online survey to validate study recommendations

A two-stage online survey was conducted to gain experts' opinion on the study recommendations. The findings from the online survey provided the validated study recommendations. These recommendations are presented in section 10.4.

10.3 Conclusion

As climate is changing, the input use at farm level for yam farmers is changing as well, which may affect the cost of production. Therefore, one way to investigate the impact of climate change on agriculture would be to explore any changes in the cost of production due to the changes in climate variables i.e., temperature and rainfall. Another way to investigate the impact of climate change would be observing changes in crop production (output), as the changes in temperature and rainfall may affect the crop plant growth and consequently the output and yield. Added to this, the net revenue of farms may change due to changes in yield and/or costs of production as a result of climate change. Therefore, another way to observe the climate change impact would be the changes observed in net revenue due to the changes in climate variables. Considering all these, the first area of focus of this study was to examine whether there was an association between the changes in climate variables on the output of yam, the cost of production, and the net revenue.

The outcome of the model in terms of rainfall effect, and the predictions in future temperature changes contradicts the views of the farmers interviewed, and the global understanding of temperature. The study predicted a decrease in temperature over 20 years in Cross River State (figure 8.3) whereas, temperature is projected to increase in future (IPCC, 2018). Likewise, the result of analysis in the study revealed that rainfall is not statistically significant in yam production, whereas the farmers interviewed in the study area reported perceived effects of rainfall in yam production. This may be due to the more general secondary rainfall data, compared to the specific conditions in terms of rainfall on a given farm. These findings however are at the time of study, and it is important to note that climate change is dynamic. Thus, the response and/or the model outcome may be different in future studies. However, the trend analysis of temperature in chapter 8 revealed temperature was moving in a downward trend overtime (1996-2017). On the other hand, the trend in rainfall was shown to be erratic overtime (1996-2017). This suggests that farmers should be provided with a weather forecast system to enable them to predict the temperature and rainfall pattern during the planting season for a suitable planting time. From the inferential statistics result, temperature was statistically significant and had a negative impact on yam production in the study area. This implies that a rise in temperature will reduce the quantity of yam produced (yam output) in the study area. Therefore, support should be given to farmers by the government to enable them to undertake adaptation strategies to increase yam production in the event of a rise in temperature. The different kinds of support to be given to the farmers are mentioned below.

Education, number of years in farming, access to weather forecast, land ownership and access to credit had a statistically significant association with the net revenue of farmers. Education in the rural area is important because it drives diversification of ideas and agricultural practices. The educated person in a family could engage in a job using his/her educational qualification and this could increase their net revenue off farm. Also, educated farmers would be more likely to gain access to credit because they understand better what is involved in obtaining credit and may be seen as less risk by the bank.

Mentor programme. Farmers with many years in farming could have more experience in farming than those with lesser years. Therefore, in future, the older farmers could teach or mentor the younger ones in farming. This could be achieved through forming small groups in different communities and having farmers with many years of farming to be leaders.

Weather forecasting systems. Providing a free weather forecast system by the government dedicated to the farmers is essential. A dedicated long-term farming weather forecast system will support higher production in agriculture as farmers will have knowledge of good planting time. Moreover, land ownership should be supported.

Encouraging land ownership provides forward thinking and long-term planning which supports sustainability of the farm, not only financially but also environmentally.

More so, certain **targeted grants** should be provided to the farmers to promote access to finance which will be a new initiative for yam farmers in Cross River State. Furthermore, with the growing population in Nigeria, food consumption is also increasing. Therefore, the country needs to grow yam more efficiently and not having to import to support food security. To achieve this, yam farmers need to be supported to produce more food for the growing population.

The study sample revealed a higher percentage of male led household (70.8%) than the female led (29.2%). This could be because the female led households have less manpower in yam production as yam production is tedious and involves physical activities. According to World Bank (2019), the world is paying dearly by failing to close the gender gap in agriculture. Women play a vital role in small-holder agriculture around the world, meeting the food needs of their households and contributing to the development and growth of their livelihoods and sustainable futures for their households and communities.

To close the gender gap in agriculture, training should be provided to support women farmers as yam farming activities are physical. Women's participation in collectives and community groups should be promoted as well as increasing their access to and control over resources; ranging from secondary education, improved seeds, agricultural inputs like land to accessing finance.

Moreover, economic rationality suggests that adverse impacts of climate change will cause farmers to take adaptive measures at the farm level, as they want to maximize their profits. However, the literature on farmers' adaptation to climate change and the technology adoption opines that there are several factors that influence adoption decisions. In this respect, farmers' perceptions about climate change impact are an important factor that underpins farmers' decisions to make any change in farming practices. Additionally, there may be factors that influence the farmers' choice to undertake adaptation to climate change. More so, the farmers may be faced with some constraints or barriers that hinder them from adopting the strategies available to them. By knowing the constraints faced by rural farmers allied to the scientific basis for improving or stabilizing production, it is possible to recommend possible adaptation strategies that will meet their needs.

Consequently, the second area of focus of this research was to explore farmers' climate change perception, adaptation strategies in the face of this change, determinants of farmers' choice to adaptation strategy and barriers to adaptation strategy. However, the most important adaptation strategy used by the farmers in the study was planting of different varieties of crops. There were also barriers to adaptation faced by the farmers, and lack of credit facilities was the most significant because the farmers need money to invest in adaptation strategy which is expensive. Thus, it is necessary for the government to provide grants targeted at farmers to support increase in yam production. Added to this, short videos could be developed with information on how smallholding farms could be upgraded and placed on the internet or shared with phones so that farmers can easily access them. Also, a guide to upgrading smallholding farms could be published in magazines mailed free and direct to farmers monthly. This similar practice can be found in the UK where Farmers Guide, a premier monthly farming magazine is mailed free and direct to farmers and contractors across the UK (Farmers guide, 2021).

Lastly, in order to refine and validate the models used in the study, experts in the field of economics, yam production, rural livelihoods, extension and agricultural policy were engaged to air their opinions on the study recommendations using a two-stage online survey.

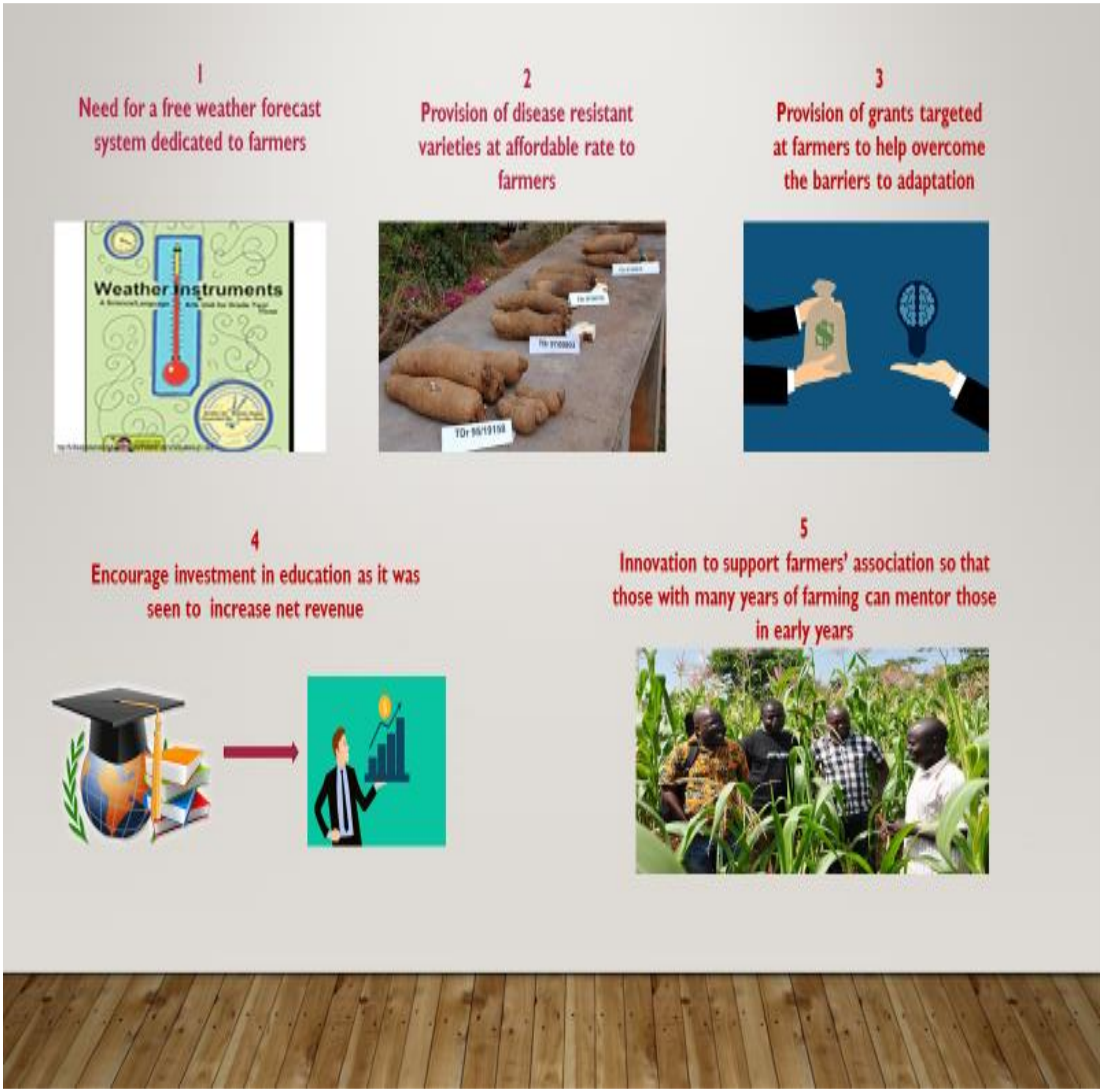


Figure 10.1: Key things to put in place by the government to increase yam production in Cross River State (see section 10.3)

10.4 Policy implications and recommendations based on the study findings

It is vital to put in place policies and programmes that will encourage food crop farmers to be proactive in using the resources available to them, and at the same time adapt to climate variability in order to attain food security. However, based on the findings of this study, the following recommendations, which have been validated by experts, are offered to maintain or improve yam production in Cross River State in the face of climate variations:

- It was observed from the co-integration analysis reported in chapter 8 that temperature had a negative effect on the quantity of yam produced. Given this observed adverse effect of temperature on yam production, the government need to create an **enabling environment for independent researchers** as well as institutes to develop pest- and disease-tolerant yam varieties, as an increase in temperature leads to the proliferation of insects, pests, and diseases that are harmful to crops. This can be achieved through **offering grants to support research and extension.**
- The government should take appropriate steps to provide an **effective weather forecast system** that can facilitate the extension of weather information to local farmers to help them know when to expect temperature increase and thus take necessary adaptation action. A weather forecast system targeted at farmers could be provided in different farming communities.
- There was a significant difference between the net revenue of educated farmers and uneducated farmers. The uneducated farmers are those with no form of formal education. Hence, illiteracy has the probability of reducing yam farmers' net revenue in the presence of climate variation. For this reason, the government should emphasize on the need for **formal education** up to secondary level to enhance the ability of farmers to adopt farming innovation and modern adaptation practices by conducting local workshops and seminars among others. In addition, policymakers should revisit the existing policy on agricultural extension, technology development and transfer to confirm its efficiency and functionality so that uneducated farmers, especially younger farmers, can access literacy classes and also gain appropriate knowledge and understanding on the extension services

and new technologies provided. Alternatively, the existing **extension services** could be reformed so that the extension agents spend more time and are more frequently on field visits to give support in enhancing farmers' knowledge.

- It was found that lack of credit facilities (most common barrier), high cost of improved varieties, lack of adequate information about the weather forecast, illiteracy of farmers, poor access to and control of land and farm labour shortage (as the least constraint) were the factors that hinder farmers' adaptation. Therefore, there is need for the government to take the required steps to combat these constraints to reduce the vulnerability of the farmers. For instance, the government should create and make functional more credit facilities in form of **agricultural loans** at the rural level to offer affordable credit services to smallholders to help them in the area of climate change adaptation because adaptation is clearly expensive. Also, the government should take appropriate measures to develop and provide **improved crop varieties** to farmers at a subsidized rate. In addition, the government should develop a reliable weather forecast system that can take weather information across to farmers to enable them to plant at the appropriate time. Added to this, the government should put in place **proactive regulatory land-use acts** that will allow the farmers to partake in a more tenable land ownership systems so that they can invest in and make use of sustainable adaptation practices whose benefits come in subsequent years.
- Policymakers should consider making the **extension programme** aspect of the agricultural policy to support farmers in Nigeria to concentrate more on the bottom-top participatory approach so that the existing and the developing adaptation practices and technologies could be focused on the farm level since the impact of climate change is crop and location specific. Extension should start where the people are at the farm level.
- Policymakers should support **institutional changes or innovation** that can make farmers to associate communally among themselves, particularly in the same locality because the farmer-to-farmer extension model can encourage a faster transfer of information than other forms of extension methods.

10.5 Contribution to the research

This study contributes in several ways to the literature, practice and policymaking. This research used secondary data collected from government statistical database and primary data gathered by the researcher using a well-structured questionnaire from yam farming-households in Cross River State, Nigeria. The data gathered holds a robust set of information that is relates to climate variables (temperature and precipitation), yam output, farmers' socio-economic situations, institutional accessibility, cost and benefit, perception of climate change, the adaptation strategies farmers undertake, constraints they have in taking adaptation and factors that determine their choice of adaptation. Importantly, this primary data set gathered by the researcher is a contribution to literature which can be used in future for other studies.

Moreover, based on the available literature, there is a paucity of research on the impact of climate change on yam crop. This research, however, contributes to addressing the issue of the limited research, before this study, on the impact of climate change on yam production. In addition, previous inquiries on the effects of climate change on yam production estimated the effect of climate variations on the yield or output of the crop (using the production function approach) at the state level. Nevertheless, to the best of the researcher's knowledge, no known study has investigated the impact of climate change on yam production both at the state level and farm level, considering climate change effect on yam output and net revenue of farmers in a single study. In this present research, climate change consequential impact on the net revenue of yam farmers was estimated, which is the first of its kind where climate change impact on yam production is explored in Cross River State. Hence, this research contributes to the analysis of climate change effects by revealing another standpoint of analysing climate change impact on food crop production in Cross River State. Temperature is predicted to increase in future in Nigeria, but not in Cross River State, and its impact will affect the output of yam. However, there may be variations across Nigeria on the effect on farmers and adaptation strategies undertaken to cope with the effects of climate change on yam production may vary (see section 10.2.4). The range of adaption strategies considered in this research is therefore of value in a number of regions.

Furthermore, this research contributes to the literature on adaptation to climate variations. The findings on farmers' adaptation reported here is for a specific crop, which is yam. However, the consideration of adaptation practices by yam farmers, the constraints to adapt, and the determinants of adaptation choice is very limited in the literature. Therefore, this research contributes to the existing knowledge of yam farmers' adaptation literature. Added to this, although there is some literature on the determinants of farmers' choice of adaptation strategy (these studies only show farmers choice of yes to adaptation and no to non-adaptation practice), there is a paucity of literature on factors that determine what specific type of adaption practice taken. This study, however, adds to the knowledge by providing the particular factors that influence a specific adaptation option chosen by the farmers.

The overall contribution of this study is that it is the first to investigate the impact of climate change at the State and farm levels using a more extensive application of theories in the context of individual crop (yam) response to climate change and farmers' adaptation in Cross River State, Nigeria. The outcome of this research could also support policymakers to design and implement programmes that will promote sustainable adaptation practices to cope with the impact of climate change. In addition, this study aims to contribute to a broader understanding of the micro- and macro-economic implications of climate change surrounding yam production in Cross River State, Nigeria. It is anticipated that the State will benefit from the development of the recommendations to support extension efforts while the farmers themselves will benefit from the study recommendations on climate change adaptation practices. This should then lead to increased yam productivity and food security at family and community levels as well as contributing to national food security. In this regard, the study will also serve as a basis for further research. Therefore, these are the gaps in knowledge this study attempts to fill.

Finally, this is the first research that has validated the models used in generating the study findings through an online survey by gaining experts' (in relevant fields) opinion on study recommendations in the setting of food crops' responses to climate variability and farmers' adaptation.

10.6 Limitations of the study and direction for further research

The major limitation of this study was the lack of historical data on yam production and agricultural input over time. The aggregate data available from relevant sources (NPAFS, 2018 and FMW&WR, 2018) was from 1996 – 2017. For this reason, the historical information for the period available and the survey data collected from the field were used. The aggregate data limitation, however, is methodological and not the quality of field data. Therefore, the findings from this research are considered to be suggestive, rather than conclusive.

Looking at the direction for future research, this PhD research focused on the impact of climate change on yam crop in general without considering the different varieties of the crop, therefore, future research could be done on the effect of climate variations on the different species of yam to know how each species respond in the face of climate change. Moreover, the field survey aspect of this study concentrated only on the tropical rain forest region in Nigeria. However, literature reports that different areas are affected in different ways by variations in climate. Thus, there is need for region-specific research to present a more robust view of the impact of climate change on yam production. Consequently, future research on yam production response to changes in climate at the farm level can be conducted in the drylands of the northern regions of Nigeria. The outcome of this may, in turn, support policymakers to form region-specific agricultural and adaptation policies which will potentially curb the harmful effects of climate change more successfully.

Furthermore, net revenue analysis in this research was based on evidence from field survey data. However, future research can extend to gathering published data from the statistical database over time and comparing it with that of field survey data to estimate farmers' net revenue. This research focused on yam crop. Future research can also be conducted separately on other agricultural staple food crops such as wheat, vegetables, beans, millet and sorghum to reveal the impact of climate change on these crops in Nigeria.

Additionally, livestock production is an important aspect of non-crop agriculture. According to literature, the livestock population is influenced by drought, heatwaves, pest and diseases and flood. Consequently, the focus of future research on climate change impact on this part of agriculture will be of utmost importance.

References

Abildtrup, J., Audsley, E., Fekete-Farkas, M., Giupponi, C., Gylling, M., Rosato, P., & Rounsevell, M. (2006). Socio-economic scenario development for the assessment of climate change impacts on agricultural land use: a pairwise comparison approach. *Environmental science & policy*, *9*(2), 101-115.

Acquah, H., & Onumah, E. E. (2011). Farmer's perception and adaptation to climate change: An estimation of willingness to pay. *Agris on-line Papers in Economics and Informatics*, *3*(665-2016-44813), 31-39.

Adams, R. M., Hurd, B. H., Lenhart, S., & Leary, N. (1998). Effects of global climate change on agriculture: an interpretative review. *Climate research*, *11*(1), 19-30.

Adegbite, A. A., Adesiyan, S. O., Agbaje, G. O., & Omoloye, A. A. (2005). Host suitability of crops under Yam intercrop to root-knot nematode (Meloidogyne incognita Race 2) in South-Western Nigeria. *Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS)*, *106*(2), 113-118.

Adegeye, A. J., & Dittoh, J. S. (1985). Essentials of agricultural economics impact. *Ibadan: Publishers Nigeria Ltd*.

Adejuwon, J. O. (2006). Food crop production in Nigeria. II. Potential effects of climate change. *Climate Research*, *32*(3), 229-245.

Adejuwon, S. A. (2004). Impact of climate variability and climate change on crop yield in Nigeria. Contributed Paper to Stakeholders Workshop on Assessment of Impact and Adaptation to Climate Change (AIACC), 2-8.

Adesina, A. A., & Zinnah, M. M. (1993). Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone. *Agricultural economics*, *9*(4), 297-311.

Adler, M., & Ziglio, E. (1996). *Gazing into the oracle: The Delphi method and its application to social policy and public health*. Jessica Kingsley Publishers.

Agbarevo, M. N. (2014). An evaluation of farmers' adoption of yam mini-sett technique in cross-river state, Nigeria. *European Journal of Research in Social Sciences Vol*, *2*(3).

Agbarevo, M. N. B. (2013). Farmers' perception of effectiveness of agricultural extension delivery in cross-river state, Nigeria. *IOSR Journal of Agriculture and Veterinary Science*, *2*(6), 1-7.

Agboola, S. A. (1979). An agricultural atlas of Nigeria. *An agricultural atlas of Nigeria.*

Agbor, G. (2007). The economics of population growth and changes in demographic structure. In *MOFINEWS*. Cross River State Privatization exercise, journey so far 6(3), 7.

Agom, D.I., Ohen, S. B., Itam, K.O., & Inyang, N. N., (2012). Analysis of technical efficiency of smallholder cocoa farmers in Cross River State, Nigeria. *International Journal of Agricultural Management and Development (IJAMAD)*, *2,* 177-185

Agwu, N.M., Nwachukwu, I.N. & Anyanwu, C.I., (2012). Climate variability: Relative effect on Nigeria's cassava productive capacity. *Rep. Opin*. 4: 11-14. Retrieved from http://www.sciencepub.net/report.

Aidoo, R. (2009). *An analysis of yam consumption patterns in Ghanaian urban communities* (Doctoral dissertation).

Ajakaiye, O., Jerome, A. T., Olaniyan, O., Mahrt, K., & Alaba, O. A. (2016). Spatial and temporal multidimensional poverty in Nigeria. *Growth and poverty in sub-Saharan Africa*, *218*.

Ajayi, J. O. (2015). Effects of climate change on the production and profitability of cassava in the Niger Delta region of Nigeria. *AGRIS on-line Papers in Economics and Informatics*, *7*(665-2016-45059), 3-11.

Ajetombi, J., & A. Abiodun (2010). Climate Change Impacts on Cowpea Productivity in Nigeria. African Journal of Food, Agriculture, Nutrition and Development, 10(1): 2258-2271.

Ajetomobi, J., Abiodun, A., & Hassan, R. M. (2011). Impacts of climate change on rice agriculture in Nigeria. *Tropical and Subtropical Agroecosystems*, 14(2011): 613-622.

Ajmi, A. N., Aye, G. C., Balcilar, M., & Gupta, R. (2015). Causality between exports and economic growth in South Africa: Evidence from linear and nonlinear tests. *The Journal of developing areas*, *49*(2), 163-181.

Ajokporise, D. (2011). Perception and Impact of Climatic Variations on Crop Production in Sapele local Government Area of delta State, Nigeria. Journal of Research in National Development, 9(1), 131-137.

Akande, A., Costa, A. C., Mateu, J., & Henriques, R. (2017). Geospatial analysis of extreme weather events in Nigeria (1985–2015) using self-organizing maps. *Advances in Meteorology*.

Akinbobola, T., Adedokun, S. A., & Nwosa, P. I. (2015). The impact of climate change on composition of agricultural output in Nigeria. *American Journal of Environmental Protection 3 (2), 44-47.*

Akpan, E. I., & Obang, C. E. (2012). Tourism: A strategy for sustainable economic development in Cross River State, Nigeria. *International Journal of Business and Social Science*, *3*(5).

Alauddin, M. & Sarker, M. A. R. (2014). Climate change and farm-level adaptation decisions and strategies in drought-prone and groundwater-depleted areas of Bangladesh: an empirical investigation. *Ecological Economics*, 106, 204-213.

Ali, M. P., Kabir, M. M. M., Haque, S. S., Qin, X., Nasrin, S., Landis, D., ... & Ahmed, N. (2020). Farmer's behavior in pesticide use: Insights study from smallholder and intensive agricultural farms in Bangladesh. *Science of the Total Environment*, *747*, 141160.

Alvaro, C., Tingju, Z., Katrin, R., Richard, S. J., & Claudia, R. (2009). Economy-wide impact of climate change on Agriculture in Sub-Saharan Afric. International food policy research Institute (IFPRI) discussion paper, 00873, 1.

Amalu, U. C. (1998). *Agricultural research and extension delivery systems in sub-Saharan Africa*. University of Calabar Press.

Angba, A. O., Eta H., & Angba, C. W. (2018). Knowledge Sharing and Learning Mechanisms for Climate Change Adaptation among Key Stakeholders of Yam and Cassava Production in Cross River State, Nigeria. *Journal of Teaching and Education,* (8)1, 177-186.

Angba, C. W., Baines, R. N. & Butler, A. J. (2020). Examining Yam Production in Response to Climate Change in Nigeria: A Co-Integration Model Approach. Soc. Sci., (9)4. https://doi.org/10.3390/socsci9040042

Angba, C. W., Baines, R. N. & Butler, A. J. (2020a). Exploring the effects of climate change on net revenue of farmers: An econometric investigation using farm-level data in Cross River State, Nigeria. Journal of Sustainable Development, (13)3.

Apata, T. G., Samuel K. D., & Adeola, A. O. (2009). *Analysis of Climate change perception and Adaptation among Arable Food Crop Farmers in south Western Nigeria. Paper presented at the conference of International Association of Agricultural Economics*, Beijing, China, 22, 2-9. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.472.1451&rep=rep1&type=pdf

Arbuckle Jr, J. G., Morton, L. W., & Hobbs, J. (2015). Understanding farmer perspectives on climate change adaptation and mitigation: The roles of trust in sources of climate information, climate change beliefs, and perceived risk. *Environment and behavior*, *47*(2), 205-234.

Arimi, K. S. (2014). Determinants of climate change adaptation strategies used by fish farmers in Epe Local Government Area of Lagos State, Nigeria. *Journal of the Science of Food and Agriculture.* 94(7), 1470-1476.

Asfaw, A., & Admassie, A. (2004). The role of education on the adoption of chemical fertiliser under different socioeconomic environments in Ethiopia. *Agricultural economics*, *30*(3), 215-228.

Ater, P. I., & Aye, G. C. (2012). Economic impact of climate change on Nigerian maize sector: A Ricardian analysis. *WIT Transactions on Ecology and the Environment, 162*, 231–239. Retrieved from https://doi.org/10.2495/EID120211

Awoniyi, O. A., & Omonona, B. T., (2007). Production efficiency in yam-based enterprises in Ekiti State, Nigeria. Journal of Central European Agriculture, 7(4), 627-636.

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

Babaleye, T. (2003). West Africa: Improving yam production technology. *ANB-BIA supplement issue/edition*, (463).

Babatunde, J. A., Ayobami, T. S., & Mark, T. (2011). Developing climate change scenarios, biophysical impacts and adaptation strategies in Nigeria. *A final report submitted to Nigerian Environmental Study/Action Team (NEST) as part of the Building Nigeria Response to Climate Change (BNRCC) Project*.

Baltagi, B. (2008). *Econometric analysis of panel data*. John Wiley & Sons.

Bamire, A. S., & Amujoyegbe, B. J. (2005). Economic analysis of land improvement techniques in smallholder yam-based production systems in the agro-ecological zones of Southwestern Nigeria. *Journal of Human Ecology*, *18*(1), 1-12.

Bandiera, O., & Rasul, I. (2006). Social networks and technology adoption in northern Mozambique. *The economic journal*, *116*(514), 869-902.

Barange, M., & Perry, R. I. (2009). Physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture. *Climate change implications for fisheries and aquaculture*, *7*.

Barnwal, P., & Kotani, K. (2010). *Impact of variation in climatic factors on crop yield: A case of rice crop in Andhra Pradesh, India* (No. EMS_2010_17).

Bartlett, J. E., Kotrlik, J. W., & Higgins, C. C. (2001). Organizational Research: Determining Appropriate Sample Size in Survey Research. Information Technology, *Learning, and Performance Journal*, 19, 43-50.

Belay, A., Recha, J., Woldeamanuel, T., & Morton, J. (2017). Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. Agriculture & Food Security. 6(24), 1-13. DOI 10.1186/s40066-017-0100-1

Berg, P., Moseley, C., & Haerter, J. O. (2013). Strong increase in convective precipitation in response to higher temperatures. *Nature Geoscience*, *6*(3), 181-185.

Bhandari, D., & Gurung, G. (2008). Increasing resilience in Nepal. *Tiempo A Bulletin on Climate and Development*, *68*, 7-10.

Bitsch, V. (2000, January). Agricultural economics and qualitative research: Incompatible paradigms? In *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research* (Vol. 1, No. 1).

Black, I. (2006). The presentation of interpretivist research. *Qualitative Market Research: An International Journal*, 9(4), 319–324.

Blaikie, N. (2010). *Designing social research*, Polity Press, Cambridge.

Blair, J., Czaja, R. F., & Blair, E. A. (2014). *Designing surveys: A guide to decisions and procedures*, 3rd edition. London, UK: Sage Publications

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., ... & Yanda, P. (2007). Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. *Africa. Climate Change*, 433-467.

Boundaries Commission Newsletter (BCN) (2010). A publication of national boundaries Commission Abuja, Nigeria, 2010, 16 – 20.

Brace, I. (2008). *Questionnaire design: how to plan, structure and write survey material for effective market research*, 2nd edition. London & Philadelphia: Kogan Page.

Bradshaw, B., Dolan, H., & Smit, B. (2004). Farm-level adaptation to climatic variability and change: crop diversification in the Canadian prairies. *Climatic change*, *67*(1), 119-141.

Bryan, E., Deressa, T. T., Gbetibouo, G. A., & Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental science & policy*, *12*(4), 413-426.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S. & Herrero, M. (2013). Adapting agriculture to climate change in Kenya: Household strategies and determinants. *Journal of Environmental Management*, 114, 26-35

Butterworth, T., & Bishop, V. (1995). Identifying the characteristics of optimum practice: findings from a survey of practice experts in nursing, midwifery and health visiting. *Journal of Advanced Nursing*, *22*(1), 24-32.

Cairns, J. E., Hellin, J., Sonder, K., Araus, J. L., MacRobert, J. F., Thierfelder, C., & Prasanna, B. M. (2013). Adapting maize production to climate change in sub-Saharan Africa. *Food Security*, *5*(3), 345-360.

Cameron, A. C., & Trivedi, P. K. (2005). *Microeconometrics: methods and applications*. Cambridge university press.

Cameron, R. (2011). “Mixed Methods Research: The Five Ps Framework” *The Electronic Journal of Business Research Methods* 9 (2), 96-108. Retrieved from www.ejbrm.com

Cantrill, J. A., Sibbald, B., & Buetow, S. (1996). The Delphi and nominal group techniques in health services research. *International Journal of pharmacy practice*, *4*(2), 67-74.

Carson, D., Gilmore, A., Perry, C., & Gronhaug, K. (2001). *Qualitative Marketing Research*. London: Sage.

Casley, D. J., & Kumar, K. (1990). *Project monitoring and evaluation in agriculture*. Baltimore and London: The Johns Hopkins University Press.

Central Bank of Nigeria- CBN (2018). *Statistical Bulletin.* Retrieved from: https://www.cbn.gov.ng/documents/Statbulletin.asp

Central Bank of Nigeria. (2003). Statistical Bullentin.

Chang, C. C. (2002). The potential impact of climate change on Taiwan's agriculture. *Agricultural Economics*, 27(1), 51-64.

Charumbira, L. T. (2013). The philosophical and methodological approaches used by sport and business management student researchers in Zimbabwe. *Global Journal of Commerce and Management Perspective*, *2*(6), 51-56.

Chatzopoulos, T., & Lippert, C. (2015). Adaptation and climate change impacts: A structural Ricardian analysis of farm types in Germany. *Journal of Agricultural Economics*, *66*(2), 537-554.

Chen, C. C., & Chang, C. C. (2005). The impact of weather on crop yield distribution in Taiwan: some new evidence from panel data models and implications for crop insurance, *Agricultural Economics*, vol. 33, pp. 503–11.

Chen, C.-C., McCarl, B. A., & Schimmelpfennig, D. E. (2004). Yield variability as influenced by climate: a statistical investigation. *Climatic Change*, 66(1-2), 239-261.

Cheng, S., & Long, J. S. (2007). Testing for IIA in the Multinomial Logit Model. *Sociological Methods & Research*, vol. 35, no. 4, pp. 583–600.

Chijioke, O. B., Haile, M., & Waschkeit, C. (2011). Implication of climate change on crop yield and food accessibility in Sub-Saharan Africa. *Centre for Development Research. Bonn: University of Bonn*.

Chikaire, J., Nwakwasi, R. N., & Jamilu, A. A. (2011). Climate change adaptation in agriculture. *African Journal of Agricultural Research and Development*, 4 (3), 76.

Chikezie, C., Ibekwe, U. C., Ohajianya, D. O., Orebiyi, J. S., Ehirim, N. C., Henri-Ukoha, A., ... & 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*, *2*(1), 47-56.

Christie, C. A., & Barela, E. (2005). The Delphi technique as a method for increasing inclusion in the evaluation process. *The Canadian Journal of Program Evaluation*, *20*(1), 105.

Chukwuone, N. (2015). *Analysis of Impact of Climate Change on Growth and Yield of Yam and Cassava and Adaptation Strategies by Farmers in Southern Nigeria.* [online] African Growth and Development Policy Working (AGRODEP) Paper 0012. Retrieved from http://www.agrodep.org/sites/default/files/AGRODEPWP0012.pdf

Churchill, G. A. (1996). *Basic Marketing Research* (*3rd Ed.),* Fort Worth, TX: The Dryden Press.

Cline, W. R. (1996). The impact of global warming of agriculture: comment, *The American Economic Review*, vol. 86, no. 5, pp. 1309–11.

Coe, R., & Stern, R. D. (2011). Assessing and addressing climate-induced risk in sub-Saharan rainfed agriculture: lessons learned. *Experimental Agriculture*, *47*(2), 395-410.

Collis, J., & Hussey, R. (2014). Business Research. sl.

Creswell, J. W. (2014). *A concise introduction to mixed methods research*. SAGE publications.

Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Sage publications.

Cross River State Tourism Bulletin (2011). Annual publication of tourism potentials of Cross River State, Calabar, Nigeria, 3-9.

Crotty, M (1998). *The Foundations of Social Research - Meaning and Perspective in The Research Process*. Allen Unwin, NSW, Austrialia

Czaja, R., & Blair, J. (1996). Designing Surveys: A Guide to Decision and Evaluation.

Da Cunha, J. G. M. C., Bach, T. M., da Silva, W. V., Matiollo, D., Souza, A., & da Veiga, C. P. (2018). Econometric analysis of cointegration and causality between markets prices toward futures contracts: Evidence from the live cattle market in Brazil. *Cogent Business & Management*, *5*(1), 1457861.

Dalkey, N., & Helmer, O. (1963). An experimental application of the Delphi method to the use of experts. *Management science*, *9*(3), 458-467.

Dalkey, N., Rourke, D. L., Lewis, R., & Snyder, D. (1972). Studies in the quality of life: Delphi and decision-making. Lexington, MA: Lexington Books.

Dawoe, E. K., Quashie-Sam, J., Isaac, M. E., & Oppong, S. K. (2012). Exploring farmers' local knowledge and perceptions of soil fertility and management in the Ashanti Region of Ghana. *Geoderma*, *179*, 96-103.

DB, Z., & Tanko, L. (2013). L. Costs and returns analysis of yam production among small scale farmers in Karu local government area, Nasarawa State, Nigeria. *PAT*, *9*(1), 73-80.

De Salvo, M., Begalli, D., & Signorello, G. (2013). Measuring the effect of climate change on agriculture: A literature review of analytical models. *Journal of Development and Agricultural Economics*, *5*(12), 499-509.

De Vaus, D. (2014). *Survey in social research*, 6th edition. London and New York: Routledge.

De Vaus, D. A. (2001). *Research Design in Social Research*. London: SAGE.

Del Prado, A., Crosson, P., Olesen, J. E., & Rotz, C. A. (2013). Whole-farm models to quantify greenhouse gas emissions and their potential use for linking climate change mitigation and adaptation in temperate grassland ruminant-based farming systems. *Animal*, *7*(s2), 373-385.

Delbecq, A. L., Van de Ven, A. H., & Gustafson, D. H. (1975). *Group techniques for program planning: A guide to nominal group and Delphi processes*. Scott, Foresman.

Demetriades, J., & Esplen, E. (2010). The gender dimensions of poverty and climate change adaptation. *Social dimensions of climate change: Equity and vulnerability in a warming world*, 133-143.

Deressa, T. T., & Hassan, R. M. (2009). Economic impact of climate change on crop production in Ethiopia: Evidence from cross-section measures. *Journal of African economies*, *18*(4), 529-554.

Deressa, T. T., Hassan, R. M. & Ringler, C. (2011). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *The Journal of Agricultural Science*, 149(01), 23-31.

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T. & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*, 19(2), 248-255.

Deressa, T., Hassan, R. M., & Ringler, C. (2008). *Measuring Ethiopian farmers' vulnerability to climate change across regional states*. Intl Food Policy Res Inst.

Deressa, T., Hassan, R., & Poonyth, D. (2005). Measuring the impact of climate change on South African agriculture: The case of sugarcane growing regions. *Agrekon*, *44*(4), 524-542.

Deschênes, O., & Greenstone, M. (2007). The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather. *American Economic Review*, *97*(1), 354-385.

Di Falco, S., & Veronesi, M. (2013). How can African agriculture adapt to climate change? A counterfactual analysis from Ethiopia. *Land Economics*, *89*(4), 743-766.

Di Falco, S., Kohlin, G. & Yesuf, M. (2012). Strategies to adapt to climate change and farm productivity in the Nile Basin of Ethiopia. *Climate Change Economics*, 3(02): 1250009-1 to 1250099-18.

Di Falco, S., Veronesi, M., & Yesuf, M. (2011). Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. *American Journal of Agricultural Economics*, *93*(3), 829-846.

Diallo, I., Sylla, M. B., Camara, M., & Gaye, A. T. (2013). Interannual variability of rainfall over the Sahel based on multiple regional climate models simulations. *Theoretical and Applied Climatology*, *113*(1-2), 351-362.

Dinar, A., Hassan R., Mendelsohn, R., & Benhin J. (2008). *Climate Change and Agriculture in Africa: Impact Assessment and Adaption Strategies*, London: Earthscan, 1-105

Dobo, E., Singh, M. K., Toth, T., Kaposzta, J., & Fekete-Farkas, M. (2008). Measuring agricultural crop vulnerability, sensitivity and adaptivity in Ceecs. *Cereal Research Communications*, *36*, 1291-1294.

Dudovskiy, J. (2016) *Positivism Research Philosophy*. [online] Retrieved from http://research-methodology.net/research-philosophy/positivism/

Dumanski, J., & Peiretti, R. (2013). Modern concepts of soil conservation. *International soil and water conservation research*, *1*(1), 19-23.

Easterby-Smith, M., Thorpe, R., & Jackson, P.R., (2012). Management Research. SAGE Publications. Retrieved from https://books.google.co.uk/books/about/Management_Research.html?id=ahbhMb-R7MQC&pgis=1

Easterby-Smith, M.,Thorpe, R., & Lowe, A. (2004). Management Research (Second Editioned). London: Sage Publications.

Easterling, W. E., Aggarwal, P. K., Batima, P., Brander, K. M., Erda, L., Howden, S. M., ... & Tubiello, F. N. (2007). Food, fibre and forest products. *Climate change*, *2007*, 273-313.

Eboh, E.C. (2009). *Social and Economic Research: Principles and Methods*. (2nd Ed). African Institute for Applied Economics, Enugu, 20-33

Ecker, O., & Breisinger, C. (2012). *The food security system: A new conceptual framework* (No. 1166). International Food Policy Research Institute (IFPRI).

Egbe, C. A., Yaro, M. A., Okon, A. E. & Bisong, F. E. (2014) Rural Peoples' Perception to Climate Variability/Change in Cross River State- Nigeria. *Journal of Sustainable Development*. 7(2), 25-37 Retrieved from https://doi.org/10.5539/jsd.v7n2p25

Eludoyin, O. M., Adelekan, I. O., Webster, R., & Eludoyin, A. O. (2014). Air temperature, relative humidity, climate regionalization and thermal comfort of Nigeria. *International Journal of Climatology*, *34*(6), 2000-2018.

Elzebroek, T., & Wind, K. (2008). Protein crops. *Guide to Cultivated Plants. Plant Production Systems Group, Crop and Weed Ecology Group, Wageningen University, Wageningen, Netherlands*, 226-262.

Enete, I.C., (2014). Impacts of climate change on agricultural production in Enugu state, Nigeria. *Journal of Earth Science & Climatic Change*, *5*(9)

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica: journal of the Econometric Society*, 251-276.

Enimu, S., Edet, G. O., & Ofem, U. I. (2016). Profitability Analysis of Cassava Production In Cross-River State, Nigeria. *International Research Journal of Human Resources and Social Sciences*, *3*(8).

Eregha, P. B., Babatolu, J. S., & Akinnubi, R. T. (2014). Climate change and crop production in Nigeria: An error correction modelling approach. *International Journal of Energy Economics and Policy*, *4*(2), 297.

Eriksen, H. K., Jewell, J. B., Dickinson, C., Banday, A. J., Górski, K. M., & Lawrence, C. R. (2008). Joint Bayesian component separation and CMB power spectrum estimation. *The Astrophysical Journal*, *676*(1), 10.

Ettah, Otu I & Angba, Austine O. (2016). Analysis of cost and returns among cassava farmers in cross river state, Nigeria. *International Journal of Science and Research (IJSR),* 5(11), 111-114. Retrieved from DOI: 10.21275/ART20162150

Eze, U.F., Ikeogu, C. Iwuh, C.F., & Nwakama, C.I. (2014). Potential application of GIS on weather forecasting to challenge climate hazards in developing countries: Nigeria as a case study. *International Journal of Development Digest*, Mid-year special edition. 15(1), 60 – 77.

Ezekiel, A. A., Olawuyi, S.O., Ganiyu, M.O., Ojedokun, I.K., & Adeyemo, S.A. (2012). Effects of climate change on cassava productivity in Ilesa–east local government area, Osun State, Nigeria. *British Journal of Arts and Social Sciences*, *10*(2), 153-162

FAO (1999). Study Group on Food Safety Issues Associated with Products from Aquaculture. *Food safety issues associated with products from aquaculture: report of a joint FAO/NACA/WHO study group* (Vol. 883). World Health Organization.

FAO (2007) Expert Committee on Food Additives. Meeting, & World Health Organization. (2007). *Evaluation of certain food additives and contaminants: sixty-eighth report of the Joint FAO/WHO Expert Committee on Food Additives* (Vol. 68). World Health Organization.

FAO (2007). National Programmes for food security: FAO's Vision of a world without hunger. FAO, Rome Itally.

FAO (2010). The State of Food Insecurity in World, 2010. Rome, Italy.

FAO (2016). Agriculture Organization, 2014. *Livestock Primary. Food and Agriculture Organization of the United Nations*.

FAO, F. A. O. S. T. A. T. (2008). Food and agriculture organization of the United Nations.

Farmers Guide (2021). Farmers guide, UK's leading monthly magazine. Retrieved from https://www.farmersguide.co.uk/about-us/

Federal Ministry of Agriculture and Rural Development (FMARD). (2009). National Food Security Programme, Federal Republic of Nigeria.

Federal Ministry of Agriculture and Water Resources (FMAWR). (2008). National Food Security Programme, Federal Republic of Nigeria.

Felix, B., & Romuald, K. S. (2012). Rainfall Shocks, Food Prices Vulnerability and Food Security: Evidence for Sub-Saharan African Countries.

FGoN (2017). Federal Republic of Nigeria. Retrieved from http://www.nigeria.gov.ng/

FGoN (2019). Federal Republic of Nigeria. Retrieved from https://redd.unfccc.int/files/2019_submission_frel_nigeria.pdf

Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., MAS-TRANDREA, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., ES-TRADA, Y.O., Genova, R.C. & Girma, B. (2014). Summary for policymakers in Climate Change. Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. *Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 1-32.

Fonta, W., Ichoku, H., & Urama, N. (2011). Climate change and plantation agriculture: A Ricardian analysis of farmlands in Nigeria. *Journal of Economics and Sustainable Development*, *2*(4).

Fonta, W., Kedir, A., Bossa, A., Greenough, K., Sylla, B. & Ayuk, E. (2018). A Ricardian valuation of the impact of climate change on Nigerian cocoa production. *International Journal of Climate Change Strategies and Management*. 10(5): 689-710. Retrieved from https://doi.org/10.1108/IJCCSM-05-2016-0074

Food and Agricultural Organization. (2012). Food Security Statistics. Nigeria FAOSTAT, Rome: FAO.

Food and Agriculture Organisation [FAO] (2007). Adaptation to climate change in agriculture, forestry and fisheries: perspective, framework and priorities. Food and Agriculture Organisation of the United Nations, Rome 2007 pp 2.

Fosu-Mensah, B., Vlek, P., & Manschadi, A. (2010). Farmers' perceptions and adaption to climate Change. *A Case Study of Sekyedumase District in Ghana. Centre for Development Research, University of Bonn*, *11*, 20-30.

Fosu-Mensah, B.Y., Vlek, P.L. & MacCarthy, D.S. (2012). Farmers' perception and adaptation to climate change: a case study of Sekyedumase district in Ghana. *Environment, Development and Sustainability*, *14*(4), 495-505

Gachene, C. K., Karuma, A. N., & Baaru, M. W. (2015). Climate change and crop yield in sub-Saharan Africa. In *Sustainable Intensification to Advance Food Security and Enhance Climate Resilience in Africa* (pp. 165-183). Springer, Cham.

Gallagher, M., Branshaw, C., & Nattress, H. (1996). Policy priorities in diabetes care: a Delphi study. Quality in Health Care, 5(1), 3-8.

Gandure, S., Walker, S., & Botha, J. J. (2013). Farmers' perceptions of adaptation to climate change and water stress in a South African rural community. *Environmental Development*, *5*, 39-53.

Garcia, F., Martínez, I., Balluerka, N., Cruise, E., Garcia, O. F., & Serra, E. (2018). Validation of the Five-Factor Self-Concept Questionnaire AF5 in Brazil: Testing factor structure and measurement invariance across language (Brazilian and Spanish), gender, and age. *Frontiers in Psychology*, *9*, 2250.

Gbetibouo, G. A. (2009). *Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa*. IFPRI Discussion Paper 00849, International Food Policy Research Institute. Retrieved from http://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/31770/filename/31771.pdf

Gbetibouo, G. A., & Hassan, R. M. (2005). Measuring the economic impact of climate change on major South African field crops: a Ricardian approach. *Global and Planetary change*, *47*(2-4), 143-152.

Gbetibouo, G. A., Hassan, R. M. & Ringler, C. (2010). Modelling farmers' adaptation strategies for climate change and variability: The case of the Limpopo Basin, South Africa. *Agrekon: Agricultural Economics Research, Policy and Practice in Southern Africa*, 49(2), 217-234.

George, J. S., & Gary S. B. (1977). "De Gustibus Non-Est Disputandum", The American Economic Review, 67(2), 76-90. Retrieved from http://surveyanalysis.org/wiki/Random_Utility_Theory

Geospatial Analysis Mapping and Environmental Research Solutions (2018). Available online: https://www.gamers.com.ng/map-of-cross-river-state-nigeria/ (accessed on 01:04:2020).

Giannarou, L., & Zervas, E. (2014). Using Delphi technique to build consensus in practice. *International Journal of Business Science & Applied Management (IJBSAM)*, *9*(2), 65-82.

Gilbert, G. N. (2008). *Researching social life*, Sage Publications Ltd, London.

Gitz, V., Meybeck, A., Lipper, L., Young, C. D., & Braatz, S. (2016). Climate change and food security: risks and responses. *Food and Agriculture Organization of the United Nations (FAO) Report*, *110*.

Goedde, L., Ooko-Ombaka, A. and Pais, G. (2019) https://www.mckinsey.com/industries/agriculture/our-insights/winning-in-africas-agricultural-market#

Gollin, D., Parente, S., & Rogerson, R. (2002). The role of agriculture in development. *American economic review*, *92*(2), 160-164.

Goshu, D., Kassa, B., & Ketema, M. (2012). Does crop diversification enhance household food security? Evidence from rural Ethiopia. *Advances in Agriculture, Sciences and Engineering Research.* 2 (11), 503 – 515.

Gray, L. C., & Kevane, M. (2001). Evolving tenure rights and agricultural intensification in southwestern Burkina Faso. *World Development*, *29*(4), 573-587.

Gray, L. C., & Morant, P. (2003). Reconciling indigenous knowledge with scientific assessment of soil fertility changes in southwestern Burkina Faso. *Geoderma*, *111*(3-4), 425-437.

Greasley, P. (2008). *Quantitative Data Analysis with SPSS*, McGraw-Hill Education, Glasgow.

Green, H., Hunter, C., & Moore, B. (1990). Application of the Delphi technique in tourism. Annals of Tourism Research, 17(2), 270-279

Greene, W. H. (2003). *Econometric analysis*. Pearson Education India.

Greene, W. H. (2012) *Econometric analysis*, Sixth edition. Essex, England: Pearson Education

Gregory, P. J., Ingram, J. S., & Brklacich, M. (2005). Climate change and food security. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *360*(1463), 2139-2148.

Groves, R. M. & Heeringa, S. G. (2006) Responsive design for household surveys: tools for actively controlling survey errors and costs. *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 169(3), 439-457.

Grundy, M., & Ghazi, F. (2009). Research priorities in haemato-oncology nursing: Results of a literature review and a Delphi study. *European Journal of Oncology Nursing*, *13*(4), 235-249.

Guba, E. G. (1990). The Alternative Paradigm Dialog. *1990*, *1*, 7-27.

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. *Handbook of qualitative research*, *2*(163-194), 105.

Guiteras, R. (2009). The impact of climate change on Indian agriculture. *Manuscript, Department of Economics, University of Maryland, College Park, Maryland*. Retrieved from: https://www.semanticscholar.org/paper/The-Impact-of-Climate_Change-on-Indian-Agriculture

Guiteras, R. (2009). The impact of climate change on Indian agriculture, Manuscript, Department of Economics, University of Maryland, College Park, Maryland.

Gujarati, D. N. (2004). Basic Econometrics. McGraw-Hill Companies. *New York*.

Gupta, V. K., & Waymire, E. C. (2008). Spatial variability and scale invariance in hydrologic regionalization. In S. Garrison (Ed.), Scale dependence and scale invariance in hydrology. New York: Cambridge University Press, pp. 88-135.

Hackett, S., Masson, H., & Phillips, S. (2006). Exploring consensus in practice with youth who are sexually abusive: Findings from a Delphi study of practitioner views in the United Kingdom and the Republic of Ireland. Child Maltreatment, 11(2), 146-156.

Hammarberg, K., Kirkman, M., & De Lacey, S. (2016). Qualitative research methods: when to use them and how to judge them. *Human Reproduction*, *31*(3), 498-501.

Hansen, J. K. (2019). *In Defense of Farmers: The Future of Agriculture in the Shadow of Corporate Power*. U of Nebraska Press.

Hassan, M. & De Leeuw, J. (2015). Enhancing the quality of African climate change science by investing in peer review capacity. Retrieved from: https://sustainabledevelopment.un.org/content/documents/623065-Muhammed_Enhancing%20the%20quality%20of%20African%20climate%20change%20science.pdf

Hassan, R. M., & Nhemachena, C. (2008). Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agricultural and Resource Economics*, *2*(311-2016-5521), 83-104.

Hasson, F., Keeney, S., & McKenna, H. (2000). Research guidelines for the Delphi survey technique. *Journal of advanced nursing*, *32*(4), 1008-1015.

Hausman, J., & McFadden, D. (1984). Specification tests for the multinomial logit model. *Econometrica: Journal of the Econometric Society*, 1219-1240.

Hausman, Jerry, & Daniel McFadden. (1984). Specification tests for the multinomial logit model. Econometrical 52(5), 1219-1240.

Hertel, T. W., Burke, M. B., & Lobell, D. B. (2010). The poverty implications of climate-induced crop yield changes by 2030. *Global Environmental Change*, *20*(4), 577-585.

Hirschman, E. C. (1985). Primitive Aspects of Consumption in Modern American Society. *Journal of Consumer Research*, 12, 237-249.

Hisali, E., Birungi, P., & Buyinza, F. (2011). Adaptation to climate change in Uganda: evidence from micro level data. *Global environmental change*, *21*(4), 1245-1261.

Hoshmand, L.T. (2003). Can lessons of history and logical analysis en-sure progress in psychological science? *Theory and Psychology*, 13, 39-44**.**

Hsu, C. C., & Sandford, B. A. (2007). The Delphi technique: Making sense of consensus. *Practical assessment, research & evaluation*, *12*(10), 1-8

Hudson, L., & Ozanne, J. (1988). Alternative Ways of Seeking Knowledge in Consumer Research. *Journal of Consumer Research*, 14(4), 508–521.

Ibrahim, K., Shamsudin, M. N., Yacob, R, & Radam, A. (2014). Economic Impact of Climate Change on Maize Production in Northern Nigeria. *Trends in Applied Sciences Research, 9, 522-533.* Retrieved from DOI**:** 10.3923/tasr.2014.522.533

Ibrahim, S. B., Ayinde, I. A., & Arowolo, A. O. (2014). Climate change and technical efficiency of crop farmers in Ogun state, Nigeria. In (eds) Amos TT, Imoudu PB, Oseni

JO. In *Proceedings of the Annual National Conference of the Nigerian Association of Agricultural Economists* (pp. 95-104).

Ifeanyi-Obi, C. C., Asiabaka, C. C., & Adesope, O. M. (2014). Determinants of climate change adaptation measures used by crop and livestock farmers in Southeast Nigeria. *IOSR Journal of Humanities and Social Science (IOSR-JHSS) India*, *19*(9), 61-70

Ifeanyi-obi, C. C., Etuk, U. R., & Uloh, C. (2013). Cassava farmers' adaption to climate change in Oron agricultural zone of Akawa Ibom State, Nigeria. *Nigerian Journal of Rural Sociology*, *14*(2202-2019-811), 6-15.

Igodan, C. O., Gwary, M. M., & Ekpere, J. A. (1990). Critical skills and competency needs of extension agents: evidence from Nigeria. *Journal of Extension Systems*, *6*(1), 100-107.

Iheoma, C. G. (2015). Impact of Climate Change on Agricultural Production and Sustainability in Nigeria. *Asian Journal of Agricultural Extension, Economics & Sociology*, 29-41.

IITA (1990). Cassava in Tropical Africa. A Reference Manual, pp. 15-16. IITA, Ibadan.

Ike, P. C. & Inoni, O. E. (2006). Determinants of yam production and economic efficiency among small-holder farmers in southeastern Nigeria. *Journal of Central European Agriculture*, 7(2), 337-342.

Ike, P.C. & Ezeafulukwe, L.C. (2015). Analysis of Coping Strategies Adopted against Climate Change by Small Scale Farmers in Delta State, Nigeria. Analysis, 5(4).

Intergovernmental Panel on Climate Change (2001). *Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK.

Intergovernmental Panel on Climate Change (2007) Climate Change: Impacts, Adaptation and Vulnerability IPPC (Contribution of Working Group II to the Forth Assessment Report) Retrieved from: https://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch9.html

Intergovernmental Panel on Climate Change (2014). *Climate change 2014 synthesis report: contribution of working groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change*. Geneva, Switzerland: IPCC. Available online: http://epic.awi.de/37530/1/IPCC_AR5_SYR_Final.pdf.

International Food Policy Research Institute (IFPRI) (2013). *Global Food Policy Report.* 50-120

IPCC (2018). Summary for Policymakers. *Global Warming of 1.5° C*.

IPCC 2001 Climate change 2001. Synthesis report. Cambridge University Press

IPCC, 2018: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

IPPC (2014). Climate Change 2014 Synthesis Report. Fifth Assessment Report.

Isik, M., & Devadoss, S. (2006). An analysis of the impact of climate change on crop yields and yield variability. *Applied Economics*, *38*(7), 835-844.

Ito, T., & Kurosaki, T. (2009). Weather risk, wages in kind, and the off-farm labor supply of agricultural households in a developing country. *American journal of agricultural economics*, *91*(3), 697-710.

Iwuchukwu, J. & Igbokwe, E. (2012). Lessons from Agricultural Policies and Programmes in Nigeria. *Journal of Law, Policy and Globalization.* 5, 11-21.

Iyoha, M. A., Oyefusi, S. A., & Oriakhi, D. E. (2003). An introduction to modern macroeconomics (revised edition). *Benin-City: Mindex Publishing Company Limited*.

Izekor, O. B., & Olumese, M. I. (2010). Determinants of yam production and profitability in Edo State, Nigeria. *African Journal of General Agriculture*, *6*(4), 205-210.

Izuchukwu, O. (2011). Analysis of the contribution of agricultural sector on the Nigerian economic development. *World review of business research*, *1*(1), 191-200.

Jain, M., Naeem, S., Orlove, B., Modi, V., & DeFries, R. S. (2015). Understanding the causes and consequences of differential decision-making in adaptation research: adapting to a delayed monsoon onset in Gujarat, India. *Global Environmental Change*, *31*, 98-109.

Jalloh, A., Nelson, G. C., Thomas, T. S., Zougmore, R. & Roy-Macauley, H. (2013) *West African Agriculture and Climate Change: A comprehensive analysis.* International Food Policy Research Institute, 259-290

Jarvis, A., Ramirez-Villegas, J., Campo, B. V. H., & Navarro-Racines, C. (2012). Is cassava the answer to African climate change adaptation? *Tropical Plant Biology*, *5*(1), 9-29.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of economic dynamics and control*, *12*(2-3), 231-254.

Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration—with appucations to the demand for money. *Oxford Bulletin of Economics and statistics*, *52*(2), 169-210.

Johnson, R. B., & Onwuegbuzie, A. J. (2004) Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educational Researcher* 33, (7) 14–26

Johnston, B. F., & Mellor, J. W. (1961). The role of agriculture in economic development. *The American Economic Review*, *51*(4), 566-593.

Johnston, R. M., Hoanh, C. T., Lacombe, G., Noble, A. N., Smakhtin, V., & Suhardiman, D. (2009). Rethinking agriculture in the Greater Mekong Subregion: how to sustainably meet food needs, enhance ecosystem services and cope with climate change. Colombo, Sri Lanka: International Water Management Institute. 26.

Johnston, R. M., Hoanh, C. T., Lacombe, G., Noble, A. N., Smakhtin, V., Suhardiman, D., *et al.,* (2009). Rethinking agriculture in the Greater Mekong Subregion: how to sustainably meet food needs, enhance ecosystem services and cope with climate change. Colombo, Sri Lanka: International Water Management Institute. 26p.

Juana, J.S., Kahaka, Z. & Okurut, F.N. (2013). Farmers' perceptions and adaptations to climate change in sub-Sahara Africa: A synthesis of empirical studies and implications for public policy in African agriculture. *Journal of Agricultural Science*, *5*(4), 121

Jumbe, C.B., (2004). Cointegration and causality between electricity consumption and GDP: empirical evidence from Malawi. *Energy economics*, *26*(1), 61-68.

Kabubo-Mariara, J. (2009). Global warming and livestock husbandry in Kenya: Impacts and adaptations. *Ecological Economics*, *68*(7), 1915-1924.

Kabubo-Mariara, J., & Karanja, F. K. (2007). *The economic impact of climate change on Kenyan crop agriculture: A Ricardian approach*. The World Bank.

Kandlinkar, M., & Risbey, J. (2000). Agricultural Impacts of Climate Change. If Adaptation Is the Answer, What Is the Question? Climate Change, 45, 529-539.

Kanyama, A. & John, J. (2016). Challenges of Adaptation to Climate Change for Cassava Farming in Musoma, Rural District, Tanzania. *International Journal of Modern Social Sciences*, 5(1), 52-65.

Keeney, S., Hasson, F., & McKenna, H. P. (2001). A critical review of the Delphi technique as a research methodology for nursing. *International journal of nursing studies*, *38*(2), 195-200.

Kelly, A. C., & Anderson, C. L. (2016). Comparing farmer and measured assessments of soil quality in Tanzania: Do they align? *Journal of Natural Resources and Development*, *6*, 55-65.

Khanal, R. C. (2009). Climate change and organic agriculture. *Journal of Agriculture and Environment*, *10*, 116-127.

Kittell-Limerick, P. (2005). *Perceived barriers to completion of the academic doctorate: A Delphi study*. Texas A&M University-Commerce.

Knowler, D., & Bradshaw, B. (2007). Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food policy*, *32*(1), 25-48.

Knox, J., Hess, T., Daccache, A. & Wheeler, T (2012). Climate change impacts on crop productivity in Africa and South Asia. *Environmental Research Letters.* Retrieved from: http://iopscience.iop.org/article/10.1088/1748-9326/7/3/034032/pdf

Konrad, K. A., & Thum, M. (2014). The role of economic policy in climate change adaptation. *CESifo Economic Studies*, *60*(1), 32-61.

Koutsoyiannis, A. (1979). Theory of Econometrics London and Basin stock.

Kpadonou, R. A. B., Owiyo, T., Barbier, B., Denton, F., Rutabingwa, F. & Kiema, A. (2017). Advancing climate-smart-agriculture in developing drylands: Joint analysis of the adoption of multiple on-farm soil and water conservation technologies in West African Sahel. *Land Use Policy*, 61, 196-207

Kumar, K., & Parikh, J. (2001). Socio-economic impacts of climate change on Indian agriculture. *International Review for Environmental Strategies*, *2*(2).

Kurukulasuriya, P & Ajwad, MI (2007). Application of the Ricardian technique to estimate the impact of climate change on smallholder farming in Sri Lanka', *Climatic Change*. 81(1), 39–59

Kurukulasuriya, P. & Mendelsohn, R. (2006). *A Ricardian analysis of the impact of climate change on African cropland*, CEEPA (Centre for Environmental Economics and Policy in Africa, University of Pretoria, South Africa) Discussion Paper 8.

Kurukulasuriya, P. & Mendelsohn, R. (2008) A Ricardian analysis of the impact of climate change on African cropland. *African Journal of Agricultural and Resource Economics*, 2(1), 1-23

Landeta, J. (2006). Current validity of the Delphi method in social sciences. *Technological forecasting and social change*, *73*(5), 467-482.

Laurence, W.F & Williamson, G.B. (2001): Positive feedback among forest fragmentation draught and climate change in the Amazon conservation Biology 28(6), 1529 – 1535.

Leedy, P. D., & Ormrod, J. E. (2014). Qualitative research. *Pracfical research: Planning and design*, *2*(24), 141-172.

Legesse, B., Ayele, Y., & Bewket, W. (2013). Smallholder farmers' perceptions and adaptation to climate variability and climate change in Doba district, west Hararghe, Ethiopia. *Asian Journal of Empirical Research*, *3*(3), 251-265.

Li, C. T., Hwang, M. S., & Chu, Y. P. (2008). A secure and efficient communication scheme with authenticated key establishment and privacy preserving for vehicular ad hoc networks. *Computer Communications*, *31*(12), 2803-2814.

Liliana H (2005). The Food Gaps: The impacts of climate change on food production: A 2020 perspective.

Lincoln, Y., & Guba, E. (1985). *Naturalistic Inquiry*. London: Sage.

Listone, H. A., & Turoff, M. (1975). Introduction to the Delphi method: Techniques and applications. In H.A.Linstone & M. Turoff (Eds.), The Delphi method: techniques and applications. Reading, MA: Addison-Wesley Publishing Company, pp 3-12.

Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P., & Naylor, R. L. (2008). Prioritizing climate change adaptation needs for food security in 2030. *Science*, *319*(5863), 607-610.

Loring, P. A., & Gerlach, S. C. (2009). Food, culture, and human health in Alaska: an integrative health approach to food security. *Environmental Science & Policy*, *12*(4), 466-478.

Mabe, F. N., Sienso, G., & Donkoh, S. A. (2014). Determinants of choice of climate change adaptation strategies in northern Ghana. *Research in Applied Economics*, *6*(4), 75-94.

Maddison D. (2006). The perception of and adaptation to climate change in Africa. CEEPA discussion paper No. 10. Centre for Environmental Economics and Policy in Africa, University of Pretoria, South Africa.

Maikasuwa, M. A., & Ala, A. L. (2013). Determination of profitability and resource-use efficiency of yam production by women in Bosso local government area of Niger State, Nigeria. *European Scientific Journal*, *9*(16), 196-205.

Manyong, V., Kling, J., Makinde, K., Ajala, S. & Menkir, A (2000). Impact of IITA-Improved Germplasm on Maize Production in West and Central Africa.

Manyong, V.M., Kling, J.G., Makinde, K.O., Ajala, S.O., & Menkir, A. (2003). Impact of IITA germplasm improvement on maize production in West andCentral Africa. In: Evenson, R.E., Gollin, D. (Eds.), Crop Variety Improve-ment and Its Effect on Productivity: The Impact of International AgriculturalResearch. CAB International, Wallingford, 159–181.

Masih, A. M., & Masih, R. (1998). A fractional cointegration analysis of the long-run relationship between black and official foreign exchange rates: the case of the Brazilian cruzeiro. *Applied economics*, *30*(7), 853-861.

Masson-Delmotte, V., Zhai, P., Pörtner, H. O., Roberts, D., Skea, J., Shukla, P. R., ... & Gomis, M. (2018). IPCC, 2018: Summary for Policymakers. *Global Warming of*, *1*.

Mbanasor, J.A., Nwachukwu, I.N., Agwu, N.M. & Onwusiribe, N.C., 2015. Impact of climate change on the productivity of cassava in Nigeria. *J. Agric. Environ. Sci*. 4, 138-147.

McKenna, H. P. (1989). The selection by ward managers of an appropriate nursing model for long-stay psychiatric patient care. *Journal of Advanced Nursing*,14(9), 762-775.

Melka Y, Kassa H, Ketema M, Abebaw D, & Schmiedel U. (2015). The effect of drought risk perception on local people coping decisions in the Central Rift Valley of Ethiopia. *J Dev Agric Econ*. 7(9), 292–302

Mendelsohn, R. (2000). Efficient adaptation to climate change. *Climatic Change*, *45*(3-4), 583-600.

Mendelsohn, R. (2012) The economics of adaptation to climate change in developing countries. *Climate Change Economics*, 3(02), 1250006. https://doi.org/10.1142/S2010007812500066

Mendelsohn, R., & Tiwari, D. (2000). *Two essays on climate change and agriculture: A developing country perspective* (No. 145). Food & Agriculture Org.

Mendelsohn, R., Nordhaus, W. D. & Shaw, D. (1994) The impact of global warming on agriculture: a ricardian analysis. *American Economic Review*, 84(4), 753-771.

Mendelsohn, R.O. & Dinar, A. (2009). *Climate change and agriculture: an economic analysis of global impacts, adaptation and distributional effects*. Edward Elgar Publishing, 10-220

Mgbenka, R. N., Mbah, E. N., & Ezeano, C. I. (2016). A review of small holder farming in Nigeria: Need for transformation. *International Journal of Agricultural Extension and Rural Development Studies*, *3*(2), 43-54.

Mishra, D., Sahu, N.C. & Sahoo, D. (2016). Impact of climate change on agricultural production of Odisha (India): a Ricardian analysis. *Regional environmental change*, *16*(2), 575-584

Molis, (2018). Retrieved from https://bizfluent.com/about-7512040-calculate-net-revenue.html

Molua, E. L. (2002). Climate variability, vulnerability and effectiveness of farm-level adaptation options: the challenges and implications for food security in Southwestern Cameroon. *Environment and Development Economics*, 529-545.

Monerie, P. A., Fontaine, B., & Roucou, P. (2012). Expected future changes in the African monsoon between 2030 and 2070 using some CMIP3 and CMIP5 models under a medium-low RCP scenario. *Journal of Geophysical Research: Atmospheres*, *117*(D16).

Moreira Campos da Cunha Amarante, J. G. (2018). Econometric analysis of cointegration and causality between market prices toward futures contracts: Evidence from the live cattle market in Brazil. *Cogent Business & Management*, *5*(1), 1457861. https://doi.org/10.1080/23311975.2018.1457861

Muijs, D. (2004). Doing Quantitative Research in Education with SPSS [E-reader version].

Muijs, D. (2010). *Doing quantitative research in education with SPSS*, Sage Publications Ltd, London, 1-175

Mullen, P. M. (2003). Delphi: myths and reality. *Journal of health organization and management*.

Muller, N. Z., Mendelsohn, R., & Nordhaus, W. (2011). Environmental accounting for pollution in the United States economy. *American Economic Review*, *101*(5), 1649-75.

Nadira I. (2017). Climate change in Nigeria. Retrieved from http//:naija.ng/1103796-climate-change-nigeria-2017.html#1103796

Natanelov, V., McKenzie, A. M., & Van Huylenbroeck, G. (2013). Crude oil–corn–ethanol–nexus: A contextual approach. *Energy Policy*, *63*, 504-513.

National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN) (2011). Building Nigeria's response to climate change. Backgrounder, Nigerian Environmental Study Action Team, Ibadan, Nigeria 7-69.

National Bureau of Statistics (2017). Retrieved from: https://www.thenbs.com/knowledge/nbs-annual-2017

National Population Commission (NPC), (2011). Census enumeration survey N. P. C. Abuja, Nigeria. *2*, 6-8.

National Population Commission. (2006). NPC (2006). *Federal Republic of Nigeria Official Gazette*, *96*(2).

Ndamani, F. & Watanabe, T. (2016). Determinants of farmers' adaptation to climate change: A micro level analysis in Ghana. *Scientia Agricola*, *73*(3), 201-208

Ndamani, F., & Watanabe, T. (2015). Farmers' perceptions about adaptation practices to climate change and barriers to adaptation: A micro-level study in Ghana. *Water*, *7*(9), 4593-4604.

Nelson G. C. (2009). Climate change: Impact on agriculture and costs of adaptation. Intl Food Policy Research Inst. Washington DC, USA

Nelson, G. C., Valin, H., Sands, R. D., Havlík, P., Ahammad, H., Deryng, D., ... & Kyle, P. (2014). Climate change effects on agriculture: Economic responses to biophysical shocks. *Proceedings of the National Academy of Sciences*, *111*(9), 3274-3279.

Nerantzidis, M. (2012). Delphic Hierarchy Process (DHP): A Methodology for the Resolution of the Problems of the Evaluation of Corporate Governance Quality. SSRN Electronic Journal. 10.2139/ssrn.2056926.

Neuman, L. W. (2000). *Social Research Methods: Qualitative and Quantitative Approaches (4th Ed.)*, USA: Allyn and Bacon….frm the web below.

Nhemachena, C., & Hassan, R. (2007). *Micro-level analysis of farmers adaption to climate change in Southern Africa*. Intl Food Policy Res Inst.

Nhemachena, C., & Mano, R. (2007). *Assessment of the economic impacts of climate change on agriculture in Zimbabwe: A Ricardian approach*. The World Bank.

Niang, I., O.C. Ruppel, M.A. Abdrabo, A. Essel, C. Lennard, J. Padgham, & P. Urquhart, 2014: Africa. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1199-1265.

Niles, M. T., Brown, M., & Dynes, R. (2016). Farmer's intended and actual adoption of climate change mitigation and adaptation strategies. *Climatic Change*, *135*(2), 277-295.

Nin-Pratt, A., & Yu, B. (2012). 13 agricultural productivity and policy changes in Sub-Saharan Africa. *Productivity growth in agriculture: an international perspective*, 273.

Nnadozie, A. K. O. (2016). Nigerian Agricultural Cooperatives and Rural Development in IVO L.G.A., Ebonyi State, Nigeria. *Global Journal of Management And Business Research*.

Noor, K, M. (2008) Case Study: A Strategic Research Methodology American Journal of Applied Sciences 5 (11) pp.1602-1604.

Nwajiuba, C. (2012). Nigeria's agriculture and food security challenges. Available on www. boell. org/downloads/4_Green_Deal_Nigeria_AGRICULTURE. pdf.

Nwaobiala, C.U. & Nottidge, D.O. (2013). Effect of climatic variables on cassava farmers' production in Abia State, Nigeria. Nigerian Journal of Agriculture, Food and Environment, 9(4), 57-62.

Nwaobiala, C.U. & Nottidge, D.O. (2015). Effect of climate variability on output of cassava in Abia State, Nigeria. *Nigeria Agricultural Journal*, *46*(1), 81-86

Nwike, M. C., & Ugwumba, C. O. A. (2015). Profitability of Rice Production in Aguata Agricultural Zone of Anambra State Nigeria: A Profit Function Approach. American Journal of Agricultural Science, 2(2), 24-28. Retrieved from http://www.ascit.org/journal/ajas

Nwocha, M. E. (2016). Impact of the Nigerian Land Use Act on Economic Development in the Country. *Acta Universitatis Danubius. Administratio*, *8*(2), 117-128.

Nyangena, W. (2008). Social determinants of soil and water conservation in rural Kenya. *Environment, Development and Sustainability*, *10*(6), 745-767.

Nzegbule E.C., Nwajiuba C., Ujor G., Onyeneke R., Ogallah S.S., & Okali D. (2019) Sustainability and the Effectiveness of BNRCC Community-Based Adaptation (CBA) to Address Climate Change Impact in Nigeria. In: Leal Filho W. (eds) Handbook of Climate Change Resilience. Springer, Cham

Obayelu, O. A., Adepoju, A. O., & Idowu, T. (2014). Factors influencing farmers' choices of adaptation to climate change in Ekiti State, Nigeria. *Journal of Agriculture and Environment for International Development (JAEID)*, *108*(1), 3-16.

Obiora, C. J. (2013). Climate Change and Sustainable Agriculture in Nigeria: Challenges and Opportunities. *Journal of Renewable Agriculture*.

Obiora, C. J., & Madukwe, M. C. (2011). Climate change mitigation: the role of agriculture. *Journal of agricultural extension*, *15*(1), 51-63.

Odjugo, P (2011). Perception Of Climate Change In The Niger Delta Region Of Nigeria. Centre for Population and Environmental Development (CPED) policy paper series.

Odjugo, P (2011a) *Climate Change and Global Warming: The Nigerian Perspective. Journal of Sustainable Development and Environmental Protection* 1(1) :6-17

Odozi, J. C., Patience, I. O., Awaebe, J., & Agbugui, M. (2018). Employment in the Nigerian Agricultural Labour Market: Barriers and Forecast.

Ofuoku, A. U. (2011). Rural farmers' perception of climate change in central agricultural zone of Delta State, Nigeria. *Indonesian Journal of Agricultural Science* 12(2), 2011: 63-69.

Ogallah, S.S., Wandiga, S.O., Olago, D. & Oriaso, S., (2017). Smallholder Farmers' Adaptation Strategies to Climate Change in Southwest Nigeria, Egbeda Local Government Area, Oyo State. *International Journal of Interdisciplinary Research and Innovations*, *5*(4), 14-19.

Ogalleh, S. A., Vogl, C. R., Eitzinger, J., & Hauser, M. (2012). Local perceptions and responses to climate change and variability: The case of Laikipia District, Kenya. *Sustainability*, *4*(12), 3302-3325.

Ogbanga, A. (2018). Agricultural development and employment generation in Nigeria. *International Journal of Advance Studies in Ecology, Development and Sustainability*, *5*(1), 1-22.

Okase K. A. (2018). What are The Types and Features of Agricultural Farming Systems? Retrieved from: https://blog.agrihomegh.com/agricultural-farming-systems/

Okorafor, O. O., Akinbile, C. O., & Adeyemo, A. J. (2017). Soil Erosion in South Eastern Nigeria: A Review. Scientific Research Journal, 5(6), 30-37.

Olagunju, K. O., Ogunniyi, A. I., Awotide, B. A., Adenuga, A. H., & Ashagidigbi, W. M. (2020). Evaluating the distributional impacts of drought-tolerant maize varieties on productivity and welfare outcomes: an instrumental variable quantile treatment effects approach. *Climate and development*, *12*(10), 865-875.

Olawepo, R. A. (2010). Determining rural farmers' income: A rural Nigeria experience. *Journal of African studies and Development*, *2*(4), 99-108.

Olayide, S. O., & Heady, E. O. (1982). *Introduction to agricultural production economics*. Ibadan University Press, University of Ibadan.

Olomola, A. & Nwafor, M. (2018). Nigeria agriculture sector performance review 2017. Retrieved from: https://www.researchgate.net/publication/327666294.

Olomola, A. S. (2013). The political economy of food price policy in Nigeria. *Food Price Policy in an Era of Market Instability*, 275.

Olomola, A. S. (2014). Determinants of Agro-Dealers' Participation in the Loan Market in Nigeria. *International Food and Agribusiness Management Review*, *17*(1030-2016-83020), 65-84.

Olukosi, J., & Erhabor, P. (2005). Introduction to farm management economics: Principles and application. Revised edition.

Oluwasusi, J. O. (2013). Farmers' adaptation strategies to the effect of climate variation on yam production in Ekiti state, Nigeria. *Journal of Food, Agriculture and Environment*, *11*(2), 724-728.

Oluwasusi, J.O. & Tijani, S.A. (2013). Farmers adaptation strategies to the effect of climate variation on yam production: a case study in Ekiti state, Nigeria. *Agrosearch*, *13*(2), 20-31

Onwueme, I. C., & Sinha, T. D. (1991). Field crop production in Tropical Africa CTA. *Ede, The Netherlands*, 545.

Onyeka, T. J., Owolade, O. F., Ogunjobi, A. A., Dixon, A. G., Okechukwu, R., & Bamkefa, B. (2008). Prevalence and severity of bacterial blight and anthracnose diseases of cassava in different agro-ecological zones of Nigeria. *African Journal of Agricultural Research*, *3*(4), 297-304.

Onyeneke, R. U., & Madukwe, D. K. (2010). Adaptation measures by crop farmers in the southeast rainforest zone of Nigeria to climate change. *Science World Journal*, *5*(1).

Orlowsky, B., & Seneviratne, S. I. (2012). Global changes in extreme events: regional and seasonal dimension. *Climatic Change*, *110*(3-4), 669-696.

Osuafor, A. M., & Nnorom, N. R. (2014). Impact of Climate Change on Food Security in Nigeria. *AFRREV STECH: An International Journal of Science and Technology*, *3*(1), 208-219.

Otitoju, M. A. (2015). *The effects of climate change adaptation strategies on food crop production efficiency in Southwestern Nigeria* (Doctoral dissertation).

Oyebo, M., Bisong, F., & Morakinyo, T. (2010). A preliminary assessment of the context for REDD in Nigeria. *Nigeria: Federal Ministry of Environment, the Cross River State's Forestry Commission and UNDP Nigeria*.

Oyegun, C. U., Lawal, O., & Ogoro, M. (2016). Vulnerability of Coastal Communities in the Niger Delta Region to Sea Level Rise. *Quest Journals, JREES*, *2*(8).

Oyekale, A. S., & Oladele, O. I. (2012). Determinants of climate change adaptation among cocoa farmers in southwest Nigeria. *ARPN Journal of Science and Technology*, *2*(1), 154-168.

Oyenuga, V. A. (1967). Agriculture in Nigeria. An introduction. *Agriculture in Nigeria. An introduction.*

Ozor, N., Madukwe, M. C., Enete, A. A., Amaechina, E. C., & Onokala, P. (2010). Barriers to climate change adaptation among farming households of Southern Nigeria. *Journal of Agricultural Extension*, *14*(1).

Ozor, N., Umunakwe, P. C., Ani, A. O., & Nnadi, F. N. (2015). Perceived impacts of climate change among rural farmers in Imo State, Nigeria. *African Journal of Agricultural Research*, *10*(14), 1756-1764.

Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2015). Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and policy in mental health and mental health services research*, *42*(5), 533-544.

Paudel, B., Acharya, B. S., Ghimire, R., Dahal, K. R., & Bista, P. (2014). Adapting agriculture to climate change and variability in Chitwan: Long-term trends and farmers' perceptions. *Agricultural Research*, *3*(2), 165-174.

Pender, J., & Gebremedhin, B. (2008). Determinants of agricultural and land management practices and impacts on crop production and household income in the highlands of Tigray, Ethiopia. *Journal of African Economies*, *17*(3), 395-450.

Perry, C 1998, 'A structured approach for presenting theses', *Australasian Marketing Journal*, vol. 6, no. 1, pp. 63–85.

Petty, N. J., Thomson, O. P., & Stew, G. (2012). Ready for a paradigm shift? Part 2: Introducing qualitative research methodologies and methods. *Manual therapy*, *17*(5), 378-384.

Picot, H., & Moss, N. (2014). The Sustainable Development Goals: Will They Deliver Climate Compatible Development for Vulnerable Countries? Retrieved from: https://www.africaportal.org/publications/the-sustainable-development-goals-will-they-deliver-climate-compatible-development-for-vulnerable-countries/

Pinsonneault, A. & Kraemer, K.L., (1993) Survey Research Methodology. In Management Information Systems: An Assessment. Journal of Management Information Systems, 10(2), pp.75-106.

Powell, C. (2003). The Delphi technique: myths and realities. *Journal of advanced nursing*, *41*(4), 376-382.

Rahman, K. M., Mia, M. I. & Bhuiyan, M. K. (2012). A stochastic frontier approach to model technical efficiency of rice farmers in Bangladesh: An empirical analysis. Agriculturist, 10(2), 9-19.

Raskin, M. S. (1994). The Delphi study in field instruction revisited: Expert consensus on issues and research priorities. Journal of Social Work Education, 30(1), 75-89.

Rayens, M. K., & Hahn, E. J. (2000). Building consensus using the policy Delphi method. *Policy, politics, & nursing practice*, *1*(4), 308-315.

Reid, S, Smit, B, Caldwell, W., & Belliveau, S. (2007). Vulnerability and adaptation to climate risks in Ontario agriculture, *Mitigation and Adaptation Strategies for Global Change*, 12(4), 609–37.

Reinsborough, M. J. (2003). A Ricardian model of climate change in Canada. *Canadian Journal of Economics/Revue canadienne d'économique*, *36*(1), 21-40.

Robert, M., Thomas, A., & Bergez, J. E. (2016). Processes of adaptation in farm decision-making models. A review. *Agronomy for sustainable development*, *36*(4), 1-15.

Roberts, M. J., Schlenker, W. & Eyer, J. (2012). Agronomic weather measures in econometric models of crop yield with implications for climate change. *American Journal of Agricultural Economics*, 95(2), 236-243.

Roehrig, R., Bouniol, D., Guichard, F., Hourdin, F., & Redelsperger, J. L. (2013). The present and future of the West African monsoon: A process-oriented assessment of CMIP5 simulations along the AMMA transect. *Journal of Climate*, *26*(17), 6471-6505.

Rongmao Zhang, Peter Robinson & Qiwei Yao (2018). Identifying Cointegration by Eigen analysis, Journal of the American Statistical Association, DOI:10.1080/01621459.2018.1458620

Rosegrant, M.W. Ewing, M, Yohe, G. Burton, I., Huq, S. & Valmonte-Santos, R. (2008). Climate change and agriculture: threats and opportunities. Deutsche Gesellschaft fur. TechnischeZusammenarbeit (GTZ). Climate protection programme for Developing Countries. Federal Ministry for Economic Cooperation and Development, Germany.

Rosenzweig C. R. & Hillel D. (1998) Climate Change and the Global Harvest: Potential Impacts of the Greenhouse Effect on Agriculture, Oxford University Press, Oxford

Rosenzweig, C., & Parry, M. L. (1994). Potential impact of climate change on world food supply. *Nature*, *367*(6459), 133-138.

Rowe, G., & Wright, G. (1999). The Delphi technique as a forecasting tool: issues and analysis. *International journal of forecasting*, *15*(4), 353-375.

Sahu, N. & Mishra, D. (2013). Analysis of Perception and Adaptability Strategies of the Farmers to Climate Change in Odisha, India. *APCBEE Procedia*. 5: 123–127. 10.1016/j.apcbee.2013.05.022

Samuel, O.S., Shem, W., Daniel, O. & Silas, O. (2017). Impacts of climate variability and climate change on agricultural productivity of smallholder farmers in Southwest Nigeria. *International Journal of Scientific & Engineering Research*. *8*(10)

Samuel, T. E., Ogonna, O. O., & Samuel, E. A. (2018). Effects of climate change on yam production in Cross River State, Nigeria. *International Journal of Agriculture and Forestry*, *8*(2), 104-111.

Sanderson, B. M., O'Neill, B. C., Kiehl, J. T., Meehl, G. A., Knutti, R., & Washington, W. M. (2011). The response of the climate system to very high greenhouse gas emission scenarios. *Environmental Research Letters*, *6*(3), 034005.

Sarker, F., Biswas, J. C. & Maniruzzaman, M. (2015) Climate change adaptation and economic profitability: crop land shifting to mango orchard in Rajshahi region. *Bangladesh Rice Journal*, 18(1-2), 8-17

Sarker, M. A. R., Alam, K. & Gow, J. (2013) Assessing the determinants of rice farmers' adaptation strategies to climate change in Bangladesh. *International Journal of Climate Change Strategies and Management*, 5(4), 382-403.

Sarker, M.A.R., Alam, K. and Gow, J., 2012. Exploring the relationship between climate change and rice yield in Bangladesh: An analysis of time series data. *Agricultural Systems*, *112*: 11-16

Saunders, M. N., & Lewis, P. (2012). *Doing research in business & management: An essential guide to planning your project*. Pearson.

Scheibe, M., Skutsch, M., & Schofer, J. (2002). IV. C. Experiments in Delphi methodology. *In: Linstone H, Turoff M (eds) The Delphi method: techniques and applications*, 257-281.

Schlenker, W. & Roberts, M. J. (2009) Nonlinear temperature effects indicate severe damages to US crop yields under climate change. *Proceedings of the National Academy of sciences*, 106(37), 15594-15598.

Schlenker, W., & Lobell, D. B. (2010). Robust negative impacts of climate change on African agriculture. *Environmental Research Letters*, *5*(1), 014010.

Schlenker, W., & Roberts, M. (2006). Nonlinear effects of weather on crop yields: implications for climate change. *Review of Agricultural Economics*, *28*.

Schlenker, W., & Roberts, M. J. (2009). Nonlinear temperature effects indicate severe damages to US crop yields under climate change. *Proceedings of the National Academy of sciences*, *106*(37), 15594-15598.

Schlenker, W., Hanemann, W. M., & Fisher, A. C. (2005). Will US agriculture really benefit from global warming? Accounting for irrigation in the hedonic approach. *American Economic Review*, *95*(1), 395-406.

Semie, N., Belay, K., Karippai, R. S., & Bogale, A. (2009). Measurement of farmers' attitude towards complete ownership of farmland in eastern Ethiopia. *Journal of Rural Development/Nongchon-Gyeongje*, *32*(1071-2016-86918), 111-131.

Semire, F. A., Adekunle, A. J., & Adegbola, O. A. (2019). Studies of climate change on rain rate prediction over southwestern Nigeria. In *1st international conference on engineering and environmental sciences* (p. 1108).

Semykina, A., & Wooldridge, J. M. (2010). Estimating panel data models in the presence of endogeneity and selection. *Journal of Econometrics*, *157*(2), 375-380.

Senanayake, S. & Rathnayaka, R. (2017). Analysis of factors affecting for adoption of good agricultural practices in potato cultivation in Badulla district, Sri Lanka. *AGRIEAST: Journal of Agricultural Sciences*, 10: 1-5

Seneviratne, S., Nicholls, N., Easterling, D., Goodess, C., Kanae, S., Kossin, J., ... & Reichstein, M. (2012). Changes in climate extremes and their impacts on the natural physical environment. Retrieved from: https://academiccommons.columbia.edu/doi/10.7916/d8-6nbt-s431

Seo, S. N., & Mendelsohn, R. (2008). An analysis of crop choice: Adapting to climate change in South American farms. *Ecological economics*, *67*(1), 109-116.

Seo, S.-N. N., Mendelsohn, R. & Munasinghe, M. (2005). Climate change and agriculture in Sri Lanka: a Ricardian valuation. *Environment and Development Economics*, 10(05), 581-596.

Serdeczny, O., Adams, S., Baarsch, F., Coumou, D., Robinson, A., Hare, W., ... & Reinhardt, J. (2017). Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions. *Regional Environmental Change*, *17*(6), 1585-1600.

Shackleton, S., Ziervogel, G., Sallu, S., Gill, T., & Tschakert, P. (2015). Why is socially-just climate change adaptation in sub-Saharan Africa so challenging? A review of barriers identified from empirical cases. *Wiley Interdisciplinary Reviews: Climate Change*, *6*(3), 321-344.

Shongwe, M. E., van Oldenborgh, G. J., van den Hurk, B., & van Aalst, M. (2011). Projected changes in mean and extreme precipitation in Africa under global warming. Part II: East Africa. *Journal of climate*, *24*(14), 3718-3733.

Singh, K. (2007). *Quantitative social research methods*, Sage Publications Ltd, New Delhi.

Singh, M.K. & E. Dobo. (2007): An Empirical Study of Climate Change Effects and Agriculture Vulnerability. Gazdálkodás 19 (61-66), 51,

Skinner, J., & Edwards, A. (2009). *Qualitative research in sport management*. Elsevier.

Skulmoski, G. J., Hartman, F. T., & Krahn, J. (2007). The Delphi method for graduate research. *Journal of Information Technology Education: Research*, *6*(1), 1-21.

Smit, B., & Skinner, M. W. (2002). Adaptation options in agriculture to climate change: a typology. *Mitigation and adaptation strategies for global change*, *7*(1), 85-114.

Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global environmental change*, *16*(3), 282-292.

Smit, B., Burton, I., Klein, R., & Street, R. (1999). The Science of Adaptation: A Framework for Assessment. *Mitigation and Adaptation Strategies for Global Change* 4, 199–213. https://doi.org/10.1023/A:1009652531101

Sofoluwe, N. A., Tijani, A. A., & Baruwa, O. I. (2011). Farmers perception and adaptation to climate change in Osun State, Nigeria. *African Journal of Agricultural Research*, *6*(20), 4789-4794.

State Bureau of Statistics, (2011). *Statistical Yearbook*. Government of Cross River State, State Bureau of Statistics (SBS). 7-46

Stern, N. (2006) *Stern Review: The Economics of Climate Change.* [online]. Available http://mudancasclimaticas.cptec.inpe.br/~rmclima/pdfs/destaques/sternreview_report_complete.pdf [Date accessed: 04.03.2018]

Tadross, M., Jack, C., & Hewitson, B. (2005). On RCM-based projections of change in southern African summer climate. *Geophysical Research Letters*, *32*(23).

Tambo, J. A., & Abdoulaye, T. (2013). Smallholder farmers' perceptions of and adaptations to climate change in the Nigerian savanna. *Regional Environmental Change*, *13*(2), 375-388.

Tazeze, A., Haji, J. & Ketema, M. (2012). Climate change adaptation strategies of smallholder farmers: the case of Babilie District, East Harerghe Zone of Oromia Regional State of Ethiopia. *Journal of Economics and Sustainable Development*, *3*(14), 1-12

Tesfaye, W. & Seifu, L. (2016). Climate change perception and choice of adaptation strategies: Empirical evidence from smallholder farmers in east Ethiopia. *International Journal of Climate Change Strategies and Management*, *8*(2): 253-270

Tesso, G., Emana, B. & Ketema, M. (2012). A time-series analysis of climate variability and its impacts on food production in North Shewa zone in Ethiopia. *African Crop Science Journal.* 20(2): 261-274

Thirtle, C., Lin, L., & Piesse, J. (2003). The Impact of Research-Led Agricultural Productivity Growth on Poverty Reduction in Africa, Asia and Latin America. *World Development, Elsevie*r, 31(12), 1959-1975.

Thomas-Hope, E. (ed) (2017) *Climate Change and food security: Africa and the Caribbean.* Routledge :1-112

Thornton, P. K., Jones, P. G., Ericksen, P. J., & Challinor, A. J. (2011). Agriculture and food systems in sub-Saharan Africa in a 4 C+ world. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *369*(1934), 117-136.

Ticehurst, G. W., & Veal, A. J. (2000). Questionnaire surveys. *Business research methods: A managerial approach*, 135-158.

Tol, R.S.J. 2005 Adaptation and mitigation: trade-offs in substance and methods. Environmental Science and Policy 8(6): 572-578.

Toulmin, C. (2009). Securing land and property rights in sub-Saharan Africa: the role of local institutions. *Land use policy*, *26*(1), 10-19.

Tubiello, F. N., Rosenzweig, C., Goldberg, R. A., Jagtap, S., & Jones, J. W. (2002). Effects of climate change on US crop production: simulation results using two different GCM scenarios. Part I: wheat, potato, maize, and citrus. *Climate research*, *20*(3), 259-270.

Tubiello, F.N., M. Donatelli, C. Rosenzweig, and C.O. Stockle, 2000: Effects of climate change and elevated CO_2 on cropping systems: Model predictions at two Italian locations. *Eur. J. Agron.*, 12, 179-189.

Turral, H., Burke, J., & Faurès, J. M. (2011). *Climate change, water and food security* (No. 36). Food and Agriculture Organization of the United Nations (FAO).

Uddin, M. N., Bokelmann, W., & Entsminger, J. S. (2014). Factors affecting farmers' adaptation strategies to environmental degradation and climate change effects: A farm level study in Bangladesh. *Climate*, *2*(4), 223-241.

Udoimuk, A. B., Osang, J. E., Ettah, E. B., Ushie, P. O., Egor, A. O., & Alozie, S. I. (2014). An empirical study of seasonal rainfall effect in Calabar, Cross River State, Nigeria. *IOSR Journal of Applied Physics*, *5*(5), 7-15.

Uleberg, E., Hanssen-Bauer, I., van Oort, B. & Dalmannsdottir, S. (2014). Impact of climate change on agriculture in Northern Norway and potential strategies for adaptation. *Climatic Change*, *122*(1-2), 27-39

Umar, O. J., & Ozohu, D. A. (2015). Impact of climate change on agricultural production and food supply in Africa. In *International Conference*.

Unamma, R. P. A., Onwudike, O. C., Uwaegbute, A. C., Edeoga, H. O., & Nwosu, A. C. (2004). Farming Systems Research and Development in Nigeria–Principles and Practice in Humid and Derived Savanna South–East Zone. *Published by Michael Okpara University of Agriculture Umudike, Nigeria*, 200.

Uza, D. V., Avibodo, S. O., Abubakar, A., & Ahmed, U. H. (1999). Transferable technology for enhancing smallholder livestock production.

Verter, N., & Bečvářová, V. (2015). An analysis of yam production in Nigeria. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, *63*(2), 659-665.

Viatte, G., De Graaf, J., Demeke, M., Takahatake, T., & de Arce, M. R. (2009). Responding to the food crisis: synthesis of medium-term measures proposed in inter-agency assessments. *Food and Agriculture Organization of the United Nations (FAO), Rome, Italy*.

Vijverberg, W. P. (2011). Testing for IIA with the Hausman-McFadden test. Retrieved from: http://ftp.iza.org/dp5826.pdf

Vizy, E. K., & Cook, K. H. (2012). Mid-twenty-first-century changes in extreme events over northern and tropical Africa. *Journal of Climate*, *25*(17), 5748-5767.

Waha, K., Müller, C., Bondeau, A., Dietrich, J. P., Kurukulasuriya, P., Heinke, J., & Lotze-Campen, H. (2013). Adaptation to climate change through the choice of cropping system and sowing date in sub-Saharan Africa. *Global Environmental Change*, *23*(1), 130-143.

Wang, D., Yu Hao, and Wang, J. (2018). Impact of climate change on China's rice production—An empirical estimation based on panel data (1979–2011) from China's main rice-producing areas. *The Singapore Economic Review* 63: 535–53. doi:10.1142/S0217590817400240.

Wang, J., Huang, J., Zhang, L. & Li, Y. (2014). Impacts of climate change on net crop revenue in North and South China. *China Agricultural Economic Review*, 6(3), 358-378.

Wei, T., Cherry, T. L., Glomrød, S. & Zhang, T. (2014). Climate change impacts on crop yield: evidence from China. *Science of the Total Environment*, 499, 133-140.

Weli, V. E., & Bajie, S. (2017). Adaptation of Root crop farming system to climate change in Ikwerre Local Government Area of Rivers State, Nigeria. *American Journal of Climate Change*, *6*(01), 40.

Wheeler, T.R., Crauford, P.Q., Ellis, R.H. Porter, J.R.X Vara & Prasad, P.V. (2000). Tempt Variability and the yield of annual crops. Agric, Ecosystem and Environment. 82: 159 – 167.

White, S. S., & Selfa, T. (2013). Shifting lands: Exploring Kansas farmer decision-making in an era of climate change and biofuels production. *Environmental management*, *51*(2), 379-391.

Wiebe, K., Lotze-Campen, H., Sands, R., Tabeau, A., van der Mensbrugghe, D., Biewald, A., ... & Müller, C. (2015). Climate change impacts on agriculture in 2050 under a range of plausible socioeconomic and emissions scenarios. *Environmental Research Letters*, *10*(8), 085010.

Williams, A. (2003). How to write and analyse a questionnaire. *Journal of Orthodontics*, vol. 30, no. 3, pp. 245–52.

Williams, E. (1984). *Reading in the language classroom*. Basingstoke: Macmillan.

Wise, R.M., I. Fazey, M. Stafford Smith, S.E. Park, H.C. Eakin, E.R.M. Archer Van Garderen, and B. Campbell, 2014: Reconceptualising adaptation to climate change as part of pathways of change and response. *Global Environment Change*, **28**, 325-336

Witkin, B. R., Altschuld, J. W., & Altschuld, J. (1995). *Planning and conducting needs assessments: A practical guide*. Sage.

Wong, K. (2014). Research 101: Paradigms and Methodologies. *Vue: the magazine of the Marketing Research and Intelligence Association*. 16-17.

Wong, P. W. H. (2006). A study of business ethical practices in Australian organisations: a multiple case study.

Wood, S. A., & Mendelsohn, R. O. (2015). The impact of climate change on agricultural net revenue: a case study in the Fouta Djallon, West Africa. *Environment and Development Economics*, *20*(1), 20.

World Bank (2003) *World Development Report 2004 (Overview): Making Services Work for Poor People*. World Bank.

World Bank (2010) *World Development Report 2010: Development and Climate Change*. Washington,DC. [online] Available from: https://openknowledge.worldbank.org/handle/10986/4387 [Date accessed: 04.03.2018]

World Bank (2018). World Bank open data. *World Bank Web site (INTERNET)*.

World Bank (2019). World Development Report 2019. *The changing nature of work*. Retrieved from: https://www.worldbank.org/en/publication/wdr2019

Yang, J., Wan, Q., & Bi, W. (2020). Off-farm employment and grain production change: New evidence from China. *China Economic Review*, *63*, 101519.

Yegbemey, R. N., Yabi, J. A., Tovignan, S. D., Gantoli, G. & Haroll Kokoye, S. E. (2013) Farmers' decisions to adapt to climate change under various property rights: a case study of maize farming in northern Benin (West Africa). *Land Use Policy*, 34, 168-175.

Yip, W. C., Wang, H. & Liu, Y. (1998). Determinants of patient choice of medical provider: a case study in rural China. *Health policy and planning*, vol. 13, no. 3, pp. 311–22.

Yirga, C., & Hassan, R. M. (2010). Social costs and incentives for optimal control of soil nutrient depletion in the central highlands of Ethiopia. *Agricultural Systems*, *103*(3), 153-160.

Zakari, D. M., Mohammed, A. B., Medugu, N. I., & Sandra, I. (2014). Impact of climate change on yam production in Abuja, Nigeria. *International Journal of Science, Environment and Technology*, *3*, 458-472.

Zewdie A (2014). Impacts of Climate Change on Food Security: A Literature Review in Sub Saharan Africa. J Earth Sci Clim Change 5: 225. Doi: 10.4172/2157-7617.1000225

Zhai, P., Pörtner, H. O., Roberts, D., Skea, J., Shukla, P. R., Pirani, A., ... & Connors, S. (2018). *Global Warming of 1.5 OC: An IPCC Special Report on the Impacts of Global Warming of 1.5° C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty* (p. 32). V. Masson-Delmotte (Ed.). Geneva, Switzerland: World Meteorological Organization.

Zhang, R., Robinson, P. and Yao, Q., (2019). Identifying cointegration by eigenanalysis. *Journal of the American Statistical Association. 114*(526): 916-927

Appendices

Appendix A

ROYAL AGRICULTURAL UNIVERSITY, CIRENCESTER, GLOUCESTERSHIRE-UK
Farmers Interview Questionnaire

To be completed by Interviewer	**To be completed by Team Leader:**
Please complete before the Interview	

<table>
<tr><td rowspan="2">0.1</td><td rowspan="2">Interviewer Name:
a. |__|__|__|__|__|__|__|__|__|__|
b. |__|__|__|__|__|__|__|__|__|__|</td><td>0.4 – Date: |__|__| / |__|__| / 2017
Day Month

0.5- Leader's Name:
|__|__|__|__|__|__|__|__|__|__|</td></tr>
<tr></tr>
<tr><td>0.2</td><td>Date: |__|__| / |__|__| / |__|__|__|__|
Day Month Year</td><td rowspan="2">Remarks:
____
____
______________________</td></tr>
<tr><td>0.3</td><td>Interview Location:_____
____

GPS Coordinates:
______________________________</td></tr>
</table>

Please read / explain to the respondent the following consent information:

My name is (…………), I am part of an assessment team that is currently reviewing the **(Your research and field research areas).**.

We like to work with you and the community to enable us to gain a deeper understanding of the constraints and opportunities in relation to your family activities/household income.

Our discussion is expected to take about 45 minutes and I would also like to visit your plots to discuss how you farm and take some pictures if that is possible.

Any information that you provide will be confidential and will not be disclosed to other people. Your participation is voluntary and you can choose not to answer any or all of the questions if you wish; however, we hope you will participate since your views are important.

Do you have any questions?

Yes ☐ No ☐

If you are happy to proceed with this interview today, can you sign here:

Interviewee Signature:
…………………………………..

Signature of Interviewer:
………………………………..

Signature of Team Leader:

To be completed by Data Entry

0.6 – Date: |__|__| / |__|__| / |__|__|__|__|
Day Month Year

0.7- |__|__|__|__|__|__|__|__|__|__|
Name of data entry operator

Remarks:

Date: ……………………………….. May I begin the interview now?	______________ ______________ **Signature of data entry:**
You may like to know what climate change is. Climate change is any change in weather patterns for an extended period such as decades. It may take several forms such as changes in temperature and rainfall pattern, more frequent and severe extreme weather events such as floods, droughts, storms, and a rise in sea level for several previous years.	

Question No	Question	Response
Q1	Name of Respondent	
Q2	Respondent Mobile Number	

<table>
<tr><td>Q3a

Q3b</td><td>Name of Respondent
LGA/Community

Respondent – religion</td><td colspan="7">
LGA/Community…………………………………….

Religion/Denomination …………………………….</td></tr>
<tr><td>Q4</td><td>Respondent – Sex</td><td>Male</td><td colspan="2"></td><td>Female</td><td colspan="3"></td></tr>
<tr><td>Q5</td><td>Respondent - Marital Status</td><td colspan="7">Single [ ] Married [ ] Widow [ ] Widower [ ]</td></tr>
<tr><td>Q6</td><td>Respondent’s number of household members</td><td colspan="7"></td></tr>
<tr><td rowspan="7">Q7</td><td rowspan="7">a) Respondent Age (tick appropriate response)

b) Family age/gender</td><td rowspan="2">Respondent age</td><td rowspan="2">Tick</td><td colspan="2" rowspan="2">Family age</td><td rowspan="2">No</td><td colspan="2">Gender</td></tr>
<tr><td>M</td><td>F</td></tr>
<tr><td>Less than 20 Years</td><td></td><td colspan="2">Less than 5 yrs</td><td></td><td></td><td></td></tr>
<tr><td>20 – 40 Years</td><td></td><td colspan="2">5 - 25 years</td><td></td><td></td><td></td></tr>
<tr><td>41 – 60 Years</td><td></td><td colspan="2">26 – 46 years</td><td></td><td></td><td></td></tr>
<tr><td>61 years & above</td><td></td><td colspan="2">47 years & above</td><td></td><td></td><td></td></tr>
<tr><td>Doesn’t Know</td><td></td><td colspan="2">Doesn’t know</td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Q8</td><td rowspan="5">a) Respondent Highest Education Level</td><td>a) Respondent</td><td colspan="6">Tick</td></tr>
<tr><td>Primary</td><td colspan="6"></td></tr>
<tr><td>Secondary</td><td colspan="6"></td></tr>
<tr><td>Tertiary</td><td colspan="6"></td></tr>
<tr><td>No Education</td><td colspan="6"></td></tr>
<tr><td>Q9a</td><td>Main occupation of the respondent (please write)</td><td>Q9b.</td><td colspan="2">How long have you been involved in farming?</td><td colspan="4">(in years)</td></tr>
<tr><td>Q10</td><td colspan="8">Assets owned by household</td></tr>
</table>

S/N	***Item***	***Year of purchase***	***Amount purchased***	***Present market value***
1.	Tractor			
2.	Generator			
3.	Television			
4.	Cell phone			
5.	Radio			
6.	Simple farm tools			
7.	Motorcycle			
8	Plough			

9.	Others (please specify) …………………………………			

Q11	**Main Livestock Assets** Do you own any cattle?	**No**	**Yes**	**If Yes – how many?**
	Do you own any sheep?			
	Do you own any goats?			
	Do you own any pigs?			
	Do you own any chickens?			
	Do you own any other livestock – list plus numbers			

Q12	**Please indicate the three most important crops that you grow including yam**	Crop	% home consumption	Amount in Naira	% to market	Amount in Naira

Q13a	**Labour** How many of the household work on the farm?	Full time		Part time	
Q13b	Do you have enough labour to facilitate crop production?	YES		NO	
Q13c	If NO, why is labour a constraint? (explain)				
Q14	Do you buy in labour or rent out family members to other farms?	Labour bought in [ ] days per month; Cost per day [ ] Labour rented out [ ] days per month; Cost per day [ ]			
Q15	Does household head have secondary (non-farm) employment?	Yes [ ]	If yes: what type of employment:		

		No [ ]			
Q16	What was the labour used and the cost spent on each of the following farm operations/ activities in food crop production				
S/N	**Farm operation**		**Family labour**	**Hired Labour**	
			Qty in man-days/ha	**Qty in man-days/ha**	**Amount in Naira(man-days/ha)**
1.	Land clearing				
2.	cultivation				
3.	Planting				
4.	Staking				
5.	Weeding				
6.	Mulching				
7.	Fertilizer application				
8.	Herbicide application				
9.	Harvesting				
10.	Other (specify)……………………………………… ……..				
Q17a	**Land and soil** What is the size of your total production land? *(use appropriate measures community are familiar with).* *If uncertain then pace out when visiting plots*	Less than 1 Ha			
		1 Ha – 2Ha			
		2 Ha – 3Ha			
		3 Ha – 4Ha			
		Larger – state size			
		Is your land in 1 or several plots	1 plot [ ] several [no......]		
Q17b	Do you have title deeds for the land?	YES [ ] NO [ ] Some with title deeds [ ]			
Q17c	What is your soil type?	Deep lateritic fertile soil [ ] Dark clayey basaltic soil [ ]			
Q18a	**Farming systems** What system of farming do you practice?	You can tick more than 1…. Mono-cropping [ ] crop rotation [ ] Mixed cropping [ ] shifting cultivation [ ] Mixed farming [ ] Other (state) ……………………			
Q18b	What components of the farming above do you mainly practice?	Farming system …………………………………………….. Why?..			

Q18c	How long have you been involved in farming?	10 – 20 Years [ ] 21 – 30 Years [ ] 31 – 40 Years [ ] 41 years & above [ ]

Q19a	**Water** Do you have a water source for your crop production activities and livestock?	YES		NO (rain fed) [Go to Q19d]	
Q19 b	If Yes what is your source of water?	River		Dam	
		Stream		Well	
		Borehole		Other (specify)………………….	
Q19c	Does this source provide you with sufficient water for crop production throughout the year?	YES		NO	
Q19 d	Do you have access to irrigation equipment for your crop production activities?	Yes		NO (Go to Q 20a)	
Q19e	Type of irrigation equipment	Treadle pump		Sprinkler	
		Drip		Buckets	
		Other (specify)			
Q19f	What percentage (%) of your farmland do you irrigate?	<50% [ ] 50% [ ] >50% [ ] 100% (All) [ ]			
Q20a	**Other Crop Inputs** a) Are the inputs required for crop production easily available to farmers in your community e.g. seeds, fertilizers and pesticides? b) If no, what are the main reasons?	Seeds Yes [ ] No [ ] Fertilizers Yes [ ] No [ ] Pesticides Yes [ ] No [ ] Herbicides Yes [ ] No [ ] Reasons:			
Q20 b		Finance		quality of inputs	

	What is the main challenge that you face to access crop production inputs?	Distance from input markets		Other (specify)………………....

Q21	**Extension Support** Do you receive extension advice from a trained extension officer?	YES		NO	
Q22	What kind of information do you get from the extension service?	Improved yam varieties		Pest and disease control	
		Agronomic practices		Marketing and storage	
Q23	The extension officers that visit you, where are they from?	Government		Private Company	
		NGO		Other (specify)	
Q24	How often do you receive visits by an extension officer for technical support linked to your yam production activities?	Weekly		Every 5 - 8 months	
		Monthly		Once every year	
		Every 2 - 4 months		Never/rarely visited	
Q25	Are you satisfied by the technical support that you receive from extension officers?	Very happy [ ]	Happy [ ]	Unhappy [ ]	Very Unhappy [ ]
Q26	If unhappy, what are your main concerns?	(Please write) ………………………………………………………………			
Q 27	**Institutional Accessibility** Do you get any climatic (e.g. temperature and rainfall) information in advance from any source?	YES		NO If no, go to Q29	
Q28	Which source do you get your climatic information?	Extension officer [ ] Television [ ] Radio [ ] Newspaper [ ] Family and friends[ ] Other (specify) ………………………………………			
Q29	Do you have access to credit facility?	YES		NO	

		If yes, formal [ ] or informal [ ]			
Q30	Do you receive any agricultural subsidy (e.g. input subsidy) from the government?	YES		NO	
Q31	Do you have access to electricity?	YES		NO	

Farm Household Yearly Income in Naira (N)

Income from farming activities		***Income from non-farming activities (off-farm jobs)***	
Items	Income (N)	Items	Income (N)
Yams		Petty trading	
Livestock		Labouring	
Other Crops		Fishing	
Others (please specify) ……………………………………		Others (please specify) …………………………………..	

Sample enterprise questions – Yam.

Y1	**Yam** What is the size of your yam production plot? *(tick appropriate response)*	Less than 1ha			
		1-2ha			
		3-4ha			
		5ha and above			
Y2	What variety of seed yam did you plant and what type?	Improved variety [ ] Unimproved variety [ ] **Type of seed-yam:** small whole tubers [ ] cut pieces of tubers [ ]			
Y3	Do you grow yams for sale or home use?	All home use Go to Y10	Some for sale [%]	All for sale	
Y4	How do you measure your yams for sale?	Counting in tubers		In heaps	
		In bags		In kg	
		Other (Specify) ……………………………………………..			
Y5	Surplus yams a) Do you store yams? b) Do you have access to market to sell?	No [ ] Yes [ ] No [ ] Yes [ ] if yes, which market …………………. Local market [ ] Big market [ ]			
Y6	How far is this market from your production plot?	Less than 2 KMs		20 – 40kms	
		2 - 10 KMs		40 – 50kms	
		10 - 20 KMs		More than 50KMs	

Y7	How long does it take you to get to this target market?	Less than 1 hour		3 – 4 hours	
		1 - 2 Hours		4 – 5 hours	
		2 – 3 Hours		More than 5 Hours	
Y8	How do you get your produce to this target market?	Walk		Bicycle	
		Bus		Car	
		Other (specify)…….			
Y9	How often do you supply yams to the market?	Daily		Only in the harvest season	
		Weekly		Occasionally	
		Every 2 weeks			
		Once a month			
Y10	**Hunger Gap** How long do you store yams?	Less than 2 Months		4 – 6 Months	
		2 – 4 Months		More than 6 Months	
Y11	Do you have stored yams for your consumption till the next planting season?	Yes If yes, go to Q32		No If no, which months?	
Y12	What measure do you take to bridge the hunger gap?	Using other stored food [ ] Planting vegetables [ ] Other (specify) ……………………………………..			

Costs and Returns on Yam Production in the previous year (2016-2017)

S/N	***Input***	***Quantity***	***Cost in Naira (N)***
1.	Fertilizer (kg)		
2.	Seed Yam (kg)		
3.	Herbicides (liters)		
4.	Pesticides (liters)		
5.	Labour (man-days/ha)		
6.	Rent on land (ha)		
7.	Irrigation (number of times)		
8.	Transport (months)		
9.	Other (specify)…………………..		
S/N	***Output***	***Quantity Produced***	***Returns in Naira(N)***

1.	Yam Tubers (kg)		
2.	Seed Yam (kg)		

Farmers' Perception and Awareness on Climate Change

Q32	Are you aware of changing weather pattern and climate?	YES		NO	
Q33	Identify which of the climatic variables you suppose have changed and how they have changed below:				
S/N	***Climate Change Component***	***Time Period***	***Increased***	***Decreased***	***No change***
1.	Temperature	Annual			
		Wet season			
		Dry season			
2.	Rainfall	Annual			
		Wet season			
		Dry season			
3.	Drought	Annual			
4.	Flood	Annual			
5.	Erratic rainfall pattern	Annual			
6.	Heat wave/hot days	Annual			
7.	Duration of rainfall	Annual			
8.	Delayed onset of rainfall	Annual			
9.	Early cessation of rainfall	Annual			
10	Other(specify) ………………………………				

Impacts of Climate Change

Q34	State to what extent you agree to the following perceived effects of climate change on your yam farm by ticking [√] the appropriate box:				
S/N	**Perceived Effect**	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
1.	Decline in crop yield				
2.	Reduced soil fertility				
3.	Poor tuberization				
4.	Late maturity				
5.	Erosion hazard				
6.	Stunted growth				
7.	Flooding of the farm				
8.	Pest and disease proliferation				
9.	Other(specify) ……………………………………………..				

Farmers' Adaptation Strategies to Climate Change

Q35	Have you made any changes to your farm operations due to changes in weather pattern and climate in order to reduce adverse impacts?	YES		NO If no, go to Q37	
Q36	State to what extent you have used the following adaptation strategies to reduce the effect of climate change on your farm by ticking [√] the appropriate box				
S/N	**Adaptation Strategies**	**Never Used**	**Used Sometimes**	**Used Most Times**	**Used All Times**
1.	Use of improved yam seeds				
2.	Use of irrigation				
3.	Use of organic fertilizer				
4.	Use of in-organic fertilizer				
5.	Changing planting date				
6.	Use of different crop variety				
7.	Planting of trees				
8.	Planting different varieties of crops				
9.	Off-farm employment				
8.	Mulching				
9.	Cover cropping				
10.	Mixed farming				
11.	Use of modern storage facility				
12.	Access to extension worker				
13.	Movement to different site				
14.	Expand area of land under cultivation				
15.	Others (specify) ……………………				

Barriers/Constraints to Adaptation

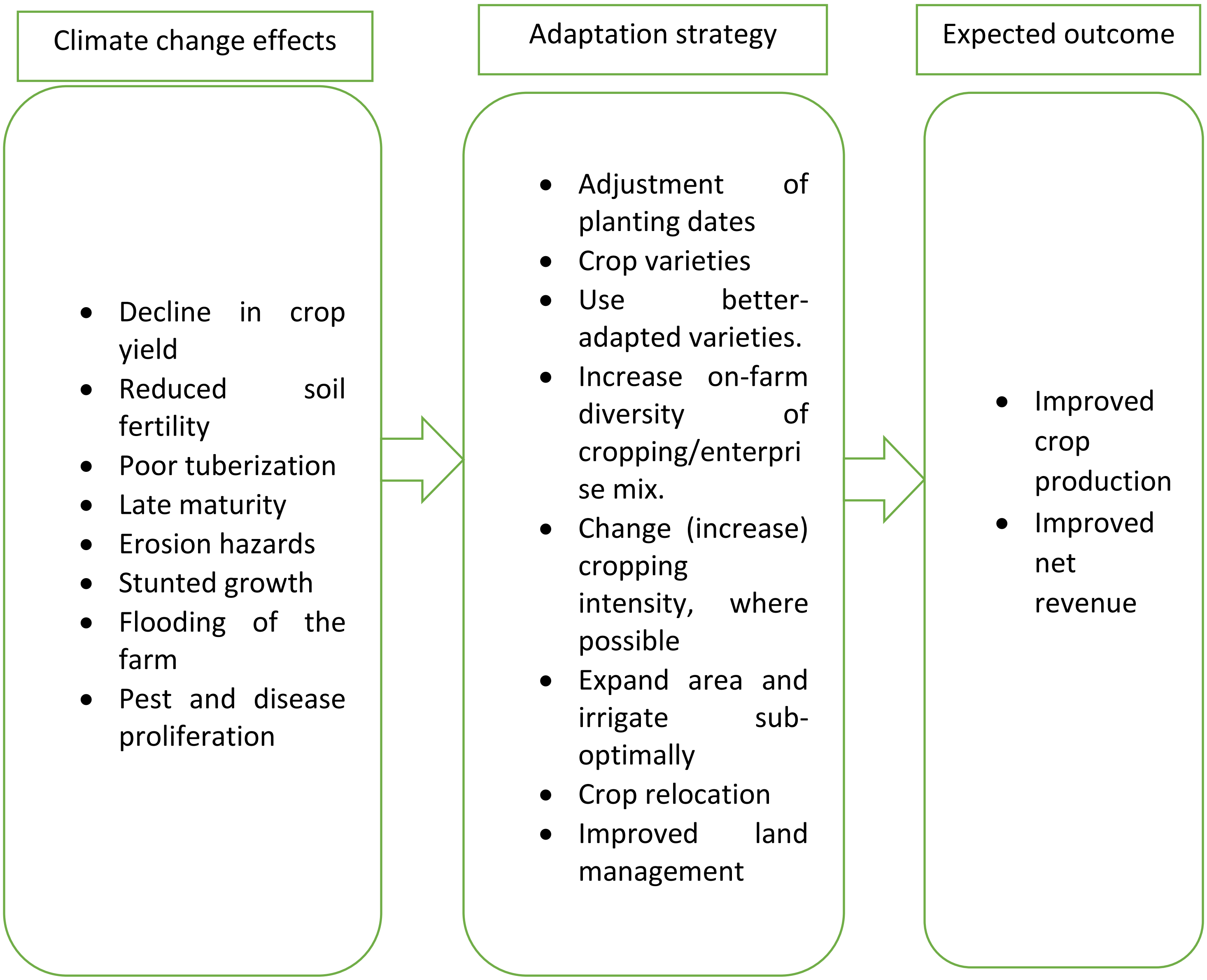
Q37	State to what extent do you agree that the following stop or hinder you from adapting to climate change by ticking [√] the appropriate box:				
S/N	***Barriers to Adaptation***	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
1.	Lack of information to climate change				
2.	Lack of adequate irrigation facility				
3.	Lack of/or inadequate access to weather forecast technologies				

4.	Lack of/inadequate extension programmes directed to meet the climate change adaptation strategies in food crop production				
5.	Poor agricultural extension service delivery				
6.	Illiteracy of the food crop farmer				
7.	Far distance of household food crop farms to the market				
8.	Lack of storage facilities				
9.	High cost of improved crop varieties				
10.	Farm labour shortage in need				
11.	Poor access to and control of land				
12.	High cost of fertilizers and other inputs				
13.	Traditional beliefs/ practices e.g. on the commencement of farming season, crop festival periods etc.				
14.	High cost of farmland				
15.	Involvement of the crop farmers in some off-farm jobs, e.g. trading				
16.	Lack of/ or inadequate government policies to empower food crop farmers				
17.	Lack of credit facility				
18.	Other(specify) …………………………………………………………..				

Thank you for your time

The questions in the questionnaire that were not analysed in the study was due to incomplete and indefinite entries from the farmers’ responses.

Appendix B Conceptual Framework

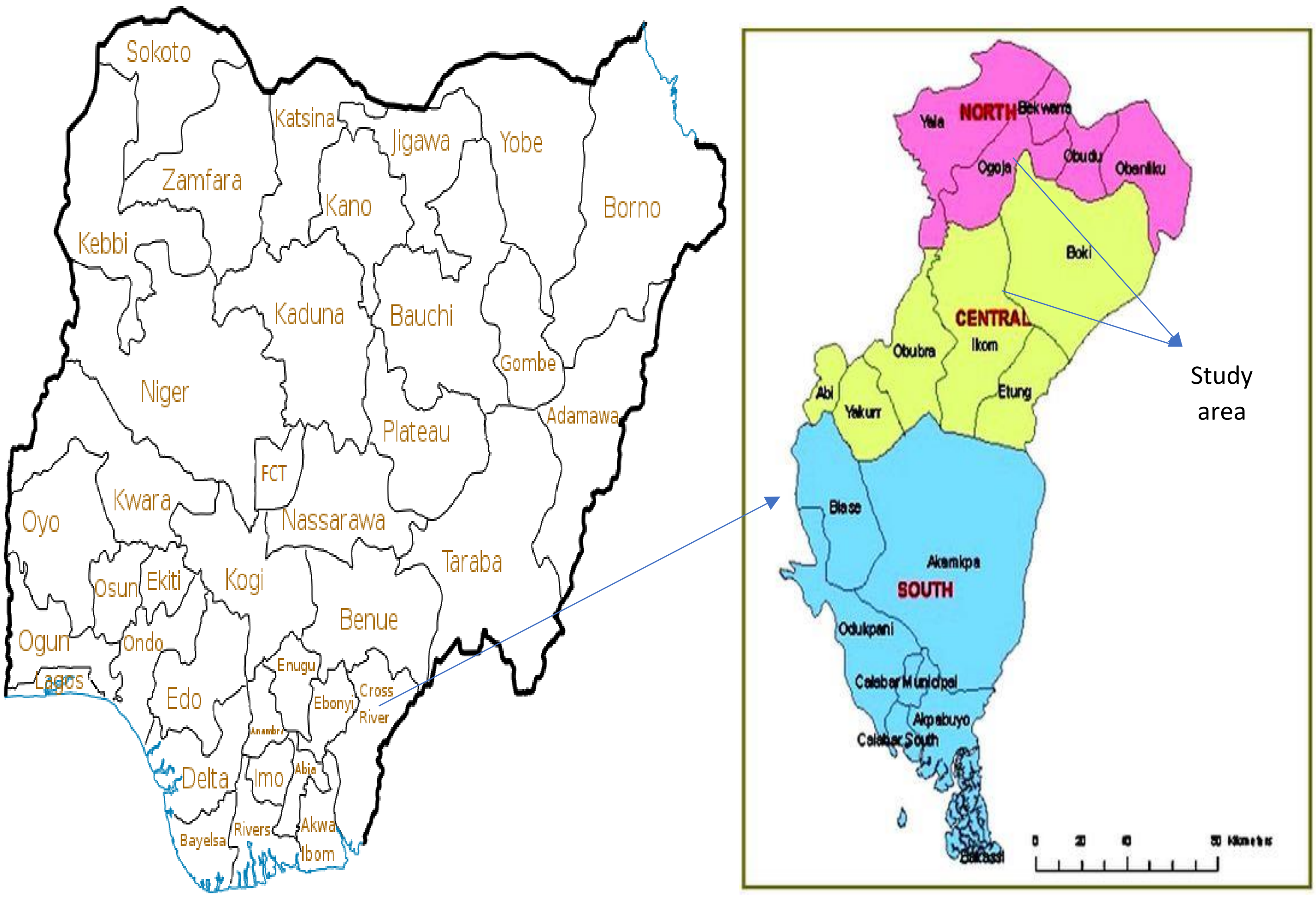


Conceptual framework for achieving a better output and net revenue in yam farming under climate change.

Appendix C

The researcher introducing the research to some of the ADP Staff and Agricultural officers in Cross River State.

Appendix D



Map of Nigeria showing the study area

Appendix E

The researcher in a brief meeting about the research and questionnaire administration with some of the farmers and ADP officers in the study area.

Appendix F

A typical yam farm in Cross River State

Appendix G

A typical yam market in Cross River State

Appendix H
Online survey

Dear Sir/Ma,

I humbly write to invite you to partake in an online survey for my Ph.D. research titled "Impact of climate change and farmers' adaptation strategies for Yam production in Cross River State, Nigeria."

I am a student in the Royal Agricultural University, Cirencester, UK conducting a research into analysing the economic impact of climate change and resultant farmers' adaptation strategies for yam production in Cross River State, Nigeria in order to develop improved extension strategies that respond to environmental challenges and embrace both technical and behavioural challenges faced by smallholders. Part of this study is to validate the recommendations made based on the study findings.

You will see below the findings from the research accompanied by some recommendations. Please indicate by marking an "X" in the appropriate box the recommendations that agree with the research findings. If you wish to justify your opinion or make a remark, please do so in the comment box.

You are to participate by answering the questionnaire which will take about twenty minutes to provide answers and send back to me as soon as possible (preferably within one week). Your response is expected to be from knowledge of the issues either from experience or research.

In order to ensure strict anonymity and privacy issues, the use of all submitted answers will be for research purpose only. For any clarification, you can contact my Director of studies: Dr Richard Baines (Richard.Baines@rau.ac.uk).

Thanks, in anticipation of your cooperation. I look forward to receiving your response.

Kind regards,

Cynthia Angba
Researcher
Cynthia.Angba@student.rau.ac.uk

First Round of online survey

✓ Which of the following best describes you? (Tick where applicable)

A. Academia
B. Extension agent/Officer
C. Independent researcher
D. Agriculturist
E. Policymaker

No		Findings/statement	Strongly agree	Agree	Disagree	Strongly Disagree	comments
Finding 1		**Temperature has a negative effect on the output of yam and the following recommendations are given**					
	1	Policymakers should make policies that support the formation of a reliable weather forecast system.					
	2	The government should provide free pesticides to farmers					
Finding 2		**Lack of education has the probability of reducing yam farmers' net revenue, and so the following policy implications should be applied**					
	3	The government should emphasize the need for education to enhance the ability of farmers to adopt farming innovation and modern adaptation practices by conducting local workshops and seminars among others.					
	4	Policymakers should revisit the existing policy on agricultural extension, technology development and transfer to confirm its efficiency and functionality					

		so that uneducated farmers, especially younger farmers, can gain appropriate knowledge and understanding on the extension services and new technologies provided.					
	5	Policymakers should consider revising the extension programme aspect of the agricultural policy to support farmers in Nigeria to concentrate more on the bottom-top participatory approach so that the existing and the developing adaptation practices and technologies could be focused on the farm level for a better farmer-education.					
	6	Institutional transformations or innovation that can make farmers associate communally among themselves, particularly in the same locality should be supported by policymakers because the farmer-to-farmer extension model can encourage faster transfer of information which in turn enhances farmers' education.					
Finding 3		**Farming experience, household size, access to weather forecast and tenure status have a statistically significant effect on the net revenue of farmers, and so, the following recommendation is given**					
	7	Policymakers should lay emphasis on how to improve these factors by working with individuals and social groups in order to enhance farmers' net revenue to achieve increased self-sufficiency in food crop production.					

Finding 4		**Lack of credit facilities (moss common barrier), high cost of improved varieties, lack of adequate information about weather forecast, illiteracy of farmers, and poor access to and control of land are the factors that hinder farmers' adaptation and so the study recommends that;**					
	8	The government should create and make functional more credit facilities at the rural level to offer affordable credit services to smallholders help them in the area of climate change adaptation because adaptation is expensive					
	9	Institutions should develop and provide free improved crop varieties to farmers.					
	10	Government should provide free land for farming to farmers					
	11	Government should encourage farmers to follow up weather report on weather stations					

Second Round of online survey

- ✓ Which of the following best describes you? (Tick where applicable)

F. Academia
G. Extension agent/Officer
H. Independent researcher
I. Agriculturist
J. Policymaker

No	Findings/statement	Strongly agree	Agree	Disagree	Strongly Disagree	comments

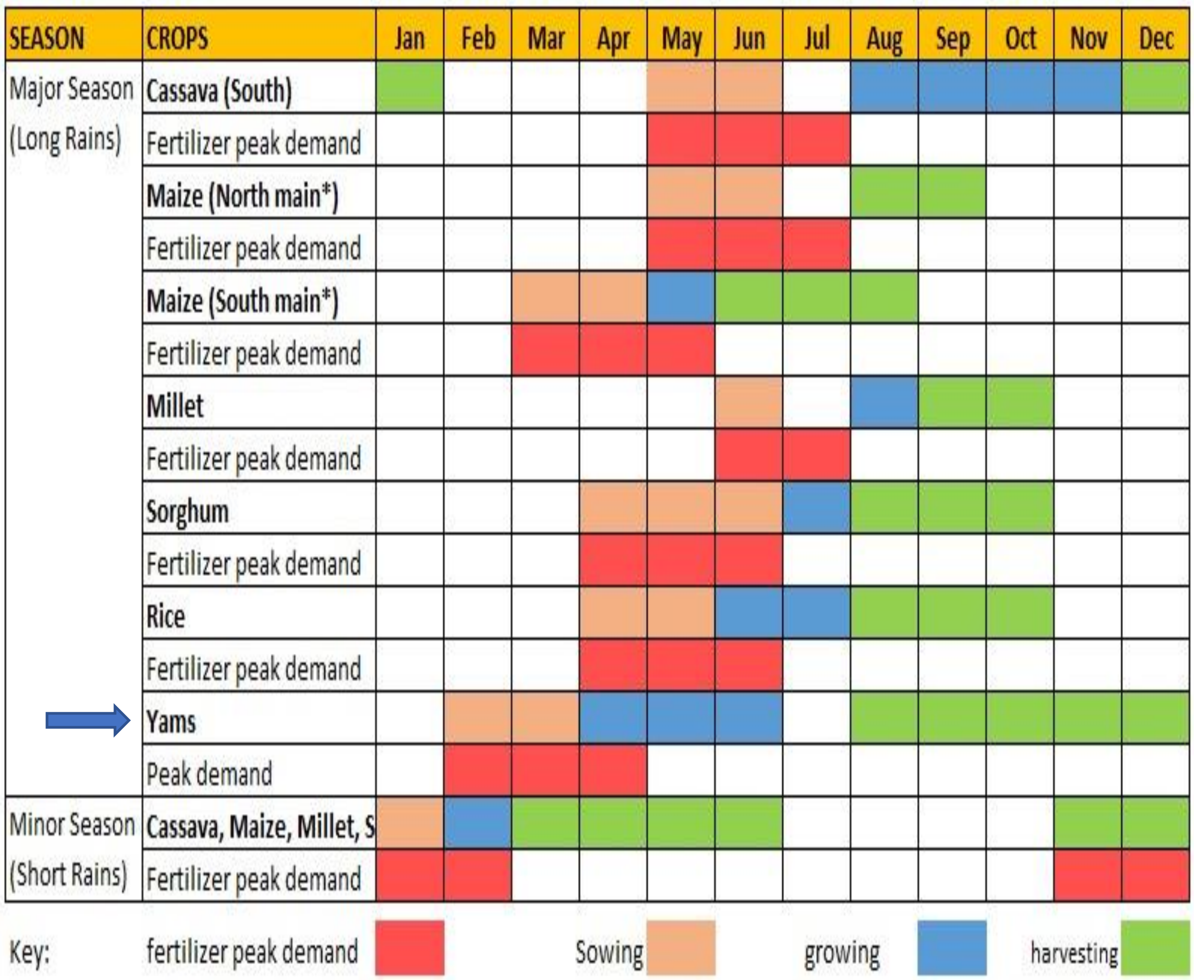
Finding 1		**Temperature has a negative effect on the output of yam and the following recommendations are given**					
	1	The government should provide an effective weather forecast system that can get to local farmers to help them know when to expect temperature increase and thus take necessary adaptation action.					
	2	The government need to create an enabling environment for independent researchers as well as institutes to develop pest- and disease-tolerant yam varieties.					
Finding 2		**Lack of education has the probability of reducing yam farmers' net revenue, and so the following policy implications should be applied**					
	3	The government should emphasize the need for education to enhance the ability of farmers to adopt farming innovation and modern adaptation practices by conducting local workshops and seminars among others					
	4	Policymakers should revisit the existing policy on agricultural extension, technology development and transfer to confirm its efficiency and functionality so that uneducated farmers, especially younger farmers, can gain appropriate					

		knowledge and understanding on the extension services and new technologies provided.					
	5	Policymakers should consider revising the extension programme aspect of the agricultural policy to support farmers in Nigeria to concentrate more on the bottom-top participatory approach so that the existing and the developing adaptation practices and technologies could be focused on the farm level for a better farmer-education.					
	6	Institutional transformations or innovation that can make farmers associate communally among themselves, particularly in the same locality should be supported by policymakers because farmer-to-farmer extension model can encourage faster transfer of information which in turn enhances farmers' education.					
Finding 3		**Farming experience, household size, access to weather forecast and tenure status have a statistically significant effect on the net revenue of farmers, and so, the following recommendation is given**					
	7	Policymakers should lay emphasis on how to improve these factors by working with individuals and social groups in order to enhance farmers' net					

		revenue to achieve increased self-sufficiency in food crop production.					
Finding 4		**Lack of credit facilities, high cost of improved varieties, lack of adequate information about weather forecast, illiteracy of farmers, and poor access to and control of land are the factors that hinder farmers' adaptation and so the study recommends that;**					
	8	The government should create and make functional more credit facilities at the rural level to offer affordable credit services to smallholders help them in the area of climate change adaptation because adaptation is expensive					
	9	The government should take appropriate measures to develop and provide improved varieties to farmers at subsidized rate.					
	10	Governments should develop a reliable weather forecast system that can take weather information across to farmers to enable the farmers to plant at the appropriate time					
	11	The government should put in place a proactive regulatory land-use acts that will enable the farmers to partake in a more tenable land ownership systems so that they can invest in and make use of sustainable					

		adaptation practices whose benefits come in subsequent years					
	12	Government should provide free education up to tertiary education to support farmers					

Appendix I Crop Calendar



Crop calendar showing the yam sowing time, growing period, fertilizer application time and harvest time

Source: https://africafertilizer.org/nigeria/