The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

THE EFFECTS OF CLIMATE CHANGE ADAPTATION STRATEGIES ON FOOD CROP PRODUCTION EFFICIENCY IN SOUTHWESTERN NIGERIA

BY

OTITOJU, MORADEYO ADEBANJO
(PG/Ph.D/09/50851)

DEPARTMENT OF AGRICULTURAL ECONOMICS
UNIVERSITY OF NIGERIA, NSUKKA

NOVEMBER, 2013

TITLE

THE EFFECTS OF CLIMATE CHANGE ADAPTATION STRATEGIES ON FOOD CROP PRODUCTION EFFICIENCY IN SOUTHWESTERN NIGERIA

**A THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL
ECONOMICS, UNIVERSITY OF NIGERIA, NSUKKA
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE AWARD OF DOCTOR OF PHILOSOPHY (Ph.D) DEGREE IN
AGRICULTURAL ECONOMICS**

BY

OTITOJU, MORADEYO ADEBANJO
(PG/Ph.D/09/50851)

SUPERVISORS: PROF. E.C. NWAGBO
DR. A.A. ENETE

NOVEMBER, 2013

CERTIFICATION

This is to certify that OTITOJU, Moradeyo Adebanjo a postgraduate student in the Department of Agricultural Economics with registration number PG/Ph.D/09/50851 has satisfactorily completed the requirements of research work for the degree of Doctor of Philosophy (Ph.D) in Agricultural Economics. The work embodied in this thesis, except where duly acknowledged, is original and has not been previously published or submitted in part or full for any other diploma or degree of this or any other University.

			21/11/13
----------------------------------	-----------------	-----------------------------	-------------
PROF. E. C. NWAGBO **Supervisor**	**Date**	**DR. A. A. ENETE** **Supervisor**	**Date**
----------------------------------	-----------------	-----------------------------	-------------
PROF. E. C. OKORJI **Head of Department**	**Date**	**PROF. J. MBANASOR** **External Examiner**	**Date**

DEDICATION

This work is dedicated to

The LORD Almighty who guarded and guided me during this programme.

And also my parent His Royal Majesty Oba Valentine Adebayo Otitoju JP M.Ed (Nig)

and Olori Alice Oluranti Otitoju

ACKNOWLEDGEMENT

I wish to express my gratitude and appreciation to God for guiding me through this study. Special gratitude goes to my supervisors Prof. E. C. Nwagbo and Dr. A. A. Enete for their patience, encouragement, guidance and fatherly role they played in the course of this study. I appreciate Profs. C. J. Arene, S. A. N. D. Chidebelu, N. J. Nweze, E. O. Arua, C. U. Okoye and E.C. Okorji (Head of Department); Dr. A. I. Achike, Dr. F. U. Agbo, Mr. Uche Okpara and other academic staff of the Department of Agricultural Economics, University of Nigeria, Nsukka for their contributions, constructive criticisms and suggestions, which helped to sharpen the focus of this study.

I specially render my appreciation to Prof. S.O. Olaitan who has been a constant source of inspiration, also for his fatherly role and moral support.

I further wish to express my sincere thanks to the following people: Messrs Olawale Olaitan, Taofeeq Amusa, Jimmy Bakare, Sunday Ogunleye, Prince Adewole Otitoju, Olaniyi Oluwole, Olumide Oni, Ebenezer Abejide; Hon. & Mrs. Mathias Omole, Engrs. Akinniyi Ekundayo and Adeniyi Samuel Dada, Mr. Oluayodele & Princess Ikeade Benjamin, Mr. & Mrs. Adesoji Kolawole, Mr. Adeola & Mrs. Folasade Alebiosu, Dr. Olawale & Mrs. Grace Otitoju, Dr. Oluwole Akinnagbe, Dr. (Mrs) Grace M. Adebo of EKSU, Ado-Ekiti, Taiwo Oni and my Sisters- Jummy Ogundana, Olabisi Ogunleye, Bisola Olanipekun & Toluse Olayode for their moral support and encouragement. Also to my friends and colleagues Chioma Chukwu, Olubunmi Ojo, Georgina Asogwa, Miebi Gbigbi and a host of others. I sincerely thank the staff of Management Information System (MIS) Unit of this University for their patience and tolerance during the period of the last stage of data analysis and the write up. I also appreciate Rt. Hon. Olatunji Odeyemi, former Speaker of EKHA for his financial support.

Moreover, I expressly thank Mr. Isreal Ajibade Adedeji of the Department of Agricultural Economics & Extension, Landmark University, Omu-Aran, Kwara State, for his support and assistance in the data analysis of this study. In addition, to my research assistants- Sunday Ikusika, Alo, Akinyede, Bobade and other extension agents of Ekiti and Ondo States Agricultural Development Programme; Mr. Akinyemi and Mr. 'Gboyega Adeojo of Ekiti State Fadama Develoment Project for their assistance.

Specifically, I want to thank the Director General, Prof. Bamidele Ogbe Solomon, and the management of National Biotechnology Development Agency (NABDA), Abuja for the study leave granted me to complete this study.

I say thanks to every other person who contributed to the successful completion of this thesis. The LORD Almighty Father rewards you all immensely.

Adebanjo Moradeyo OTITOJU

TABLE OF CONTENTS

CHAPTER ONE

1.0 INTRODUCTION

CHAPTER TWO

2.0 LITERATURE REVIEW

CHAPTER THREE

3.0 METHODOLOGY

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This study examined the effects of climate change adaptation strategies on food crop production efficiency in Southwestern Nigeria. The study used multistage sampling technique and primary data were collected from 360 food crop farmers (i.e. 180 respondents were randomly selected from each selected state from the savanna and the rainforest agro-ecological zones that dominates the region). The analytical techniques involved descriptive and inferential statistics. Results of the multinomial logit analysis showed that household size negatively influenced the use of multiple crop varieties, land fragmentation (i.e. multiple farm plots), multiple planting dates and crop diversification. Age of household head had an inverse relationship with the choice and use of multiple crop varieties, land fragmentation (multiple farm plots), multiple planting dates and off-farm employment. Education had a negative effect on the choice and use of multiple crop varieties and multiple planting dates. Sex had positive influence on the choice and use of multiple crop varieties, multiple planting dates and off-farm employment but average distance had a positive relationship with the choice and use of land fragmentation. Tenure security positively influenced the choice and use of crop diversification but access to credit negatively correlated with multiple crop varieties, multiple planting dates and crop diversification. The stochastic frontier analysis showed that labour, farm size and other agrochemicals are highly significant at 1% level of probability in food crop production. The computed mean technical efficiency estimate was 0.84. The technical inefficiency model showed that land fragmentation (i.e. multiple farm plots) and multiple planting dates had significant positive relationship with technical inefficiency but years of climate change awareness and social capital had significant inverse relationship with it. The stochastic frontier profit function showed that rent on farm land and price of labour were highly significant at 1% level of probability. The computed average profit efficiency of the respondents was 0.67. The profit inefficiency model revealed that off-farm employment, multiple planting dates, crop diversification and education level had significant positive relationship with profit inefficiency but land fragmentation (i.e. multiple farm plots), years of climate change awareness and social capital had negative relationship with it. The factor analysis revealed that the major constraints to climate change adaptation among the food crop farmers were public, institutional and labour constraints; land, neighbourhood norms and religious beliefs constraints; high cost of inputs, technological and information constraints; farm distance, access to climate information, off-farm-job and credit constraints; and poor agricultural programmes and service delivery constraints. The study, therefore, recommends, inter alia, proactive regulatory land use systems that will make food crop farmers to participate in a more secured land ownership system should be put in place to enhance their investment in climate change adaptation strategies that has a long-term effect. Morealso, Government and non-governmental organizations should help the farmers in the area of provision and/ or facilitate the provision of input-based adaptation strategies in the study area. Again, intensive use of already proven adaptation strategies at farm-level by the farmers at their present resource technology will still make them to reduce technical and profit inefficiencies by 16% and 33% respectively, in the study area.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

The process of producing food requires resources, which could be natural or man-made resources. Natural resources include all the materials and forces that are supplied by nature. Those that are most essential for food crop production are land, water, sunshine, air, temperature and soil conditions. Man-made resources (include labour, capital or entrepreneurship) are supplied and influenced by man (Olayide & Heady, 1982; Oyekale, Bolaji & Olowa, 2009). Among the natural resources, climate is the predominant factor that influences food crop production. Climate as defined by Oyekale *et al.* (2009) is the state of atmosphere, which is created by weather events over a period of time. A slight change in the climate will affect agriculture.

According to Intergovernmental Panel on Climate Change (IPCC) report, the United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global and/or regional atmosphere and which is in addition to natural climate variability observed over comparable time periods (IPCC, 2001). It is obvious from this definition that change is an inherent attribute of climate, which is caused by both human activities (anthropogenic) and natural processes (biogeographical) (Odjugo, 2007, 2009). Climate change is already affecting people, their livelihoods and ecosystems and presents a great development challenge for the global community in general and for the poor people in developing countries in particular (Khanal, 2009). This also presents major challenges to scientists and policy makers.

Literature have shown that for the past decades, anthropogenic factors like urbanization, deforestation, population explosion, industrialization and the release of green house gases (GHGs) are the major contributing factors to the depletion of the ozone layer and its associated global warming and climate change (Buba, 2004; Nigerian Environmental Study/ Action Team [NEST], 2003; Odjugo, 2007). For example, unsustainable industrialization, which releases green house gases (GHGs), is viewed as the main cause (Odjugo, 2009). The level of greenhouse gases (GHGs) mainly Carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) have been rapidly increasing after industrial revolution. The increased level of GHGs has created a greenhouse effect which subsequently altered precipitation patterns and global temperatures around the world. Impacts have been witnessed in several areas due to change in precipitation and temperature. The areas affected include agriculture, forestry, water resources, biodiversity, desertification, human health, and ecosystems goods and services globally (Khanal, 2009; Rosegrant *et al.*,2008).

Between 1960 and 1998 a decline in mean annual precipitation of between 20% and 40% has been noted in West Africa compared to a 2% to 4% decline in tropical rain forest regions (IPCC, 2007). It is also important to note that rural people and agricultural production in Africa rely on rainfall for water supply with as little as less than 4% of cultivated land under irrigation (Inter Academy Council [IAC], 2004; World Bank, 2008). The predominance of rain-fed agriculture, the scarcity of capital for adaptation measures, their warmer baseline climates and their heightened exposure to extreme events (Nnamchi & Ozor, 2009) reportedly in Africa agriculture to be more vulnerable to climate change. Food crop is particularly sensitive to climate change because crop yields depend largely on prevailing climate conditions (temperature and rainfall patterns) (Palatnik & Roson, 2009), Southwestern Nigeria is not exempted. The principal food crops grown in Southwestern Nigeria are cassava, yams, maize, and cocoyams, which are also sensitive to climate variability and climate change. Subsistence crop production in Southwestern Nigeria is traditional and rain-fed, with very limited areas under irrigation. Small-scale traditional irrigation has been practiced for decades in the area, where small streams are diverted seasonally for limited dry season cropping. Medium and large-scale schemes are very few.

Clear impacts from climate change are being witnessed in agriculture. Impacts are both positive as well as negative. They are dependent on latitude, altitude and type of crop. There have been noticeable impacts on plant production, insect, disease and weed dynamics, soil properties and microbial compositions in farming systems (Khanal, 2009; Rosegrant *et al.*, 2008). Intergovernmental Panel on Climate Change (IPCC) in her synthesis Report on climate change explained how hard it is to find evidence of negative consequences of climate on the world agricultural productivity in aggregate agricultural statistics. One reason is the positive gains from global warming observed in the temperate regions due to reduced risk of frost and longer growing season. The other important reason is that the world agriculture in general but particularly temperate regions had witnessed noticeable increases in productivity of most crops as a result of major technological advances (breeding and improved fertility and pest and diseases management) (IPCC, 2007).

Although there is some evidence that agriculture in temperate regions of the world has benefitted in some ways from global warming the same report states with high confidence that “agricultural production and food security, including access to food, in many African countries and regions are likely to be severely affected by climate change and climate vulnerability”. This is because African economies and the livelihoods of its population are highly dependent on agriculture which is mainly practiced in already harsh climatic condition (e.g. high temperature, marginal environment, and considerable water stress) (IPCC, 2007a). About 60% of the Nigeria population is employed in agricultural sector (National Bureau of Statistics [NBS], 2011).

Nigerian agriculture is already under significant pressure to meet the demand of rising population using finite, often degraded soil and water resources, which are now further stressed by the impact of climate change (Awotoye & Mathew, 2010). As a result, it is of interest to stakeholders in the agricultural sector to understand the kind of impact climate change will have on food and crop production. There will undoubtedly be shifts in agro-ecological conditions that will warrant changes in processes and practices in order to meet daily food requirements. In addition, climate change could become a significant constraint on economic development in developing countries that rely on agriculture for a substantial share of gross domestic production and employment (Rosegrant *et al.,* 2008).

The agro-ecological zones across the Southwestern Nigeria are guinea savanna, derived savanna, freshwater swamp forest, lowland rainforest, and mangrove forest and coastal land (Fasola, 2007). Some changes in agricultural practices might also be taking place across the agro-ecologies of the zone, in order to ensure food security in southwestern Nigeria, a region that feeds about 45 per cent of the nation's population (Awotoye & Mathew, 2010). Climate change is another challenge to the initial inability of food production to meet up with the demand which is already identified in Nigeria.

Impacts of climate change on the socio-economic sector are projected to include; decline in yield and production, reduced marginal GDP from agriculture, fluctuation in world market price, change in geographical distribution of trade regimes, increased number of people at risk of hunger and food security and migration and civil unrest (Khanal,2009). Increase in temperature, at the same time, might affect both the physical and chemical properties in the soil. Increased temperature may accelerate the rate of releasing CO_2 resulting in less than optimal conditions for plant growth. When temperatures exceed the optimal level for biological processes, crop often respond negatively with a steep drop in net growth and yield. Heat stress might affect the whole physiological development, maturation and finally yield of cultivated crops (Khanal, 2009; Rosegrant *et al*., 2008). Steps must be taken to reduce the negative effects of climate change on Nigeria agriculture, especially food crop production in Southwestern Nigeria.

There are two central ideas for dealing with climate change, namely, mitigation and adaptation. Mitigation is a response strategy to global climate change, and can be explained as measures that reduce the amount of emissions (abatement) or enhance the absorption capacity of greenhouse gases (sequestration). Adaptation to climate change is an adjustment made to human, ecological or physical system in response to vulnerability (Adger *et al*., 2007). Climate change adaptation through the modification or improvement of agricultural practices will be imperative to continue meeting the growing food demands of modern society (Rosegrant *et al*., 2008).

The climate is changing and mitigation efforts to reduce sources or enhance the sinks of greenhouse gases will take time. Adaptation is therefore critical and of concern in developing countries, particularly Africa (including Nigeria) where vulnerability is high because the ability to adapt is low. Climate change is expected to affect food and water resources critical to livelihood in Africa and much of the population, especially the poor, rely on local supply systems that are sensitive to climate variations. Disruptions of the existing food and water systems will have devastating implications for development and livelihoods and are expected to add to the challenge already posed by climate change for poverty eradication (De Wit & Stankiewcz, 2006; International Institute of Sustainable Development [IISD], 2007). Adaptation helps farmers achieve their food, income and livelihood security objectives in the face of changing climatic and socioeconomic conditions, including volatile short-term changes in local and large-scale markets (Kandlinkar & Risbey, 2000). Farmers especially food crop farmers can reduce the potential damage by making tactical responses to these changes. Jagtap (1995) identified crop diversification, mixed cropping, using different crop varieties, changing planting and harvesting dates, drought resistant varieties, while Enete *et al*. (2011) also identified multiple/intercropping, agro-forestry/afforestation, mulching, purchase/harvest of water for irrigation, among others as some of the climate change adaptation strategies in Southeastern Nigeria. Analyzing adaptation strategies is therefore important for finding ways to help food crop farmers adapt in the rural economies of Africa including Nigeria in general and Southwestern Nigeria in particular. There is also evidence of changes in agronomic and management practices in order to cope with climate change and variability across the agro-ecologies in the southwestern Nigeria (Adebayo *et a*l., 2011).

Constant evolution of crop patterns, farm management practices and land use occur across the globe, partly in response to climatic variation. Such farm-level adaptations aim at increasing the productivity, improving efficiency and dealing with existing climatic conditions, and draw farmers' current knowledge and experience (Commission of the European Communities [CEC], 2009). Although African farmers have a low capacity to adapt to changes, they have, however, survived and coped in various ways over time. Better understanding of how they have done this is essential for designing incentives to enhance private adaptation. Supporting the coping strategies of local farmers through appropriate public policy and investment and collective actions can help increase the adoption of adaptation measures that will reduce the negative consequences of predicted changes in future climate, with great benefits to vulnerable rural communities in Africa (Hassan & Nhemachena, 2008), especially food crop farmers in Southwestern Nigeria. Deressa (2008) posited that farmers adapt to climate change to maximize profit by changing crop mix, planting and harvesting dates, and a host of agronomic practices. The coping strategies adopted by food crop farmers, which are mainly initiated at the farm and village-level in the southwestern Nigeria, are expected to enhance their farm productivities, efficiency and improve their profit as a producing unit.

The ability of farms to employ the “best practice” in the production process so that not more than the necessary amount of a given set of inputs is used in producing the “best” level of output is referred to as technical efficiency (Timmer, 1980). But profit efficiency as defined by Abdulai and Huffman (2000) is the ability of a firm to achieve potential maximum profit, given the level of fixed factors and prices faced by the firm. This study will then want to know how climate change adaptation strategies influence technical and profit inefficiencies of farmers in food crop production in Southwestern Nigeria when linked with related socio-economic variables. The study will go further to simulate some of these variables at various percentages to know their effects on technical and profit inefficiencies in food crop production and see how these can help in policy formulation on climate change adaptation strategies *vis-à-vis* food crop production efficiency in Nigeria in general and the southwestern part of the country in particular.

1.2 Statement of the Problem

Food production in Nigeria has not kept pace with its population growth, because the population is growing at about 3.2 per cent per annum while food production is at about 2.0 per cent (NBS, 2011). In a bid to address the differentials in the food production and population growth rates, successive governments in Nigeria have come up with policies and programmes. Among them are; National Fadama Development Programme, Root and Tuber Expansion Programme (RTEP), and National Programme for Food Security (NPFS). These policies and programmes were aimed at raising the productivity and the efficiency of agricultural sector. Farmers face challenges of tragic crop failures, reduced agricultural productivity, increased hunger, malnutrition and diseases (Zoellick, 2009).The declining agricultural productivity in

Nigeria is worrisome and a real challenge for Government with a population of approximately 150 million people to feed.

Climate change affects agriculture in several ways, one of which is its direct impact on food production. It brings additional perspective to the national challenge of increasing agricultural production to keep pace with the rising population while keeping high standards of environmental protection. Negative effects on agricultural yields will be exacerbated by more frequent extreme weather events (CEC, 2009).

Adaptation reduces the negative impact of climate change (Adger *et al.*, 2003; Kurukulasuriya & Mendelson, 2006a). Adaptation of agronomic techniques and farm strategies is already happening (CEC, 2009). The modification of agricultural practices and production in order to cope with climate change will be imperative in order to meet and continue meeting the growing food demands of Nigerians. Evidence shows that farming systems and farming technologies within the region have been changing in response to the effects of climate change (Adebayo et al., 2011). In their study conducted in Southwest Nigeria, Adebayo *et al.* (2011) showed that the farmers agreed that the main climate change effect is on reduction of their personal productivity. Adapting to climate change and climate variability at the farm-level by the farmers especially through the modification of agricultural practices and farming systems has been recognized as the main coping strategies. It is believed that these strategies are supposed to help the farmers improve their personal productivity and efficiency in food crop production and also raise their returns to farming as a business.

Previous studies (Ajibefun, 2006; Ajibefun, Batesse & Daramola, 2002; Ajibefun, Daramola & Falusi, 2006; Ogundari, 2006; Otitoju, 2008; Otitoju & Arene, 2010) conducted on efficiency (technical and profit) of farmers only used socioeconomic, farmers’ and farm-specific characteristics to determine the efficiency level of their production. Some other climate-related studies, also in Africa, have analyzed factors affecting the perception and adaptations to climate change (Deressa, 2007; Hassan, 2008; Kurukulasuriya & Mendelsohn, 2006b; Nzeadibe, Egbule, Chukwuone & Agu, 2011), few available climate-related studies (Enete *et al.*, 2011; Nzeh & Eboh, 2011; Onyeneke & Madukwe, 2010) examined adaptation in other parts of Nigeria, only the studies of Adebayo *et al.* (2011) examined climate change in southwestern Nigeria; Oyekale *et al.* (2009) also examined the effects of climate change on cocoa production in Ondo state, Nigeria. Awotoye and Matthew (2010) also examined effects of temporal changes in climate variables on crop production in tropical sub-humid southwestern, Nigeria. However, none of these studies looked at the influence of climate change adaptation strategies on food crop production efficiency in the southwestern Nigeria. There is paucity of information on the influence of climate change adaptation strategies on efficiency of food crop farmers in Nigeria especially in the Southwest region of the country. Hence, this study attempts to look at the effects of climate change adaptation strategies on food crop production efficiency (technical and profit) in the southwestern Nigeria to fill these existing knowledge gaps.

1.3 Objectives of the Study

The broad objective of this study is to examine the influence of climate change adaptation strategies on efficiency in food crop production in Southwestern Nigeria. The specific objectives are to:

(i). describe the socio-economic characteristics of farmers and farming systems in food crop production in the study area;

(ii). identify climate change adaptation strategies used by food crop farmers in the study area;

(iii). identify factors that influence the choice of climate change adaptation strategies used by food crop farmers;

(iv). estimate technical and profit efficiencies in food crop production in the study area;

(v). determine the influence of climate change adaptation strategies used by the farmers on food crop production efficiency in the study area;

(vi). assess the variations in levels of technical efficiency in food crop production as a result of simulated changes in selected climate change adaptation strategies that could be influenced by policy;

(vii). identify constraints to climate change adaptation by the respondents in the study area;

(viii). make recommendations for improving food crop production efficiency *vis-à-vis* the climate change.

1.4 Hypotheses of the study

The following null hypotheses were tested:

(i). socioeconomic factors do not influence use of climate change adaptation strategies by food crop farmers;

(ii). institutional and farm-specific variables do not influence use of climate change adaptation strategies by food crop farmers;

(iii). climate change adaptation strategies do not influence technical efficiency in food crop production in the study area; and

(iv). climate change adaptation strategies do not influence profit efficiency of food crop farmers in the study area.

1.5 Justification of the Study

The present inability of food crop production sector to meet the foods demand of Nigerians and the challenge posed by climate change and variability emphasized the need for the improvement of food crop farmers.

Failure to know the present food crop production efficiency (technical and profit) and the influence of climate change coping strategies on efficiency level of food crop production will inhibit designing and formulating appropriate policies to meet food crop production demands of the country. Developing economies can benefit much from inefficiency studies especially a type like this that incorporates farmers' adaptation strategies to climate change to explain efficiencies.

The results of this study are expected to give direction for policy makers in designing appropriate public policies to increase agricultural productivity and mitigating effects of climate change on food crop production in Nigeria especially in the Southwestern zone. It will provide a useful guide to international and local donor agencies interested in climate change mitigation and adaptation in their provision of grants and funds for environmental and resource management studies. The results of this study will also help agricultural planners in the Agricultural Development Programmes (ADPs) and Ministries of Agriculture, Science and Technology; and Environment in the southwestern region and Nigeria as a whole and those states in the zone with Agro-climatological and Ecological zone study Units in their planning activities and providing useful weather data that will guide in planning public (or planned) adaptations to complement the farm-level (or autonomous) adaptation strategies.

Researchers are going to have a good resource base to look at climate change for further work. Farmers are also going to benefit by knowing those adaptation strategies to climate change that are more productive and efficiency-enhancing.

1.6 Limitations of the Study

The major limitation was on data collection. The enumerators elicited information from the respondents using interview schedule as against the supposed structured questionnaire. The respondents were interviewed all through because of the importance of the information the questionnaire to elicit. It was not self-administered as it is supposed of questionnaire but rather enumerator and researcher-administered (Eboh, 1998). This made the collection of data to take more time than necessary but the data were free of error due to omission of relevant information needed for the study.

Another limitation was the issue of finance for the data collection. This was overcome as the researcher sought for money to address this issue in order to still meet up with the set time for the data collection.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Concept of Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) (as cited in Onyeneke & Madukwe, 2010) defines climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global and/or regional atmosphere and which is in addition to natural climate variability observed over comparable time periods.

IPCC (2007) defines climate change as a change in the state of the climate that can be identified (e.g. by using statistical tests) by change in the mean and/or the variability of its properties, and that persists for an extended period typically decades or longer.

Although the Earth's climate is constantly changing and global climate change occurs naturally, the rate of future climate change may be more rapid than at any time in the last 10,000 years. The majority of the world's scientists who study this topic conclude that this expected climate change would differ from previous climate change because of human activities. Therefore, climate change is the slow change in the composition of the global atmosphere, which is caused directly and indirectly by various human activities in addition to natural climate variability over time (Koehler-Munro & Goddard, 2010).

Koehler-Munro and Goddard (2010) further observed that the atmosphere has an effect like a greenhouse on the earth's atmosphere. The energy from the sun reaching the earth is balanced by the energy that the earth emits back to space. Greenhouse gases (GHGs) trap some of this energy that the earth releases to space. These GHGs in the atmosphere act as a thermostat controlling the earth's climate. Without this natural greenhouse effect, the average temperature on earth would be –18°C instead of the current +15°C. Therefore, life as we know it would be impossible.

The major GHGs in our atmosphere are water vapour, carbon dioxide (CO_2), methane (CH_4), halocarbons, which are used as refrigerants, and nitrous oxide (N_2O). Since 1750, the atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased by approximately 31%, 151%, and 17%, respectively. Modern industry and lifestyles have led to elevated levels on existing GHGs such as carbon dioxide, methane and nitrous oxide and in some cases, completely new GHGs such as halocarbons. Current rates of increase per year are 0.5% for carbon dioxide, 0.6% for methane and 0.3% for nitrous oxide. The scientific evidence for this is very solid. In a 2001 scientific assessment, the Intergovernmental Panel on Climate Change (IPCC) concluded, "the balance of evidence suggests a discernible human influence on climate change." (Koehler-Munro & Goddard, 2010). IPCC (2007) reported that 90-95% of climate change is likely to have been in part caused by human action.

Human activities increase the GHG levels in the atmosphere by introducing new sources or removing natural sinks, such as forests. Sources are processes or activities that release greenhouse gases; sinks are processes, activities or mechanisms that remove greenhouse gases. A balance between sources and sinks determines the levels of greenhouse gases in the atmosphere (Koehler-Munro & Goddard, 2010).

2.2 Concept of Adaptation

Adaptation to climate change is an adjustment made to human, ecological, physical or socio-economic systems, in response to perceived vulnerability or expected and actual climatic stimuli, their effects or impacts.(Adger *et al.*, 2007; IPCC, 2001; Smit, Burton, Klein, & Wandel, 2000).

Nhemachena and Hassan (2007) explained adaptation to climate change as changes in agricultural management practices in response to changes in climate conditions.

Various types of adaptation can be distinguished, including (i). anticipatory and reactive adaptation, (ii). private and public adaptation, and (iii). autonomous and planned adaptation.

Adaptation is an important component of climate change impact and vulnerability assessment. Adaptation responses can be categorized by the level of ownership of the adaptation measure or strategy.

(i). Individual or autonomous adaptations are considered to be those that take place in reaction to climatic stimuli (after manifestation of initial impact), that is, as a matter of course without the intervention of any public agency (Smit *et. al*, 2001).Autonomous adaptations are widely interpreted to be initiatives by private actors rather than by governments, usually triggered by market or welfare changes induced by actual or anticipated climate change.

(iii). Policy-driven or planned adaptation is often interpreted as being the result of a deliberate policy decision on the part of a public agency, based on an awareness that conditions are about to change or have changed, and that action is required to minimize losses or benefit from opportunities (Pittock & Jones, 2000).

Thus autonomous and policy-driven adaptation largely correspond to private and public adaptation, respectively (Smit *et al.*, 2001). As implied, autonomous adaptation responses will be evaluated by individual farmers in terms of costs and benefits. It is anticipated that farmers will adapt ‘efficiently’, and that markets alone can encourage efficient adaptation in traded agricultural goods (Mendelson, 2000). Yet, in situations where market imperfections exist, such as the absence of information on climate change or land tenure insecurity, climate change will further reduce the capacity of individual farmers to manage risk effectively. As a result, an appropriate balance between public sector efforts and incentives, such as capacity building, creation of risk insurance and private investment, needs to be struck so that the burden can shift away from poor producers (Rosegrant, *et al.*, 2008).

2.2.1 Characteristics of Adaptations

There is a huge number and variety of measures or actions that could be undertaken in agriculture to adapt to climate change (Brklacich, McNabb, Bryant & Dumanski, 1997; Kelly & Granich, 1995; Reilly, 1995; Reilly & Schimmelpfening, 1999; Smit,1993). There also exist numerous characteristics by which adaptations can be distinguished, and which could serve as bases for a typology of agricultural adaptations (Burton *et al.*, 1993; Smithers & Smit, 1997; Stakhiv, 1993). Among the distinguishing characteristics of adaptation are intent and purposefulness; timing and duration; scale and responsibility; and form.

Intent and Purposefulness

Intent and purposefulness differentiate between adaptations that are undertaken spontaneously, or as regular part of on-going management from those that are consciously and specifically planned in light of a climate-related risks (Bryant *et al.*, 2000; Smit *et al.*, 2000). Within socio-economic systems are usually consciously planned strategies, such as investments in governments programmes, but private sector and individual adaptations can be autonomous, planned or a combination of the two (Bryant *et al.*,2000). For example, the decisions of a producer who, over many years, gradually phases out one crop variety in favourof another that seems to do better in the climatic conditions, might be considered spontaneous and autonomous, but they are consciously undertaken (Smit & Skinner, 2002).

Timing and Duration

According to Smit and Skinner (2002), timing of adaptation differentiates responses that are anticipatory (proactive), concurrent (during), or responsive (reactive). While logical in principle, this distinction is less clear-cut in practice. For example, a producer who has experienced several droughts over recent years, and expects drought frequency to remain similar or increase in the future, may adjust certain production practices or financial arrangements to manage drought risks. The timing distinction is not helpful here, as this is both a reactive and proactive adaptation.

Duration of adaptation distinguishes responses according to the time frame over which they apply, such as tactical (short-term) versus strategic (longer-term) (Smit *et al.,* 1996; Stakhiv, 1993). In agriculture, tactical adaptations might include adjustments made within a season that involve dealing with a climatic condition, such as drought, in the short-term. Tactical adaptations might include selling of livestock, purchasing feed, plowing down a crop or taking out a bank loan. Strategic adaptations refer to structural changes in the farm operation or changes in enterprises or management that would apply for a subsequent season, or a longer term. Thus, strategic adaptations might include changes in land use, enterprises mix, crop type or use of insurance (Smit & Skinner, 2002).

Scale and Responsibility

Adaptations can be distinguished according to the scale at which they occur and the agent responsible for their development and employment. In agriculture, adaptations occur at a variety of spatial scales, including plant, plot, field, farm, region and nation (Smithers & Smit, 1997). At the same time, responsibility can be differentiated among the various actors that undertake or facilitate adaptations in agriculture including individual producers (farmers), agri-business (private industries), and governments (public agencies) (Smit *et al.,* 2000).

Form

Adaptation in agriculture occurs via a variety of processes and can take many different forms at any given scale or with respect to any stakeholder. Smithers and Smit (1997) considered adaptations according to their administrative, financial, institutional, legal, managerial, organizational, political, practical, structural, and technological characteristics. In their own classification Bryant *et al.* 2000) identified forms of adaptation at the farm-level, including modification of resource management, purchasing crop insurance and diversification.

2.3 Climate trend in Nigeria

The temperature trend in Nigeria since 1901 shows increasing pattern (Fig 2.1). The increase was gradual until the late 1960s and this gave way to a sharp rise in air temperatures from the early 1970s, which continued till date (Fig 2.1). The mean air temperature in Nigeria between 1901 and 2005 was 26.6^{o}C while the temperature increase for the 105 years was 1.1^{o}C.This is obviously higher than the global mean temperature increase of 0.74^{o}C recorded since 1860 when actual scientific temperature measurement started (Spore 2008; IPCC 2007). Should this trend continue unabated, Nigeria may experience between the middle (2.5^{o}C) and high (4.5^{o}C) risk temperature increase by the year 2100.

Rainfall trend in Nigeria between 1901 and 2005 shows a general decline (Fig 2.2). Within the 105 years, rainfall amount in Nigeria dropped by 81mm. The declining rainfall became worst from the early 1970s, and the pattern has continued till date. This period of drastic rainfall decline corresponds with the period of sharp temperature rise (Fig 2.2). Although there is a general decrease in rainfall in Nigeria, the coastal areas of Nigeria like Warri, Brass and Calabar are observed to be experiencing slightly increasing rainfall in recent times (Odjugo,2005, 2007).

This is a clear evidence of climate change because a notable impact of climate change is, increasing rainfall in most coastal areas and decreasing rains in the continental interiors (IPCC

1996; NEST 2003). Odjugo (2005, 2007) observed that the number of rain days dropped by 53% in the north-eastern Nigeria and 14% in the Niger-Delta Coastal areas. These studies also showed that while the areas experiencing double rainfall maximal is shifting southward, the short dry season (August Break) is being experienced more in July as against its normal occurrence in the month of August prior to the 1970s. These are major disruptions in climatic patterns of Nigeria showing evidences of a changing climate. The computed R^2=0.82 and R^2=0.18 in temperature (Fig 2.1) and rainfall (Fig 2.2) respectively shows that within the past 105 years the temperature increase (warming) in Nigeria is statistically significant while the rainfall decline is not. This is a pointer that Nigeria is going to be hardly hit by global warming in the nearest future while the declining and shifts in rainfall pattern are becoming a worrisome development (Odujgo, 2010).

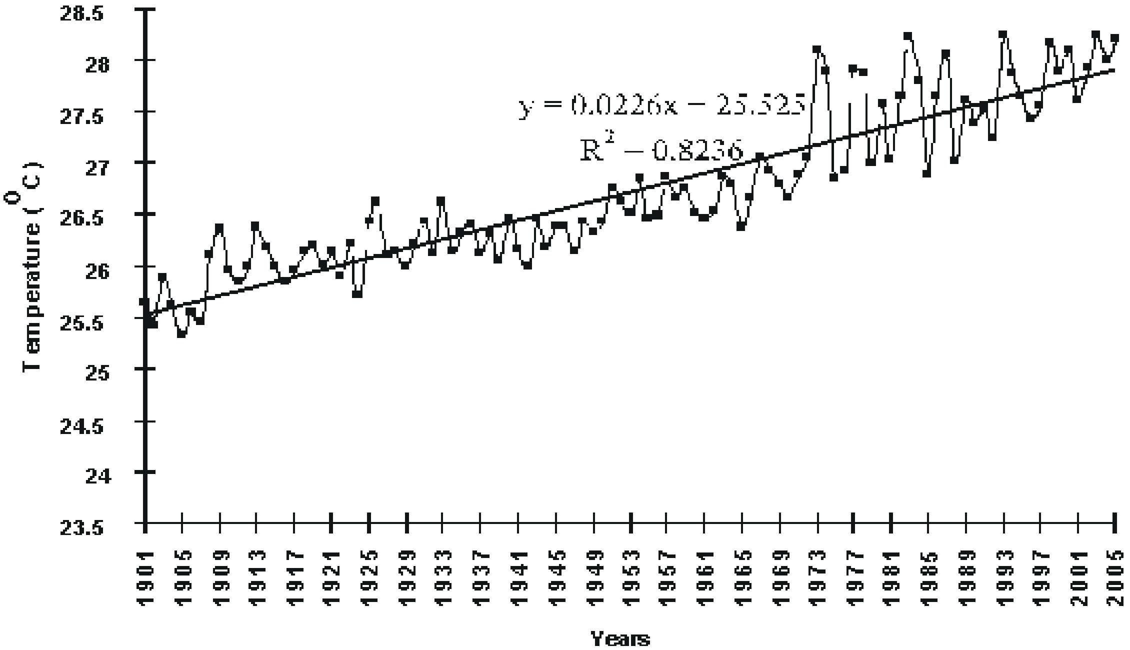

Fig. 2.1 Air temperature distribution in Nigeria between 1901 and 2005

Source: Odjugo, 2010.

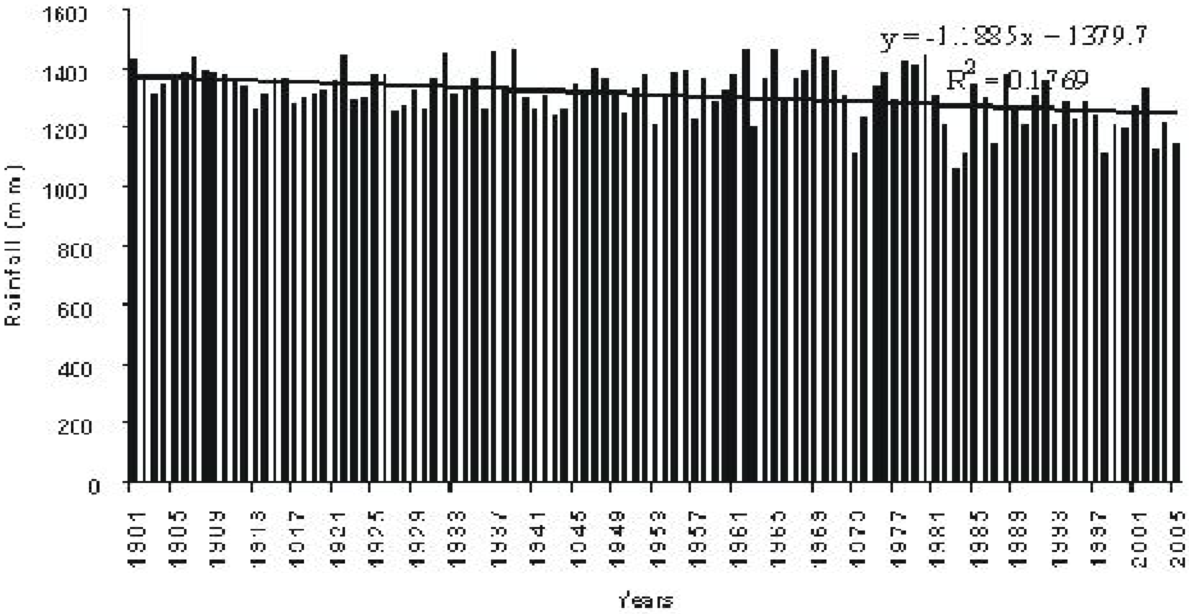

Fig. 2.2 Rainfall distribution in Nigeria between 1901 and 2005

Source: Odjugo, 2010

2.4 Conceptual framework

Climate change events are being adapted to with corresponding adaptation strategies that are being used or some agronomic practices already practiced are being intensified by the food crop farmers in order to cope with the change in climate as seeing in figure 2.3 and the expected results should be improved efficiency and productivity in food crop production.

The conceptual framework is on page 188

2.5 Impact of Climate change on Agricultural Production

Climatic change will have complex effects on the bio-physical processes that underpin agricultural systems, with both negative and positive consequences. Rising atmospheric CO_2 concentration, higher temperatures, changes in annual and seasonal precipitation patterns and in the frequency of extreme events will affect the volume, quality and stability of food production and the natural environment in which agriculture takes place. Climatic variations will have consequences for the availability of water resources, pests and diseases and soils, leading to significant changes in the conditions for agriculture and livestock production. In extreme cases, the degradation of agricultural ecosystems could mean desertification, resulting in a total loss of the productive capacity of the land in question. Although climate change is a global process, its local impacts are diverse. (CEC, 2009).

In the short term the frequency and intensity of extreme weather events and seasonal variations in precipitation patterns are the factors likely to have the most serious consequences for agriculture (CEC, 2009), especially for crop production. Food crop production is largely driven by favourable weather conditions. And this agricultural-subsector is the dominant subsector. Some areas will have simultaneous negative and positive effects with unknown net results, as the crop responses to climatic variations are still not well understood (CEC, 2009).

According to IPCC (2007a), a temperature change in tropical areas has in general had a negative impact on food production. Crop productivity is projected to increase slightly at mid to high latitudes for local mean temperature increases of up to 1-3% depending on the crop, and then decrease beyond that in some regions. At lower latitude, especially seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increase (1-2^{o}C), which would increase risk of hunger. Globally, the potential for food production is projected to increase in local average temperature over a range of 1-3^{o}C, but above this it is projected to decrease. Increases in the frequency of droughts and floods are projected to affect local crop production negatively, especially in subsistence sectors at low latitudes. Taken together and considering the influence of rapid population growth and urbanization, the risk of hunger is projected to remain very high in several developing countries (Khanal, 2009).

Some aspects of climate change such as warmer temperatures, enhanced photosynthesis due to more CO_2 in the air and longer growing seasons can have moderately positive effects on the productivity of arable crops in some areas, at least until mid-century. In Northern regions, yields may increase and the range of possible crops may become wider, but these benefits will only emerge from a low level of temperature, and are highly uncertain. Further warming will be increasingly detrimental because plant growth and yields are conditioned by temperature thresholds linked to the key reproductive stages. The acceleration of the vegetative cycle can have negative effects on grain filling and quality. A range of adverse impacts can be expected from the increased inter-annual and seasonal variability of rainfall. Extreme weather conditions, such as heat waves and droughts may severely disrupt production, in particular during critical phases of crop growth (CEC, 2009). In mid-to high latitudes, increases in temperature produce increases in yields, but with diminishing effect when temperature changes are greater than 3^{o}C. Yet stronger yield-depressing effects are found in tropical and sub-tropical regions for all crops, which reflect a lower growing temperature threshold capacity in these areas (Rosegrant *et al.*, 2008).

Cline (2007) additionally demonstrated the effect of carbon fertilization on agricultural productivity - measured in net revenue changes – for disaggregated global regions. Overall, agricultural productivity in developing countries is expected to decline by between 9 to 21 percent due to global warming. Meanwhile, agricultural productivity in industrialized countries is foreseen declining by up to 6 percent or increasing by up to 8 percent, depending on carbon fertilization.

The production of vegetables is highly sensitive to water availability and to even minor stress related to temperature outside the optimal range, making this type of production highly vulnerable to climatic changes. For perennial crops extreme events represent a serious risk as they can affect production capacity over several years. Perennial cultivations are also affected by the move forward in time of the phonological phases, while having fewer possibilities than arable crops to adapt by changing the calendar of farming operations. Many fruit trees are susceptible to spring frosts during the flowering period and winter temperature plays a significant role in productivity. As warmer temperature will advance both the date of the last spring frosts and the date of flowering, the risk of damage is likely to remain largely unchanged. Difficulties related to pests and diseases are expected to increase. Impacts on the wine sector include a higher risk of frosts, a shortening of the ripening period, water stress, which can be highly damaging at the maturity stage, and changes in pest and disease patterns. (CEC, 2009).

Kassahun (2009) examined the impacts of climate change on crop agriculture in Nile Basin of Ethiopia using the Ricardian model. Annual crop net revenue was regressed on climate and other variables. The results indicated that an annual increase of 1^{o}C in temperature would have a positive impact on annual crop net revenue for irrigated farms, but a negative impact for dry land farms and farms that represent Nile basin of Ethiopia. However, marginal impact of increasing precipitation would increase crop net revenue for both irrigated and dry land farms. The results suggested that farmers are aware of climate change. In addition, the study examined the impact of uniform climate scenarios on the crop net revenue per hectare of farmers. These are increasing temperature by 2.5^{o} C and 5^{o} C; and decreasing precipitation by 7% and 14%. Based on the results of these simulations, the study predicted that crop net revenues would fall for all farms under the four uniform climate scenarios except irrigated ones for a 2.5^{o}C increase in temperature. The study also found out that most farmers did not use any adaptation option (42%) for a number of reasons. The adaptation strategy most commonly used (about 21%) is planting trees. Other adaptation strategies farmers used are soil conservation (15%), using different crop varieties (13%), early and late planting (5%) and irrigation (4%). It was also indicated that there are five major constraints to adaptation perceived by farmers in Nile basin of Ethiopia. These are lack of information (43%), lack of access to credit (22%), shortage of labor (16%), shortage of land (11%), and poor potential for irrigations (8%).

In his study Benhin (2006) on the impacts of climate change on crop farming in South Africa using a cross-sectional Ricardian approach to measure relationship between net revenue from growing crops and climate. The study explored two specification of the Ricardian model. The first included only climate, soil and hydrology variables and is referred to as the ‘without adaptation’ model. The second included the relevant socioeconomic variables and is referred to as the ‘with adaptation’ model. This was to assess the extent to which these additional variables increase or decrease the effect of climate on crop sector. Climate impacts were also found to have, to a large extent, a non-linear relationship with net revenue. That is, increase in temperature and precipitation will be beneficial to crop farming but beyond a certain limit the impacts will be negative. In addition to irrigation and farm type, other socio-economic variables tested in the ‘with adaptation’ models included the area of cropland, a dummy for livestock ownership, access to electricity, access to public extension services and other sources of extension services, distance to crop market, farming experience and household size. The size of cropland area was found to be important, especially for dry land farmers, since a larger area enables them to spread their risk from adverse climate effects. Ownership of livestock was also found to be possible adaptation option; small-scale farmers and dry land farmers, especially the latter, are more likely to switch to livestock farming in response to adverse climate effects. Easy accessibility of markets means relatively higher prices for products and therefore helps to cover additional costs caused by the adverse effects of climate.

Kurukulasuriya and Mendelsohn (2006a) examined the impact of climate change on cropland in Africa. The study used a Ricardian cross-sectional approach to measure the relationship between the net revenue from growing crops and climate. They found out that net revenue fall as precipitation falls or as temperatures warm across all the surveyed farms. Specially, the elasticity which involves that a 10% increases in temperature would lead to a 13% decline in net revenue. The elasticity of net revenue with respect to precipitation is 0.4. From the simple climate scenarios, a 2.5^{o}C warming would reduce the net revenue from farming in all Africa by $23 billion. It is also examined at 7^{o}C decrease in precipitation would cause it to fall $9 billion. Increase in precipitation would have the opposite effect on net revenue.

The study of Sene, Diop and Dieng (2006) on impacts of climate change on revenue and adaptation of farmers in Senegal used the Ricardian method to measure how climate affects net revenue. It was suggested that small farmers in Senegal have low net revenue and that small rain-fed farms were highly vulnerable to climate change. The model showed that net revenue depends on crop harvest, humidity and temperature. The study also revealed that farmers have several ways of adapting to climate change: diversify crops, choosing crops with a short growing cycle, weeding early in the north and late in the south, praying and so on.

Kabubo-Maria and Karanja (2006) observed in their study that climate affects agricultural productivity and increased winter temperatures are associated with higher crop revenue, but increased summer temperatures have a negative impact. Increased precipitation is positively correlated with net crop yield. The results further showed that there is a non-linear relationship between temperature and revenue on the one hand and between precipitation and revenue on the other hand. Andosols, irrigation and household size are positively correlated with revenue, but livestock ownership, farm size and wage rates are inversely correlated with crop revenue. Estimated marginal impacts of climate variables suggest that global warming is harmful for agricultural productivity. Diversification (changes in crop mix) is the most common adaptation measure, particularly in high potential zones, while water conservation, irrigation and shading/sheltering of crops are the main adaptation in drier region.

Khnanal (2009) compared conventional agriculture, organic agriculture is reported to be more efficient and effective both in reducing GHGs (CO_2, CH_4, and N_2O) emission mainly due to the less use of chemicals and fossil fuel. Organic agriculture also reported to be climate change resilience farming systems as it promotes the proper management of soil, water, biodiversity and local knowledge thereby acting as a good option for adaptation to climate change.

Dryer conditions and rising temperatures will affect livestock activities in different ways, including implications for animal health and welfare. Climate change has a complex influence on the livestock sector due to the great diversity of production systems. Warming and extreme events, such as heat spells, will have direct impacts on animal health, growth and output, as well as on reproduction. There will also be indirect effects through changes in the productivity of pastures and forage crops, and in the distribution of animal diseases. Highly adverse impacts are likely to be felt in extensive grazing systems which are directly dependent on climate conditions for the provision of feed and shelter. In Mediterranean areas, warmer temperatures and summer precipitation deficits will shorten the grazing period and decrease forage production and its quality. In the North-Western humid areas, moderate warming can, however, be beneficial to livestock activities in the short to medium term because of the productivity increase of pastures (CEC, 2009).

In their study, Seo and Mendelsohn (2006) analysed the impact of climate change on animal husbandry in Africa using ricardian method, a cross- sectional approach, to examine the economics of animal husbandry in Africa. The net revenue from raising animal on small and large farms across Africa is regressed on climate, soils, and other control variables to test the climate sensitivity of livestock in Africa. Two empirical models were tested. A single- equation model examines net revenue per farm regressed on climate and other control variables. The second model has two equations: the first examines the value of animals owned per farm and the second the revenue per value of owned animal. Both equations in the second model regress the dependent variable on climate and other control variables. The single-equation Ricardian model finds that the livestock net revenue of large farms in Africa fall as temperatures rises but that small farms are not temperature sensitive. The two-equation model finds that higher temperature reduces both the size of the stock and the net revenue per value of stock for large farms.

However, for small farms, higher temperatures do not affect the size of the stock and they increase the net revenues per value of stock. Large farms in Africa are vulnerable to warming but small farms are not. The single-equation model finds that increase in precipitation would reduce livestock net revenue per farm for both small and large farms. The elasticity of net revenue per farm is particularly large for small farms. The two-equation model reveals that increased precipitation reduces both the size of the stock and the net revenue per animal owned. As precipitation increase, many farmers find it advantageous to shift from livestock to crops. A warming of $2.5^{o}c$ increase small farm livestock income by 26% (+ $ 1.4 billion). This increase comes strictly from an expansion of the stock. If the temperature rises, the net revenue per animal falls slightly. By contrast, a warming of $2.5^{o}C$ reduces large farm livestock income by 22% (-$ 13 billion) (Seo & Mendelson, 2006).

Seo and Mendelsohn (2008) used a traditional Ricardian regression to analyze the impacts of climate change on animal husbandry and the way farmers adapt. The net revenues of large farms in Africa are more sensitive to temperature than those of small ones. Using the Ricardian results and examining climate change scenarios for 2060 and beyond, the net revenues of small farms are predicted to increase as much as 120% (+USD6 billion) but those of large farms are predicted to fall by 20%(-USD12 billion).

Eid, El-Marsafawy and Ouda (2006) in their study the economic impacts of climate change on agriculture in Egypt using a Ricardian approach, showed that a rise in temperature would have negative effects on net farm revenue in Egypt. Marginal analysis indicated that the harmful effect of temperature was reduced by adding the hydrology term and heavy machinery to the analysis. The results also showed that raising livestock on the farm to cope with climate change was not effective, probably as a result of small farm ownerships. The results also indicated that irrigation could defeat the adverse effect of higher temperatures and increase net revenue. Again it was also showed that using irrigation and investing in heavy machinery could reduce the harmful effects of global warming and improve the revenue. Irrigation and technology among other things are therefore the recommended adaptation options. The coping policy strategy should focus on crop management, water and land management.

As observed by Johnston *et al.*, (2009), climate change has impacts on agriculture:

- Directly, at local scale, due to change in temperature, rainfall and sea-level;
- At local to substantial scales, through changes in water regimes; and
- Indirectly, at global scale, by physical, social or economic means, such as sea-level rise, migration or changes in food prices. The following are the manifestations of climate change;

(i) **Increased temperature:** Warmer conditions can reduce yields of crops and pastures by preventing pollination. For example, rice yields decrease by 10% for every $1^{o}C$ increase in minimum temperature during the growing season (Johnston *et al.*, 2009). Increases in temperature, at the same time, might affect lower altitude areas where temperatures are already high. Higher temperatures affect both the physical and chemical properties in the soil. Increased temperatures may accelerate the rate of releasing CO_2 resulting in less than optimal conditions of net growth. When temperatures exceed the optimal level for biological processes, crops often respond negatively with a steep drop in net growth and yield. Heat stress might affect the whole physiological development, maturation and finally yield of cultivated crops (Khanal, 2009).

(ii). **Increased Carbon dioxide ($CO_{2)}$:** This has a fertilization effect and can increase the yield of some crops (including rice, wheat, grasses and most trees) (Johnston *et al.*, 2009). Khanal (2009) opined that increased concentration of CO_2 in the atmosphere increases the likelihood of higher absorption of CO_2 inside the plant through stomata during photosynthesis which provides carbohydrates for plant growth. Crop species vary in their responses to CO_2 according to their physiological class i.e. C_3 versus C_4 plants.

(iii). **Increased pests and diseases**: Higher temperatures and longer growing seasons could favour damaging pest populations (Johnston *et al.*, 2009). In his opinion Khanal (2009) posited that higher temperatures provide a conducive-environment for the majority of insect pests. He further observed that longer growing seasons, higher night temperatures, and warmer winters help insect pests undergo multiple life-cycles and increase the chances of affecting plant production.

(iv). **Increased Water demand:** Higher temperatures will increase evapotranspiration, raising the water needs of rain-fed and irrigated crops and pastures. Scientists believe demand for irrigation in semi-arid regions of Asia will increase by at least 10% per 1^{o}C temperature rise. The water needs of livestock will also rise (Johnston *et al*., 2009). As observed by Khanal (2009) change in climate affects the pattern and extent of rainfall and evapotranspiration processes which affect soil moisture storage, run-off, and water absorption by the plant. Both lack of and access to water might affect the different stages of plant production. Moisture stress during flowering, pollination, and grain-filling stage is harmful to most crops. Increased evaporation from soil and accelerated transpiration in the plants themselves will cause moisture stress.

(v). **Change in variability of crops:** Changes to temperature and rainfall may require farmers to use new varieties or alter cropping patterns (Johnston *et al*., 2009), especially if they want to continue meeting their dual objectives of output and profit maximization. Food crop farmers in Southwestern Nigeria are not in isolation of this.

(vi). **Vertical shifts in ecosystems:** Average annual temperature decreases by about 1^{o}C for every 100m of elevation in tropical to subtropical areas. Some vertical shifts in ecosystems are likely as temperatures rise (Johnston *et al*., 2009).

(vii). **Changes to seasonal timing:** Shifts in the onset, and of, the wet season may affect crop yields and irrigation demand (positively or negatively, depending on the crop calendar).

(viii). **Sea-level rise and saltwater intrusion:** Rising sea waters will reduce viable crop areas in the deltas and along coasts. Further rises in sea-level will require adaptation measures to protect crops. In the longer term, if the current situation is maintained, sea-level rise could have catastrophic impacts on deltas and coastal areas (Johnston *et al.,* 2009). The current global estimate of sea level rise is 0.2m and it is projected to increase to 1m by the year 2100 (Hengeveld & Whitewood, 2005). Coastal settlements in Nigeria like Bonny, Forcados, Lagos, Port Harcourt, Warri and Calabar among others that are less than 10m above the sea-level would be seriously threatened by a metre rise of sea-level (Odjugo, 2010).

(ix). **Impacts on fisheries:** Climate change will likely affect the metabolism, growth and distribution of many aquatic organisms as well influencing diseases that afflict them. Fisheries are vulnerable to reduced dry-season flows: these could dwindle further as temperatures rise. Changes to wild fish stocks, particularly of marine origin, will affect supplies of fish meal and fish oils that support the aquaculture and livestock industries. However, coastal and delta areas rendered unsuitable for crop production as sea-level rise may provide new opportunities for aquaculture (Johnston *et al.,* 2009).

According to the nature of impact of climate change on agriculture Food and Agricultural Organization (2007) has divided impacts into two groups i.e. biophysical and socio-economic.

The impacts presented in Table 2.1 are generally negative. However, while looking critically on plant production, the climate change has both negative and positive impacts. Rises in temperature, for example, would help to grow crop in high altitude areas and towards the poles. In these areas, increase in temperature extend the length of the potential growing season, allowing earlier planting, earlier harvesting and opening the possibility of completing two crop cycles in the same season. The warmer conditions support the process of natural decomposition of organic matter and contributing to the nutrient uptake mechanism. The process of nitrogen fixation, associated with greater root development, is also predicted to increase in warmer conditions and with higher CO_2, if soil moisture is not limiting (Khanal, 2009).

Table 2.1: General impacts on biophysical and socio-economic areas

Biophysical impacts	Socio-economic impacts
• Physiological effects on crop, pasture, forest and livestock (quantity and quality)	• Decline in yield and production
• Change in land, soil and water resources	• Reduced marginal GDP from agriculture
• Increased weed and pest challenges	• Fluctuation in world market prices
• Shifts in spatial and temporal distribution of impacts	• Changes in geographical distribution of trade regimes
• Sea level rise and changes to ocean salinity	• Increased number of people at risk of hunger and food security
• Sea temperature rise causing fish to inhabit in different ranges	• Migration and civil unrest

Source: Khanal, 2009.

2.6 Agricultural Adaptation Strategies to Climate Change

Adaptation to climate change involves changes in agricultural management practices in response to changes in climate conditions. It often involves a combination of various individual responses at the farm-level and assumes that farmers have access to alternative practices and technologies (Nhemachena & Hassan, 2007).

Because the rates and timings of climate change are uncertain, it is important to build resilient communities that are able to deal with unforeseen changes. Capacity to adapt to climate change is very closely linked to socioeconomic factors, such as poverty, diversification of income sources, level of education, and access to infrastructure and technology. Promoting broad-based agricultural development to lift rural communities out of poverty is probably the effective adaptation strategy available (Johnston *et al*., 2009).

At a technical level, there is a large body of knowledge about changes in agricultural systems that could help safeguard production. Farmers have always lived with climate variability and have many coping strategies for droughts and floods that will form the basis for adapting to climate change. Many of these adaptation measures are ‘no-regrets’ responses, which also provide benefits in terms of production or environmental outcomes, including reducing greenhouse gases emissions to mitigate the impacts of climate change (Johnston *et al*., 2009)

The Table 2.2 below shows the response strategy adopted by crop farmers to climate change in the Greater Mekong Sub-region (GMS) by Johnston *et al*., 2009.

Smit and Skinner (2002) grouped agricultural adaptation options to four (4) main categories, but observed that they are not mutually exclusive, namely (1) technological developments, (2) government programmes and insurance, (3) farm production practices, and (4) farm financial management. The typology is based on the scale at which the stakeholders are involved. Adaptations based on technological developments, and government programmes and insurance are principally the responsibility of public agencies and agri-business, they might also be thought of as system-wide (or systematic) or macro-level. The two remaining categories that is, farm production practices and farm financial management mainly involves farm-level decision making by producers (farmers). Of course, the categories are often interdependent.

CEC (2009) observed that, adaptive measures in agriculture range from technological solutions to farm management or structures, and to political changes, such as adaptation plans. In the short-term, autonomous farm-level adaptation may be sufficient, but in the longer run adaptation in the form of technological and structural changes will become necessary. This will require planned strategies based on analysis of local and regional conditions.

Table 2.2: Adaptation responses and issues

Type of response	Autonomous	Policy-driven
Short-run	- Crop choice, crop area, planting date - Risk-pooling insurance	- Improved forecasting - Research for improved understanding of climate risk
Long-run	- Private investment (on-farm irrigation) - Private crop research	- Large-scale public investment (water, storage, roads) - Crop research
Issues	- Costly to the poor - Social safety nets - Trade-offs with integration	- Uncertain returns on investment - Costs

Source: Rosegrants *et al.*, 2008.

1. Farm Production Practices Adaptation Strategies

Farm production practices involve changes by producers in their farm operational practices, which may be stimulated or informed by government and industry programmes. Farm production adaptations include farm-level decisions with respect to farm production, land use, land topography, irrigation, and the timing of operations (Table 2.3).

Changing farm production activities has the potential to reduce exposure to climate-related risks and increase the flexibility of farm production to changing climatic conditions. Farm production practices adaptations could include;

(i). diversification of crop and livestock varieties,

(ii). changes in the intensity of production, (iii). changes in the land use practices which involve altering the location of crop and livestock production (i.e. land fragmentation),

(iv). conservation of moisture and nutrients,

(v). implementation and intensification of irrigation practices, and

(vi). Changes in the timing of farming operations.

(i). Diversification: Garnevska, Edwards and Vaughan (2006) explained diversification in agriculture to be of two strategic options ‘related’ diversification (introducing new agricultural activities) and ‘unrelated’ diversification (introducing new non-agricultural activities). Altering crop and livestock varieties, including the substitution of plant types, cultivars and hybrids, and animal breeds designed for higher drought or heat tolerance, has the potential to increase farm efficiency in light of changing temperature and moisture stresses (Chiotti, Johnston, Smit & Ebel, 1997; Johnston *et al*., 2009; Smit *et al*., 1996). This has been used in the past for mitigating risk in agriculture but this study is looking at diversification as a coping strategy to climate change at the farm-level. Poon & Weersink (2011) noted that diversification and off-farm employment appear to be substitute for risk management strategies for commercial operations.

(ii). Altering the intensity of chemical (i.e. fertilizers and pesticides), capital and labour inputs has the potential to reduce the risks in farm production in light of climate change (Brklacich *et al*., 1997; Brklacich *et al*., 2000; Hucq, Kowalshi, Gutek & Gray, 2000; Johnston *et al*., 2009). Decisions about changes in farm production practices are unlikely to be made in light of climate change risks separately from the risks associated with other economic, technological, social and political forces.

(iii). Changing land use practices involve altering the location of crop and livestock production. Rotating or shifting production between crops and livestock, and shifting production away from marginal areas has the potential to reduce soil erosion and improve moisture and nutrient retention. (Delcourt & Van Kooten, 1995).

(iv). The conservation of moisture and nutrients in light of more frequent droughts can also be improved through the use of alternative fallow and tillage practices (Chiotti *et al.*, 1997; Hucq *et al.*, 2000). Changing tillage operations involves minimum tillage operations, full tillage operations and digging ridges across slopes in the farm against erosion (Onyeneke & Madukwe, 2010).

(v). The conservation of moisture and nutrients involves land contouring and terracing, and the construction of diversions, reservoirs, and water storage and recharge areas (Easterling, 1996; Smit, 1993). This type of adaptation reduces farm production vulnerability by decreasing runoff and erosion, improves the retention of moisture and nutrients, and improves water uptake (de Loë *et a*l., 1999).

(vi). Implementing irrigation practices involves the introduction or the enhancement of specific water management innovations including centre pivot irrigation, dormant season irrigation, drip irrigation, gravity irrigation, pipe irrigation and sprinkler irrigation (Smit, 1993). Irrigation practices also involve changing the scheduling of existing systems (Chiotti & Johnston, 1995). This type of adaptation will increase moisture retention in light of decreasing precipitation and increasing evaporation, and more frequent droughts. Irrigation practices could improve farm productivity and enable diversification of production in light of climate-related changes (i.e. switching to crops that would otherwise not thrive in dryland agriculture) (Brklacich *et al.*, 1997; Klassen & Gilpen, 1998).

(vii). Changes in the timing of farming operations involves production decisions, such as planting, spraying and harvesting, to take advantage of the changing duration of growing seasons and associated changes in temperature and moisture. This type of adaptation includes the scheduling of crop and livestock production activities such as chemical inputs (Chiotti& Johnston, 1995), grazing (Chiotti *et al*., 1997), irrigation (de Loë *et al.*, 1999), harvesting, mulching, planting, seeding, and tillage (Smit, 1993). Changing the timing of these farm practices has the potential to maximize farm productivity during the growing season and to reduce losses associated with heat stresses and moisture deficiencies.

(2). Technological Development Adaptation Strategies

Technological adaptations are developed through research programmes undertaken or sponsored by federal and provincial governments, and through research and development programmes of private sector industries (Smit & Skinner, 2002). Technological adaptation options (or measures) have been developed to increase the tolerance and suitability of plants to temperature, moisture and other relevant climatic conditions); weather and climate information systems (development of early warning systems that provide daily weather predictions and seasonal forecast); and resource management innovations, including irrigation, to address the risk of moisture deficiencies and increasing frequency of droughts; also development of farm-level resource management innovations to address the risk associated with changing temperature, moisture and other relevant climatic conditions (Smit & Skinner, 2002). CEC (2009) opined that adapting crops with the help of existing genetic diversity and new possibilities offered by biotechnology. Also introducing more heat tolerant livestock breeds and adapting diet patterns

of animals under heat stress conditions.

3. Farm Financial Management Adaptation Strategies

Farm financial adaptation options are farm-level responses based on the use of farm income strategies (both government supported and private) to reduce the risk of climate-related income loss. As a result, government agricultural support and incentive programmes often influence farm financial management decisions. Farm financial adaptations involve farm-level decisions with respect to:

(i). crop insurance,

(ii). crop shares and futures,

(iii). income stabilization programmes, and

(iv). household income (see Table 2.3).

(i). Crop insurance reduces income loss as a result of reduced crop yields from droughts, floods and other climate-related events, and in the case of subsidized programmes (as in Canada) this spreads exposure to climate-related risks publicly (de Loë *et al.*, 1999; Smit, 1993). Purchasing insurance entails financial decision-making aimed at stabilizing income from crop production in light of climate change risks. This type of adaptation includes participation in established federal and provincial subsidized crop insurance programmes (Smit & Skinner, 2002).

(ii). Investment in crop shares and futures has also been proposed to spread exposure to climate-related risks and reduce vulnerability to income loss (Mahul & Vermersch, 2000). This adaptation option involves the use of securities, shares and other financial options developed by government and industry, including banks, as an alternative financial management strategy to crop insurance (Chiotti *et al.,* 1997; McCulloch *et al.*, 1994; Turvey & Baker, 1990).

(iii). Participation in income stabilization programmes also has the potential to spread exposure to risk borne by farmers and reduce their vulnerability to climate change. Many farmers already participate in established federal and provincial income stabilization programmes, such as the Dairy Subsidization Programme, Agricultural Income Disaster Assistance (AIDA) and the Net Income Stabilization Account (NISA) (Agriculture and Agri-Food Canada, 2001). Although the use of income stabilization programmes is recognized as a potential climatic adaptation (Schweger & Hooey, 1991), it is unlikely to be considered independently of other political and economic influences.

(iv). Household income strategies have long been important adaptation options in Canadian agriculture. Such financial decisions may also represent a means of dealing with economic losses or risks associated with climate change. Diversification of income sources including off-farm employment and pluriactivity, has been identified as an adaptation option with the potential to reduce vulnerability to climate-related income loss (Brklacich *et al.*, 1997; de Loë*et al.*, 1999; Smithers & Smit, 1997). As with many adaptations, diversification of household incomes is unlikely to be undertaken directly in response to climatic perturbations alone (Bradshaw, Dolan & Smit, 2001).

4. Government Programmes and Insurance Adaptation Strategies

Government programmes and insurance are institutional responses to the economic risks associated with climate change and have the potential to influence farm-level risk management strategies. These include;

(i). government agricultural subsidy and support (to decrease the risk of climate-related income loss, and spread exposure to climate-related risks publicly);

(ii). private insurance (to decrease the risk of climate-related income loss, and spread exposure to climate-related risks privately); and

(iii). resource management programmes (to influence resource management in light of changing climate conditions).

(i). Agricultural subsidy and support programmes involve modifications to and investment in both established and ad hoc federal and provincial programmes. Ad hoc programmes provide compensation for disaster-related income loss independent of the support provided by established crop insurance, income stabilization and farm production subsidy, support and incentive programs (Schmitz, Just & Furtan., 1994; Smit, 1994). All of these programs greatly influence farm-level production and management strategies by transferring risk in agriculture. Modifications to the terms of reference for crop insurance or other farm production subsidies, supports and incentives have the potential to encourage or discourage changes in farm-level production and management by spreading exposure to climate-related risks (Wang, Hanson, Meyers & Black, 1998). Changes to government investment in income stabilization and disaster relief have the potential to make more funds available to farmers to reduce the risk of income loss as a result of increased incidence, severity and duration of droughts, floods and other climate related-events (Changnon *et al.*, 1997; Love, Boyd, Lyons & Ginson, 1997; Romain & Calkins, 1996). The success of agricultural subsidy and support programmes has been difficult to determine as government programmes seldom address climate-related risks independently of other risks to agriculture (Van Kooten & Arthur, 1997).

(ii). The development of private insurance represents an adaptation to climate-related risks that is primarily the responsibility of the financial services sector, which is generally influenced by government programmes. This involves the development of insurance schemes by private companies to address crop and property damage from such climate-related hazards as droughts, floods and other climate-related events.

Table 2.3: Climate Change Adaptation Strategies in Agriculture

S/NO	ADAPTATION STRATEGIES
1.	**FARM PRODUCTION PRACTICES** **Farm Production** • Diversify crop types and varieties, including crop substitution, to address the environmental variations and economic risks associated with climate change. • Diversify livestock types and varieties to address the environmental variations and economic risks associated with climate change. • Change the intensification of production to address the environmental with respect to climate-related income loss. • Modify subsidy, support and incentive programmes to influence farm-level production practices and financial management. • Change ad hoc compensation and assistance programmes to share publicly the risk of farm-level income loss associated with disasters and extreme events. • variations and economic risks associated with climate change. **Land Use** • Change the location of crop and livestock production to address the environmental variations and economic risks associated with climate change. • Use alternative fallow and tillage practices to address climate change-related moisture and nutrient deficiencies. **Land Topography** • Change land topography to address the moisture deficiencies associated with climate change and reduce the risk of farm land degradation. **Irrigation** • Implement irrigation practices to address the moisture deficiencies associated with climate change and reduce the risk of income loss due to recurring drought. **Timing of Operations** • Change timing of farm operations to address the changing duration of growing seasons and associated changes in temperature and moisture.
2.	**GOVERNMENT PROGRAMMES AND INSURANCE** **Agricultural Subsidy and Support Programmes** • Modify crop insurance programmes to influence farm-level risk management strategies with respect to climate-related loss of crop yields. • Change investment in established income stabilization programmes to influence farm-level risk management strategies **Private Insurance** • Develop private insurance to reduce climate-related risks to farm-level production, infrastructure and income. **Resource Management Programmes** • Develop and implement policies and programmes to influence farm-level land and water resource use and management practices in light of changing climate conditions.
3.	**TECHNOLOGICAL DEVELOPMENT** **Crop Development** • Develop new crop varieties, including hybrids, to increase the tolerance and suitability of plants to temperature, moisture and other relevant climatic conditions. **Weather and Climate Information Systems** • Develop early warning systems that provide daily weather predictions and seasonal forecasts. **Resource Management Innovations** • Develop water management innovations, including irrigation, to address the risk of moisture deficiencies and increasing frequency of droughts. • Develop farm-level resource management innovations to address the risk associated with changing temperature, moisture and other relevant climatic conditions.
4.	**FARM FINANCIAL MANAGEMENT** **Crop Insurance** • Purchase crop insurance to reduce the risks of climate-related income loss. **Crop Shares and Futures** • Invest in crop shares and futures to reduce the risks of climate-related income loss. **Income Stabilization Programmes** • Participate in income stabilization programmes to reduce the risk of income loss due to changing climate conditions and variability. **Household Income** • Diversify source of household income in order to address the risk of climate-related income loss.

Source: Smit and Skinner, 2002.

(iv). Resource management programmes involve the development of federal and provincial policies and programmes that encourage or discourage changes in land use, water use and management practices. This type of adaptation includes the development of land use regulations (Chiotti & Johnston, 1995), water use permits (Easterling, 1996) and ‘best management’ practices (Agriculture and Agri-Food Canada, 2001). Resource management programmes also have the potential to address broad-scale changes such as northward shifts in pest infestations (Smit, 1993) and boreal forest patterns (Van Kooten, 1995). Implementation of these programmes will require an assessment of existing institutional and economic arrangements and could require changes to existing legislation (Chiotti *et al*., 1997; de Loë *et al*., 1999). These policy instruments of governments represent adaptations at an aggregate scale and also influence farm-level adaptation decision-making.

2.7 Efficiency

The concept of efficiency has been interpreted in many forms or ways. Efficiency in itself is concerned with relative performance of the processes used in transforming a set of inputs into output. Farrel (1957) and Carlson (1972) distinguished between two components of productive efficiency: technical (or physical) and allocative (or price). Also included in this study is profit efficiency as another form of distinguishing efficiency.

2.7.1 Technical Efficiency

The purely technical or physical efficiency is the ability to avoid waste by producing as much output as input usage allows or by using as little input as output production allows (Lovell, 1993). Thus the analysis of technical efficiency can have an output-augmenting orientation and an input-conserving orientation (Kebede, 2001). It is also defined by Timmer (1980) as the ability of farms to employ the “best practice” in the production process so that not more than the necessary amount of a given set of inputs is used in producing the “best” level of output.

Olayide and Heady (1982) defined technical efficiency to represent a firm's ability to produce maximum level of output from a given level of inputs. Technical efficiency is the ratio of total output to total input. For a perfectly efficient farm, the ratio is unity. This means that the larger the amount of the input the smaller the size of the ratio and in turn the more inefficient the farm becomes. It indicates all those gains that can be obtained by simply gingering up the management (Olayide & Heady, 1982). Chavanapoonphol *et al.* (2005) described technical efficiency of an individual farmer as the ratio of observed output to its corresponding stochastic frontier output, given the levels of the inputs used by the farmer. Yotopoulos and Nuggent (1973) described technical efficiency as macroeconomic concepts. Based on Farrell (1957) measure of technical efficiency can be obtained by using input and output quantity without introducing prices of these inputs and outputs. Technical efficiency can be decomposed into three components: scale efficiency, congestion and pure technical efficiency.

2.7.2 Allocative or Price Efficiency

The allocative or price efficiency refers to the ability to combine inputs and outputs in optimal proportions in light of prevailing prices (Lovell, 1993). Farrell (1957) defined price efficiency as the measure of a firm's success in choosing an optimal set of inputs. This is an indication of the gains that can be obtained by varying the input ratios on certain assumptions about the future price structure. Yotopoulos and Nuggent (1976) described allocative efficiency as a micro economic concept.

2.7.3 Profit Efficiency

This is the ability of a firm to achieve potential maximum profit, given the level of fixed factors and prices faced by the firm (Abdulai & Huffman, 2000). As defined by Ogundari (2006), profit efficiency is the profit gain from operating on the profit frontier, taking into consideration farm-specific prices and factors. The advantage of using this approach is that when input and output prices are exogenous to farm household decision making, they can be used to explain input use and output supply. The resulting parameter estimates, in general, will be statistically consistent (Abdulai & Huffman, 2000).

2.8 Production Frontier Measures

The production frontier serves as a standard against which to measure the efficiency of production. It should contain only the efficient observations (Kebede, 2001).

The level of technical efficiency of a particular farmer is characterized by the relationship between observed production and some ideal or potential production (Greene, 1980), even the profit efficiency level of a particular farmer is also characterized by the relationship between observed profit and potential profit. The measurement of firm- specific or farmer- specific efficiency is based upon deviations of observed output or profit from the best production or efficient production and/or profit frontiers. If a farmer's actual production point lies on the frontier it is perfectly efficient. If it lies below the frontier then it is technically inefficient, with the ratio of the actual to the potential production defining the level of efficiency of the individual farmer (figure 2.3). For example, $0_0/0_b$ is a comparison of output at points C_0 and C_b, each with the same level of input but C_b lying on the best practices frontier function Q_b(passing through 100%- efficient sample point) whilst C_0 lies on Qo, which represents a locus that is a neutral- shift of the frontier Q_b and passes through the point C_0 in figure 2.3

The concept could be measured relative to other frontiers, for example the absolute frontier Q_a lying above all sample points. Here, the ratio will be $0o\backslash 0_a$ or a comparison of output at points C_a on 0_a and C_0. The potential absolute frontier is also represented by Qp, which is the maximum output obtained from all conceivable observations embodying the current technology (including over all periods in which adoption takes place) and it lies above Q_a. Over time, there would be a sequence of absolute frontier functions Qa's (and associated levels of technical/profit efficiency) moving up to the potential absolute frontier function Qp (Ogundele & Okoruwa, 2006; Okoruwa & Ogundele, 2006).

The production frontier has a property of scale economies: Constant returns to scale (CRS), decreasing returns to scale (DRS) and increasing returns to scale (IRS). (Kebede, 2001).Farrell's definition of technical efficiency led to the development of methods of estimating the relative

79

technical efficiencies of farmers. The common feature of these estimation techniques is that information is extracted from extreme observations from a body of data by determining the best practice production frontier (Lewin & Lovell, 1990). From this, the relative measure of technical efficiency for the individual farmer can be derived.

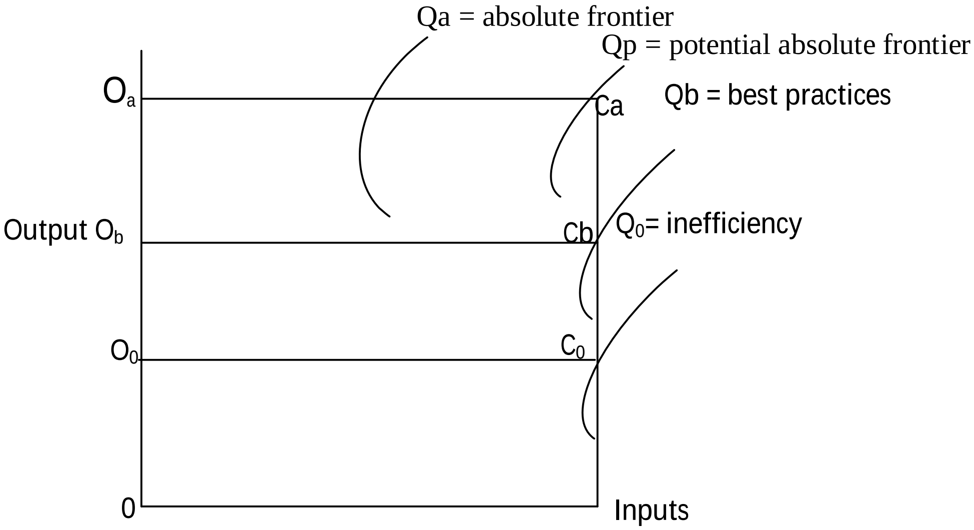

Figure 2.3: Best practices, potential absolute frontier and measure of inefficiency
Source: Okoruwa and Ogundele , 2006.

2.9 Stochastic Frontier Analytical Technique of Efficiency Measurement

Measurement of efficiency is one of the very important topics of research in both developing and developed countries. Applications vary in context because most studies in developing countries are focused on agriculture, while in developed countries the interest on technical efficiencies has been confined to the industrial sector, or the manufacturing sector, in general. (Obwona, 2000; 2006).

The literature emphasizes two broad approaches to production frontier estimation and technical efficiency measurement:

- The non- parametric programming approach, and
- The statistical or econometric approach.

The econometric approach has been motivated to develop stochastic frontier models based on the deterministic parameter frontier of Aigner & Chu (1986). The Stochastic Frontier Analysis (SFA) makes a distinction between statistical noise and random noise around the estimated production frontier and inefficiency (Kebede, 2001; Oren &Alemdar, 2006), but the Data Envelopment Analysis (DEA) do not make such distinction in error term. This point is very important for studies of farm level data in developing economies like Nigeria, as data generally include measurement errors (Ogundari, 2006).

However, SFA is criticized for assuming *a priori* distributional forms for the inefficiency component and imposes an explicit functional form for the underlying technology. This is the weakness of the SFA approach (Kebede, 2001; Oren & Alemdar, 2006). In a simple case of a single and multiple inputs, the approach predicts the outputs from inputs by the functional relationships $Y_i = f(X_i, \beta) + \varepsilon_i$ where i denotes the production or economic unit being evaluated and β's are the parameters to be estimated. The residual $\varepsilon_{i\ is}$ composed by random error, Vi and an inefficiency component, $U_{i;}$ when we assume that $V_i = 0$, SFA is reduced to the Deterministic Frontier Analysis (DFA); if we further let $U_i= 0$, SFA will be reduced to central tendency analysis (Kebede, 2001).

In agricultural economics literature, the use of Stochastic Frontier Analysis (SFA) is recommended because of the inherent nature of uncertainty/ variability associated with agricultural production due to weather, fires, pests, diseases, etc. (Coelli & Battese,1996; Coelli, *et al.* 1998).

2.10 Econometric Approaches for Examining Factors Influencing Efficiency from Stochastic Frontier Analysis (SFA)

There are several approaches to analyze the factors influencing efficiency (technical, profit, allocative and economic) from Stochastic Frontier Production Function (SFPF). Two of these approaches are discussed here: two-step approach and one step approach. One set of authors followed a two- step procedure in which the frontier production function is first estimated to determine efficiency indicators while the indicators thus obtained are regressed against a set of explanatory variables that are usually firm- specific characteristics. Researchers in this category include Pitt and Lee (1981), Kalirajan (1981a); Parikh, *et al.* (1995); Ogundele (2003) and Asogwa *et al.* (2006). While this approach is very simple to handle the major drawback is that it violates the assumption of the error term. In the stochastic frontier model, the error term (the inefficiency effects) is assumed to be identically independently distributed with zero mean and constant variance i.e. Vis ~ iid N $(0, \sigma^2)$ (Jondrow, *et al.* 1982). In the second step, however, the technical efficiency indicators obtained are assumed to depend on certain number of factors specific to the firm, which implies that the inefficiency effects are not identically distributed.

This major drawback has led to the development of a more consistent approach that modeled inefficiency effects as an explicit function of certain factors specific to the firm, and all parameters are estimated in one-step using maximum likelihood procedure. Researchers in this category include Reifschneider and Stevenson (1999), Huang and Liu (1994), and Battese and Coelli (1995) who proposed a Stochastic Frontier Production Function (SFPF) for panel data. Other researchers in recent time include Ajibefun (2006; 2007), Ajibefun *et al.* (2002), Ajibefun*et al.* (2006), Coelli & Battese (1996), Battese & Sarfaz (1998), Seyoum *et al.* (1998), Kurkalova & Jensen (2000), Obwona (2006), Okoruwa & Ogundele (2006), Ogundele & Okoruwa (2006), Otitoju(2008) and Otitoju & Arene (2010).

2.11 Production Efficiencies and their Determinants

Some studies that adopted the stochastic frontier approach for efficiency analysis are hereby reviewed. Ajibefun and Abdulkadri (1999) estimated technical efficiency for food crops farmers under the National Directorate of Employment in Ondo State, Nigeria. The result of the analysis indicated wide variation in the level of technical efficiency, between 0.22 and 0.88 on a scale of 1.0 (indicating that the level of technical efficiency of the farmers ranged between 22% and 88%). Ajibefun *et al.* (2002) used the translog stochastic frontier production function methodology to estimate the level of technical efficiency of smallholder food crop farmers in Oyo State of Nigeria. The results revealed that the inefficiency effects of the smallholder croppers were significant. The technical inefficiency varied widely, ranging from 19% to 95%, with a mean value of 82% indicating that the farmers are 82% efficient in the use of their production input. Age of farmers, farming experiences, level of education, size of farm holdings as well as the ratio of hired labour to total labour use, were factors that significantly influenced the level of technical efficiency. The results showed that the technical inefficiency of farmers increases with age; farm size and the ratio of hired labour to total labour, while the level of technical inefficiency tends to decline with years of experience and level of education. The results also indicated an increasing return-to-scale parameter 1.17, (i.e. significantly different from 1).

Ogundele and Okoruwa (2006) in their study, “technical efficiency differentials in rice production technologies in Nigeria,” estimated technical efficiency following the maximum likelihood estimation using data from 302 farmers. The findings indicated that there was no absolute differential between the two groups (local and improved) of farmers. The average technical efficiency for the two groups were correspondingly high (>0.90), which indicated that there is little opportunity for increased efficiency, about 10%, given the present state of technology. The variables that tend to contribute to technical efficiency are hired labour, herbicides and seeds.

Ojo (2003) examined the productivity and technical efficiency of poultry egg production in Nigeria using the stochastic frontier production function analysis using data from 200 farmers. The results showed that poultry egg production was in the rational stage of production (stage II) as depicted by the returns-to-scale (RTS) of 0.771. The technical efficiencies of the farmers varied widely between 0.239 and 0.933 with a mean of 0.763. He further observed that only location of farm (nearness to urban centre) positively affected technical efficiency while increase in the other socio economic variables – age, experiences and education led to decrease in technical efficiencies.

Ajibefun (2006) used the translog stochastic frontier production function to analyze and link the level of technical efficiency of Nigeria small scale farmers to specific farmer's socio-economic and policy variables. The results showed that while farmers' socio-economic and policy variables significantly influenced the level of technical efficiency; education has the highest marginal effect. The highest mean technical efficiency of 0.77 occurs among group of farmers within 7-12 years of schooling (secondary school education group) while the least mean technical efficiency (0.54) occurs within the category of farmers with years of schooling within 1-6 years. It implies that technical efficiency has a direct relationship with years of schooling.

Ehirim and Onyekea (2002) in their study "a stochastic frontier approach to technical efficiency in aquacultures in Oyo State, Nigeria. The study revealed that an average relative inefficiency index of 24% was found using Cobb- Douglas functional model and a total return to scale of 1.12 was recorded, which shows an increasing return-to-scale (IRS). It implies that an additional increasing of 0.12% of output will be recorded if there is an increasing in 1% use of all these input resources like capital, labour and chemical.

Fasoranti (2006) in her study examined the influence of socio-economic variables on the technical and allocative inefficiencies of farmers in cassava-based cropping systems in Ondo State, Nigeria using cross-sectional data collected on 305 cassava farmers. The analysis was based on the three cassava cropping systems (cassava-sole, cassava plus maize and cassava with other crops) identified in the study area. The result showed that farming experience and the level of education helped to reduce technical inefficiency among farmers that planted cassava-sole crop; while farming experience helped to reduce technical inefficiency among farmers within the cassava plus other crops cropping system. Cooperative membership significantly reduced technical inefficiencies in all the three cropping systems. On the other hand, land acquisition method increased technical inefficiency in the study area. Results on the allocative inefficiency showed that the level of education and farming experience reduced allocative inefficiencies in cassava-sole crop while land acquisition method and cooperative membership reduced allocative inefficiency under cassava-maize mixture cropping system. Farming experience and land acquisition method helped to reduce allocative inefficiency under cassava and other crops cropping system.

Otitoju (2008) in his study on the determinants of technical efficiency in small and medium-scale soybean production in Benue State, Nigeria discovered that the mean technical efficiency of small and medium-scale soybean farmers were 0.842 and 0.725 respectively. Family size, age and non-family labour were statistically significant and decreases technical inefficiency among small-scale soybean farmers, while age and off-farm income were statistically significant and reduces technical inefficiencies in medium-scale soybean production. Otitoju and Arene (2010) in their study ‘constraints and determinants of technical efficiency in medium-scale soybean production in Benue State, Nigeria observed that, the average technical efficiency was about 73%. The determinants of technical efficiency which were statistically significant were sex, age and experience. Sex and age had an inverse relationship with technical inefficiencies of the farmers while experience had a direct relationship.

In his study Ogundari (2008) examined the resource-productivity, technical efficiency and allocative efficiency of rainfed rice farmers in Nigeria using translog stochastic production function. He found that the mean technical efficiency index was 0.75 (75%). Extension contact and access to credit are found to be to be significant determinants of technical efficiency among the sampled farmers. Amaza, Bila and Iheanacho (2006) examined the determinants of food crop production and technical efficiency in the guinea savanna of Borno State, Nigeria. Land area, fertilizer and hired labour had positive effects on output and their coefficients are significant at 1%. The mean farmers' technical efficiency index was found to be 0.68 (68%). Farmer-specific efficiency factors, which comprise age, education, credit, extension had positive coefficients and were significant at 1% but crop diversification had negative coefficient and was significant at 5%.

Kalirajan (1981b) used a Cobb- Douglas stochastic frontier approach to estimate the economic efficiency of farmers growing high yielding, irrigated rice in India. He compared the small and large farm groups and concluded that there was equal relative economic efficiency in the cultivation of IR2O in Rabi season between the groups. Najafi and Abdulahi (1996) considered technical efficiency of pistachio farmers in Rafsanjan area and the results showed that average technical efficiency at Noogh, Anar and Kabootarkhan fields of Rafsanjani area were 40%, 50% and 52% respectively. Najafi and Zibahi (1995) have investigated on technical efficiency of wheat farmers at Far province and in this study; they applied maximum likelihood

(ML) method in estimation of Stochastic Frontier Production Function (SFPF). The results of the study implied that although technical efficiency at 1989-92 has increased from 67.6% to 79.7% yet there is possibility of increasing the production of wheat by improving the technical efficiency up to 20.3%.

Ekanayake (1987) examined efficiency of 123 Sri-Lankan farmers. Cobb-Douglas production frontiers were estimated for farms that had either good or poor water access. He found that literacy, experience and credit availability had a significant positive impact on the technical efficiency level of the farms with poor water access. Taylor and Shonkwiler (1986) analyzed the effect of agricultural credit programmes on the technical efficiency for a sample of 433 farmers in Brazil. The frontier parameters were estimated by maximum likelihood method (MLM), assuring that the technical inefficiency effects had half-normal distribution. It was found that the credit programmes had no impact on improving technical efficiency.

Kalirajan and Shand (1986) estimated a translog production frontier for paddy using unbalanced panel data for 34 farm households for the three year, 1981-1983, in South India. The results showed a positive relationship between technical efficiency and farming experience, education, access to credit and extension services. Wiboonpongse and Sriboonchitta (2004) estimated the effects of production inputs and technical efficiency on jasmine and non-jasmine rice for 489 farmers (i.e.282 jasmine rice and 207 non-jasmine rice) in Chiang Mai province, Phitsanulok province and Tung GulaRonghai in 1999. Factors affecting technical efficiency were also analyzed contemporaneously with the production frontier using the maximum likelihood method (MLM). Moreover, they analyzed factors, especially nest blast, affecting the Jasmine and non-Jasmine production in Thailand.

Battese and Coelli (1995) defined a Stochastic Frontier Production Function (SFPF) for panel data for India farms and the technical inefficiency were assumed to be a function of firm-specific variables and time. The hypothesis that inefficiency effects are not a linear function of age and schooling of farmers as well as year of observation was rejected. In Uganda, Obwona (2000) estimated a translog production function to determine technical efficiency differentials amongst small- and medium-scale tobacco farmers using a stochastic frontier approach. The results showed the efficiency level of tobacco farmers ranged between 44.5% and 98.1% on a scale of 100% efficiency with mean technical efficiency of 78.4%. He further estimated the factors influencing technical efficiency differentials explained by socio-economic variables and institutional factors, the results indicated that family size, education, credit accessibility and extension services contributed positively towards the improvement of efficiency.

In Ukraine, Kurkalova and Jensen (2000) estimated a stochastic frontiers production model with technical inefficiency effects on a representative and collective grain- producing farms. The results showed that technical efficiency declined from 1989 to 1992. The mean efficiencies in the sample were estimated 0.82, 0.76, 0.68 and 0.60 for the four-year (1989-1992), respectively. They further found that, more experienced managers were found to be more productive, with the effect of experience diminishing with age and on farm provision of production infrastructure was associated with higher efficiency.

Karbasi, *et al.* (2004) in their study, “technical efficiency analysis of pistachio production in Iran using maximum likelihood method (MLM) to estimate Cobb-Douglas Frontier Production Function on 163 farmers for two years of 2000-2001 and 2001-2002 from two districts of Kashmar and Bardescan in Khorasan province of Iran. The research results indicated that average technical efficiency were 81% and 59% for 2001, 69% and 52% for 2002 in Kashmar and Bardescan, respectively. The inefficiency effects model incorporated in the production frontier model showed that in both districts, direct and significant relationship existed between the technical efficiency and factors like farm size, attending extension classes, and literacy level. However, this relation of technical efficiency and farmers' age was indirect and significant.

Ali and Flinn (1989) examined farm- specific profit efficiency for 120 rice farmers in Pakistan. A translog stochastic profit frontier was estimated by maximum likelihood. The findings showed that education had a significant role in reducing profit inefficiency. In addition, off- farm employment and difficulties in securing credit (credit inaccessibility) to purchase fertilizer increased profit inefficiency. Abdulahi and Huffman (1998) applied a stochastic translog profit frontier to examine production efficiency for 256 rice farmers in Northern Ghana in 1992-93. The results showed a negative and statistically significant relationship between access to credit and profit inefficiency. It means that farms lacking credit to purchase fertilizer tended to experience higher profit inefficiency.

In Kenya, Marinda, *et al.* (2006) applied Cobb-Douglas stochastic frontier function in the analysis of farm level data of maize production. The empirical results showed that out of the explanatory variables identified, the main factors that tended to contribute significantly to technical efficiency are; education of the farmers, access to credit, fertilizer use, and distance of the farm to the main road. Access to credit was a constraint to female farmers and affected their technical efficiency; while in Thailand Chaovanapoonphol *et al.* (2005) estimated Stochastic Frontier Production Function (SFPF) using the survey data collected from 656 rice farmers in 2004. The results indicated average technical efficiency of rice farmers was 79 percent and also found that factors affecting the technical inefficiencies of rice farmers were land, amount of loans used for major rice production, experience, formal education and age. The estimated elasticity of mean rice output with respect to land is 0.801, estimated at mean input levels.

The production function approach, however, is not able to capture inefficiencies associated with different factor endowment and different input and output prices across farms

(Abdulai & Huffman, 1998). Therefore, either the profit function approach or the cost function approach, have been used in the analyses of efficiency. It is because the dual relationships provide the flexibility in problem- solving when data are limited or are of a specific type. Nevertheless, the quality of the estimated dual relationship may not be too good if price variability is small, firms have market power or measurement error has occurred (Lusk, *et al.* 1999).

Ogundari (2006) applied stochastic Cobb-Douglas profit frontier model to examine the determinants of profit efficiency among the small-scale paddy rice farmers in Nigeria. The results showed that the profit efficiency of the paddy rice farmers were positively influenced by (age, educational level, farming experiences and household size) but negatively influenced by the price of fertilizer /kg. The average profit efficiency estimated was 0.60 on 1.0 scale.

In their study Abdulai and Huffman (2000) showed that the mean profit efficiency was 27.4 and the results showed that the level of education (human capital) of the household head tends to have a highly significant impact on profit inefficiency. The negative sign indicates that higher levels of education reduce profit inefficiency. The coefficient of the interaction term was also negative, albeit significant at the 10% level, suggesting that more educated farmers without credit constraints were more efficient than their counterparts who face credit constraints. The positive and significant coefficient of the nonfarm employment variable indicates that the farmers engaged in nonfarm activities tend to exhibit higher levels of inefficiency. A negative and statistically significant relationship was also found between access to credit and profit inefficiency.

2.12 Factors Influencing Adoption of Agricultural Technologies and Management Practices

The use of new agricultural technologies has generally been found to be a function of farm and farmer characteristics and specific features of the particular technology (Feder, Just, &

Zilberman, 1985; Marra & Carlson, 1987; Rahm & Huffman, 1984). A considerable set of literature has developed regarding factors that influence the adoption of new technologies by farmers through use of innovativeness theory (Feder *et al.,* 1985; Rogers, 1995). Adoption and diffusion theory has been widely used to identify the factors that influence an individual's decision to adopt and use or reject an innovation.

Land ownership *i*s widely believed to encourage the adoption of new technologies (Daberkow & McBride, 2003). Fernandez-Cornejo *et al.* (2002; 2007) hypothesized that tenants can be assumed less likely than landowners to adopt new technological innovations, as the benefits may not necessarily flow to them, while land ownership is likely to influence the adoption decision. It was also found out by Birungi and Hassan (2010) that land tenure security increases the probability of adoption of most technologies. However, there has been some disagreement in the literature regarding this hypothesis (Feder *et al*., 1985). It has been suggested that the inconsistencies in the literature are likely due to the nature of the technological innovation being examined. Regardless of these disagreements, the effect of tenure on the adoption of new technologies should be examined.

The human capital of the farmer is also assumed to have a significant bearing on the decision to adopt new technologies. Most adoption studies have attempted to measure human capital through the farmer's age and their education or years of experience growing the crop (Fernandez-Cornejo, Daberkow, & Huang, 1994; Fernandez- Cornejo *et al.,* 2007). Education of the farmer has been found to have a positive effect on adoption of GM oilseed rape in Germany (Breustedt, Muller-Scheesel, and Latacz-Lohmann, 2008) and on Bt and HT corn adoption in the United States (Fernandez-Cornejo & McBride, 2002; Marra, Hubbell, and Carlson, 2001) and on terracing adoption in the rain-fed semi-arid lands of Kenya (Ogada, Nyangena & Yesuf, 2010) and on intercropping of immature rubber (*Hevea brasiliensis*) adoption in major rubber-growing regions of Sri Lanka and on investment adaptation practices in Southeastern, Nigeria. It is assumed here that more years of education will increase the probability of adoption, as better educated farmers (farmers with some third-level qualification) can be expected to be more aware of the positive benefits associated with new GM technologies. In addition, if the farm operator or the farmer has formal agricultural education it is assumed that he/she will be more likely to innovate due to the higher associated skill level. The agricultural system in which the farmer primarily specializes is likely to also influence the farmer's agricultural experience and human capital. Other studies have found education to have a negative relationship with adoption of agricultural and farm technologies, among them are, Birungi and Hassan (2010) on adoption of terracing and inorganic fertilizer as land management practices in Uganda and on adoption of rock walls as soil conservation practice in Fort- Jacques (Bayard, Jolly & Shannon, 2006).

It is assumed that the younger the farmer, the more likely he/she is to adopt innovations early in his/her respective life cycle (Rogers, 1995). Older farmers may have a shorter time horizon and be less likely to invest in novel technologies. Alexander and Mellor (2005) found that GM corn adoption increased with age for younger farmers as they gain experience and increase their stock of human capital but declines with age for those farmers closer to retirement. Similar result was discovered by Bayard et al. (2006) that the age of farmers has a negative influence on adoption of rock walls as soil management practice in Fort- Jacques in Haiti and on adoption of rbST in Connecticut Dairy Farms (Foltz & Chang, 2001). Experience is measured by whether the farm operator is a specialist crop farmer. These farmers can be assumed to have greater knowledge and awareness of tillage crops, including GM crops, than farmers in other agricultural sectors. Enete *et al.* (2011) and Enete and Onyekuru (2011) found that age was a factor driving farmer's investment in adaptation practices. A number of studies did not find strong evidence to support the hypothesis that age of the farm operator has an impact on the adoption decision (Boz & Akbay, 2005; Daberkow & McBride, 2003), which contradicts the innovations theory.

Several studies have shown that access to credit is an important determinant enhancing the adoption of various technologies (Hassan, Kiare, Mugo, Robin & Laboso, 1998; Kandlinkar & Risbey, 2000; Tizale, 2007). With more financial and other resources at their disposal, farmers are able to make use of all their available information to change their management practices in response to changing climatic and other conditions. Hassan and Nhemachena (2008) found a positive relationship between access to credit and probability of choosing and using multiple crops under irrigation, mono crop-livestock under dryland, mono crop-livestock under irrigation, multiple crop-livestock under irrigation; and multiple crop-livestock under dryland as adaptation strategies by African farmers. Nhemachena and Hassan (2007) also confirmed positive and significant relationship between access to credit and farm-level adaptations (different crops, different varieties, crop diversification, different planting dates, increase irrigation, increase water conservation and changing from farming to non-farming) in Southern Africa.

Extension services are an important source of information on agronomic practices as well as on climate. Extension education was found to be an important factor motivating increased intensity of use of specific soil and water conservation practices (Anderson & Thampallai, 1990; Tizale, 2007). Studies have found positive influence of extension contact/ services on adoption of agricultural and farm technologies, among them are; in Uganda on adoption of inorganic fertilizer as land management technology (Birungi & Hassan, 2010); on adoption of multiple crops under irrigation, mono crop-livestock under dry land, mono crop-livestock under irrigation, multiple crop-livestock under irrigation and multiple crop-livestock under dryland as adaptation strategies employed by African farmers (Hassan & Nhemachena, 2008); on Ogada *et al.* (2010) also found positive relationship between fertilizer intensity and extension contact in farm technology adoption in rain-fed semi-arid lands of Kenya; on adoption of adaptation measures in Southern Africa, on the probability of adopting different crops, different varieties, crop diversification, increase irrigation and increase water conservation as adapting strategies (Nhemachena & Hassan 2007) and on adoption of maize varieties in hills of Nepal (Ransom, Paudal, & Adhikari, 2003).

A basic hypothesis regarding technology transfer is that the adoption of an innovation will tend to take place earlier on larger farms than on smaller farms. It has been hypothesized that larger farmers would be more receptive to innovation than their smaller neighbors and that this was largely due to cost issues.

Breustedt *et al*. (2008), in a German study forecasting the adoption of GM oilseed rape, found that farm size had a positive effect on adoption. Marra *et al.* (2001) found that farm size had a positive influence on the adoption of Bt cotton in the Southeast United States. Fernandez-Cornejo, Klotz-Ingram, and Jans (2002), in a US study of the adoption of herbicide tolerant (HT) soybeans, found that adoption rates increased with the size of the farm operation and also Keelan, Thorne, Flanagan, Newman & Mullins (2009) found that farm size had a positive influence on the adoption of GM technology among Irish farmers.

Enete, *et al.* (2011) in their study identified that factors driving farmers' investment in adaptation practices were age, level of formal education and level of awareness of climate change issues. They also found out that the major factors constraining them from adapting to climate change were; poverty, farmland scarcity and inadequate access to more efficient inputs, lack of information and poor skills, land tenure and labour constraints. Some of the coping strategies adopted by the farmers with a relatively high profitability index include multiple/ intercropping, agro-forestry/afforestation, mulching, purchase/harvest of water for irrigation and use of resistant varieties.

Herath and Takeya (2003) identified variables related to farmers' awareness and attitude towards intercropping of immature rubber (*Hevea brasiliensis*) stands, extension contacts, educational level and experience with farming other crops are positively associated with the probability of adoption. Social participation, family size, experience with farming rubber, immature, and mature rubber stands size, and the nature of the land (flat/slopped) do not significantly influence adoption. These conclusions were obtained from a logit model estimated on 588 small-holder rubber farmers from major rubber-growing regions in Sri Lanka.

Birungi and Hassan (2010) investigated the impact of poverty, social capital and land tenure in the adoption of soil fertility management (SFM) and conservation technologies in Uganda. The study estimated a multinomial logit model to link farmers' characteristics to the choice technologies. The findings showed that investments in land management are driven by factors such as land tenure security, level of poverty and participation in community organizations (social capital), and most importantly, that household level of property reduces the probability of adoption of most technologies, while social capital and land tenure security increase it.

Hassan and Nhemachena (2008) analysed determinants of farm-level climate change adaptation measures in Africa using a multinomial choice model fitted to data on over 8000 farmers in 11 African countries. The results indicated that specialized crop cultivation (mono-cropping) is the agricultural practice most vulnerable to climate change in Africa. Better access to markets, extension and credit services are critical for helping African farmers adapt to climate change. Nhemachena and Hassan (2007) examined farmers' adaptation strategies to climate change in Southern Africa based on a cross-sectional database of three countries (South Africa, Zambia and Zimbabwe) and results confirmed access to credit, information (climatic and agronomic) as well as to markets (input and output) can significantly increase farm-level adaptation.

In their study, Ransom, *et al.* (2003) used a tobit model to determine socio-economic, physical and technology factors that influence the use of improved varieties by farmers. Khetlandarea, ethnic group, years of fertilizer use, off-farm income, and contact with extension significantly and positively affected adoption of improved varieties. Farmers in Village Development

Committees (VDCs) in central Nepal reported lack of seed to be the major constraint to the adoption of improved varieties while lack of knowledge of new varieties was the major constraint for farmers in the western VDCs.

Ogada, *et al.* (2010) observed in their study on production risk and farm technology adoption in the rain-fed semi-arid lands of Kenya, that household size, education level of household head, social capital, average plot slope, secure land tenure were statistically significant and positively correlated with terracing while sex of household head, location, loamy soil were negatively correlated. Sex of household head, average plot distance from farm household had positive relationship with manure adoption while distance of plot from homestead, location, average soil type and extension contact had negative relationship. Sex of household head, and extension contact were positively related with fertilizer adoption while location had negative relationship.

2.13 Theoretical Framework

One of the theories reviewed in this study is utility theory which is concerned with people’s choices and decisions. It is concerned also with preferences and with judgments of preferability, worth, value, goodness or any of a number of similar concepts (Fishburn, 1968). This theory provides a methodological framework for the evaluation of alternative choices made by individuals, firms and organizations. Utility refers to the satisfaction that each choice provides to the decision maker. Thus, this theory assumes that any decision is made on the basis of the utility maximization principle according to which the best choice is the one that provides the highest utility (satisfaction) to the decision maker.

Utility theory is often used to explain the behaviour of individual consumers. In this case the food crop farmer plays the role of the decision maker that must decide how much each of the many available climate change adaptation strategies to use so as to secure the highest possible level of total utility subject to his or her available income, prices, and other factors.

The traditional framework of utility theory has been extended over the past three decades to multi-attribute case, in which decisions are taken by multiple criteria. In all cases the utility that the decision maker (i.e. food crop farmer) gets from selecting a specific choice of climate change adaptation strategy is measured by a utility function U, which is a mathematical representation of the decision maker's (food crop farmer) system of preferences such that: $U(x_1) > U(x_2)$, where choice of climate change adaptation x_1 is preferred over choice x_2 or$Ux_1 = Ux_2$, where choice x_1 is indifferent from choice x_2 – both choices are equally preferred.The climate change adaptation strategies adopted by the food crop farmers will be modelled into stochastic frontier models to determine their technical and profit efficiency levels in their food crop production activities in south-western Nigeria and those strategies that can lend themselves to policy formulation will be simulated to see their effects on the efficiency levels.

Another theory relevant to this study is the theory of production. Production is the process of transforming set of inputs to output. The economic theory of production provides the analytical framework for most empirical research on productivity and efficiency. Productive efficiency means the attainment of a production goal without waste. Beginning with this basic idea of "no waste", economists have built up a variety of theories on efficiency. The fundamental idea underlying all efficiency measures, however, is that of the quantity of goods and services per unit of input. Consequently, a production unit is said to be technically inefficient if too little output is being produced from a given bundle of inputs. There are two basic methods of measuring efficiency—the classical approach and the frontier approach. The classical approach is based on the ratio of output to a particular input, and is termed partial productivity measure. Dissatisfaction with the shortcomings of this approach led economists to develop advanced econometric and linear programming methods for analysing productivity and efficiency. The frontier measure of efficiency implies that efficient firms are those operating on the production frontier. The amount by which a firm lies below its production frontier is regarded as the measure of inefficiency. The earliest work on the frontier approach dates back to Farrell (1957).

The production function stipulates the technical relationship between inputs and output in any production schema or processes (Olayide & Heady, 1982). In their own view, Adegeye and Dittoh (1985) explained production function as the relationship between factors of production or inputs and product (or output). They also said that production function can be studied under the following main headings namely; factor- product relationship, factor- factor relationship and product – product relationship.

In his view, Oji (2002) explained the production function to mean, the technical relationship, which connects factor inputs with outputs. It describes the way in which the quantity of a particular product depends upon the quantities of particular inputs used. He further said that production function could be represented in a mathematical, tabular, or graphical form. The theoretical definition of a production function has been based on expressing the maximum amount of output obtainable from given input bundles with fixed technology. This is regarded as estimating average production. This definition assumes that technical inefficiency is absent from the production function. This is exactly what ordinary least square (OLS) model assumes, that is, any deviation of output from frontier (actual) output is due to traditional errors (such as measurement error and error resulting from the inability of the model to capture all variables). For this, OLS assumes that producing units are fully efficient in the use of production resources. The stochastic frontier production and profit functions assume that there are inefficiencies in food crop production as explained below.

2.14 Analytical Framework

The type of analytical tools or techniques to be used in research studies depend to a considerable extent on the purpose for which the model is being estimated, nature of the study, available data, type of data (cross-sectional, time series and panel), convenience of the analysis, other econometric underpins and advantages derived from the tools. Available studies on effects of climate change on agriculture made use of Ricardian model, which capture climate variables like temperature and precipitation to look at the effect of climate on crop and livestock. The Ricardian approach is a cross-sectional model which was named after David Ricardo (1772–1823) because of his original observation that land rents would reflect the net productivity of farmland (Mendelsohn & Dinar, 2003). In Ricardian model net revenue or land value were used as the dependent variable modeled against temperature and precipitation and other variables as the independent (or explanatory) variables. The Ricardian approach has been applied to examine the sensitivity of agriculture to changes in climate. It was mainly used to assess economic impacts of climate change on agriculture in some studies (Benhin, 2006; Deressa, 2008; Eid *et al.*, 2006; Sene *et al.,* 2006) by regressing net revenue (or crop net revenue) per hectare as response variable with climate (temperature and precipitation), hydrological, soils and socio-economic variables taken as explanatory variables. But this present study is not looking at the effect of climate change on crop production but the effects of climate change adaptation strategies on food crop production efficiency in southwestern Nigeria. It has already been established in literature that the climate has changed in Nigeria in general and southwest in particular. Selected farmers' coping strategies are going to be linked with some socio-economic variables as determinants (i.e. efficiency changing variables) of technical and profit efficiencies in food crop production in southwestern Nigeria. Hence the use of stochastic production and profit models to measure efficiency levels of the food crop farmers, which have been widely used in efficiency measurement. Other analytical tools that will be used in this study are multinomial discrete choice model (particularly multinomial logit model) and factor analysis.

2.14.1 Stochastic Frontier Production Function

The Stochastic Frontier Production Function (SFPF) also known as “composed error model” of Aigner *et al.* (1977), Meeusen, & Van den Broeck (1977). The modeling, estimation and application of stochastic frontier production function to economic analysis assumed prominence in econometrics and applied economic analysis during the last two decades (Ojo, 2003). Early applications of Stochastic Frontier Production Function (SFPF) to economic analysis include those of Aigner *et al.* (1977) in which they applied the stochastic frontier production function in the analysis of the US agricultural data.

Battese and Corra (1977) also applied the technique to the pastoral zone of Eastern Australia. And more recently, empirical applications of the technique have been reported in the Africa setting, such as Ajibefun & Abdulkadri (1999), Ajiibefun (2006; 2007), Ajibefun *et al. (*2006), Obwona (2006). In addition, the economic applications of Stochastic Frontier Production Function (SFPF) for inefficiency analysis in non-African settings include Huang and Liu (1994); Kurkalova & Jensen (2000); Oren & Alemdar (2006) and Chavanapoonphol *et al.* (2005).

The stochastic frontier model in terms of a general production function for the its production unit (PU) is;

$$y_i = f(x_i, \beta) + V_i - U_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

$$= f(x_i, \beta) + \varepsilon_i$$

Where i = 1,. . . N

y_i is the scalar output in a specified unit for ith production unit.

x_i denotes the vector of inputs used for production.

$\beta_i$is a vector of production function parameters to be estimated.

The frontier production function *f* (x_i, β) is a measure of maximum potential output for any particular input vector x_i. The V_i and U_i cause the actual production to deviate from this frontier. The V_{ii}s the usual symmetric noise associated with random factors not under the control of the firms or farmers (e.g. climate, natural hazards, etc.). The V_i is assumed to be independently identically distributed with zero mean and constant variance that is, V_{is}~iid N (0 σv^2) and independent of $U_{i..}$ The U_i is a non-negative term representing the deviation from the frontier production function, which is attributed to controllable factors (technical inefficiency). The U_{is} are also assumed to be independently and identically distributed as for example, exponential (Meeusen & Van den Broeck, 1977); half normal (Aigner *et al.,* 1977); a truncated normal distribution (Stevenson, 1980) and the gamma density (Greene, 1980).

The stochastic frontier production model was established using the Maximum Likelihood Estimation (MLE) procedure- a maximization technique (Olowofeso & Ajibefun, 1999).

Assumptions of the Maximum Likelihood Method (MLM), according to Koutsoyiannis (1977) are as follows;

(i) the form of the distribution of the parent population of Y's is assumed known. In particular, we assume the distribution Y_i is normal;

(ii) the sample is random, and each e_i is independent of any other value e_j (or, equivalently, Y_i is independent of Y_j); and

(iii) the random sampling always yields the simple most probable results: any sample is representative of the underlying population. This is a strong assumption, especially for small samples. The estimation of normality is crucial for the estimation procedure in ML, while in OLS the assumption of normality is only necessary for the tests of significance but not for the estimation procedure of the b's.

The Maximization Likelihood Method (MLM) consists of the maximization of the likelihood function. From the general conditions of maximization, we know that the maximum value of a function is that value where the first derivatives of the function with respect to its parameters are equal to zero (Koutsoyiannis, 1977)

Technical efficiency (TE) of an individual firm or producer is defined as the ratio of the observed output (y) to the corresponding frontier output (y*), conditional on the levels of inputs used by the firm or production unit. Thus the technical efficiency (TE) of a firm or production unit i in the context of the Stochastic Frontier Production Function (SFPF) (1) is

$TE = y_i/y^* = \ln y_i/\ln y^*$

$= f\ (x_i, \beta) + v_i - u_i\ /\ f\ (x_i, \beta) + v_i$

$= \exp\ (-u_i)$……………….. ……………………………………... (2)

So that, $0 \geq TE \leq 1$.

Following Jondrow*et al.* (1982), the density function of u and v, respectively, can be written as:

$f\ (u) = 1\sqrt{}\ (1/2\pi)\ (1/\sigma_v)\ \exp\ (-u^2/2\sigma_u^2);\ u \geq 0$ …………………………...(3)

$f\ (v) = 1\sqrt{}\ (1/2\pi)\ (1/\sigma_v)\ \exp\ (-v^2/2\sigma_V^2);\ -\infty \leq v \leq \infty$……………………..(4)

The density function of y which is the joint density of (V-U) is given as

$f\ (y) = 1/\{\sigma\sqrt{(1/2\pi)}\}\exp\ (-\omega^2/2\sigma^2)[1-F\{(\omega/\sigma)\gamma/1-\gamma)\}$………..………(5)

Where F (.) is the cumulative distribution function of the standard normal variable and

$\omega = v - u$

$\sigma^2 = \sigma_u^2 + \sigma_v^2$; and

$\gamma = \sigma_u^2 / \sigma_u^2 + \sigma_u^2)$…………………………………………………..…..(6)

Where r lies in the interval (0,1).

The likelihood function of the sample is then written as;

$F(y;\Theta) = \pi[1/\sigma\sqrt{}\,(\pi/2)\exp(-1/\omega^2/2\sigma^2)\,(1-F\,\{(\omega/\sigma)\,(\gamma/(1-\gamma\}]$……………(7)

Where t is the parameter, σ^2 and γ.

Measurement of u for individual observations is derived from the conditional distribution of u, given (v-u). (Jondrow *et al.*, 1982; Kalirajan & Flinn, 1983). Given the normal distribution for v and a half- normal distribution for u, the conditional mean of U given (v-u) is:

$E\,(u/v-u) = \int uf\,(u/v-u)\,\delta u$ ……………………………………….………(8)

Where f (u/v-u) / f (v-u). The density function of u, given (v-u), using equations (3) and (4) is equivalent to

$F(u/v-u) = 1\sqrt{2}\pi\sigma/\sigma_u\sigma_v \exp\,[-\sigma_u^2 / 2\sigma_u^2\,\sigma_v^2\,(u+\sigma_u^2/\sigma^2)^2]\;1/\{-F(.)\}$….……..(9)

Where f(.) is the standard normal distribution function Now,

$E\,(u/v-u) = (-\sigma u\sigma v/\sigma)\,[f\,(.) / (1-F(.) - (v-u)/\sigma\,\sqrt{}\gamma/(1-y)]$………………. (10)

Where f (.) and F(.) are the values of the standard normal and cumulative normal density functions, respectively

Estimates of E (u/v-u) are obtained by evaluating

Equation 10 at the ML estimates of γ,σv and σu. Technical efficiency for each farmer is then calculated as:

TE= exp (E (u/v-u) ……………………….…………………………….. (11)

2.14.2 The Stochastic Frontier Profit Function

The stochastic frontier profit function has been used by various authors like Rahman (2003) in determining the efficiency of Bangledish rice farmers. Abdulai and Huffman (2000) also applied this methodology in their study on structural adjustment and economic efficiency of rice farmers in Northern Ghana. Ogundari (2006) also used stochastic frontier profit analysis in his study determinants of profit efficiency among small scale rice farmers in Nigeria.

Consider a farm that maximizes profits subject to competitive input and output markets and a single-output technology that is quasi-concave in the (n x 1) vector of variable inputs, X, and the (m x 1) vector of fixed factors, Z. Although competitive input and output markets are assumed, what is essential is the fact that all output and input prices be exogenous to the agricultural household and farm. This applies fully in the case of inputs used in food crop production and their prices in Nigeria. The actual normalized profit function that is assumed to be‘‘well-behaved’’ can be expressed as:

$\Pi(p, Z) = Y(X^*, Z) - \Sigma\, piX^*i\ , X^* = g(p, Z)$.. (1)

Where $Y(\bullet)$ is the production function; the asterisk denotes optimized values; $pi = W/P$; pi is the normalized price of input i; and P and W are the output and input prices, respectively. The stochastic profit function can then be expressed as

$p = f\,(pij, zkj)\ .\exp\ ej$,... (2)

where Π_j is normalized profit of the jth farm, computed as gross revenue less variable cost, divided by farm specific output price P; pij is the normalized price of input i for the j th farm, calculated as input price divided by farm specific output price P; Zkj is the level of the kth fixed factor for the jth farm; and ej is an error term. The error term, ej, is assumed to behave in a manner consistent with the frontier concept

$ej = Vj - Uj$,... (3)

where Vj is the symmetric error term and Uj is a one-sided error term. The Vjs are assumed to be independently and identically distributed as $N(0,\sigma^2_v)$. We assume that Uj has a half-normal nonnegative distribution $(0, \sigma^2_u)$. The error terms Uj and Vj are also assumed to be independent of each other. The error term Uj is used to represent inefficiency. That is, it represents profit shortfall from its maximum possible value given by the stochastic frontier. Thus, if $Uj= 0$, the firm lies on the profit frontier, obtaining potential maximum profit given the prices it faces and the levels of fixed factors. If $Uj>0$, the firm is economically inefficient, and profit is less than the maximum.

An average frontier model results if the frontier model is estimated without the one-sided disturbance term, Uj. Farrell has criticized this approach. By contrast, a full deterministic or full frontier model, often estimated by linear programming techniques, results if the random error term Vj is omitted. It is essential to estimate the frontier function to provide an estimate of industry best-practice profit for any given level of prices and fixed factors. An estimated value of profit efficiency for each observation can be calculated as exp $(-Uj)$.

Following Jondrow, Lovell, Materov, and Schmidt (1982) the unobservable value of Uj may be obtained from its conditional expectation given the observable value of $Vj-Uj$. The farm-specific profit inefficiency index (PIE) is given as

$\text{PIE} = (1 - \exp[-Uj])$.. (4)

The objective of the study on determining effects of the adaptation strategies to climate change on profit efficiency will be achieved by relating the profit inefficiency index to farm and climate change adaptation strategies or measures. This can be specified as $\text{PIE} = g(X) + w$, where PIE is the profit inefficiency index, X is a vector of climate change adaptation strategies and wi is the unexplained component of inefficiency, for example, weather and prices peculiar to a particular farm. The profit inefficiency index is therefore hypothesized to be related to attributes of the farm household. In this case climate change adaptation strategies used by the food crop farmers linked with their socio-economic characteristics is hypothesised as the efficiency changing variables.

2. 14. 3 Multivariate Discreet Choice Model

The analytical approaches that are commonly used in an adoption decision involving bivariate choices are logit, probit, and tobit models, among others but for those studies involving multiple choices are the multinomial logit (MNL); multinomial probit (MNP); ordered probit; and ordered logistic models, among others. Both the MNL and MNP are important for analysing farmer adaptation decisions as these are usually made jointly. These approaches are also appropriate for evaluating alternative combinations of adaptation strategies, including individual strategies (Hausman & Wise, 1978; Wu & Babcock, 1998). This study adds to these analyses by distinguishing household and other socioeconomic factors affecting propensity of use of each of the main adaptation measures available to farmers. The distinguishing feature is that it uses a multivariate discrete choice econometric model to simultaneously examine the relationships between each adaptation option and a common set of explanatory variables (Nhemachena & Hassan, 2007).

The advantage of using this approach as opposed to univariate (single-equation) technique is that it explicitly recognizes and controls for potential correlation among adaptation options and therefore provides more accurate estimates of relationships between each adaptation option and its explanatory variables. The univariate technique on the other hand is prone to biases due to common factors in situations where there are unobserved and unmeasured common factors affecting the different adaptation options (Nhemachena & Hassan, 2007). This study also used a

MNL logit model to analyse the determinants of farmers' decisions because it is widely used in adoption decision studies involving multiple choices and is easier to compute than its alternative, the MNP.

MNP models are, however, not commonly used, since it is difficult to compute the multivariate normal probabilities for any dimensionality higher than two, i.e. more than two (bimodal) choices (Greene, 2000).

The advantage of using a MNL model is its computational simplicity in calculating the choice probabilities that are expressible in analytical form (Tse,1987). This model provides a convenient closed form for underlying choice probabilities, with no need of multivariate integration, making it simple to compute choice situations characterized by many alternatives. In addition, the computational burden of the MNL specification is made easier by its likelihood function, which is globally concave (Hausman & McFadden, 1984). The main limitation of the model is the independence of irrelevant alternatives (IIA) property, which states that the ratios of the probabilities of choosing any two alternatives remain the same irrespective of the number of alternatives available (Hausman & McFadden, 1984; Tse, 1987).

Farmers' adaptation strategies can be evaluated on the basis of alternative adaptation strategies, which can be easily linked to utility. According to Greene (2000), the unordered choice model could be motivated by a random utility framework, where for the i_{th} household faced with j technology choices, the utility of technology choice j is given by

$$U_{ij} = \beta_j X_{ij} + \varepsilon_{ij} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where U_{ij} is the utility of food crop farmer household i derived from adaptation strategy choice j, X_{ij} is a vector of factors that explain the decision made on adaptation strategies, and β_j is a set of parameters that reflect the impact of changes in X_{ij} on U_{ij}. The disturbance terms εij are assumed to be independently and identically distributed. If farmers choose adaptation strategy *j*, then *Uij* is the maximum among all possible utilities. This means that

$$U_{ij} > U_{ik} \forall k \neq j \text{ ....} (2)$$

where U_{ik} is the utility to the i_{th} farmer from technology k. Equation (2) means that when each adaptation strategy is thought of as a possible adoption decision, food crop farmers will be expected to choose the adaptation strategy that maximizes their utility given available alternatives (Dorfman, 1996). The choice of *j* depends on X_{ij}, which includes aspects specific to the household and plot of farm, among other factors. Following Greene (2000), if Y_i is a random variable that indicates the choice of adaptation measure by any food crop farming household. We assume that each farmer faces a set of discreet, mutually exclusive choices of adaptation strategies or measures. The MNL model for adaptation choice specifies the following relationship between the probability of choosing option A_i and the set of explanatory variables X as (Greene, 2003):

$$\Pr(Y_i = j) = \frac{e\beta_j'{}_{ij}}{\sum_{j=0}^{j} e^{\beta_j x_{ij}}}, \; j = 0,1,2,...,J \text{ ....}(3)$$

Estimating equation (3) provides a set of probabilities for *j*+1 technology choices for a decision maker with characteristics *Xij*. The equation can be normalized by assuming that $\beta_0 = 0$, in which case the probabilities can be estimated as

$$\Pr(Y_i = j) = \frac{e\beta_j' x_{ij}}{1 + \sum_{m=1}^{3} e^{\beta_m x_{ij}}}, \; j = 1,2,...,J \text{ ....}(4)$$

$$\Pr(Y_i = j) = \frac{1}{1 + \sum_{m=1}^{j} e^{\beta_m x_{ij}}} \text{.......... ....}(5)$$

Normalizing on any other probabilities yields the following log-odds ratio:

$$\ln\left[\frac{P_{ij}}{P_{ik}}\right] = x_i^{'}(\beta_j - \beta_m)\text{.........}\quad\text{..........}\quad\text{..........}\quad\text{..........}\quad\text{..........}\quad\text{..}(6)$$

In this case, the dependent variable is the log of one alternative relative to the base /reference alternative. The coefficients in an MNL model are difficult to interpret, and associating the β_j with the j^{th} outcome is tempting and misleading. To interpret the effects of explanatory variables on the probabilities marginal effects are usually derived as Greene (2000):

$$m_j = \frac{\partial P_j}{\partial x_i} = P_j\left[\beta_j - \sum_{k=0}^{j} P_k \beta_k\right] = P_j\left[\beta_j - \sum_{k=0}^{j} P_k P_k\right] = P_j\left[\beta_j - \overline{\beta}\right]\text{.....}(\ 7)$$

The marginal effects measure the expected change in probability of a particular choice being made with respect to a unit change in an explanatory variable (Long, 1997; Greene, 2000). The signs of the marginal effects and respective coefficients may be different, as the former depend on the sign and magnitude of all other coefficients.

2.14.4 Factor Analysis Model

Another econometric model that was used in this study is factor analysis (FA). FA seeks to reduce a large set of measured variables in terms of relatively few new dimensions, known as factors. According to Johnson and Wichern (1992) and Hair, Anderson, Tatham, and Black (1995), the purpose of FA is to describe the covariance relationships among many variables in terms of a few underlying, but unobservable, random quantities called factors, interpreted through weights of the variable called factor loadings organised in a matrix of factor loadings. The FA model is organised in such a way that all variables within a particular group are highly correlated among themselves, but have relatively small correlations with variables in another group (Makhura, Goode & Coetzee, 1997). Typically, factors used for further analysis should contain unique variables. However, such a restriction can be relaxed when the results are just intended for understanding the pattern of relationships. Thus, factor analysis is an appropriate method of answering the basic question of which constraints the food crop farmers are facing in adoption of climate change adaptation strategies in the south-western zone of Nigeria. This procedure will be applied in this study to identify dimensions in which these constraints affect the adoption of adaptation strategies to climate change in food crop production.

The factor analysis model can be expressed in matrix form as:

$$\mathbf{x} = \mathbf{\Lambda f} + \mathbf{e}$$

Where $\mathbf{x}$ is the vector of n observable variables

$\mathbf{f}$is the vector of m unobservable factors,

$\mathbf{\Lambda}$ is called the loading matrix of the order nfm

$\mathbf{e}$is the error vector of $nx1$.

As indicated earlier, the aim of the factor analysis is to account for the correlation of the covariance between the response variables in terms of a smaller number of factors.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Area

The study area is the Southwestern zone of Nigeria. There are six states in the zone namely, Ekiti, Ondo, Osun, Ogun, Oyo and Lagos. It is located in the coastal region of the Nigeria and is characterized by humid to sub-humid eco-climate. The vegetation ranges from forest to savanna woodland or forest-savanna transition zone (Adebayo *et al.,* 2011), as shown in figure 3.1. It is bounded in the north and east by Kwara and Kogi states of Nigeria; in the west by the Republic of Benin and in the south by the Atlantic Ocean. Adebayo *et al*. (2011) observed that crop production is the dominant agricultural enterprise that farmers in southwest Nigeria engage in. It is practiced by over 90% in the savanna and rainforest zone, but only 37.82% in the swamp regions where the primary agricultural enterprise is fishing/fish farming. Based on this, Lagos State was exempted from the study.

The principal food crops grown in the zone are yams, cassava and maize, (Fasola, 2007). Root crops grown in the zone are cassava, yams, taro (*cocoyams*), and sweet potatoes. The main cash crops in the zone are cocoa, oil palm, and rubber. This study focused on the major food crops (yam, cassava, maize and cocoyam).

According to 2006 Census as stipulated by the National Bureau of Statistics {NBS}, the population of the south-west zone is 27,581,992.

Figure 3.1: Map of Southwestern Nigeria showing Ecological zones

Source: Fasola, 2007.

3.2 Sampling Technique

For the purpose of this study, multistage sampling techniques were used in the selection of respondents (food crop farmers). Firstly, two (2) states were randomly selected from five south-western states, considering the two dominant agro-ecological zones (i.e. savanna and rainforest) in the region. Ekiti and Oyo states belong mainly to savanna dominated agro-ecological zone. Ondo, Ogun and Osun states mainly belong to rainforest agro-ecological zone. Ekiti and Ondo states were randomly selected from the savanna and the rainforest agro-ecological zones respectively. (Lagos state was not included). For administrative reasons, each of the two (2) states was divided into two agricultural zones by Agricultural Development Programme (ADP). Secondly, the four (4) agricultural zones in the two (2) states were selected. Thirdly, three (3) extension blocks were randomly selected from each agricultural zone, making twelve (12) extension blocks in all. Fourthly, two (2) farming villages/ communities were randomly selected from each extension blocks making a total of twenty-four (24) villages/communities. Lastly, in each community/farming village, with the assistance of the local extension personnel, a list of food crop farm households was compiled and then fifteen (15) food crop farmers were randomly selected, making a sample size of three hundred and sixty (360) food crop farmers, 180 from each state were selected for the in-depth interview.

Table 3.1: Summary of the Study Location and Sample Chosen

State	Zone	Block	Farming village/ Community	Respondents (Sample)
Ondo (Rainforest)	Ondo North	Akoko South West (Oka)	Oka Akoko	15
			Akungba Akoko	15
		Akoko North East (Ikare)	Ikare Akoko	15
			Okorun	15
		Akure North	Igoba	15
			Ita Ogbolu	15
	Ondo Central	Okitipupa	Ode Aye	15
			Igbotako	15
		Irele	Irele	15
			Ore	15
		Odigbo	Araromi-Obu	15
			Aiyesan	15
Ekiti (Savanna)	Zone I	Ekiti West (Aramoko)	Erio	15
			Aramoko	15
		Moba	Osun	15
			Otun	15
		Ekiti South West (Ilawe Ekiti)	Ilawe	15
			Ogotun	15
	Zone II	Ikole	Odo-Oro	15
			Ipao	15
		Emure	Eporo	15
			Gbooge	15
		Ekiti East	Omuooke	15
			Ilasa	15
Total	**4**	**12**	**24**	**360**

3.3 Data Collection

Data for this study were collected from primary source. Primary data was collected through survey with the help of Agricultural Development Programmes (ADPs) extension workers and/or Fadama community facilitators of the two (2) selected states as the enumerators at the extension block level. Primary data was collected using structured interview schedule and/or questionnaire. The data collection instrument focused on input-output data, socio-economic factors, climate change adaptation strategies used by the farmers, capital resource used, agrochemicals used and other relevant information. The data were collected between October and December, 2011(9 weeks).

3.4 Data Analysis

The data for this study were analysed using both descriptive and inferential statistics. Objectives (i) and (ii) were realised using descriptive statistics, namely percentages and frequencies. Objective (iii) was realised using multivariate discreet choice model (i.e. multinomial logit model); Objective (iv) was realised using stochastic frontier production and profit models; Objective (v) was achieved using technical and profit inefficiency models; Objective (vi) was achieved using stochastic frontier models through simulation at different percentages (10% and 20%); and Objective (vii) was achieved using factor analysis model. The following models were specified for the data analysis;

3.4.1. Likert-Type Rating Scale Technique

This technique was used to compliment and further explain objective (ii). To actually know that an adaptation strategy is used by the food crop farmers to cope with climate change, this 3- point likert-type rating technique was developed to know the level of intensification of each strategy.

The 3-point likert-type rating scale was graded as Very High Intensification (VHI) = 3, High Intensification (HI) = 2, and Low Intensification (LI) = 1. The mean score of respondents based on the 3-point likert-type rating scale was computed;

$$3 + 2 + 1 = \frac{6}{3} = \underline{\textbf{2.00}\text{ cut off point}}$$

Using the interval scale of 0.05, the upper limit cut-off point is 2.00 + 0.05 = 2.05; the lower limit is 2.00 – 0.05 = 1.95. On the basis of the limit, mean scores below 1.95, (i.e. MS < 1.95) were ranked "Low Intensification" (LI); those between 1.95 and 2.49 were considered "High Intensification" (i.e. 1.95 ≥ MS ≤ 2.04) while mean scores that are greater than or equal to 2.05 (i.e. MS ≥ 2.05) were considered "Very High Intensification" (VHI).

3.4.2 Multivariate Discreet Choice Model

The Multinomial logit (MNL) model for climate change adaptation choice specifies the following relationship between the probability of choosing option A_i and the set of explanatory variables X as (Greene, 2003):

$$\Pr(Y_i = j) = \frac{e\beta_j^{'} x_{ij}}{1 + \sum_{m=0}^{6} e^{\beta_m x_{ij}}}, \quad j = 0,1,2,3,\ldots, 6$$

Where β_j is a vector parameter that relates the socio-economic, farm and institutional characteristics x_i to the probability that $Y_i = j$. Because the probabilities of the six (6) main climate change adaptation strategies must sum to one, a convenient normalization rule is to set one of the parameter vectors, say $\beta_{0,}$ equal to zero ($\beta_0 = 0$). The probabilities for the six (6) alternatives then become (Greene,2000):

$$P_j \equiv \Pr(Y_i = j) = \frac{e^{\beta_j^{'}} x_{ij}}{1 + \sum_{m=0}^{6} e^{\beta_m x_{ij}}}, \; j = 1,2,3,\ldots, 6$$

$$P_0 \equiv \Pr(Y_i = 0) = \frac{1}{1 + \sum_{m=1}^{6} e^{\beta^{'}_m x_{ij}}}$$

The estimated parameters of a multinomial logit system are more difficult to interpret than those in a bivariate (or binomial) choice model. Insight into the effect that the explanatory variables have on the climate change adaptation strategies decision can be captured by examining the derivative of the probabilities with respect to the kth element of the vector of explanatory variables. These derivatives are defined as (Greene, 2000):

$$\frac{\partial \Pr(Y_i = j)}{\partial x_{ik}} = P_j \left[\beta_{jk} - \sum_{m=0}^{6} \Pr(Y_i = m) \beta_{jk} \right] j = 0, 1, ,..., 6; k = 1,..., k$$

Clearly, neither the sign nor the magnitude of the marginal effects need bear any relationship to the sign of coefficients.

The Y_i is the probability of choosing a climate change adaptation strategy. The following are the main climate change adaptation strategies used among the food crop farmers;

1. using different or multiple crop types and varieties
2. change in location of food crop farmlands/plots (i.e. land fragmentation/ land use planning)
3. change in timing of operations/ change in planting dates (i.e. multiple planting dates)
4. crop diversification (i.e. changes in crop mix)
5. diversification of source of household income to unrelated off-farm employment (off-farm employment opportunities)
6. planting of cover crops (cover cropping).

X_i= socio-economic, farm-specific and institutional variables.

- Socio-economic variables that were used partly as independent variables include:

Household size (X_1) = Number of individuals in the household.

Age (X_2) = Age of household head in years.

Education level of farmer (X_3)= number of years of schooling of household head.

Years of climate change awareness (X_4) = number of years of household head's awareness of climate change.

Sex of household head (X_5) = sex category of household head (dummy1for male; 0 otherwise).

- Farm-specific variables that were used partly as independent variables include:

Farm size (X_6) = measured in hectares.

Average distance from homestead to the farm(s) (X_7) = Average distance from homestead in kilometres.

- Institutional variables that were used partly as independent variables include:

Access to extension services (X_8) = number of formal extension visit in the cropping season.

Tenure security (X_9) = Dummy 1 for the right of the farmer to transfer the farm land to the next generation; 0 otherwise.

Social capital (X_{10}) = Number of relatives involved in the discussion of farming issues in the village, excluding the farmer's household members.

Access to credit facilities (X_{11}) = access to formal credit (dummy 1 for access to credit; 0 otherwise).

3.4.3 Stochastic Frontier Models

3.4.3.1 Stochastic Frontier Production Function

The data in this study was fitted into Cobb-Douglas and average production forms of stochastic frontier production function and the best form will be selected through the use of generalized log-likelihood test after meeting the econometric requirements.

Cobb-Douglass production form:

$$\ln Y_i = \beta_o + \sum \beta_i \ln(X_i) + (V_i - U_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (1)$$

Where:

β_{is} = parameters estimates. Σ is the sign of summation.

Y_i = the value of output in naira,

X_1=the total labour used in food crop production in mandays;

X_2=the total land area (farm size) used in food crop production in hectares;

X_3= the total quantity of fertilizer used in food crop production in kilogrammes;

X_4= the total value of other agrochemicals (i.e. pesticides and herbicides) used in food crop production in naira, and

X_5= the depreciated value of farm implements (i.e. hoes, cutlasses, watering can, etc.) in naira. It was calculated using straight line method of calculating depreciation. That is, Depreciation is

$$\frac{\text{Purchasing cost of the asset- salvage value}}{\text{Life span of the asset in years}}$$

The V_is are random errors that are assumed to be independent and identically distributed as N $(0,\sigma v^2)$ random variables; and the U_is are non-negative technical inefficiency effects that are assumed to be independently distributed among themselves and between the V_is such that U_i is defined by the truncation of the N (U_i, σ) distribution, where U_i is defined by:

Technical Inefficiency Effects Model

$$U_i = \delta_o + \sum_{i=1}^{8} \delta_i Z_{ji}$$

U_i= inefficiency effect; δ_i= coefficients of climate change adaptation strategies and socio-economic factors.

Z_{ji}= climate change adaptation strategies and socio-economic factors (i.e. hypothesised efficiency changing variables).

Z_1= land fragmentation (number of farm plots used for food crop production as a result of change in climate);

Z_2= off-farm employment (income from unrelated employment in naira in order to adapt to climate change);

Z_3= Adjustment in farm size (1 if increase in farm size in order to adapt to climate change, 0 otherwise);

Z_4= multiple sowing dates/ different planting dates (number of sowing dates as a result of climate change in the cropping season);

Z_5= crop diversification (number of crop mix practiced by the farmer as a result of climate change);

Z_6= level of education in years (number of years of schooling);

Z_7= years of awareness of climate change, and

Z_8= social capital (number of relatives involved in the discussion of farming issues in the village, excluding the farmer's household).

To choose the functional form that best describes the inefficiency effect, the following hypothesis was tested;

> H_0: $\gamma = \delta_0 = \delta_1 = \ldots \delta_8 = 0$, this hypothesis specifies that the technical inefficiency effects are not present in the model. If this hypothesis is accepted, then the food crop farmers are fully technically efficient. Then, the data will be better analysed using average production function rather the frontier function, which assumes the presence of inefficiency in food crop production.

Test of the above hypothesis was obtained by using the generalized likelihood-ratio statistic, which is defined by;

$\lambda = -2 \ln [L(H_0)/L(H_1)] = -2 \ln[L(Ho)-L(Hi)]$

Where L (H_0) is the value of the likelihood function for the average production function (Model 1), in which the parameter restrictions specified by the null hypothesis, H_0 are imposed; and L (H_1) is the value of the likelihood function for the general frontier model. If the null hypothesis is true, then λ has approximately a Chi-square (or a mixed square) distributed with degrees of freedom equal to the difference between the parameters under H_1 and H_0, respectively; that is the number of parameters excluded in the model.

3.4.3.2 Stochastic Frontier Profit Function

The data in this study was fitted into average and Cobb-Douglas profit functional forms and the best form was selected through the use of generalized log-likelihood test after meeting the econometric requirements.

Cobb-Douglass profit functional form:

$$\ln \prod_i = \alpha_0 + \sum \alpha_i \ln(X_i) + (V_i - U_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where:

α_{is} are parameters to be estimated.

Π_i= the normalized profit of the j_{th} food crop farmer, computed as gross farm revenue from food crop farm less variable cost divided by the sample mean of the output value in naira,

X_1=the price of labour used in food crop production normalized by the sample mean of the output value in naira;

X_2=the rent on farm land used in food crop production normalized by the sample mean of the output value in naira;

X_3= the price of fertilizer used in food crop production normalized by the sample mean of the output value in naira;

X_4= the price of other agrochemicals (i.e. pesticides and herbicides) used in food crop production normalized by the sample mean of the output value in naira, and

X_5= the price of fixed assets (i.e. hoes, cutlasses, watering can, etc.) normalized by the sample mean of the output value in naira. It was calculated using straight line method of calculating depreciation.

Profit Inefficiency Effects Model

$$U_i = \delta_o + \sum_{i=1}^{8} \delta_i \lambda_{ji}$$

U_i= inefficiency effect; δ_j= coefficients of climate change adaptation strategies and socio-economic factors.

λ_{ji}= climate change adaptation strategies and socio-economic factors (i.e. hypothesized as efficiency changing variables).

λ_1= land fragmentation (number of farm plots used in food crop production as a result of change in climate);

λ_2= off-farm employment (income from unrelated employment in naira in order to adapt to climate change);

λ_3= change in farm size in hectares in order to adapt to climate change;

λ_4= multiple sowing dates/ different planting dates (number of sowing dates as a result of climate change in the cropping season);

λ_5= crop diversification (number of crop mix practised by the farmer as a result of climate change in the cropping season);

λ_6= level of education in years (number of years of schooling);

λ_7= years of awareness of climate change, and

λ_8= social capital (number of relatives involved in the discussion of farming issues in the village, excluding the farmer's household members).

To choose the functional form that best describes the inefficiency effect, the following hypothesis was tested;

> H_0: $\gamma = \delta_0 = \delta_1 =\ldots\delta_8 = 0$, this hypothesis specifies that the profit inefficiency effects are not present in the model. If this hypothesis is accepted, then the food crop farmers are fully profit efficient. Then, the data will be better analysed using average

production function rather the frontier function, which assumes the presence of inefficiency in food crop production

Test of the above hypotheses was obtained by using the generalized likelihood-ratio statistic, which is defined by;

$\lambda = -2 \ln [L(H_0)/L(H_1)] = -2 \ln[L(Ho)-L(Hi)]$

Where L (H_0) is the value of the likelihood function for the frontier model, in which the parameter restrictions specified by the null hypothesis, H_0 are imposed; and L (H_1) is the value of the likelihood function for the general frontier model. If the null hypothesis is true, then λ has approximately a Chi-square (or a mixed square) distributed with degrees of freedom equal to the difference between the parameters under H_1 and H_0, respectively; that is the number of parameters excluded in the model.

Objective (vii) was achieved using stochastic frontier production model and the selected climate change adaptation strategies and socio-economic variables were increased at 10% and 20%. This was done to establish the trend of the technical efficiency in food crop production in Southwestern Nigeria and suggestions were made on the importance of these variables to policy formulation.

3.4.4. Factor Analysis Model

Principal component analysis model was used in achieving objective (iv), which is specified as:

$Y_1 = a_{11}X_1 + a_{12}X_2 + * \ * *+ a_{1n}X_n$

$Y_2 = a_{21}X_1 + a_{22}X_2 + * \ * * + a_{2n}X_n$

$Y_3 = a_{31}X_1 + a_{32}X_2 + * * * + a_{3n}X_n$

* = *

* = *

* = *

$$Y_n = a_{n1}X_1 + a_{n2}X_2 + * * * + a_{nn}X_n$$

Where:

$Y_1, Y_2 \ldots Y_n$ = observed variables / constraints of food crop farmers on adoption of climate change adaptation strategies.

$a_1 - a_n$ = factor loadings or correlation coefficients.

$X_1, X_2, \ldots X_n$ = unobserved underlying factors constraining food crop farmers from adopting climate change adaptation strategies were retained, the study selected factors with high factor loadings scores ±0.4 or greater.

Hypotheses (i) and (ii) were tested using z-test and hypotheses (iii) and (iv) were tested using t-test as embedded in multinomial logit and stochastic frontier models, respectively.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1: SOCIO-ECONOMIC CHARACTERISTICS OF FOOD CROP FARMERS

4.1.1: Age of food crop farmers

Majority (70%) of all the food crop farmers, about 79% and about 61% of them in the Savanna and the Rainforest agro-ecological zones, respectively fall within 20-60 years age bracket. The average age of the respondents was 53 years in Southwestern Nigeria. And the age of the food crop farmers in the Savanna and Rainforest agro-ecological zones were about 51 years and 55 years, respectively (Table 4.1). These results imply that food crop farmers in the area were above the dependent age i.e. not within the economically active age range, which means that food crop production is tending towards the declining productivity class of greater than 50 years. This further implies that if the occupation does not witness the injection of young able men from now, food crop production may suffer set back. These findings agree with the study of Chavanapoonphol *et al.* (2005) that found out that Thailand rice farmers were quite old of average age of 51 years, and also agrees with the study of Nwaru and Onuoha (2010) that the respondents were a bit old with average age of about 52 and 55 years for smallholder food crop farmers using credit and those not using credit respectively in Imo State, Nigeria. But this disagrees with the findings of Otitoju (2008) which found out that small and medium-scale soybean farmers in Benue State, Nigeria had average age of about 33 and 39 years respectively.

4.1.2: Sex of the food crop farmers

Majority of (about 86%) of the respondents; 84% and 83% of them in the Savanna and the Rainforest agro-ecological zones respectively were male (Table 4.1). This implies that food crop production in Southwestern Nigeria is mainly dominated by male. This has implications for gender equality and calls for mainstreaming of women especially in agriculture where they constitute a bulk of the workforce.

4.1.3: Level of Education of food crop farmers

The results show that 17% of the food crop farmers, about 19% and 15% of them in the Savanna and the Rainforest agro-ecological zones, respectively never attended school, that is, they had no formal education, while about 83% of the respondents had formal education, about 81% and 85% of the respondents from the savanna and the rainforest agro-ecological zones, respectively, had formal education. Out of the 83% of the respondents that had formal education, about 32% of them only attended primary school, 30% attended secondary school while about 20% attended higher institution at various levels (Table 4.1). The average years of schooling of the respondents as estimated by this study was about 8 years (8.38 years for southwestern Nigeria, 8.63 years for the Savanna and 8.13 years for the Rainforest agro-ecological zones) as seen in Table 4.2. This implies that majority of them only attempted secondary schools or its equivalents. This agrees with the finding of Nwaru and Onuoha (2010) that found out that a greater parentage of smallholder food crop farmers (both credit using farmers and non-credit farmers) in Imo state, Nigeria, only attempted secondary school or its equivalent with average years of schooling of about 10 years and also agrees with the findings of Ogundari (2008) that rainfed rice farmers in Nigeria had the average age of schooling of 10 years. This suggests that majority of the food crop farmers in the study area were at least lettered (they could read and write).

4.1.4: Household size of the respondents

Family labour is recognized as a major source of labour supply in smallholder food crop production in most parts of Africa, Nigeria included. This comprises the labour of all males, females and children in a household, who contribute their mental and physical efforts to the household holdings. Majority of the respondents (47.8%) fell within the household size of 6 to

10, followed by 33% of the respondents which fell within the range of 1 to 5 household size (Table 4.1).

The result shows that, the average household size was 7.40 (about 7) for the respondents (food crop farmers). The average household size was 6 (6.21) and 9 (8.61) for those in the Savanna and the Rainforest agro-ecological zones, respectively. (Table 4.2). Household size for farmers in the Rainforest agro-ecological zone was more than their Savanna agro-ecological zone counterpart. However, this larger size does not translate to higher use of family labour. This result agrees with the finding of Otitoju and Arene (2010) that majority of the respondents (medium-scale soybean farmers in Benue State Nigeria) had the average family size of about 7 people. And this also agrees with the finding of Abdulai and Huffman (2000) that the rice farmers in Northern Ghana had the average household size of about 8 (8.4), but disagrees with the result of Nchare (2007) that found that the average family size of arabica coffee producers in Cameroun was 11.

4.1.5: Marital status of the respondents

The result shows that 0.8 % of the sampled food crop farmers were single. About 92% were married while 7% were divorced and none was widowed. And majority (90%) and about 94% of the respondents were married in the Savanna and Rainforest agro-ecological zone, respectively. About 8% and 6% of the respondents were widowed in the Savanna and the Rainforest agro-ecological zones, respectively as seen in Table 4.1. It is also shown in the table that none of the farmers was single in the rainforest agro-ecological zone but about 2% of those in the Savanna agro-ecological zone were single.

4.1.6 Extension Contact of the respondents

Majority of the respondents (about 29%) had no contact with extension services in the study area. About 21% and 37% of them had no contact with extension services in the Savanna and in the Rainforest agro-ecological zones, respectively. About 27% of the respondents had contact with extension services within the range of 11 to 15 times in the cropping season; 30% and about 24% of the respondents from the Savanna and Rainforest agro-ecological zones, respectively, had at least eleven (11) and at most fifteen (15) contacts with extension personnel and services in the cropping season. About 17% of the respondents had at least six (6) contacts with extension services in the cropping season; about 18% and 15% of the respondents had at least one and at most five contacts with extension services in the Savanna and Rainforest agro-ecological zones, respectively in the cropping season. About 13% of the respondents had contact with extension personnel and services for at least 16 and at most 20 times in the cropping season. The average extension contact the respondents had in the cropping season was about 9 times. On average, respondents from the Savanna and the Rainforest agro-ecological zones of the study had contact with extension personnel and services for about 10 and 8 times respectively in the cropping season. Nchare (2007) noted that the average contacts with extension workers by arabica coffee producers in Cameroun was 3, this is at variance with the result of this study. It is also at variance with the findings of Ogundari and Okoruwa (2006) which found that the average number of contacts with extension agents was 4.

It is established in the literature that the more number of contact farmers have with extension personnel and services the better their production, productivity, and the more efficient the farmers in the use of resources, and invariably the more the profits.

4.1.7 Social Participation of the respondents

Majority (35%) of the respondents participated in or belonged to two (2) social associations/organizations. Also in the cropping season, about 39% and about 31% of the respondents in the Savanna and Rainforest agro-ecological zones respectively belonged to two (2) social associations or organizations. Respondents from the Savanna and the Rainforest agro-ecological zones that belonged to one (1) social group or association in the cropping season were 25% and about 24% respectively, while about 24% of the respondents participated in one (1) social organization in the cropping season (Table

4.1). The average number of the social organization or association the respondents belonged to in the cropping season was one (1) in the study area. It is expected that social participation enhance farmers' production activities.

Table 4.1: Frequency Distribution of Respondents by their Socio-economic Characteristics

Variable	**Full**	**Sample (N = 360)**	**Savanna Zone**	**Agro-Ecological (N =180)**	**Rainforest Zone**	**Agro Ecological (N = 180)**
Age (years)	**Frequency**	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
20 – 40	70	20.0	40	22.2	32	17.8
41 – 60	180	50.0	102	56.7	78	43.3
61 – 80	104	28.9	36	20.0	68	37.8
> 80	4	1.1	2	1.1	2	1.1
Total	**360**	**100**	**180**	**100**	**180**	**100**
Sex						
Male	311	86.4	152	84.4	159	83.3
Female	49	13.6	28	15.6	21	11.7
Total	**360**	**100**	**180**	**100**	**180**	**100**
Level of Education	**Mean = 8.38**			**Mean = 8.63**		**Mean = 8.13**
No Formal Education	61	17.0	34	18.9	27	15.0
Primary	116	32.2	48	26.7	68	37.8
Secondary	108	30.0	55	30.6	53	29.4
Tertiary	75	20.8	43	23.8	32	17.8
Total	**360**	**100**	**180**	**100**	**180**	**100**
Household size	**Mean =7.41**			**Mean = 6.21**		**Mean = 8.61**
1 – 5	119	33.0	79	43.9	40	22.3
6 – 10	172	47.8	83	46.1	89	49.4
11 – 15	59	16.4	18	10.0	41	22.8
> 15	10	2.8	0	0.0	10	5.5
Marital status						
Single	3	0.8	3	1.7	0	0.0
Married	332	92.2	162	90.0	170	94.4
Widow/widower	25	7.0	15	8.3	10	5.6
Divorced	0	0.0	0	0.0	0	0.00
Total	**360**	**100**	**180**	**100**	**180**	**100**
Extension contact	**Means = 9.12**			**Means = 10.31**		**Means = 7.93**
1 – 5	33	9.2	19	10.6	14	7.8
6 – 10	60	16.6	33	18.3	27	15.0
11 – 15	97	26.9	54	30.0	43	23.9
16 – 20	46	12.8	23	12.8	23	12.8
> 20	20	5.6	14	6.8	6	3.3
No Contact	104	28.9	37	20.6	67	37.2
Total	**360**	**100**	**180**	**100**	**180**	**100**
Social Participation						
0	115	31.9	48	26.7	67	37.2
1	88	24.4	45	25.0	43	23.9
2	126	35.0	71	39.4	55	30.6
3	31	3.6	16	8.9	15	8.3
Total	**360**	**100**	**180**	**100**	**180**	**100**

Source: Computed from field data, 2011

Table 4.2: Summary Statistics of Variables of Food Crop Farming in Southwestern Nigeria

Variable	Sample Mean	Standard Deviation	Minimum Value	Maximum Value
Age (years)				
Full sample	52.98	12.60	25	84
Savanna AEZ	51.23	11.77	29	82
Rainforest AEZ	54.74	13.17	25	84
Output Value (Naira)				
Full sample	506,010.00	446,970.00	55,600.00	5,450,000.00
Savanna AEZ	463,066.30	590,974.00	55,600.00	5,450,000.00
Rainforest AEZ	548,937.20	321,414.00	55,600.00	1,771,500.00
Profit (Naira)				
Full sample	376,860.00	293,410.00	600.00	1,940,000.00
Savanna AEZ	317,387.89	283,964.00	2600.00	1,940,000.00
Rainforest AEZ	436,331.50	291,408.00	600.00	1,534,200.00
Off-farm Income (Naira)				
Full sample	100,306.67	187,307.00	20,000.00	2,000,000.00
Savanna AEZ	106,703.89	232,589.00	20,000.00	2,000,000.00
Rainforest AEZ	93,909.44	127,215.00	50,000.00	530,000.00
Fertilizer (Kg)				
Full sample	215.0250	696.97	50	9000
Savanna AEZ	245.2944	953.77	50	9000
Rainforest AEZ	184.7556	250.46	50	1000
Farm Size (Hectares)				
Full sample	2.1449	2.62	0.20	30.0
Savanna AEZ	2.0510	3.28	0.21	30.0
Rainforest AEZ	2.2389	1.71	0.20	7.0
Labour (Mandays)				
Full sample	204.88	124.09	42.0	960.0
Savanna AEZ	193.51	131.66	44.0	960.0
Rainforest AEZ	216.25	113.12	42.0	538.0
Land Fragmentation (Number)				
Full sample	2.33	1.02	1.0	6.0
Savanna AEZ	2.27	1.08	1.0	6.0
Rainforest AEZ	2.39	0.96	1	6.0
Credit Volume (Naira)				
Full sample	58,763.89	126,826.00	10,000.00	750,000.00
Savanna AEZ	63,027.78	123,579.00	10,000.00	750,000.00
Rainforest AEZ	54,500.00	130,198.00	20,000.00	750,000.00

AEZ stands for Agro-Ecological Zone

Source: Computed from field data, 2011

4.2 FARMING SYSTEMS OF THE RESPONDENTS

Majority of the respondents (91.4%) practiced mixed cropping; about 82% of them who practiced shifting cultivation. These are not practiced in isolation but usually in combination with one or more farming systems. About 39% of them practiced mono cropping on some food crop farm plots while 25% of them practiced mixed farming. Ninety percent (90%) and about 93% of the respondents in the Savanna and Rainforest agro-ecological zones, respectively were practicing mixed cropping. Also 79.4% and 85% of the respondents practiced shifting cultivation in the Savanna and the Rainforest agoecological zones respectively. About 19% and 30.6% of the respondents in the Savanna and the Rainforest agro-ecological zones respectively practiced mixed farming (Table 4.3). This suggests that the farmers diversify their production because of the risks and uncertainties involved in farming (Adegeye & Dittoh, 1985).

Table 4.3: Frequency Distribution of Farming Systems Practiced by Food Crop Farmers in Southwestern Nigeria

	Full Sample		Savanna Agro-ecological Zone		Rainforest Agro-ecological Zone	
Farming System	**Frequency**	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Mono Cropping	142	39.4*	64	35.6*	78	43.3*
Mixed Cropping	329	91.4*	162	90.0*	167	92.8*
Shifting Cultivation	296	82.2*	143	79.4*	153	85.0*
Strip Cropping	38	10.8*	7	3.9*	31	17.2*
Mixed Farming	90	25.0*	35	19.4	55	30.6*

* Multiple Responses

Source: Computed from field data, 2011.

4.3 CLIMATE CHANGE ADAPTATION STRATEGIES USED BY FOOD CROP FARMERS

This section deals with the farm-level climate change adaptation strategies used by the respondents during 2010 cropping year. Majority of the respondents (98.6%) used multiple crop types/varieties as a crop management practice to adapt to climate change both in the full sample, while it was being used by 97.8% and 99.4% of the respondents in the Savanna and rainforest agro-ecological zones, respectively. Mulching as a crop and soil management practice was used by 84.2% of all the respondents with about 77.2% and 91.1% of them using it in the Savanna and Rainforest agro-ecological zones respectively. Multiple planting dates was used by about 79.4% of the respondents in both the full sample, and 75.6% in the Savanna agro-ecological zone while about 83.3% % used it in the Rainforest agro-ecological. About 77% of the respondents used land fragmentation (i.e. multiple number of farm plots) as a land management practice to adapt to climate change in all the segments of the sample. About 73.3% of them from both Southwestern Nigeria used cover cropping as a soil management practice for coping with climate change, while 66.7% of them in the Savanna agro-ecological zone and 80% in the Rainforest agro-ecological zone used it. Fertilizer application was used by the food crop farmers as a climate change coping strategy by about 54% of the respondents in both the full sample and the Rainforest agro-ecological zone, while 55% of them used it in the Rainforest agro-ecological zone. About 55% of the whole respondents adjusted their farm size (increased) in order to adapt to climate change, while 50.6% and 60% of those sampled in the Savanna and Rainforest agro-ecological zones, respectively also used this strategy (change in farm size). About 51% of the whole respondents diversified their crops in order to adapt to climate change, while 50.6% and 60% of those sampled in the Savanna and Rainforest agro-ecological zones, respectively also used this strategy (Crop diversification) as shown in Table 4.4.

Table 4.4: Frequency Distribution of Farm-level Climate Change Adaptation Strategies Used by Food Crop Farmers in Southwestern Nigeria

Adaptation Strategies	Full Sample		Savanna Agro-Ecological Zone		Rainforest Agro-Ecological Zone	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Multiple crop types/varieties	355	98.6	176	97.8	179	99.4
Land fragmentation	277	76.9	130	72.2	147	81.7
Alternative fallow/tillage practices	141	39.2	54	30.0	87	48.3
Multiple Planting Dates	286	79.4	136	75.6	150	83.3
Irrigation practices	52	14.4	36	20.0	16	8.9
Crop Diversification	183	50.8	93	51.7	90	50.0
Off-farm Employment	162	45.0	84	46.7	78	43.3
Mulching	303	84.2	139	77.2	164	91.1
Cover Cropping	264	73.3	120	66.7	144	80.0
Fertilizer Application	196	54.4	99	55.0	97	53.9
Planting of Trees	61	16.9	38	21.1	23	12.8
Shading/ Sheltering	37	10.3	23	12.8	14	7.8
Change in farm size	199	55.3	91	50.6	108	60.0

Source: Computed from field data, 2011.

To ascertain that the aforementioned crop, soil and land management practices used by the food crop farmers were climate change adaptation strategies, the level of intensity of use of the practices was examined as shown in table 4.5. The following crop, soil and land management practices were very highly intensified by food crop farmers in Southwestern

Nigeria with their mean scores not less than 2.05 (i.e. MS≥ 2.05) namely; multiple crop types/varieties (2.65), land fragmentation (2.09), and mulching (2.17). Those highly intensified as a result of change in climate with mean score between 1.95 and 2.05 (i.e. 1.95≥ MS < 2.05) were; alternative fallow/ tillage practices (1.96), and cover cropping (1.99); the remaining pracices that were lowly intensified with mean score below 1.95 (i.e. MS <1.95) are; irrigation practice (1.21), crop diversification (1.70), off-farm employment (1.65), fertilizer application (1.75), planting of trees (1.21), shading/sheltering (1.12) and change of food crop farmland size (1.91).

In Savanna agro-ecological zone, the following crop, soil and land management practices were very highly intensified as a result of change in climate by the respondents; multiple crop types/varieties (2.44), multiple planting dates (2.23) and mulching (2.07). The only strategy highly intensified is land fragmentation (2.02); while the following were lowly intensified; alternative fallow/tillage practices (1.84), irrigation practice (1.27), crop diversification (1.66), off-farm employment (1.67), cover cropping (1.88), fertilizer application (1.73), planting of trees (1.31), shading/sheltering (1.15) and change of food crop farmland size (1.85).

The following crop, soil and land management practices were very highly intensified by the food crop farmers in the Rainforest agro-ecological zone; multiple crop types/varieties (2.60), land fragmentation (2.10), multiple planting dates (2.14), mulching (2.21), and alternative fallow/ tillage practices (2.10) while those that were highly intensified is cover cropping (2.04); while the following were lowly intensified; irrigation practice (1.14), crop diversification (1.62), off-farm employment (1.68), fertilizer application (1.75), planting of trees (1.14), shading/sheltering (1.11) and change of food crop farmland size (1.91).

Table 4.5: Distribution of the Respondents by Level of Intensity of Use of Farm-level Climate Change Adaptation Strategies

	Full Sample		Savanna Agro-Ecological Zone		Rainforest Agro-Ecological Zone	
Adaptation Strategies	**Mean**	**S.D**	**Mean**	**S.D**	**Mean**	**S.D**
Multiple crop types/varieties	2.65**	0.51	2.44**	0.58	2.60***	0.55
Land fragmentation	2.09***	0.59	2.02**	0.64	2.10**	0.57
Alternative fallow/tillage practices	1.96**	0.73	1.84*	0.75	2.10***	0.69
Multiple Planting Dates	2.24***	0.70	2.23***	0.73	2.14***	0.67
Irrigation practices	1.21*	0.51	1.27*	0.57	1.14*	0.44
Crop Diversification	1.70*	0.74	1.66*	0.75	1.62*	0.70
Off-farm Employment	1.65*	0.79	1.67*	0.78	1.68*	0.80
Mulching	2.17***	0.61	2.07***	0.66	2.21***	0.55
Cover Cropping	1.99***	0.65	1.88*	0.67	2.04**	0.62
Fertilizer Application	1.75*	0.74	1.73*	0.70	1.75*	0.75
Planting of Trees	1.21*	0.53	1.31*	0.63	1.14*	0.42
Shading/ Sheltering	1.12*	0.34	1.15*	0.39	1.11*	0.36
Change in farm size	1.91*	0.03	1.85*	0.79	1.91*	0.75

*** stands for very high intensification (VHI)
** stands for high intensification (HI)
* stands for low intensification (LI)
S. D. means standard deviation.
Source: Computed from field data, 2011.

Majority (43.33%) of the respondents chose or were using multiple crop type as the main climate change adaptation strategy in the study area. Majority (40%) and (46.67%) of the respondents in the savanna and the rainforest agro-ecological zones of southwestern, Nigeria, respectively chose multiple crop types/ varieties as the main adaptation strategy. About 28% of the respondents chose land fragmentation (different farm plots/lands) as the main climate change adaptation strategy. Meanwhile, in the savanna and the rainforest agro-ecological zones, about 26% and 29% respectively chose and used land fragmentation as the main adaptation strategy. About 12% of the respondents chose multiple planting dates as the main climate change adaptation strategy. About 9% and 15% of them chose multiple planting dates as the main climate change adaptation strategy in the Rainforest and Savanna agro-ecological zones, respectively. About 9% of the respondents chose crop diversification as the main climate change adaptation strategy in all the segments of the samples. About 4% of the respondents chose and used off-farm employment as the main climate change adaptation strategy both in the full sample and the Savanna agro-ecological zone while about 3% of them chose it in the rainforest agro-ecological zone. About 4% of the respondents chose or were using cover cropping as the main climate change adaptation strategy, while about 3% and 5% chose or were using cover cropping in the rainforest and the savanna agro-ecological zones, respectively (Table 4.6). This result partly agree with the finding of Nhemachena & Hassan (2007) that noted different varieties, crop diversification and different planting dates as main farm-level adaptation strategies in Southern Africa.

Table 4.6: Frequency Distribution of Respondents by the Main Farm-level Climate Change Adaptation Strategies Used

Adaptation Strategies	Full Sample		Savanna Agro-Ecological Zone		Rainforest Agro-Ecological Zone	
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Multiple crop types/varieties	156	43.33	72	40.00	84	46.67
Land fragmentation	100	27.78	47	26.11	53	29.44
Multiple planting dates	44	12.22	27	15.00	17	9.44
Crop diversification	33	9.17	17	9.44	16	8.89
Off-farm employment	13	3.61	8	4.45	5	2.78
Cover cropping	14	3.89	9	5.00	5	2.78
Total	**360**	**100**	**180**	**100**	**180**	**100**

Source: Computed from field data, 2011.

4.4. PERCEPTION AND AWARENESS OF CLIMATE CHANGE BY THE RESPONDENTS

This section presents the perception and awareness of the food crop farmers about climate change in the study area. About 35% of the respondents had been aware of climate change for at least 6 years and at most 10 years in the study area; about 31% of the respondents were aware of climate change for at most five (5) years, about 13% were aware of climate change for at least 16 years and at most 20 years; about 11% of the respondents were aware for at least 11 years and at most 15 years while about 3% for at least 25 years and above (Table 4.6). Majority (43.9%) and 27% of the respondents in the Savanna agro-ecological and

Rainforest zones, respectively were aware of climate change for at least 6 years and at most 10 years; while 35% and about 26% were aware of climate change for at most 5 years in the Savanna and the Rainforest agro-ecological zones, respectively. About 12% and 10% of those in the Savanna and Rainforest agro-ecological zones, respectively were aware of climate change for at least 11 years and at most 15 years. Also about 9% and 31% were aware of climate change for at least 16 years and at most 25 years in the Savanna and Rainforest agro-ecological zones, respectively. In the Rainforest agro-ecological zone, about 7% of the respondents were aware of climate change for not less than 26 years. There is tendency of the years of awareness of climate change to have positive effect on the adaptation strategies used by the food crop farmers, that is, the higher the number of years of awareness the more experienced the farmer in coping with the change in climate. Maddison (2006) found that farmers' awareness of changes in climate attributes (temperature and precipitation) is important for adaptation decision making.

Table 4.7: Frequency Distribution of Respondents by their Years of Awareness of Climate Change

	Full Sample		**Savanna Agro-Ecological Zone**		**Rainforest Agro-Ecological Zone**	
Awareness (years)	**Frequency**	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
≤5	110	30.6	63	35.0	47	26.1
6 – 10	127	35.3	79	43.9	48	26.7
11 – 15	39	10.8	21	11.7	18	10.0
16 – 20	47	13.1	13	7.2	34	18.8
21 – 25	25	6.9	4	2.2	21	11.7
> 25	12	3.3	0	0.0	12	6.7
Total	**360**	**100**	**180**	**100**	**180**	**100**

Source: Computed from field data, 2011.

The farmers were asked whether they noticed changes in temperature and rainfall in the cropping season and for some years, to measure their perception of climate change. Results show that 92.2% and 90.6% of the respondents perceived higher temperature and decreased rainfall, respectively while 78.1% of them perceived delayed/erratic rainfall, and 46.7% perceived increased rainfall and 3.6% perceived lower temperature (Table 4.8). The result of the majority of the respondents perceived higher temperature for at least 10 years agrees with the finding of Kassahun (2009) who noted that majority of the respondents for his study perceived that there is an increase in the mean temperature for at least two decades.

In the Savanna agro-ecological zone, 93.3% of the respondents perceived decreased rainfall and 91.7% of them perceived higher temperature while 72.2% of them perceived delayed/erratic rainfall; 4.4% of them perceived increase rainfall and 3.3% of them perceived lower temperature (Table 4.8). This result of majority of the respondents perceived decreased temperature agrees with the finding of Kassahun (2009) which noted about that 62% of the respondents for his study perceived decreased rainfall (i.e. upward trend in the percentage of respondents).

In the Rainforest agro-ecological zone, 92.8% of the respondents perceived higher temperature while 87.8% and 83.9% of them perceived decreased rainfall and delayed/erratic rainfall respectively while 11.1% of them perceived increased rainfall and about 3.9% of them perceived lower temperature (Table 4.8).

Table 4.8: Frequency Distribution of Respondents by their Perception of Climate Change

	Full Sample		**Savanna Agro-Ecological Zone**		**Rainforest Agro-Ecological Zone**	
Perception (years)	**Frequency**	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Higher Temperature	332	92.2	165	91.7	167	92.8
Lower Temperature	13	3.6	6	3.3	7	3.9
Increased Rainfall	28	46.7	8	4.4	20	11.1
Decreased Rainfall	326	90.6	168	93.3	158	87.8
Delayed/Erratic Rainfall	281	78.1	130	72.2	151	83.9

* Multiple Responses

Source: Field Survey, 2011.

4.5 FACTORS THAT INFLUENCE THE CHOICE OF CLIMATE CHANGE ADAPTATION STRATEGIES USED BY FOOD CROP FARMERS IN SOUTHWESTERN NIGERIA

The estimation of the multinomial logit (MNL) model for this study was undertaken by normalizing one category, which is referred to as the “reference state,” or the “base category.”

In this analysis, the base category is cover cropping. The result of the multinomial logit (MNL) model indicate that different socio economic factors (household size, age of the household head, years of education of household head, sex of the household head, and years of climate change awareness) farm-specific variables (farm size and average distance) and institutional variables (extension contact, tenure security, social capital and access to credit) affect the farmers' choice of the main farm-level climate change adaptation strategies in food crop production in Southwestern Nigeria. Results of the parameter estimates (the estimated coefficients along with the robust standard errors) from the multinomial logit (MNL) models are presented in Tables 4.9, 4.11 and 4.13 for southwestern Nigeria, the Savanna and the Rainforest agro-ecological zones, respectively.

The likelihood ratio statistics as indicated by χ^2 statistics were highly significant ($P < 0.0000$), suggesting the models (for the full sample, the savanna and the rainforest agro-ecological zones) has a strong explanatory power. As indicated earlier, the parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent (response) variable; estimates do not represent actual magnitude of change or probabilities. Thus, the marginal effects from the MNL, which measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable, are reported and discussed. In all cases the estimated coefficients should be compared with the base category (cover cropping), this is only used as the reference point against which other climate change adaptation strategies are contrasted. Marginal effects of the explanatory variables are presented in tables 4.10, 4.12 and 4.14 for Southwestern Nigeria, the Savanna and Rainforest agro-ecological zones, respectively.

Household size

The result shows that there is a negative relationship between household size and the probability of choosing multiple crop types/varieties, land fragmentation, multiple planting dates and crop diversification as adaptation strategies among food crop farmers in Southwestern Nigeria (Table 4.9), in the Savanna agro-ecological zone (Table 4.11) and in the Rainforest agro-ecological zone of the study area (Table 4.13). This implies that the smaller food crop families are able to choose these main climate change adaptation strategies except off-farm employment than the larger families in the whole southwestern Nigeria and in the Savanna and rainforest agro-ecological zones. This result agrees with the finding of Birungi and Hassan (2010) which found out that household size is negatively related to adoption of fallow as land management technology in Uganda.

Age of the household head

Age is significantly and negatively correlated to the probability of choosing and using multiple crop varieties, land fragmentation, multiple planting dates, off-farm employment as adaptation strategies to climate change in Southwestern Nigeria (Table 4.9). This shows that young food crop farmers have a longer planning horizon and have ability to cope with climate change and climate variability risks in food crop production than the older counterparts. This result agrees with the findings of Alexander and Mellor (2005) which found that GM corn adoption increased with age for younger farmers as they gain experience and increase their stock of human capital but declines with age for those farmers closer to retirement and also the work of Hassan and Nhemachena (2008) which found that age is inversely related to the probability of choosing and using mono crop-livestock under irrigation. Similar result was discovered by Bayard et al. (2006) that the age of farmers has a negative influence on adoption of rock walls as soil management practice in Fort- Jacques in Haiti and on adoption of rbST in Connecticut Dairy Farms (Foltz & Chang, 2001). From this, it seems experience is measured by whether the farm operator is a specialist crop farmer and not basically on age. It is assumed that the younger the farmer, the more likely he/she is to adopt innovations early in his/her respective life cycle

(Rogers, 1995). Older farmers may have a shorter time horizon and be less likely to invest in novel technologies.

A unit increase in the age of food crop farmers would decrease adaptation of multiple crop varieties, land fragmentation, multiple planting dates, and off-farm income by 0.00176 (0.18%), 0.00576 (0.58%), 0.000223 (0.022%), 0.00236 (0.24%) and 0.00155 (0.16%), respectively in the study area (Table 4.10).

Education

Education of the household head has an inverse relationship with the probability of a farm household choosing and using multiple crop varieties and multiple planting dates as climate change adaptation strategies in Southwestern Nigeria (Table 4.9). This implies that a one-unit increase in education would lead to 0.00536 (0.54%) and 0.00549 (0.55%) in the probability of choosing and using multiple crop varieties and multiple planting dates respectively in the study area (Table 4.10).

Also, there is an inverse relationship between education and the probability of choosing and using multiple crop varieties as an adaptation strategy in the Savanna agro-ecological zone of the study area (Table 4.11). This implies that a one-unit increase in years of education (or education level) would lead to a 0.00965 (0.97%) decrease in the probability of choosing and using multiple crop varieties in the Savanna agro-ecological zone (Table 4.12).

In the Rainforest agro-ecological zone, education is negatively and significantly related to the probability of choosing and using multiple planting dates, crop diversification and off-farm employment (Table 4.13). The marginal effects in Table 4.14 indicate that a one-unit increase in education level (or years of education) would lead to 0.00550 (0.55%), 0.00281(0.28%) and 0.000161(0.16%) decrease in the probability of choosing and using multiple planting dates, crop diversification and off-farm employment respectively.

This inverse relationship between education and these adaptation strategies, contrary to expectations that better educated household head are more likely to choose and use climate change adaptation strategies in the study area. It could be probably deduced that the education acquired by these farmers is not formal agricultural education; it is assumed that a farmer with formal agricultural education will be more likely to innovate due to the higher associated skill level. This result agrees with the finding of Birungi and Hassan (2010) that found out that education was negatively related to adoption of terracing and inorganic fertilizer as land management practices in Uganda and also the study of Bayard et al. (2006) found that education is inversely related to adoption of rock walls as soil conservation practice in Forte- Jacques.

Sex of household head

Male household heads have a higher probability of choosing, using and intensifying multiple crop varieties, multiple planting dates and off-farm employment than their female counterparts among the whole sampled food crop farmers in Southwestern Nigeria (Table 4.9). An additional unit of a male-headed household would lead to 0.00333 (0.33%), 0.1067 (10.67%) and 0.0393 (3.93%) increase in probability of choosing and using multiple crop varieties, multiple planting dates and off-farm employment respectively in the study area (Table 4.10).

In the Savanna agro-ecological zone, male-headed household has a direct relationship with the probability of choosing and using multiple cropping varieties, land fragmentation and off-farm employment (Table 4.11). This means that male-headed households have a higher probability of choosing and using multiple cropping varieties, land fragmentation and off-farm employment than the female-headed food crop farm households in the Savanna agro-ecological zone.

The marginal effects in Table 4.12 indicate that a one-unit increase in male-headed household means that food crop household headed by male are 0.364%, 7.1% and 6.15% respectively more likely to use multiple cropping varieties, land fragmentation and off-farm employment, respectively than female-headed food crop farmers households, *ceteris paribus*. Correspondingly, the following previous studies found that male household heads have a positive relationship in adoption of manure and intensity of its use and fertilizer adoption and intensity of its use of farm technology adoption in Kenya (Ogada *et al.*, 2010); on multiple crops under irrigation and multiple crop-livestock under irrigation as African farmers' strategies for adapting to climate change (Hassan & Nhemachena, 2008); on choices of sold livestock; and sold livestock and borrowed from relatives as coping strategies with climate extremes in the Nile Basin of Ethiopia (Deressa *et al.* 2010) and on adoption of fallow and terracing as land management technologies in Uganda (Birungi & Hassan, 2010).

But in the Rainforest agro-ecological zone, male-headed household has an inverse relationship with all the main climate change adaptation strategies (multiple crop varieties, land fragmentation, multiple planting dates, crop diversification and off-farm employment) as seen in Table 4.13. This means that female-headed households have a higher probability of choosing and using the main climate change adaptation strategies than the male-headed food crop farm households in the Rainforest agro-ecological zone. This implies a unit increase in the male-headed would lead to a 4.67%, 4.24%, 2.16%, 5.83%, 0.26% and 0.76% respectively decrease in the probability of choosing and using multiple crop varieties, land fragmentation, multiple planting dates, crop diversification and off-farm employment in the Rainforest agro-ecological zone of Southwestern Nigeria (Table 4.14).

Years of climate change awareness

Years of climate change awareness has a positive relationship with the probability of choosing and using multiple crop varieties and multiple planting dates among the food crop farmers in the Savanna agro-ecological zone of the study area (Table 4.11). This means that a marginal increase in the years of climate change awareness would lead to a 0.00595 (0.60%) and

0.0000866 (0.0087%) in the probability of choosing and using multiple crop varieties and multiple planting dates respectively (Table 4.12).

Average Distance

Average distance of the farms to the residents of the farmers’ households is positively related to the probability of choosing and using land fragmentation in the study area (Table 4.9). This means a one-unit increase in average distance would lead to 1.2% in the probability of choosing and using land fragmentation as an adaptation in Southwestern Nigeria (Table 4.10). It implies that long distance (i.e. remoteness of the food crop farmers’ residents to their farms) permits the use of land fragmentation as an adaptation strategy to climate change in the study area. This agrees with the study of Birungi and Hassan (2010) that found out that distance for plot to farmer’s residence had positive relationship with adoption of fallow, inorganic fertilizer and terracing as land management practices in Uganda.

Extension contact

Extension contact/ services significantly and positively correlated with multiple crop varieties, land fragmentation (i.e. number of parcels of food crop farm) and crop diversification in the Rainforest agro-ecological zone (Table 4.13). This means that a one-unit increase in extension contact/ services would increase the probability of choosing and using multiple crop varieties, land fragmentation and crop diversification by 0.0076 (0.76%), 0.00769 (0.77%) and 0.00146 (0.15%) respectively (Table 4.14). This result supports the innovation theory (Rogers, 1995). This suggests that the food crop farmers in the Rainforest agro-ecological zone of Southwestern Nigeria have made use of these adaptation strategies (multiple crop varieties, multiple planting dates and land fragmentation) among other adaptation strategies probably because of their personal conviction as a result of advice received from extension personnel.

Previous studies have found positive influence of extension contact/ services on adoption of agricultural and farm technologies among them are Birungi and Hassan (2010) that found positive relationship between agricultural extension and adoption of inorganic fertilizer as land management technology in Uganda; Hassan and Nhemachena (2008) found out that extension contact had positive influence on adoption of multiple crops under irrigation, mono crop-livestock under dry land, mono crop-livestock under irrigation, multiple crop-livestock under irrigation and multiple crop-livestock under dryland as adaptation strategies employed by African farmers; Ogada *et al.* (2010) also found positive relationship between fertilizer intensity and extension contact in farm technology adoption in rain-fed semi-arid lands of Kenya; on adoption of adaptation measures in Southern Africa, Nhemachena and Hassan (2007) found a positive effect of free extension services on probability of adoption of different crops, different varieties, crop diversification, increase irrigation and increase water conservation and Ransom, *et al.* (2003) found that contact with extension significantly and positively affected adoption of improved varieties in hills of Nepal.

Tenure security

Tenure security has positive relationship with the probability of choosing and using crop diversification both in the study area (Southwestern Nigeria) and in the Savanna agro-ecological zone of the region as seen in tables 4.9 and 4.11, respectively. This means that food crop households that own their plots or lands have higher probability of choosing and using crop diversification as adaptation strategy than their counterparts that are land tenants. Tenants can be assumed less likely than landowners to use new or emerging climate change adaptation strategies, as the benefits may not necessarily flow to them, while land ownership influences the farmers' decisions. An additional unit of land secured food crops household would increase the probability of choosing and using crop diversification by 0.0615 (6.15%) and 0.0750 (7.50%) in Southwestern region and the Savanna agro-ecological zone of the region, respectively (Tables

4.10 and 4.12). This finding agrees with the study of Ogada *et al.* (2010) that found that secure land tenure had a positive influence on the probability of adopting terrace as a farm technology in the rain-fed semi-arid lands of Kenya; it was also found out by Birungi and Hassan (2010) that land tenure security increases the probability of investment in land management.

Access to credit

Access to credit has negative effect on the probability of choosing and using multiple crop varieties, multiple planting dates and crop diversification in the whole Southwestern region (Table 4.9). This implies that an additional unit of food crop household would increase the probability of choosing and using multiple crop varieties, multiple planting dates and crop diversification by 0.0598 (5.98%), 0.00122 (0.12%) and 0.725 (72.5%) respectively among the whole sampled food crop farm households (Table 4.10). But this contradicts innovation theory (Rogers, 1995).

In the Rainforest agro-ecological zone, access to credit has negative effect on the probability of choosing and using multiple crop varieties, land fragmentation, multiple planting dates and crop diversification as climate change adaptation strategies (Table 4.13). This implies a marginal increase in access to credit would lead to a decrease in the probability of choosing and using multiple crop varieties, land fragmentation, multiple planting dates and crop diversification by 0.0164 (1.64%), 0.0675 (6.75%), 0.000475 (0.048%) and 0.0574 (5.74%) respectively (Table 4.14).

In the Savanna agro-ecological zone, access to credit has an inverse and significant relationship with the probability of choosing and using crop diversification as a climate change adaptation strategy (Table 4.11). The marginal effects in Table 4.12 indicate that a marginal increase in access to credit would cause a 0.0839 (8.4%) decrease in the probability of choosing and using crop diversification among the food crop farmers in the Savanna agro-ecological zone of the study area.

Table 4.9: Parameter Estimates of the Multinomial Logit (MNL) Analysis of Factors that Influence Climate Change Adaptation Strategies Used in Food Crop Production in Southwestern Nigeria

Explanatory Variables	Coefficients				
	MLTCRPV	**LANGFRAG**	**MLTPLNTDT**	**CRPDVER**	**OFFFMEMP**
Household Size (number)	-0.202 (0.078)***	-0.221 (0.0825)***	-0.419 (0.103)***	-0.352 (0.0999)***	-0.0626 (0.132)
Age of Household Head (years)	-0.0790 (0.437)*	-0.102 (0.0439)**	-0.0804 (0.0463)*	-0.0476 (0.0470)	-0.0880 (0.0508)*
Years of Education	-0.129 (0.058)**	-0.120 (0.0605)	-0.112 (0.0656)*	-0.0756 (0.0642)	-0.107 (0.0893)
Sex (male) (1/0)	1.27 (0.775)***	0.989 (0.0605)	3.114 (1.276)**	1.258 (0.934)	2.403 (1.247)*
Years of Climate Change Awareness	0.0917 (0.0582)	0.0954 (0.0593)	0.123 (0.0614)	0.0642 (0.0654)	0.164 (0.0775)
Farm Size (ha)	-0.130 (0.156)	0.0587 (0.147)	-0.0705 (0.180)	0.182 (0.148)	-0.0670 (0.205)
Average Distance (km)	0.153 (0.114)	0.203 (0.101)**	0.253 (0.122)	0.138 (0.149)	-0.255 (0.293)
Extension Contact (number)	0.0555 (0.0550)	0.0775 (0.0546)	0.0154 (0.0583)	0.0621 (0.0638)	0.0867 (0.0648)
Tenure Security (1/0)	0.570 (0.627)	0.584 (0.639)	0.733 (0.708)	1.653 (0.832)**	0.807 (0.835)
Social Capital (number)	-0.0155 (0.0289)	0.019 (0.0289)	-0.00409 (0.0341)	-0.0444 (0.0346)	-0.0451 (0.0415)
Access to Credit (1/0)	-1.742 (0.810)**	-1.304 (0.820)	-1.492 (0.874)*	-2.728 (0.994)***	-2.029 (0.986)
Constant	7.952 (2.723)***	7.434 (2.745)***	5.542 (3.049)**	4.822 (2.956)	5.237 (3.301)
Number of Observations			**360**		

Wald chi-square (χ^2) (55) = 122.83
Prob > χ^2 = 0.0000
Pseudo R^2 = 0.1081
Log pseudo likelihood = -462.44765

Note: MLTCRPV stands for multiple crop types/ varieties; LANDFRAG stands for land fragmentation; MLTPLNTDT stands for multiple planting dates; CRPDVER stands for crop diversification; OFFMEMP stands for off-farm employment; and CVRCRP stands for cover cropping.

Cover cropping **(**CVRCRP) is the base category. Figures in parentheses are the robust standard errors

*** denotes $P \leq 0.01$, ** denotes $0.01<P\leq0.05$, while * denotes $0.05<P\leq0.10$

Source: Computed from field data, 2011.

Table 4.10: Marginal Effects from Multinomial Logit (MNL) Analysis of Factors that Influence Climate Change Adaptation Strategies Used in Food Crop Production in Southwestern Nigeria

Explanatory Variables	**Marginal Effects**					
	MLTCRPV	**LANGFRAG**	**MLTPLNTDT**	**CRPDVER**	**OFFFMEMP**	**CVRCRP**
Household Size (number)	0.0147 (1.61)	0.00343 (0.41)	-0.0187 (-3.30)***	-0.00803 (-2.09)**	0.00423 (2.01)**	0.00436 (2.52)**
Age of Household Head (years)	0.00176 (0.63)	-0.00576 (-2.16)**	0.000223 (0.14)	0.00236 (1.82)*	-0.000133 (-0.19)	0.00155 (2.46)**
Years of Education	-0.00536 (-0.98)	-0.000524 (-0.10)	0.00549 (0.17)	0.00285 (1.34)	0.000282 (0.16)	0.00221 (2.09)**
Sex^b (male) (1/0)	0.00333 (0.04)	-0.0898 (-1.06)	0.1067 (3.70)***	-0.000356 (-0.01)	0.0194 (1.32)	-0.0393 (-1.08)
Years of Climate Change Awareness	0.000561 (0.11)	0.00148 (0.30)	0.00326 (1.23)	-0.00177 (-0.83)	-0.00184 (-1.47)	-0.00170 (-2.08)**
Farm Size (ha)	-0.0438 (-1.98)**	0.0303 (1.88)*	-0.00285 (-0.27)	0.0151 (3.06)**	-0.000621 (-0.16)	0.000788 (0.31)
Average Distance (km)	-0.00535 (-0.36)	0.0118 (0.97)	0.00886 (1.23)	-0.00178 (-0.26)	-0.01043 (-1.85)*	-0.00308 (-1.32)
Extension Contact (number)	0.000137 (0.34)	0.00579 (1.68)*	-0.00430 (-1.99)**	-0.000261 (-0.12)	0.000707 (0.86)	-0.00109 (-1.02)
Tenure Security^b (1/0)	-0.0398 (-0.67)	-0.0201 (-0.36)	0.00804 (0.25)	0.0615 (2.44)**	0.00375 (0.27)	-0.0134 (-0.95)
Social Capital (number)	-0.00443 (-1.45)	0.00760 (2.81)***	0.000231 (0.12)	-0.00256 (-1.74)*	-0.000961 (-1.22)	0.000120 (0.23)
Access to Credit^b (1/0)	-0.0598 (-1.02)	0.0939 (1.66)*	0.0122 (0.37)	-0.725 (-2.44)**	-0.00990 (-0.72)	0.0360 (1.56)
Number of Observations			**360**			

(*b*) dy/dx is for discreet change of dummy variable from 0 to 1

Note: MLTCRPV stands for multiple crop types/ varieties; LANDFRAG stands for land fragmentation; MLTPLNTDT stands for multiple planting dates; CRPDVER stands for crop diversification; OFFMEMP stands for off-farm employment; and CVRCRP stands for cover cropping.

Cover cropping **(**CVRCRP) is the base category.

Figures in parentheses are z- ratios;

*** denotes P ≤ 0.01, ** denotes 0.01<P≤0.05, while * denotes 0.05<P≤0.10

Source: Computed from field data, 2011.

Table 4.11: Parameter Estimates of the Multinomial Logit (MNL) Analysis of Factors that Influence Climate Change Adaptation Strategies Used in Food Crop Production in the Savanna Agro-ecological Zone of Southwestern Nigeria

Explanatory Variables	Coefficients				
	MLTCRPV	**LANDFRAG**	**MLTPLNTDT**	**CRPDVER**	**OFFFMEMP**
Household Size (number)	-0.279 (0.0892)***	-0.292 (0.0942)***	-0.493 (0.135)***	-0.523 (0.176)**	-0.204 (0.173)
Age of Household Head (years)	-0.110 (0.0839)	-0.128 (0.0862)	-0.114 (0.0878)	-0.0479 (0.0885)	-0.119 (0.091)
Years of Education	-0.0118 (0.0595)**	-0.0897 (0.0623)	-0.114 (0.0878)	-0.0489 (0.0722)	-0.0111 (0.112)
Sex (male) (1/0)	1.841 (0.908)**	1.617 (0.971)*	-0.0446 (0.0714)	0.895 (1.202)	18.527 (1.09)***
Years of Climate Change Awareness	0.202 (0.122)*	0.199 (0.128)	18.406 (0.901)***	0.0992 (0.133)	0.0746 (0.131)
Farm Size (ha)	0.00329 (0.261)	0.0650 (0.265)	-0.244 (0.128)	0.243 (0.266)	0.0746 (0.131)
Average Distance (km)	-0.110 (0.153)	-0.0911 (0.146)	-0.0727 (0.176)	0.0956 (0.293)	-0.316 (0.384)
Extension Contact (number)	0.0685 (0.836)	0.0746 (0.0880)	0.0190 (0.0910)	0.0681 (0.103)	0.127 (0.105)
Tenure Security (1/0)	1.331 (0.836)	0.972 (0.861)	1.527 (0.966)	2.768 (1.116)**	0.914 (1.079)
Social Capital (number)	-.0.631 (0.600)	0.0265 (0.0593)	-0.0537 (0.0698)	-.0111 (0.0678)	-0.00755 (0.0741)
Access to Credit (1/0)	-1.856 (1.469)	-1.083 (1.516)	-1.174 (1.526)	-3.163 (1.721)*	-2.233 (1.619)
Constant	9.0999 (4.621)**	7.866 (4.703)*	-7.340 (4.790)	5.512 (5.082)	-10.029 (5.256)*
Number of Observations			**180**		

Wald χ^2(53) = MS****

Prob > χ^2 = MS

Pseudo R^2 = 0.1948

Log pseudo likelihood = -219.25045

Note: MLTCRPV stands for multiple crop types/ varieties; LANDFRAG stands for land fragmentation; MLTPLNTDT stands for multiple planting dates; CRPDVER stands for crop diversification; OFFMEMP stands for off-farm employment; and CVRCRP stands for cover cropping.

Cover cropping (CVRCRP) is the base category. Figures in parentheses are the robust standard errors

MS**** the chi-square (χ^2) model statistic reported to be missing in the multinomial logit climate change adaptation model for food crop farmers in the Savanna agro-ecological zone of Southwestern Nigeria. Stata has done that so as to not be misleading, not because there is something necessarily wrong with the model (StataCorp, 2009).

*** denotes $P \leq 0.01$, ** denotes $0.01<P\leq0.05$, while * denotes $0.05<P\leq0.10$

Source: Computed from field data, 2011.

Table 4.12: Marginal Effects from Multinomial Logit (MNL) Analysis of Factors that Influence Climate Change Adaptation Strategies Used in Food Crop Production in the Savanna Agro-ecological Zone of Southwestern Nigeria

Explanatory Variables	Marginal Effects					
	MLTCRPV	**LANDFRAG**	**MLTPLNTDT**	**CRPDVER**	**OFFFMEMP**	**CVRCRP**
Household Size (number)	0.008196 (0.55)	0.000493 (0.04)	-0.00283 (-2.16)**	-0.0115 (-2.66)*	0.000323 (0.64)	0.00536 (1.56)
Age of household head (years)	0.000389 (0.08)	-0.00567 (-1.20)	-0.0000371 (-0.11)	0.00332 (2.04)**	-0.0000298 (-0.23)	0.00203 (1.94)*
Years of Education	-0.00965 (-1.15)	0.00391 (0.46)	0.000803 (1.21)	0.00276 (1.04)	0.000326 (1.19)	0.00185 (1.28)
Sex[b] (male) (1/0)	-0.00364 (-0.03)	-0.0710 (-0.62)	0.156 (3.84)***	-0.0606 (-1.11)	0.0406 (1.43)	-0.0615 (-0.91)
Years of Climate Change Awareness	0.00595 (0.57)	0.00273 (0.26)	0.0000866 (0.15)	-0.00485 (-1.23)	-0.000422 (-1.15)	-0.00349 (-1.71)*
Farm Size (ha)	-0.0169 (-0.70)	0.01093 (0.46)	-0.00391 (-1.35)	0.0111 (1.90)*	-0.00640 (-0.61)	-0.000596 (-0.12)
Average Distance (km)	-0.0109 (-0.39)	-0.0000298 (-0.00)	0.000260 (0.15)	0.00982 (0.90)	-0.000813 (-0.76)	0.00166 (0.67)
Extension Contact (number)	-0.000155 (-0.03)	0.00195 (0.35)	-0.000706 (-1.49)	-0.0000392 (-0.01)	0.000210 (1.50)	-0.00126 (-0.84)
Tenure Security[b] (1/0)	0.0443 (0.47)	-0.0951 (-1.05)	0.00374 (0.54)	0.0750 (2.48)**	-0.00124 (-0.39)	-0.0267 (-1.24)
Social Capital (number)	-0.0167 (-2.91)**	0.0204 (3.87)***	-0.000281 (-0.57)	-0.00406 (-1.30)	0.0000953 (0.67)	0.000619 (0.48)
Access to Credit[b] (1/0)	-0.1305 (-1.43)	0.178 (1.97)**	0.00617 (0.88)	-0.0839 (-2.06)**	-0.00215 (-0.73)	0.0325 (1.12)
Number of Observations			**180**			

(*b*) dy/dx is for discreet change of dummy variable from 0 to 1

Note: MLTCRPV stands for multiple crop types/ varieties; LANDFRAG stands for land fragmentation; MLTPLNTDT stands for multiple planting dates; CRPDVER stands for crop diversification; OFFMEMP stands for off-farm employment; and CVRCRP stands for cover cropping.

Cover cropping **(**CVRCRP) is the base category.

Figures in parentheses are z- ratios

*** denotes $P \leq 0.01$, ** denotes $0.01<P\leq0.05$, while * denotes $0.05<P\leq0.10$

Source: Computed from field data, 2011.

Table 4.13: Parameter Estimates of the Multinomial Logit (MNL) Analysis of Factors that Influence Climate Change Adaptation Strategies Used in Food Crop Production in the Rainforest Agro-ecological Zone of Southwestern Nigeria

Explanatory Variables	**Coefficients**				
	MLTCRPV	**LANGFRAG**	**MLTPLNTDT**	**CRPDVER**	**OFFFMEMP**
Household Size (number)	-0.297 (0.132)**	-0.344 (0.133)***	-0.536 (0.169)**	-0.436 (0.156)**	-0.0513 (0.184)
Age of Household Head (years)	-0.0713 (-0.730)	-0.109 (0.0731)	-0.0709 (0.0797)	-0.0626 (0.0780)	-0.102 (0.781)
Years of Education	-0.279 (0.121)	-0.293 (0.123)	-0.367 (0.144)**	-0.250 (0.128)*	-0.337 (0.178)*
Sex (Male) (1/0)	-12.427 (1.294)***	-12.469 (1.329)**	-11.997 (1.833)***	-11.201 (1.714)***	-11.084 (1.617)***
Years of Climate Change Awareness	0.0120 (0.0661)	0.0346 (0.0685)	0.0569 (0.070)	0.333 (0.0765)	-0.0458 (0.0951)
Farm Size (ha)	-0.109 (0.299)	0.197 (0.296)	0.187 (0.334)	0.282 (0.312)	0.0813 (0.365)
Average Distance (km)	0.502 (0.201)	0.599 (0.193)**	0.664 (0.204)***	0.408 (0.263)	-0.759 (0.666)
Extension Contact (number)	0.119 (0.0702)*	0.157 (0.0701)**	0.115 (0.778)	0.152 (0.084)*	0.116 (0.112)
Tenure Security (1/0)	-1.336 (1.357)	-1.104 (1.365)	-1.190 (1.469)	-0.613 (1.631)	-0.133 (1.661)
Social Capital (number)	0.039 (0.0432)	0.0411 (0.0452)	0.0799 (0.0537)	0.00364 (0.0492)	-0.0945 (0.0987)
Access to Credit (1/0)	-2.532 (1.141)**	-2.292 (1.156)**	-2.508 (1.294)*	-3.305 (1.494)**	-0.263 (1.991)
Constant	24.173 (5.580)***	24.397 (5.580)***	21.919 (6.231)***	20.990 (6.118)***	23.899 (6.378)***
Number of Observations			**180**		

Wald $\chi^2(55) = 720.37$
Prob > $\chi^2 = 0.0000$
Pseudo $R^2 = 0.1374$
Log pseudo likelihood = -210.03154

Note*:* MLTCRPV stands for multiple crop types/ varieties; LANDFRAG stands for land fragmentation; MLTPLNTDT stands for multiple planting dates; CRPDVER stands for crop diversification; OFFMEMP stands for off-farm employment; and CVRCRP stands for cover cropping.

Cover cropping **(**CVRCRP) is the base category. Figures in parentheses are the robust standard errors; *** denotes $P \leq 0.01$, ** denotes $0.01<P\leq0.05$, while * denotes $0.05<P\leq0.10$

Source: Computed from field data, 2011.

Table 4.14: Marginal Effects from Multinomial Logit (MNL) Analysis of Factors that Influence Climate Change Adaptation Strategies Used in Food Crop Production in the Rainforest Agro-ecological Zone of Southwestern Nigeria

Explanatory Variables	**Marginal Effects**					
	MLTCRPV	**LANGFRAG**	**MLTPLNTDT**	**CRPDVER**	**OFFFMEMP**	**CVRCRP**
Household Size (in number)	0.0216 (1.66)*	-0.00203 (-0.16)	-0.0136 (-2.34)**	-0.00750 (-1.23)	0.000914 (0.64)	0.000614 (1.73)*
Age of household head (years)	0.00599 (1.45)	-0.00838 (-2.15)**	0.000795 (0.37)	0.00151 (0.72)	-0.0000636 (-0.42)	0.000150 (1.20)
Years of Education	0.00429 (0.47)	-0.00196 (-0.22)	-0.00550 (-0.98)	0.00281 (0.74)	-0.000161 (-0.51)	0.000522 (1.44)
Sex^b (male) (1/0)	-0.0467 (-0.31)	-0.0424 (-0.32)	0.02059 (0.30)	0.0583 (1.49)	0.00262 (0.54)	0.00761 (1.15)
Years of Climate Change Awareness	-0.00622 (-0.84)	0.00349 (0.53)	0.00227 (0.99)	0.000727 (0.22)	-0.000222 (-0.67)	-0.0000431 (-0.46)
Farm Size (ha)	-0.0790 (-2.17)**	0.0504 (1.74)*	0.0101 (0.90)	0.0184 (1.69)*	0.000134 (0.14)	-0.0000715 (-0.13)
Average Distance (km)	-0.0162 (-0.76)	0.0216 (1.26)	0.00903 (1.42)	-0.00940 (-0.81)	-0.00412 (-0.67)	-0.000969 (-1.27)
Extension Contact (number)	-0.00760 (-0.88)	0.00769 (1.29)	-0.00124 (-0.47)	0.00146 (0.40)	-0.0000553 (-0.15)	-0.000242 (-1.08)
Tenure Security^b (1/0)	-0.0752 (-0.88)	0.0292 (0.39)	0.000455 (0.01)	0.407 (0.86)	0.00299 (0.40)	0.00189 (1.20)
Social Capital (number)	-0.000152 (-0.04)	0.000574 (0.15)	0.00278 (1.30)	-0.00270 (-1.30)	-0.000427 (-0.78)	-0.00715 (-0.72)
Access to Credit^b (1/0)	-0.0164 (-0.18)	0.0675 (0.79)	-0.000475 (-0.01)	-0.0574 (-1.13)	-0.000536 (-0.12)	0.00733 (1.48)
Number of Observations			**180**			

(*b)* dy/dx is for discreet change of dummy variable from 0 to 1

Note*:* MLTCRPV stands for multiple crop types/ varieties; LANDFRAG stands for land fragmentation; MLTPLNTDT stands for multiple planting dates; CRPDVER stands for crop diversification; OFFMEMP stands for off-farm employment; and CVRCRP stands for cover cropping.

Cover cropping **(**CVRCRP) is the base category.

Figures in parentheses are z- ratios

*** denotes P ≤ 0.01, ** denotes 0.01<P≤0.05, while * denotes 0.05<P≤0.10

Source: Computed from field data, 2011.

4.6 ESTIMATES FOR PARAMETERS OF AVERAGE AND STOCHSTIC FRONTIER PRODUCTION FUNCTIONS

The analysis of the data for the technical efficiency estimates was achieved through the Maximum Likelihood Estimation (MLE), which involved the estimation of the average production (Model 1) and the production frontier (Model 2) models. The selection of the preferred model for the food crop production was carried out with the generalized log likelihood-ratio statistic. The estimated stochastic frontier models (Models 1 and 2) for the food crop production in Southwestern Nigeria (full sample), in the Savanna and the Rainforest agro-ecological zones is given in tables 4.16, 4.17 and 4.18. Tests of hypotheses were carried out to select the model that better represents the data for food crop farmers (Table 4.15). The null hypothesis, H_0:$\gamma = \delta_o = \delta_1 \ldots = \delta_8 = 0$, which states that inefficiency effects are absent from the frontier model, is rejected for the food crop farmers.

Table 4.15: Generalised log likelihood-ratio tests of null hypothesis

H_0: Food crop farmers are fully technically efficient (γ=0)

Food Crop Farmers	Log likelihood function Model 1	Model 2	λ	Critical value*	Decision
Full Sample (N=360)	-190.614	-165.505	50.218	15.51	Reject H_0
Savanna Agro-ecological Zone (N=180)	-101.932	-101.932	29.026	15.51	Reject H_0
Rainforest Agro-ecological Zone (N=180)	-77.271	-63.189	28.164	15.51	Reject H_0

Degree of freedom is the number of restricted parameters, here 8 parameters were restricted.

* Critical value is obtained from table 3 pp. 661-662 in Koutsoyiannis (1977) the abridged table from 'Table of percentage points of the χ^2 (0.05) distribution' by Catherine M. Thompson, *Biometrika,* vol. 32, 1941.

Source: Computed from field data, 2011.

Given the results of the test of hypotheses, the Cobb-Douglass frontier model (Model 2) was selected as the preferred model that better fits the data of food crop farmers. Hence, the discussions are based on the Cobb-Douglas frontier model (Model 2) as seen in table 4.15. This results that Cobb-Douglass frontier model as the lead functional form agrees with the findings of Ajibefun and Daramola (2003) for microenterprises in the Nigerian economy; Nwaru and

Onuoha (2010) for food crop farmers in Imo state, Nigeria; Amaza *et al.* (2006) for food crop farmers in Borno state, Nigeria and Otitoju (2008) for medium-scale soybean farmers in Benue State, Nigeria.

Maximum likelihood estimates for parameters of the two estimated models are presented in table 4.16 for the full sample, table 4.17 for savanna agro-ecological zone and table 4.18 for the rainforest agro-ecological zone. Labour, farm size and other agrochemicals are highly significant at 1% level of probability for all the respondents and those respondents (food crop farmers) from the Savanna agro-ecological zone. While labour and farm size are significant at 1% level of significance for the respondents in the rainforest agro-ecological zone. The estimated value for the γ-parameter in the preferred models (Cobb-Douglas stochastic frontier production function) for the food crop farmers are 0.287 in Southwestern Nigeria; 0.087 and 0.656 for those in the savanna and the rainforest agro-ecological zones, respectively. The values are significant at 1% level of probability for all the categories of the respondents. These values indicate that technical inefficiency is highly significant in the food crop production activities. The γ- parameter shows the relative magnitude of the variance in output associated with technical efficiency. The coefficients of the variables derived from the Maximum Likelihood Estimation (MLE) are very important for discussing results of the analysis of the data. These coefficients represent percentage change in the dependent variables as a result of percentage change in the independent (or explanatory) variables.

Table 4.16: Maximum Likelihood Estimates (MLE) of the Stochastic Frontier Production Function for Food Crop Farmers in Southwestern Nigeria

Variable		**Model 1**		**Model 2^{a}**	
	Parameter	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Production Model					
Constant	β_0	10.179 (0.319)	31.889^{***}	10.861 (0.306)	35.44^{***}
Ln (Labour) (X_1)	β_1	0.486 (0.0562)	8.658^{***}	0.401 (0.055)	7.275^{***}
Ln (Farm size) (X_2)	β_2	0.358 (0.0372)	9.622^{***}	0.377 (0.0338)	11.137^{***}
Ln (Fertilizer) (X_3)	β_3	0.00372 (0.00809)	0.460	0.00783 (0.00769)	1.019
Ln (other agrochemical) (X_4)	β_4	0.0262 (-0.0205)	4.175^{***}	0.0202 (0.00579)	3.493^{***}
Ln (Farm assets) (X_5)	β_5	-0.0205 (0.0317)	-0.649	-0.0233 (0.304)	-0.767
Technical Inefficiency Model					
Constant	Z_0	0	-	0.344 (0.162)	2.127^{**}
Land fragmentation	Z_1	0	-	0.0729 (0.0376)	1.939^{*}
Off-farm employment	Z_2	0	-	0.00000016 (0.000000258)	-0.623
Change in farm size	Z_3	0	-	0.00754 (0.112)	-0.622
Multiple planting dates	Z_4	0	-	0.133 (0.0474)	2.802^{***}
Crop Diversification	Z_5	0	-	-0.0119 (0.0383)	-0.310
Education level	Z_6	0	-	-0.00169 (0.0383)	-0.269
Years of climate change	Z_7	0	-	-0.0183 (0.00879)	-2.078^{**}
Social capital	Z_8	0	-	-0.0416 (0.00668)	-6.231^{***}
Variance Parameters					
Total Variance	δ^2_s	0.174		0.183 (0.0208)	8.833^{***}
Gamma	γ	0.0500		0.287 (0.0937)	3.064^{***}
Log likelihood function	Llf	-190.614		-165.505	

*, **, *** stand for level of significance at 10%, 5%, and 1%, respectively.
a is the preferred model
Values in parentheses are standard errors.

Source: Computed from field data, 2011.

Table 4.17: Maximum Likelihood Estimates (MLE) of the Stochastic Frontier Production Function for Food Crop Farmers in the Savanna Agro-ecological Zone of Southwestern Nigeria

Variable		**Model 1**		**Model 2^{a}**	
	Parameter	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Production Model					
Constant	β_0	9.798 (0.440)	22.278^{***}	10.583 (0.446)	23.731^{***}
Ln (Labour) (X_1)	β_1	0.563 (0.0794)	7.094^{***}	0.466 (0.0791)	5.883^{***}
Ln (Farm size) (X_2)	β_2	0.327 (0.0541)	6.042^{***}	0.383 (0.0338)	7.103^{***}
Ln (Fertilizer) (X_3)	β_3	0.0339 (0.0122)	1.115	0.0147 (0.00123)	1.193
Ln (other agrochemical) (X_4)	β_4	0.0339 (0.00879)	3.876^{***}	0.0303 (0.00899)	3.37^{***}
Ln (Farm assets) (X_5)	β_5	-0.0426 (0.039)	-1.091	-0.0533 (0.0384)	-1.387
Technical Inefficiency Model					
Constant	Z_0	0	-	0.261 (0.204)	1.278
Land fragmentation	Z_1	0	-	0.0873 (0.0379)	2.303^{**}
Off-farm employment	Z_2	0	-	0.000000443 (0.000000301)	-0.147
Change in farm size	Z_3	0	-	0.124 (0.118)	1.055
Multiple planting dates	Z_4	0	-	0.0823 (0.0379)	2.171^{***}
Crop Diversification	Z_5	0	-	-0.00447 (0.0399)	-0.112
Education level	Z_6	0	-	-0.00383 (0.00815)	-0.470
Years of climate change	Z_7	0	-	-0.0119 (0.0106)	-1.122
Social capital	Z_8	0	-	-0.0324 (0.00858)	-3.778^{***}
Variance Parameters					
Total Variance	δ^2_s	0.188		0.163 (0.0188)	8.681^{***}
Gamma	γ	0.050		0.0874 (0.0455)	1.923^{**}
Log likelihood function	Llf	-101.932		-87.419	

*, **, *** stand for level of significance at 10%, 5%, and 1%, respectively.

a is the preferred model

Values in parentheses are standard errors

.

Source: Computed from field data, 2011.

Table 4.18: Maximum Likelihood Estimates (MLE) of the Stochastic Frontier Production Function for Food Crop Farmers in the Rainforest Agro-ecological Zone of Southwestern Nigeria

Variable	Parameter	Model 1 Coefficient	t-ratio	Model 2^{a} Coefficient	t-ratio
Production Model					
Constant	β_0	10.544 (0.465)	22.675^{***}	11.187 (0.467)	23.933^{***}
Ln (Labour) (X_1)	β_1	0.358 (0.077)	4.629^{***}	0.299 (0.0799)	3.749^{***}
Ln (Farm size) (X_2)	β_2	0.384 (0.0495)	7.748^{***}	0.348 (0.0486)	7.158^{***}
Ln (Fertilizer) (X_3)	β_3	-0.0024 (0.0104)	-0.232	0.00645 (0.0109)	0.594
Ln (other agrochemical) (X_4)	β_4	0.0153 (0.0088)	1.735^{*}	0.0104 (0.00876)	1.190
Ln (Farm assets) (X_5)	β_5	0.0433 (0.055)	0.787	0.0254 (0.0536)	0.473
Technical Inefficiency Model					
Constant	Z_0	0	-	-0.0869 (0.391)	-0.222
Land fragmentation	Z_1	0	-	-0.0437 (0.701)	-0.624
Off-farm employment	Z_2	0	-	0.00000228 (0.00000074)	3.100^{***}
Change in farm size	Z_3	0	-	-0.803 (0.339)	-2.368^{***}
Multiple planting dates	Z_4	0	-	0.194 (0.135)	1.441
Crop Diversification	Z_5	0	-	-0.00528 (0.0646)	-0.082
Education level	Z_6	0	-	0.0338 (0.0175)	1.926^{*}
Years of climate change	Z_7	0	-	-0.0249 (0.0170)	-1.462
Social capital	Z_8	0	-	-0.0458 (0.0258)	-1.774^{*}
Variance Parameters					
Total Variance	δ^2_s	0.143		0.272 (0.0715)	3.801^{***}
Gamma	γ	0.630		0.656 (0.138)	4.766^{***}
Log likelihood function	Llf	-77.271		-63.189	

*, **, *** stand for level of significance at 10%, 5%, and 1%, respectively.
a is the preferred model
Values in parentheses are standard errors.

Source: Computed from field data, 2011.

4.7 TECHNICAL EFFICIENCY ESTIMATES FOR FOOD CROP FARMERS IN SOUTHWESTERN NIGERIA

The technical efficiency shows the ability of farmers to derive maximum output from the inputs used in food crop production. Given the results of the preferred models (Cobb-Douglas stochastic frontier models), the technical efficiency estimates are presented and discussed subsequently (Table 4.19 and figure 4.1).

The results show high variability in technical efficiency among the food crop farmers in the study area; the computed technical efficiency varies between 0.48 and 0.98 with a mean of 0.84 for the full sample (Southwestern Nigeria). This result of the mean efficiency (0.84) is similar to the finding of Otitoju (2008) on small-scale soybean farmers in Benue State, Nigeria and the work of Kurkalova and Jesen (2000) also found that the average technical efficiency of grain-producing farms in Ukraine was 0.82 in 1989 cropping year. There is also variation in the technical efficiency estimates across the two dominant agro-ecological zones; the computed technical efficiency varies between 0.53 and 0.98 with a mean of 0.83 for those from the savanna agro-ecological zone; and between 0.38 and 0.96 with a mean of 0.84 for those from the rainforest agro-ecological zone. This variation in the level of the technical efficiencies in food crop production imply there is opportunity to improve the current level of technical efficiency by 16% for both the whole respondents (full sample) and those from the rainforest agro-ecological zone and 17% improvement opportunity exists for those from the Savanna agro-ecological zone. (Table 4.19 and figure 4.1).

Table 4.19: Distribution of Technical Efficiency Estimates of Food Crop Farmers in Southwestern Nigeria

	Frequency		
Efficiency index	**Full sample**	**Savanna Agro-ecological Zone**	**Rainforest Agro-ecological Zone**
≤ 0.50	3 (0.83)	-	7 (3.89)
0.51≤ 0.60	19 (5.28)	11 (6.11)	2 (1.11)
0.61≤ 0.70	30 (8.33)	27 (15.00)	6 (3.33)
0.71 ≤ 0.80	49 (8.33)	27 (15.00)	25 (13.89)
0.81 ≤ 0.90	155 (43.06)	42 (23.33)	81 (45.00)
0.91 ≤ 1.00	104 (28.89)	73 (40.56)	59 (32.78)
Total	**360 (100)**	**180 (100)**	**180 (100)**
Mean	0.84	0.83	0.84
Minimum	0.48	0.53	0.38
Maximum	0.98	0.98	0.96

Source: Computed from field data, 2011.

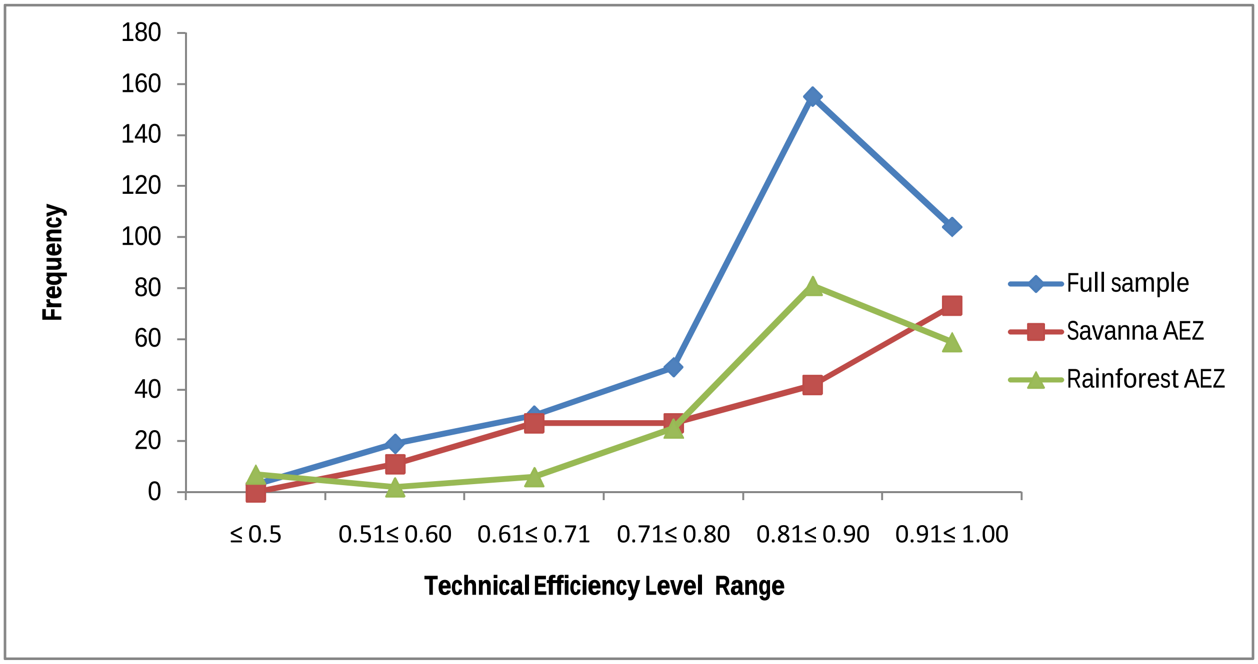

Figure 4.1: Frequency Distribution of Technical Efficiency of Food Crop Production in Southwestern Nigeria

Source: Computed from field data, 2011.

4.8 THE INFLUENCE OF CLIMATE CHANGE ADAPTATION STRATEGIES ON TECHNICAL EFFICIENCY OF FOOD CROP FARMERS IN SOUTHWESTERN NIGERIA

This section presents the results of the analysis of the factors (climate change adaptation strategies) that determine or influence technical efficiency in food crop production in Southwestern Nigeria. These explanatory variables (or factors) are of interest in this study because they have important policy implications. The following variables were hypothesized as climate change adaptation strategies and other farmers and farm-specific variables; land fragmentation (i.e. number of farm plots), off-farm employment, change (increase) in farm size, multiple planting dates, crop mix/ diversification, education level, years of climate change awareness, and social capital.

The results of the inefficiency models of food crop farmers in Southwestern Nigeria, those in the savanna and rainforest agro-ecological zones are shown in Tables 4.16, 4.17, and 4.18, respectively. For the whole respondents (full sample) the following variables, land fragmentation (i.e. number of farm plots) and multiple planting dates had significant positive relationship with technical inefficiency while years of climate change awareness, and social capital had significant inverse relationship with the technical inefficiency (Table 4.16).

In the savanna agro-ecological zone, land fragmentation and multiple planting dates had significant positive relationship with technical inefficiency while only social capital had significant inverse relationship with technical inefficiency (Table 4.17). However, in the rainforest agro-ecological zone, off-farm employment and education level had a positive relationship with technical inefficiency while change in farm size and social capital had an inverse relationship with technical inefficiency (Table 4.18).

The positive coefficients imply that the variables have the effect of decreasing the level of technical efficiency. Any increase in the value of such variables would lead to an increase in the level of technical inefficiency. The inverse relationship implies that any increase in the value of the variable would lead to an increase in technical efficiency.

Factors influencing technical inefficiency are discussed in this section:

Land fragmentation

The result shows that the coefficient for land fragmentation is positive and significant at 5% level of probability for all the respondents (full sample) and also for those in the Savanna agro-ecological zone, but negative and insignificant for the respondents in the rainforest agro-ecological zone (Tables 4.16, 4.17 and 4.18). For the positive significant coefficient, it implies that an increase in land fragmentation tends to increase the level of the technical inefficiency (i.e. decrease technical efficiency). This finding agrees with the findings of Obwona (2000, 2006) and partly with the finding of Otitoju (2008) of small-scale soybean production in Benue state, Nigeria, which found out that increase in the number of fragmented land decreased technical efficiency.

Off farm employment:

The estimated coefficient for off-farm employment is negative and not significant for food crop farmers in the study area (Table 4.16) and for those in the savanna agro-ecological zone of the region (Table 4.17), but has positive sign and is significant at 1% level of probability for the respondents in the rainforest agro-ecological zone (Tables 4.18). This positive relationship implies that as off-farm employment increases, the level of technical inefficiency tends to increase (i.e. decrease technical efficiency). The positive relationship suggests that increases in nonfarm work are accompanied by a reallocation of time away from farm-related activities, such as adoption of new technologies, intensification of other crop management practices that are adaptation strategies and gathering of technical information that is essential for enhancing production efficiency.

The finding on the respondents in the Rainforest agro-ecological zone agrees with the finding of Abdulai and Huffman (2000) in which inefficiency increases with off-farm employment.

Change in farm size:

The result shows a negative and statistically significant (at 5% level of probability) relationship is also found between change in farm size and technical inefficiency in the rain forest agro-ecological zone of the study area (Table 4.18). This suggests that food crop farmers in the agro-ecological zone who did not change (i.e. increase) their farm size experienced higher technical inefficiency. A positive and negative insignificant relationship is found among the respondents in the savanna agro-ecological zone and among all the respondents, respectively (Tables 4.16 and 4.17).

Multiple planting dates:

The estimated coefficient of multiple planting dates for all the respondents (full sample) and those from the savanna agro-ecological zone was positive and statistically significant as seen in tables 4.16 and 4.17, respectively. This implies that a further increase in multiple planting dates tends to increase technical inefficiency.

Crop Diversification:

An inverse and statistically insignificant relationship is found between crop diversification and technical inefficiency in all the categories of respondents (food crop farmers) (Tables 4.16, 4.17 and 4.18). This implies that further diversification of crops may lead to more inefficiency in food crop production in the area. This disagrees with the findings of Amaza *et al.* (2006) which found that crop diversification had positive and significant relationship with technical inefficiency in food crop production in Borno State, Nigeria.

Education level:

The estimated coefficient of education is positive and statistically significant at 10% level of probability among the respondents (food crop farmers) in the rainforest agro-ecological zone of Southwestern Nigeria (Table 4.18). This implies that an increase in the level of education tends to increase the level of technical inefficiency. This positive value obtained is unexpected. This result may be linked to the average education level of about 8 years among the food crop farmers as revealed by this study. A relevant and functional vocational education (e.g. agricultural education) must be emphasized for it to have a reasonable effect on inefficiency (i.e. improving technical efficiency). Similar results have been found by Obwona (2006) among tobacco growers in Uganda and also Nwaru and Onuoha (2010) in smallholder food crop production in Imo state, Nigeria. In the savanna and the rainforest agro-ecological zones of the study area there is an inverse relationship between education level and technical inefficiency, but it is not significantly different from zero. Education programmes for the farmers in the agro-ecological zones must focus more on skill-based education that has high tendency of increasing their technical efficiency. This negative coefficient of education level was in conformity with Ali and Flin (1989) and Ogundari (2006).

Years of Climate change awareness:

A negative and statistically significant relationship is found between years of climate change awareness and technical inefficiency in food crop production in Southwestern Nigeria and among the respondents in the rainforest agro-ecological zone as seen in tables 4.16 and 4.17, respectively. This implies that an increase in the years of awareness tends to increase technical efficiency (i.e. decrease technical inefficiency). This is in line with the *a priori* expectation.

Social capital:

An inverse and statistically significant relationship is found between social capital and technical inefficiency in food crop production in all the categories of the respondents (Tables 4.16, 4.17 and 4.18). This implies that the social capital that farm families have access to makes a big difference in their abilities to surmount these adverse events such as climate change. This implies an increase in social capital tends to increase technical efficiency (or decrease technical inefficiency). Social capital can help to mitigate shocks to income and food supplies in times of crises. Generally, the severity of the shock to income and food supplies and what coping strategies families may choose to utilize to cope with the shock may depend primarily on the strength of the social networks they have access to (Kaschula 2008; Muga & Onyango-Ouma 2009; Mtika 2001). Consequently, social capital has the capacity to impact the efficiency level of food crop farming households.

4.9 ESTIMATES FOR PARAMETERS OF AVERAGE AND STOCHSTIC FRONTIER PROFIT FUNCTIONS

Profit efficiency is the profit gain from operating on the profit frontier, taking into consideration farm-specific prices and factors. The analysis of the data for the profit efficiency estimates was achieved through the Maximum Likelihood Estimation (MLE), which involved the estimation of the average profit (Model 1) and the profit frontier (Model 2) models. The selection of the preferred model for the food crop production was carried out with the generalized log likelihood-ratio statistic. The estimated stochastic frontier models (Models 1 and 2) for the food crop production in Southwestern Nigeria (full sample), in the Savanna and the Rainforest agro-ecological zones is given in tables 4.21, 4.22 and 4.23, respectively. Tests of hypotheses were carried out to select the model that better represents the data for food crop farmers (Table 4.20). The null hypothesis, $H_0:\gamma = \delta_o = \delta_1 \ldots = \delta_8 = 0$, which states that inefficiency effects are absent from the frontier model, is rejected for the food crop farmers.

Given the results of the test of hypotheses, the Cobb-Douglass frontier profit model (Model 2) was selected as the preferred model that better fits the data of food crop farmers. Because the values of the chi-square calculated are greater than the critical values. Hence, the discussions are based on the Cobb-Douglas frontier profit models for all the categories of the farmers (Model 2).

Table 4.20: Generalised log likelihood-ratio tests of null hypothesis

H_0: Food crop farmers are fully profit efficient (γ=0)

Food Crop Farmers	Log likelihood function Model 1	 Model 2	λ	Critical value*	Decision
Full Sample (N=360)	-402.175	-303.321	197.708	15.51	Reject H_0
Savanna Agro-ecological Zone (N=180)	-195.542	-162.360	66.364	15.51	Reject H_0
Rainforest Agro-ecological Zone (N=180)	-200.616	-122.427	156.378	15.51	Reject H_0

Degree of freedom is the number of restricted parameters, here 8 parameters were restricted.
* Critical value is obtained from table 3 pp. 661-662 in Koutsoyiannis (1977) the abridged table from 'Table of percentage points of the χ^2 (0.05) distribution' by Catherine M. Thompson, *Biometrika,* vol. 32, 1941.

Source: Computed from field data, 2011.

Maximum likelihood estimates for parameters of the two estimated models are presented in tables 4.21, 4.22 and 4.23. Price of labour and rent on farmland variables are highly significant at 1% level of probability for all the categories of the food crop farmers. However, price of farm assets is significant at 10% level of probability for the sampled food crop farmers in the rainforest agro-ecological zone. The estimated value for the γ-parameter in the Cobb-Douglas stochastic frontier profit function (the preferred models) for the food crop farmers are 0.949 in southwestern Nigeria; 0.890 and 0.656 for those in the savanna and the rainforest agro-ecological zones of Southwestern Nigeria, as seen in tables 4.21, 4.22 and 4.23, respectively. The values are significant at 1% level of probability for all the categories of food crop farmers. These values indicate that profit inefficiency is highly significant among the food crop farmers in southwestern Nigeria. The γ- parameter shows the relative magnitude of the variance in the value associated with profit efficiency. The coefficients of the variables derived from the

Maximum Likelihood Estimation (MLE) are very important for discussing results of the analysis of the data. These coefficients represent percentage change in the dependent variables as a result of percentage change in the independent (or explanatory) variables.

Table 4.21: Maximum Likelihood Estimates (MLE) of the Stochastic Frontier Profit Function for Food Crop Farmers in Southwestern Nigeria

Variable		**Model 1**		**Model 2^a**	
	Parameter	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Profit Model					
Constant	α_0	5.216 (1.125)	4.635^{***}	8.150 (0.833)	9.780^{***}
Ln (Price of Labour) (X_1)	α_1	0.655 (0.102)	6.436^{***}	0.397 (0.0779)	5.093^{***}
Ln (Rent on Farmland) (X_2)	α_2	0.351 (0.0684)	5.134^{***}	0.353 (0.0492)	7.186^{***}
Ln (Price of Fertilizer) (X_3)	α_3	-0.0284 (0.00822)	-3.456^{***}	-0.00467 (0.00623)	-0.750
Ln (Price of other agrochemical) (X_4)	α_4	0.00420 (0.0113)	0.371	0.00750 (0.00872)	0.861
Ln (Price of farm assets) (X_5)	α_0	-0.0544 (0.0578)	-0.942	0.00777 (0.0422)	0.184
Profit Inefficiency Model					
Constant	λ_0	0	-	-3.266 (1.331)	2.453^{**}
Land fragmentation	λ_1	0	-	-0.499 (0.175)	-2.851^{***}
Off-farm employment	λ_2	0	-	0.00000196 (0.000000697)	2.806^{***}
Change in farm size	λ_3	0	-	0.330 (0.373)	0.885
Multiple planting dates	λ_4	0	-	0.0159 (0.243)	4.185^{***}
Crop Diversification	λ_5	0	-	0.207 (0.112)	1.841^{*}
Education level	λ_6	0	-	0.183 (0.056)	3.291^{***}
Years of climate change	λ_7	0	-	-0.269 (0.0691)	-3.891^{***}
Social capital	λ_8	0	-	-0.0965 (0.0296)	-3.261^{***}
Variance Parameters					
Total Variance	δ^2_s	0.556		2.590 (0.477)	5.428^{***}
Gamma	γ	0.910		0.949 (0.0126)	75.177^{***}
Log likelihood function	Llf	-402.175		-303.321	

*, **, *** stand for level of significance at 10%, 5%, and 1%, respectively.
a is the preferred model
Values in parentheses are standard errors.

Source: Computed from field data, 2011.

Table 4.22: Maximum Likelihood Estimates (MLE) of the Stochastic Frontier Profit Function for Food Crop Farmers in the Savanna Agro-ecological zone of Southwestern Nigeria

Variable		**Model 1**		**Model 2^{a}**	
	Parameter	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Profit Model					
Constant	α_0	5.060 (1.466)	3.451***	7.343 (1.167)	6.293***
Ln (Price of Labour) (X_1)	α_1	0.675 (0.133)	5.058***	0.501 (0.109)	4.587***
Ln (Rent on Farmland) (X_2)	α_2	0.281 (0.0942)	2.986***	0.299 (0.0743)	4.026***
Ln (Price of Fertilizer) (X_3)	α_3	-0.0188 (0.0115)	-1.639*	-0.00649 (0.0101)	-0.641
Ln (Price of other agrochemical) (X_4)	α_4	0.00788 (0.0147)	0.535	0.0138 (0.0123)	1.126
Ln (Price of farm assets) (X_5)	α_0	-0.0890 (0.0671)	-1.327	-0.0851 (0.0576)	-1.477
Profit Inefficiency Model					
Constant	λ_0	0	-	-2.918 (1.598)	-1.825*
Land fragmentation	λ_1	0	-	-0.5023 (0.207)	-2.426**
Off-farm employment	λ_2	0	-	0.00000238 (0.00000112)	2.131**
Change in farm size	λ_3	0	-	0.524 (0.453)	1.157
Multiple planting dates	λ_4	0	-	1.099 (0.391)	2.808***
Crop Diversification	λ_5	0	-	0.00954 (0.135)	0.071
Education level	λ_6	0	-	0.106 (0.0549)	1.935*
Years of climate change	λ_7	0	-	-0.208 (0.0776)	-2.684***
Social capital	λ_8	0	-	-0.181 (0.0862)	-2.095**
Variance Parameters					
Total Variance	δ^2_s	0.532		2.194 (0.432)	5.075***
Gamma	γ	0.840		0.890 (0.0325)	27.519***
Log likelihood function	Llf	-195.542		-162.360	

*, **, *** stand for level of significance at 10%, 5%, and 1%, respectively.
a is the preferred model
Values in parentheses are standard errors.

Source: Computed from field data, 2011

Table 4.23: Maximum Likelihood Estimates (MLE) of the Stochastic Frontier Profit Function for Food Crop Farmers in the Rainforest Agro-ecological zone of Southwestern Nigeria

Variable	Parameter	Model 1 Coefficient	 t-ratio	Model 2^a Coefficient	 t-ratio
Profit Model					
Constant	α_0	5.174 (1.735)	2.982^{***}	9.457 (0.987)	9.580^{***}
Ln (Price of Labour) (X_1)	α_1	0.618 (0.154)	4.003^{***}	0.247 (0.0889)	2.773^{***}
Ln (Rent on Farmland) (X_2)	α_2	0.378 (0.0995)	3.803^{***}	0.346 (0.0593)	5.830^{***}
Ln (Price of Fertilizer) (X_3)	α_3	-0.0348 (0.0117)	-2.972^{*}	-0.00187 (0.00676)	-0.276
Ln (Price of other agrochemical) (X_4)	α_4	-0.00463 (0.0176)	-0.263	-0.00708 (0.0111)	-0.639
Ln (Price of farm assets) (X_5)	α_0	0.0383 (0.108)	0.354	1.106 (0.0571)	1.854^{*}
Profit Inefficiency Model					
Constant	λ_0	0	-	-3.024 (1.535)	-1.970^{**}
Land fragmentation	λ_1	0	-	-0.890 (0.253)	-3.516^{***}
Off-farm employment	λ_2	0	-	0.00000945 (0.00000185)	5.119^{***}
Change in farm size	λ_3	0	-	-1.764 (0.537)	-3.282^{***}
Multiple planting dates	λ_4	0	-	1.073 (0.326)	3.289^{***}
Crop Diversification	λ_5	0	-	0.191 (0.170)	1.112
Education level	λ_6	0	-	0.249 (0.046)	5.438^{***}
Years of climate change	λ_7	0	-	-0.271 (0.034)	-7.867^{***}
Social capital	λ_8	0	-	-6.939 (0.024)	-2.924^{***}
Variance Parameters					
Total Variance	δ^2_s	0.563		2.194 (0.432)	7.185^{***}
Gamma	γ	0.950		0.890 (0.0325)	120.285^{***}
Log likelihood function	Llf	-200.616		-122.427	

*, **, *** stand for level of significance at 10%, 5%, and 1%, respectively.
a is the preferred model
Values in parentheses are standard errors.

Source: Computed from field data, 2011

4.10 PROFIT EFFICIENCY ESTIMATES FOR FOOD CROP FARMERS IN SOUTHWESTERN NIGERIA

The average measure of inefficiency is 33 % (i.e. 67% efficiency), which suggests that about 33% of potential maximum profit is lost owing to inefficiency (Table 4.24). Kurkalova and Jesen (2000) found a similar result among grain-producers in Ukraine of mean technical efficiency of 0.68 (68%) in 1991 cropping year. This implies that the food crop farmers have the opportunity to improve their profit efficiency level by 33%. This discrepancy between observed profit and the frontier profit is due to inefficiency in the use of the climate change adaptation strategies and other farmer-specific characteristics as suggested by this study. The frequency distribution of the farm specific profit inefficiency is reported in table 4.24 and figure 4.2. The result shows that sample farm profit inefficiency varies widely. Although the minimum observed profit efficiency is 0.003 (i.e. 0.997 inefficiency), and the maximum is 0.93 (i.e. 0.07 inefficiency) 29.72% of the sampled farms exhibited a profit efficiency between 0.81 and 0.90 (i.e. 0.81≤0.90); 24.17% of the sampled farms exhibited a profit efficiency between 0.71 and 0.80 (i.e. 0.71≤ 0.80); while about 11.11% of them had a profit efficiency of 0.40 or less (i.e. ≤ 0.40) (Table 4.24).

Also estimated in this study are a stochastic frontier profit function of the food crop farmers from the savanna and the rainforest agro-ecological zones of southwestern Nigeria to ascertain profit efficiency of the sampled food crop farms. The profit efficiencies range between 0.02 and 0.92; and between 0.02 and 0.94 for the respondents from the Savanna and the rainforest agro-ecological zones of southwestern Nigeria, respectively (Table 4.24). Also, the average profit efficiency of the respondents from is 0.72 and 0.66 for the food crop farmers from the savanna and the rainforest agro-ecological zones respectively. This implies that the food crop farmers in the savanna and the rainforest agro-ecological zones have the privilege to raise their profit efficiency levels by 28% and 34% respectively. The result of mean profit efficiency of food crop farmers from the rainforest agro-ecological zone of the study area agrees with the finding of Ajibefun *et al.* (2006) that found out that mean technical efficiency of small-scale rural farmers in Ondo state was 0.66. Also, the result of the average profit efficiency of food crop farmers from the Savanna agro-ecological zone agrees with the findings of Otitoju and Arene (2010) and Otitoju (2008) that the medium-scale soybean farmers' mean technical efficiency was 0.725.

About 33% and 34% of the respondents have a profit efficiencies between 0.81 and 0.91 (i.e. 0.81≤ 0.90) for the savanna and the rainforest agro-ecological zones. About 32% (31.67%) and 15% of the respondents from the savanna and the rainforest agro-ecological zones fall within the profit efficiency range of 0.71 and 0.80 (i.e. 0.71≤ 0.80). Again, about 6% (5.56%) and 14% (13.89%) of the respondents have a profit efficiencies of 0.40 or less in the savanna and the rainforest agro-ecological zones of Southwestern Nigeria respectively (Table 4.24).

Table 4.24: Distribution of Profit Efficiency Estimates of Food Crop Farmers in Southwestern Nigeria

	Frequency		
Efficiency index	**Full sample**	**Savanna Agro-ecological Zone**	**Rainforest Agro-ecological Zone**
≤ 0.40	40 (11.11)	10(5.56)	25(13.89)
0.41≤ 0.50	32 (8.89)	11(6.11)	20(11.12)
0.51≤ 0.60	35(15.28)	7 (3.89)	22 (12.22)
0.61≤ 0.70	55 (15.28)	33(18.33)	18 (10.00)
0.71 ≤ 0.80	87 (24.17)	57 (31.67)	27 (15.00)
0.81 ≤ 0.90	107 (29.72)	60 (33.33)	62 (34.44)
0.91 ≤ 1.00	4 (1.11)	2 (1.11)	6 (3.33)
Total	**360 (100)**	**180 (100)**	**180 (100)**
Mean	0.67	0.72	0.66
Minimum	0.003	0.02	0.002
Maximum	0.93	0.92	0.94

Values in parentheses are percentages.

Source: Computed from field data, 2011.

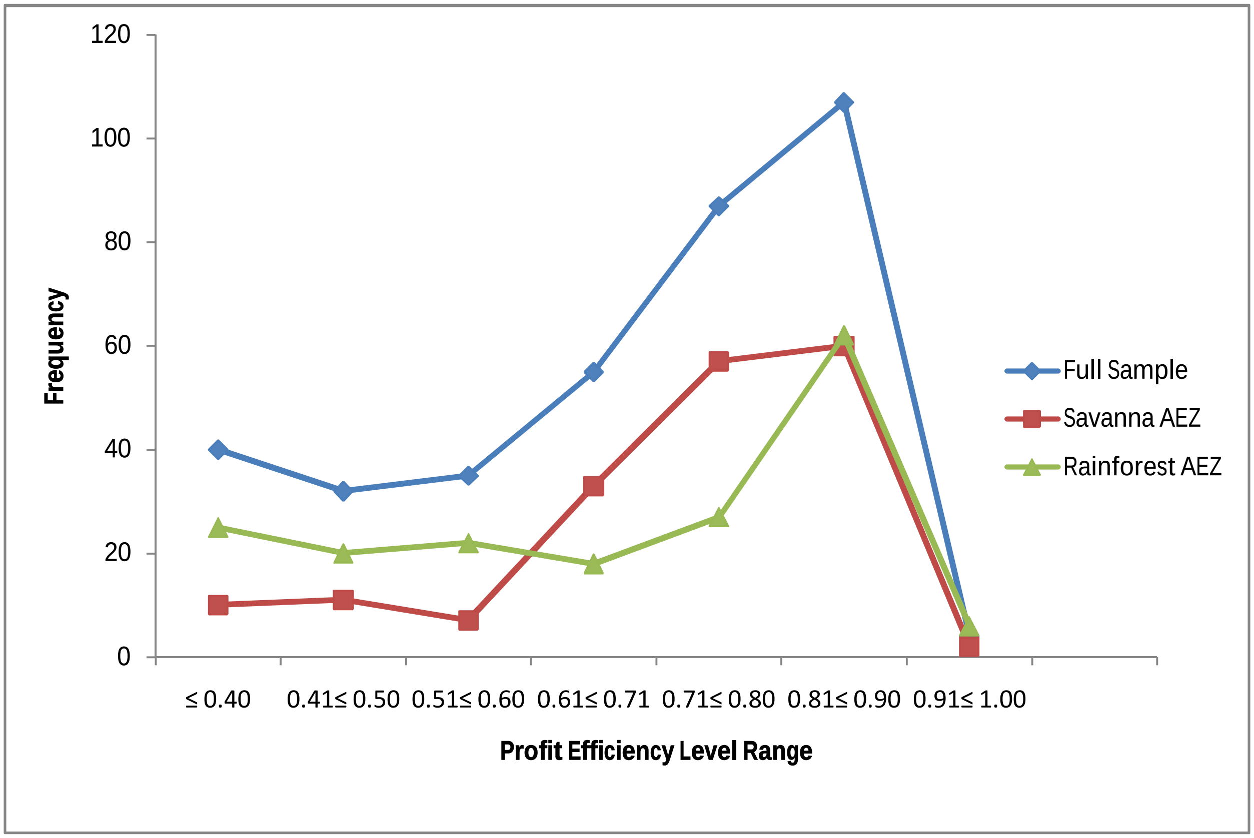

Figure 4.2: Frequency Distribution of Profit Efficiency of Food Crop production in Southwestern Nigeria

Source: Computed from field data, 2011.

4.11 THE INFLUENCE OF CLIMATE CHANGE ADAPTATION STRATEGIES ON PROFIT EFFICIENCY OF FOOD CROP FARMERS IN SOUTHWESTERN NIGERIA

This section presents the results of the analysis of the factors (climate change adaptation strategies and farm-specific variables) that determine or influence profit efficiency in food crop production in Southwestern Nigeria. These explanatory variables (or factors) are of interest in this study because they have important policy implications. The following variables were hypothesized as climate change adaptation strategies and other farmers and farm-specific variables; land fragmentation, off-farm employment, change in farm size, multiple planting dates, crop diversification, education level, years of climate change awareness, and social capital.

The results of the profit inefficiency model of food crop farmers in Southwestern Nigeria, those in the savanna and the rainforest agro-ecological zones of the study area as shown in tables 4.21, 4.22 and 4.23. For the whole respondents (full sample) the following variables, off-farm employment, multiple planting dates, crop diversification, and education level had significant positive relationship with profit inefficiency while land fragmentation, years of climate change awareness, and social capital had significant inverse relationship with the profit inefficiency (Table 4.21).

In the savanna agro-ecological zone, off-farm employment, multiple planting dates and education level had significant positive relationship with profit inefficiency while land fragmentation, years of awareness of climate change and social capital had significant indirect relationship with profit inefficiency (Table 4.22).

However, in the rainforest agro-ecological zone, off-farm employment, multiple planting dates and education level had positive relationship with profit inefficiency while land fragmentation, change in farm size, years of awareness of climate change and social capital had inverse relationship with the profit inefficiency (Table 4.23).

The positive coefficients imply that the variables have the effect of decreasing the level of profit efficiency. Any increase in the value of such variables would lead to a decrease in the level of profit efficiency, while the negative coefficients imply that any increase in the value of the variable would lead to an increase in the profit efficiency (or a decrease in profit inefficiency).

The following variables (climate change adaptation strategies and farm-specific characteristics) in relation to profit inefficiency are discussed below:

Land fragmentation:

A negative and statistically significant relationship is found between land fragmentation and profit inefficiency in food crop production among the food crop farmers in all the categories in the study area as seen in tables 4.21, 4.22 and 4.23. This shows that the numbers of farm plots can still be increased reasonably to adapt to climate change that will still lead to decrease in profit inefficiency in the study area. This implies an increase in land fragmentation tends to decrease profit inefficiency. This disagrees with the findings of Obwona (2000, 2006) on technical efficiency among tobacco farmers in Uganda.

Off-farm employment:

The estimated coefficient of off-farm employment is positive and statistically significant at 1% level of probability among the respondents (food crop farmers) in study area (full sample) and in the rainforest agro-ecological zone of Southwestern Nigeria, but at 5% level of probability for food crop farmers in the savanna agro-ecological zone of southwestern Nigeria (Tables 4.21, 4.22 and 4.23), suggesting that an increase in off-farm work tends to decrease the level of profit efficiency. The positive sign on the estimated coefficient points towards a situation where those food crop farmers who have higher opportunity to engage in off-farm work or investment fail to pay much attention to their crops relative to other farmers. These results agree with the findings of Otitoju (2008) for small-scale soybean farmers in Benue state, Nigeria and also with Rahman (2003) that found this among Bangladesh rice farmers. This also agrees with the work of Ogunniyi (2011) that found that positive relationship exist between off-farm employment and profit efficiency among maize producers in Oyo state, Nigeria.

Change in farm size:

A negative and statistically significant relationship is found between change in farm size (i.e. increase) and profit inefficiency in food crop production only in the rainforest agro-ecological zone of Southwestern Nigeria (Table 4.23). This implies that an increase in farm size tends to increase technical efficiency. This suggests that farmers that increase their farm size will be able to pay adequate attention to other crop management activities that have the tendency to increase profit efficiency.

Multiple planting dates:

A positive relationship is found between multiple planting dates and profit inefficiency and statistically significant at 99% level of confidence in the study area as seen in tables 4.21, 4.22 and 4.23. This suggests that more different dates of planting of food crops tend to decrease profit efficiency in the study area. This result is unexpected.

Crop diversification:

A direct and statistically significant relationship exists between crop diversification and profit inefficiency in the study area as seen in table 4.21. This implies that an increase in diversification of crops tends to decrease profit efficiency. This agrees with the finding of Amaza *et al.* (2006) that found out positive relationship between food crop farmers and technical efficiency in Borno state, Nigeria.

Education level:

The estimated coefficient of education level is positive and statistically significant at 1% level of probability among all the respondents in study area (full sample) and in the rainforest agro-ecological zone, but significant at 5% level of probability in the savanna agro-ecological zone of Southwestern Nigeria (Tables 4.21, 4.22 and 4.23). This result is not surprising because the average years of schooling of the respondents in the study area is about 8 years, this helps explain this. More efforts still need to be taking in giving the citizens in the area relevant skill-based education for profit inefficiency to be reduced.

Years of Climate change awareness:

A negative and statistically significant relationship is found between years of climate change awareness and profit inefficiency in food crop production in Southwestern Nigeria as seen in tables 4.21, 4.22 and 4.23, respectively. This implies that an increase in the years of awareness of climate change tends to increase profit efficiency (i.e. decrease profit inefficiency). This is in line with the *a priori* expectation.

Social capital:

An inverse and statistically significant relationship is found between social capital and profit inefficiency in food crop production among the food crop farmers in the study area as seen in tables 4.21, 4.22 and 4.23. This implies an increase in social capital tends to increase profit efficiency. This is the expected result because the more the social contact (bonding and bridging social capital) the farmer makes the more his understanding of farm-level climate change adaptation measures used by other famers that are more efficient and invariably the tendency of being more efficient is there. Extra-family social capital may serve as a transmission mechanism from resources into outcomes through their effects on preferences, constraints and expectations, thereby influencing economic decisions. Generally, the severity of the shock to income and food supplies and what coping strategies families may choose to utilize to cope with the shock may depend primarily on the strength of the social networks they have access to. In times of financial hardship, food shortages, or severe illnesses, various studies in Africa have shown that the social capital that families have access to makes a big difference in their abilities to surmount these adverse events (Kaschula 2008; Muga & Onyango-Ouma 2009; Mtika 2001). Consequently, social capital has the capacity to impact the profit efficiency level of farming households.

4.12 SIMULATION OF SELECTED CLIMATE CHANGE ADAPTATION STRATEGIES

This analysis then went further to simulate the impact of selected climate change adaptation strategies (i.e. land fragmentation, off-farm employment and multiple planting dates) on mean technical efficiency of the food crop farmers in Southwestern Nigeria. These variables are determinants of technical efficiency that could be influenced by policy implementation to improve the current level of observed technical efficiency. The simulation is done with an increase in the value of these selected variables at 10% and 20%. The results of the simulations are presented in table 4.25.

The results of the simulation of climate change adaptation variables show that the level of mean technical efficiency would significantly increase with 10% rise in land fragmentation (i.e. number of farm plots). The mean technical efficiency rise from 0.84 to 0.87, which represents about 4% (3.57%) increase in mean technical efficiency. But at 20% rise in the value of land fragmentation the mean technical efficiency dropped drastically from 0.84 to 0.39 which represent about 54% (53.57%) decrease.

At 10% rise in the value of off-farm income (employment), the mean technical efficiency increase from 0.84 to 0.87, this represents about 4% (3.57%) increase also. But when its value was increased by 20% the mean technical efficiency dropped slightly from 0.84 to 0.83, which represent 1.19% decrease.

Also for multiple planting dates, when its value was increased by 10% there is no change in the mean technical efficiency. Then at 20% increase in the value of multiple planting dates, the mean technical efficiency dropped from 0.84 to 0.83, which represents 1.19% decrease. The sign of the coefficient is positive and statistically significant, which means an increase in different planting dates would lead to increase in technical inefficiency.

From the foregoing, it could be deduced that land fragmentation and off-farm employment are the main climate change adaptation strategies that could be improved reasonably among the small-scale food crop farmers to improve their efficiency technically to a reasonable level. However, further increase in these variables would lead to declining mean technical efficiency in food crop production in Southwestern Nigeria. Having different plots (Land fragmentation) and multiple planting dates reduces the risk of complete crop failure and invariably improve the crop production efficiency. It is important to note that these adaptation strategies should not be taken as independent measures but should be used in a complementary manner.

Table 4.25: Effects of Selected Climate Change Adaptation Variables on Mean Technical Efficiency of Food Crop Farmers in Southwestern Nigeria

Variables	**Before Simulation**	**After Simulation**					
		Land Fragmentation		**Off-farm income**		**Multiple Planting Dates**	
		10%	**20%**	**10%**	**20%**	**10%**	**20%**
Productive inputs:							
Labour	+++	+++	NS	+++	+++	+++	+++
Farm size	+++	+++	NS	+++	+++	+++	+++
Fertilizer	NS	NS	NS	NS	NS	NS	NS
Other agrochemical	+++	+++	**	+++	+++	+++	+++
Depreciation	NS	NS	NS	NS	NS	NS	NS
Climate change adaptation variables:							
Land fragmentation	+	**NS**	*	*	NS	+	NS
Off-farm income	NS	NS	NS	**NS**	**NS**	NS	NS
Change in farm size	NS	NS	NS	NS	NS	NS	NS
Multiple planting dates	+++	+	NS	+++	++	**++**	**+++**
Crop Diversification	NS	NS	*	NS	NS	NS	NS
Education level	NS	NS	*	NS	NS	NS	NS
Years of climate change	**	NS	NS	NS	NS	NS	NS
Social capital	***	***	NS	***	***	***	***
Mean technical efficiency	**0.84**	**0.87**	**0.39**	**0.87**	**0.83**	**0.84**	**0.83**

NS stands for not significant

+, ++, +++ stands for level significance at 10%, 5%, and 1% respectively with positive relationship.

*, **, *** stands for level of significance at 10%, 5% and 1% respectively with inverse relationship.

Source: Computed from field data, 2011.

4.13 CONSTRAINTS TO CLIMATE CHANGE ADAPTATION BY FOOD CROP FARMERS IN SOUTHWESTERN NIGERIA

Table 4.26 shows the varimax-rotated principal component analysis of major factors constraining food crop farmers in adapting to climate change in the study area. From the result, five (5) factors were extracted based on the responses of the respondents (food crop farmers). The Kaiser criterion (1960) was used for selecting the number of underlying factors or

principal components explaining the data. In this study, the number was decided by leaving out components with corresponding Eigen values (a measure of explained variance) of less than one. Only variables with factor loadings of /0.40/ and above at 10% overlapping variance were used in naming the factors. Variables that have factor loading of less than /0.40/ were not used while variables that loaded in more than one constraints were also discarded (Madukwe, 2004). The communalities represent the relation between the variable and all other variables (i.e., the squared multiple correlation between the item and all other items). These factors are; factor 1 (Public, institutional and labour constraints), factor 2 (Land, neighbourhood norms and religious beliefs constraints), factor 3 (High cost of inputs, technological and poor information on early warning systems constraints), factor 4 (Far farm distance, poor access to climate change adaptation information, off-farm job and credit constraints); and factor 5 (Poor agricultural extension programmes and service delivery constraints).

After rotation, the first factor accounted for 11.9% of the variance, the second factor accounted for 11.5%, the third factor accounted for 8.8%, the fourth factor accounted for 8.7%, and the fifth factor accounted for 7.6%. The true factors that were retained explained 48.5% of the variance in the 29 constraining factor or variable components.

Among the food crop farmers in Southwestern Nigeria, the specific issues that amplified public, institutional and labour constraints (factor 1) include; lack of access to weather forecast technologies (0.755), lack of/or inadequate government policies to empower food crop farmers (0.753), lack of access to supporting institutional facilities (e.g. cooperative, adult education programme) (0.655), lack of access to and awareness about NGOs programme on climate change adaptation (0.568), lack of access to weather and climate forecast information (0.561), non-availability of farm labour (0.485) and limited Government irresponsiveness to climate risk management (0.417). In the present information age, information problems could pose serious challenges to farmers' coping or adaptation strategies as they may not be aware of recent developments regarding climate change adaptations and the necessary readjustments needed. The lack of adaptive capacity due to constraints on resources such as the lack of access to weather forecasts creates serious gaps between the farmers and useful information that should help them in their farm work. Weather forecasts are supposed to guide farmers on climate variability so that they can make informed decisions and useful farm plans. However, the absence of this facility will undoubtedly make the farmers become ignorant of the weather situations and hence become vulnerable to the impact of changes in the climate and weather. Ozor *et al.* (2010) noted that poor climate change information and farmers' lack of access to weather forecast technologies as major barriers to climate change adaptation among farming households in Southern Nigeria.

Under factor 2 (land, neighbourhood norms and religious beliefs constraints), the variables or factors that loaded high were; high cost of farmland (0.791), poor access to and control of land (0.783), inherited system of land ownership (0.743), neighbourhood norms, customs, culture and traditional belief against adaptation (0.655), religious belief of the farming household (0.591), lack of collateral security required to secure loan to support food crop farming (0.400). Kassahun (2009) noted that shortage of land is a major constraint on adapting to climate change in Nile basin of Ethiopia. This result agrees with the findings of Enete and Onyekuru (2011) which noted that land tenure is a major challenge of agricultural adaptation to climate change in Southeast Nigeria.

Variables that loaded under factor 3 (high cost of inputs, technological and poor information on early warning systems constraints) include; high cost of improved varieties (0.669), traditional beliefs/ practices (e.g. commencement of farming season, crop festival) (0.504), high cost of irrigation facilities (0.488), illiteracy of the food crop farmers (0.487), and poor information on early warning systems (0.427). Benhin (2006) noted that farmers' level of education is a major determinant of speed of adoption of adaptation measures to climate change. The result of this study agrees with that of Ozor *et al.* (2010) which discovered that high cost of inputs is also a major barrier to climate change adaptation among farming households in Southern Nigeria.

The main constraints as perceived by the respondents (food crop farmers) limiting them on climate change adaptation in Southwestern Nigeria under factor 4 (Far farm distance, poor access to climate change adaptation information, off-farm job and credit constraints) include; far distance of household food crop farms to their homesteads (0.613), involvement of the food crop farmers in some off-farm jobs (e.g. artisans, trading, civil service) (0.580), small scale production of some of the food crop farming household (0.536), poor access to climate change adaptation strategies information by food crop farmers (0.516), insufficient knowledge of credit source to support farm work (0.469), and tedious nature of climate change adaptation strategies (0.451). Benhin (2006) reported that lack of access to credit or saving and lack of adequate information about climate change are some of the major constraints encountered by farmers in adapting to climate change in Africa. Kassahun (2009) further confirmed that lack of access to credit and lack of information as major constraints on adapting to climate change in Ethiopia.

The variables that loaded high under factor 5 (poor agricultural extension programmes and service delivery constraints) were; lack of/or inadequate extension programmes directed to meet the climate change adaptation strategies in food crop production (0.774) and poor agricultural extension delivery (0.746). The results of lack of/or inadequate extension programmes directed to meet the climate change adaptation strategies in food crop production and that of poor agricultural extension delivery agree with the study of Amusa (2010) that noted lack of agricultural extension programme as a major constraint among cocoa agroforestry households in Ekiti State, Nigeria. Benhin (2006) noted further that farmers' access to extension service is a major determinant of speed of adoption of adaptation measures to climate change.

4.14 Constraints to Climate Change Adaptation by Food Crop Farmers in the Savanna Agro-Ecological Zone of Southwestern Nigeria

The result shows the varimax-rotated principal component analysis of major factors constraining food crop farmers in adapting to climate change in the Savanna agro-ecological zone of Southwestern Nigeria (Table 4.27). From the results in the table, five (5) factors were extracted based on the responses of the respondents (food crop farmers) as seen in table 4.19b. These include factor 1 (Lack of access to weather information, public and private institutions constraints); factor 2 (land, neighbourhood norms and religious beliefs constraints); factor 3 (Poor access to climate change adaptation information and credit sourcing constraints); factor 4 (High cost of supporting facilities and inputs and illiteracy constraints); and factor 5 (Poor agricultural extension service delivery and Poor information on early warning systems constraints). The Kaiser criterion (1960) was used for selecting the number of underlying factors or principal components explaining the data. After rotation, the first factor accounted for 12.1% of the variance, the second factor accounted for 10.7%, the third factor accounted for 9.4%, the fourth factor accounted for 8.5%, and the fifth factor accounted for 7.8%. The true factors that were retained explained 48.5% of the variance in the 29 constraining factor or variable components.

Table 4.26: Varimax Rotated Factors/Variables Constraining Food Crop Farmers on Climate Change Adaptation in Southwestern Nigeria

	Constraints	Components*					Communality
		Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	
1.	Lack of access to weather forecast technologies	**0.755**					0.643
2.	Lack of or inadequate government policies to empower food crop farmers	**0.753**					0.612
3.	Lack of access to supporting institutional facilities	**0.655**					0.591
4.	Lack of access to and awareness about NGOs programme on climate change adaptation	**0.568**					0.452
5.	Lack of access to weather and climate forecast information	**0.561**					0.440
6.	Non-availability of farm labour	**0.485**					0.490
7.	Limited Government irresponsiveness to climate risk management	**0.417**					0.285
8.	High cost of farmland		**0.791**				0.691
9.	Poor access to and control of land		**0.783**				0.645
10.	Inherited system of land ownership		**0.743**				0.636
11.	Neighbourhood norms, customs, culture and traditional belief against adaptation		**0.655**				0.488
12.	Religious belief of the farming household		**0.591**				0.441
13.	Lack of collateral security required to secure loan to support food crop farming		**0.400**				0.481
14.	High cost of improved crop varieties			**0.669**			0.560
15.	Traditional beliefs/practices e.g. on the commencement of farming season, crop festival period, etc			**0.504**			0.509
16.	High cost of irrigation facilities			**0.488**			0.426
17.	Illiteracy of the food crop farmers			**0.487**			0.365
18.	Poor information on early warning systems			**0.427**			0.461
19.	Far distance of household food crop farms to their homesteads				**0.613**		0.549
20.	Involvement of the food crop farmers in some off farm jobs				**0.580**		0.412
21.	Small scale production of some of the food crop farming household				**0.536**		0.369
22.	Poor access to climate change adaptation strategies information by food crop farmers				**0.516**		0.404
23.	Insufficient knowledge of credit source to support farm work				**0.469**		0.333
24.	Tedious nature of climate change adaptation strategies				**0.451**		0.315
25.	Lack of /or inadequate extension programmes directed to meet the climate change adaptation strategies in food crop production					**0.774**	0.620
26.	Poor agricultural extension service delivery					**0.746**	0.653
27.	**Non-availability of storage facilities			0.630	0.404		0.643
Percentage (%) of total variance		**11.9**	**11.5**	**8.8**	**8.7**	**7.6**	

* Factor1= Public, institutional and labour constraints; Factor 2= Land, neighbourhood norms and religious beliefs constraints; Factor 3= High cost of inputs, technological and poor information on early warning systems constraints; Factor 4= Far farm distance, poor access to climate change adaptation information, off-farm job and credit source constraints; Factor 5= Poor agricultural extension programmes and service delivery constraints. ** Constraints that loaded under more than one factor

Source: Computed from field data, 2011.

The main constraints as perceived by the respondents (food crop farmers) limiting food crop farmers on climate change adaptation in Savanna agro-ecological of Southwestern Nigeria under factor 1 (Lack of access to weather information, public and private institutions constraints) were; lack of access to weather forecast technologies (0.728), lack of access to supporting institutional facilities (0.712), lack of/or inadequate government policies to empower food crop farmers (0.703), lack of access to weather and climate forecast information (0.614), lack of collateral security required to secure loan to support food crop farming (0.504); and lack of access to and awareness about NGOs programme on climate change adaptation (0.503). In the present information age, information problems could pose serious challenges to farmers' coping strategies as they may not be aware of recent developments regarding climate change adaptations and the necessary readjustments needed. The lack of adaptive capacity due to constraints on resources such as the lack of access to weather forecasts technologies and information creates serious gaps between the farmers and useful information that should help them in their farm work. Weather forecasts are supposed to guide farmers on climate variability so that they can make informed decisions and useful farm plans. However, the absence of this facility will undoubtedly make the farmers become ignorant of the weather and situations and hence become vulnerable to the impact of changes in the climate and weather. This result agrees with the findings of the study of Ozor *et al*. (2010) that identified lack of access to weather forecasts as a major barrier to climate change adaptation among households in Southern Nigeria.

Under factor 2 (land, neighbourhood norms and religious beliefs constraints) the constraining variables or factors that loaded high were; poor access to and control of land (0.799), high cost of farmland (0.778), inherited system of land ownership (0749), neighbourhood norms, customs, culture and traditional belief against adaptation (0.609); and religious belief of the farming household (0.578). Individual farmers in traditional and/or rural societies do not usually have title to farmland but enjoy user rights, which could be withdrawn at any time by the custodian of the communal land. Benhin (2006) noted that farm size and land tenure status are some of the major determinants of speed of adoption of adaptation measures to climate change.

The variables or factors that loaded high under factor 3 (Poor access to climate change adaptation information and credit constraints) include; involvement of the food crop farmers in some off-farm jobs (0.668), poor access to climate change adaptation strategies information by food crop farming household (0.512); and insufficient knowledge of credit source to support farm work (0.499).

Under factor 4 (High cost of supporting facilities and inputs and illiteracy constraints) the constraining variables or factors that loaded high were; high cost of improved crop varieties (0.613), traditional beliefs/ practices e.g. on the commencement of the farming season, crop festival period, etc. (0.611), non-availability of storage facilities (0.607), illiteracy of the food crop farmers (0.527); and high cost of irrigation facilities (0.439). Kassahun (2009) noted that poor potential for irrigation as a major constraint on adapting to climate change in Nile basin of Ethiopia.

The variables or factors that loaded high under factor 5 (Poor agricultural extension service delivery and poor information on early warning systems constraints) include; poor agricultural extension service delivery (0.739), lack of/or inadequate extension programmes directed to meet the climate change adaptation strategies in food crop production (0.729), far distance of household food crop farms to the farm household residential areas (-0.508), poor information on early warning systems (0.433); and tedious nature of climate change adaptation strategies (-0.402). Amusa (2010) noted lack of agricultural extension programme as a major constraint among cocoa agroforestry households in Ekiti State, Nigeria.

Table 4.27: Varimax Rotated Factors/ Variables Constraining Food Crop Farmers on Climate Change Adaptation in the Savanna Agro-Ecological Zone of Southwestern Nigeria

Constraints	Components*					Communality
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	
1. Lack of access to weather forecast technologies	**0.728**					0.648
2. Lack of access to supporting institutional facilities	**0.712**					0.625
3. Lack of /or inadequate government policies to empower food crop farmers	**0.703**					0.635
4. Lack of access to weather and climate forecast information	**0.614**					0.481
5. Lack of collateral security required to secure loan to support food crop farming	**0.504**					0.503
6. Lack of access to and awareness about NGOs programme on climate change adaptation	**0.503**					0.369
7. Poor access to and control of land		**0.799**				0.691
8. High cost of farmland		**0.778**				0.693
9. Inherited system of land ownership		**0.749**				0.625
10. Neighbourhood norms, customs, culture and traditional belief against adaptation		**0.609**				0.491
11. Religious belief of the farming household		**0.578**				0.453
12. Involvement of the food crop farmers in some off farm jobs, e.g. trading, artisans etc			**0.668**			0.493
13. Poor access to climate change adaptation strategies information by food crop farmers			**0.585**			0.461
14. Small scale production of some of the food crop farming household			**0.512**			0.414
15. Insufficient knowledge of credit source to support farm work			**0.499**			0.305
16. High cost of improved crop varieties				**0.613**		0.572
17. Traditional beliefs/practices e.g. on the commencement of farming season, crop festival period, etc				**0.611**		0.530
18. Non-availability of storage facilities				**0.607**		0.615
19. Illiteracy of the food crop farmers				**0.527**		0.332
20. High cost of irrigation facilities				**0.439**		0.305
21. Poor agricultural extension service delivery					**0.739**	0.573
22. Lack of /or inadequate extension programmes directed to meet the climate change adaptation strategies in food crop production					**0.729**	0.625
23. Far distance of household food crop farms to their homesteads					**-0.508**	0.563
24. Poor information on early warning systems					**0.433**	0.432
25. Tedious nature of climate change adaptation strategies					**-0.402**	0.350
26. **Non-availability of farm labour	0.419			0.417		0.447
Percentage (%) of total variance	**12.1**	**10.7**	**9.4**	**8.5**	**7.8**	

* factor 1 = Lack of access to weather information, public and private institution constraints; factor 2 = Land, neighbourhood norms and religious beliefs constraints; Factor 3= Poor access to climate change adaptation information and credit sourcing constraints; Factor 4= High cost of supporting facilities and inputs and illiteracy constraints; and Factor 5= Poor agricultural extension service delivery and Poor information on early warning systems constraints.

** Constraints that loaded under more than one factor.

Source: Computed from field data, 2011.

4.15 Constraints to Climate Change Adaptation by Food Crop Farmers in the Rainforest Agro-Ecological Zone of Southwestern Nigeria

The result shows the constraints on effective climate change adaptation among food crop farming households in the Rainforest agro-ecological zone of Southwestern Nigeria (Table 4.28). The results show that five factors were mainly responsible for the difficulties in adaptation to climate change by the respondents (food crop farmers). The Kaiser criterion (1960) was used for selecting the number of underlying factors or principal components explaining the data. After rotation, the first factor accounted for 12.9% of the variance, the second factor accounted for 11.1%, the third factor accounted for 10.3%, the fourth factor accounted for 9.2%, and the fifth factor accounted for 7.2%. The true factors that were retained explained 50.7% of the variance in the 29 constraining factor or variable components. These factors include; factor 1 (land, neighbourhood norms, cultural and religious beliefs constraints), factor 2 (weather forecast, public policies and institutional constraints), factor 3 (poor agricultural extension programmes, government irresponsiveness to climate risk management and poor information on early warning systems), factor 4 (high cost of supporting facilities and off-farm job constraints) and factor 5 (high cost of fertilizers and other inputs and far farm distance constraints).

Under factor 1(land, neighbourhood norms, cultural and religious beliefs constraints), the constraining variables or factors that loaded high were; high cost of farm land (0.778), poor access to and control of land (0.776), inherited system of land ownership (0.712), neighbourhood norms, customs culture and traditional belief against adaptation (0.671), religious belief of the farming household (0.610), lack of collateral security required to secure loan to support food crop farming (0.472) and traditional beliefs/practices e.g. on the commencement of farming season, crop festival, etc. (0.471). In traditional societies, individual farmers do not usually have title to farmland but enjoy user rights, which could be withdrawn at any time by the custodian of the communal land. This finding agrees with the study of Ozor *et* *al.* (2010) that reported that land is a major barrier to effective climate change adaptation among farming households. This is further supported by Benhin (2006) who noted that farm size and land tenure status are some of the major determinants of speed of adoption of adaptation measures to climate change. Kassahun (2009) also noted that shortage of land is a major constraint on adapting to climate change in Nile basin of Ethiopia.

The variables that loaded high under factor 2 (weather forecast, public policies and institutional constraints) were; lack of or inadequate government policies to empower food crop farmers (0.751), lack of access to weather forecast technologies (0.708), lack of access to and awareness about NGOs programme on climate change adaptation (0.660), lack of access to supporting institutional facilities (0.642); and lack of access to weather and climate forecast information (0.527). Enete and Amusa (2010) noted policies, institutions and public goods as a critical challenge to agricultural adaptation to climate change in Nigeria.

The main constraints as perceived by the respondents (food crop farmers) limiting food crop farmers on climate change adaptation in Rainforest agro-ecological of Southwestern Nigeria under factor 3 (poor agricultural extension programmes, government irresponsiveness to climate risk management and poor information on early warning systems) were; lack of/ or inadequate extension programmes directed to meet the climate change adaptation strategies in food crop production (0.695), In adequate knowledge of how to cope or build resilience (0.629); illiteracy of food crop farmers (0.572), government irresponsiveness to climate risk management (0.538); and poor information on early warning systems (0.465). Ozor *et al.* (2010) noted that government irresponsiveness to climate risk management is a major barrier to climate change adaptation among farming households in Nigeria.

The variables or factors that loaded high under factor 4 (high cost of supporting facilities and off-farm job constraints) include; non-availability of storage facilities (0.730), high cost of improved crop varieties (0.638), involvement of the food crop farmers in some off-farm jobs

(0.564); and high cost of irrigation facilities (0.502). Kassahun (2009) noted that poor potential for irrigation as a major constraint on adapting to climate change in Nile basin of Ethiopia.

Under factor 5 (high cost of fertilizers and other inputs and far farm distance constraints) the constraining variables or factors that loaded high were; far distance of household food crop farmers to the farm household residential areas (0.584), small scale production of some of the food crop farming household (0.579), poor access to climate change adaptation strategies information by food crop farmers (0.558); and high cost of fertilizers and other inputs (0.546). Ozor *et al*. (2010) noted that high cost of farm inputs and poor access to climate information as major barriers to climate change adaptation among farming households in Southern Nigeria.

Table 4.28: Varimax Rotated Factors/Variables Constraining Food Crop Farmers on Climate Change Adaptation in the Rainforest Agro-Ecological Zone of Southwestern Nigeria

		Components*					
	Constraints	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Communality**
1.	High cost of farmland	**0.778**					0.626
2.	Poor access to and control of land	**0.776**					0.637
3.	Inherited system of land ownership	**0.712**					0.655
4.	Neighbourhood norms, customs, culture and traditional	**0.671**					0.463
5.	belief against adaptation						
6.	Religious belief of the farming household	**0.610**					0.454
7.	Lack of collateral security required to secure loan to support food crop farming	**0.472**					0.486
8.	Traditional beliefs/practices e.g. on the commencement of farming season, crop festival period, etc	**0.471**					0.509
9.	Lack of or inadequate government policies to empower		**0.751**				0.613
10.	food crop farmers						
11.	Lack of access to weather forecast technologies		**0.708**				0.635
12.	Lack of access to and awareness about NGOs programme on climate change adaptation		**0.660**				0.499
13.	Lack of access to supporting institutional facilities		**0.642**				0.653
14.	Lack of access to weather and climate forecast information		**0.527**				0.519
15.	Lack of /or inadequate extension programmes directed to meet the climate change adaptation strategies in food crop production			**0.695**			0.500
16.	Inadequate knowledge of how to cope or build resilience			**0.629**			0.488
17.	Illiteracy of the food crop farmers			**0.572**			0.402
18.	Government irresponsiveness to climate risk management			**0.538**			0.521
19.	Poor information on early warning systems			**0.465**			0.471
20.	Non-availability of storage facilities				**0.730**		0.674
21.	High cost of improved crop varieties				**0.638**		0.561
22.	Involvement of the food crop farmers in some off-farm jobs				**0.564**		0.426
23.	High cost of irrigation facilities				**0.502**		0.448
24.	Far distance of household food crop farms to their homesteads					**0.584**	0.522
25.	Small scale production of some of the food crop farming household					**0.579**	0.439
26.	Poor access to climate change adaptation strategies information by food crop farmers					**0.558**	0.555
27.	High cost of fertilizers and other inputs					**0.546**	0.408
28.	**Non-availability of farm labour	0.493				**0.453**	0.508
29.	**Poor agricultural extension service delivery	0.506		0.554			0.637
Percentage (%) of total variance		**12.9**	**11.1**	**10.3**	**9.2**	**7.2**	

*Factor 1= Land, neighbourhood norms, cultural and religious beliefs constraints; Factor 2= Weather forecast, public policies and institutional constraints; Factor 3 = Poor agricultural extension programmes, government irresponsiveness to climate risk management and poor information on early warning systems constraints; Factor 4= High cost of supporting facilities and off-farm job constraints and; Factor 5= High cost of fertilizers and other inputs and far farm distance constraints.

** Constraints that loaded under more than one factor.

Note: Factor loading of /**0.40/** is used at 10% overlapping variance. Variables with factor loadings of less than /**0.40/** were not reported.

Source: Computed from field data, 2011.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1: SUMMARY

This study examined the effects of climate change adaptation strategies on food crop production efficiency in Southwestern Nigeria. A multi-stage random sampling technique was used to select 360 farm units (180 from savanna and 180 from the rainforest agro-ecological zones). Structured interview scheduled was used to obtain the required information from the selected food crop farm units.

Descriptive and relevant inferential statistics such as frequency, percentages, mean, line graph, standard deviation, likert-type rating technique, multinomial logit (MNL) model, stochastic frontier production and profit models, z-test, t-test, and factor analysis were used for data analysis. Socioeconomic, farm-specific and institutional characteristics of the food crop farmers and the climate change adaptation strategies used constitute the explanatory variables for the study. Possible constraints to climate change adaptation among food crop producing households were also identified.

Considering the socioeconomic characteristics of food crop producing households in the study area, greater percentage of about 50% of them fell between age range of 41-60years while their computed average age was about 53 years in the study area. In the savanna and the rainforest agro-ecological zones of the region, the greater percentage of about 57% and 43% fell between the age range of 41-60 years while their average age range was about 51 and 55 years, respectively. Male dominated food crop production in the study area, about 86% in the study area were male; about 84% and about 83% were male in the savanna and the rainforest agro-ecological zones of the region, respectively. Greater percentage of about 32% of the food crop farmers had primary education with average of about 8 years of formal education in the study area; while greater percentage of about 31% had secondary education with average of about 9 years of formal education and about 38% had primary education with average of about 8 years of formal education in the savanna and the rainforest agro-ecological zones, respectively. Greater percentage of about 48% the food crop producing households fell within the household size of 6 -10 with computed average of about 7 people; while greater percentage of about 46% with average of about 6 people and 49% with computed average of about 9 people fell between the household size between 6 – 10 in the savanna and the rainforest agro-ecological zones of the southwestern region, respectively. Majority of the respondents were married (about 92% in the whole region, 90% in the savanna AEZ and about 94% in the rainforest AEZ). About 27% of the respondents had extension contact that fell between 11- 15 times with computed average of about 8 contacts or visits in the cropping season; 30% with average of about 9 contacts or visits in the cropping year and about 24% with average of about 8 contacts or visits had extension contact that fell between 11- 15 times in the cropping season among the respondents in the Savanna AEZ and the Rainforest AEZ of the region, respectively.

Information on the farming systems practiced by respondents revealed that majority of about 37% were practicing mixed cropping in the region; while 39% and about 34% of the respondents from the two agro-ecological zones were practicing mixed cropping in the savanna and the rainforest agro-ecological zones of Southwestern Nigeria, respectively. On the issue of the farm size, it was revealed that the average food crop farm size was about 2 hectares in the study area. The estimated average output value of food crop farms was ₦506,010.00 for the whole study area while ₦463,066.30 and ₦548,937.20 for the savanna and the rainforest agro-ecological zones of the region, respectively. The estimated profit in naira from food crop production in the study area was ₦376,860.00; while for the savanna and the rainforest agro-ecological zones of the study area was ₦317,387.89 and ₦436,331.50, respectively.

The mean and standard deviation of the estimates of level of intensity of farm-level of climate change adaptation strategies used by food crop farmers in the study area for those categorized as very highly intensified were multiple crop types/varieties, land fragmentation, multiple planting dates and mulching; those estimated to be highly intensified were alternative fallow/tillage practices, and cover cropping. Multiple crop types/varieties strategy was very highly intensified both in the Savanna and the rainforest agro-ecological zones of Southwestern Nigeria. Majority of the food crop farmers of about 35% fell within the range of 6 -10 years of climate change awareness in the study area. Greater number of the respondents of about 44% and about 27% had awareness of climate change fell between the age range of 6-10 years in the Savanna and Rainforest agro-ecological zones, respectively.

On the information on climate change perception, the respondents perceived that there was higher temperature (about 34%), decreased rainfall (about 33%) and delayed/erratic rainfall (29%) in the study area.

In Southwestern Nigeria, the multinomial logit analysis showed that household size negatively influences the use of multiple crop types or varieties, land fragmentation, multiple planting dates and crop diversification. Age of household head had an inverse relationship with the choice and use of multiple crop types or varieties, land fragmentation, multiple planting dates and off-farm employment as climate change adaptation strategies in the study area. Years of education attained by the food crop farmers had a negative effect on the choice and use of multiple crop varieties and multiple planting dates as adaptation strategies. Sex (male-headed household) had positive influence on the choice and use of multiple crop varieties, multiple planting dates and off-farm employment but average distance had a positive relationship with the choice and use of land fragmentation in the study area. Tenure security positively influence the choice and use of crop diversification but access to credit negatively correlated with multiple crop varieties, multiple planting dates and crop diversification in the study area.

In the Savanna agro-ecological zone, the multinomial logit analysis showed that household size negatively influences the use of multiple crop types or varieties, land fragmentation, multiple planting dates and crop diversification. Years of education attained by the food crop farmers had a negative effect on the choice and use of multiple crop varieties as an adaptation strategy. Sex (male-headed household) had positive influence on the choice and use of multiple crop varieties, land fragmentation and off-farm employment. Tenure security positively influenced the choice and use of crop diversification but access to credit negatively related to crop diversification as a climate change adaptation strategy.

In the Rainforest agro-ecological zone, the multinomial logit analysis showed that household size negatively influences the use of multiple crop types or varieties, land fragmentation, multiple planting dates and crop diversification. Years of education attained by the food crop farmers had a negative effect on the choice and use of multiple planting dates, crop diversification and off-farm employment as climate change adaptation strategies. Sex (male-headed household) had positive influence on the choice and use of multiple crop varieties, land fragmentation, multiple planting dates, crop diversification and off-farm employment. Extension contact positively influenced multiple crop varieties, land fragmentation and crop diversification but average distance had a positive relationship with the choice and use of land fragmentation and multiple planting dates in the agro-ecological zone. Access to credit negatively correlated with multiple crop varieties, land fragmentation, multiple planting dates and crop diversification in the zone.

Maximum Likelihood Estimation was used to estimate technical efficiency in the study area and Stochastic Cobb-Douglass frontier Production models best fit the data. From the study, labour, farm size and other agrochemicals are highly significant at 1% level of probability for all the sampled food crop farmers and those (food crop farmers) from the Savanna agro-ecological zone of Southwestern Nigeria. While labour and farm size are significant at 1% level of significance for the sampled food crop farmers in the rainforest agro-ecological zone of Southwestern Nigeria. The computed mean technical efficiency estimate is 0.84 for both the food crop farmers in the whole study area and in the rainforest agro-ecological zone and 0.83 for those from the savanna agro-ecological zone of the region.

In the technical inefficiency model, for all the sampled respondents (full sample) the following variables, land fragmentation and multiple planting dates had significant positive relationship with technical inefficiency while years of climate change awareness, and social capital had significant inverse relationship with the technical inefficiency. In the savanna agro-ecological zone, land fragmentation and multiple planting dates had significant positive relationship with technical inefficiency while only social capital had significant indirect relationship with technical inefficiency. However, in the rainforest agro-ecological zone, off-farm income and education level had positive relationship with technical inefficiency while change in farm size and social capital had inverse relationship with the technical inefficiency.

Stochastic Cobb-Douglass frontier profit model was selected as the preferred model that better fits the data of food crop farmers. From the model, Maximum likelihood estimates of the parameters showed that cost of labour and farm size variables were highly significant at 1% level of probability for all the categories of the respondents. However, depreciation variable was significant at 10% level of probability for the sampled food crop farmers in the rainforest agro-ecological zone. The computed average profit efficiency of the respondents is 0.67 for the whole sampled food crop farmers; and 0.72 and 0.66 for the food crop farmers from the savanna and the rainforest agro-ecological zones, respectively.

The profit inefficiency model revealed that off-farm income, multiple planting dates, crop diversification, and education level had significant positive relationship with profit inefficiency while land fragmentation, years of climate change awareness, and social capital had significant inverse relationship with the profit inefficiency for the whole respondents (full sample). In the savanna agro-ecological zone, off-farm income, multiple planting dates and education level had significant positive relationship with profit inefficiency while land fragmentation, years of awareness of climate change and social capital had significant indirect relationship with profit inefficiency. However, in the rainforest agro-ecological zone, off-farm income, multiple planting dates and education level had positive relationship with profit inefficiency while land fragmentation, change in farm size, years of awareness of climate change and social capital had an inverse relationship with the profit inefficiency.

The simulated technical efficiency model revealed that land fragmentation has to be less used but off-farm employment and multiple planting dates should still be much more encouraged.

The factor analysis revealed that the constraints to climate change adaptation among the food crop farmers in the study area are public, institutional and labour constraints; land, neighbourhood norms and religious beliefs constraints; high cost of inputs, technological and information constraints; farm distance, access to climate information, off-farm-job and credit constraints; and poor agricultural programmes and service delivery constraints.

CONCLUSION

With the use of different climate change adaptation strategies, the farmers are still underutilizing their present resources and this make them to be both technically and profit inefficient. Right combination of different adaptation rather than using one of these strategies through their wealth of experience and making judicious use of their resources at the present technology level will make them to be more efficient.

RECOMMENDATIONS

There is need for putting in place policies and programmes that will make the food crop farmers to be proactive in the use of resources and at the same time adapting to climate change. Particularly the following recommendations are proffered:

- There is need to make the food crop farmers participate in programmes that address adaptation policies in the country;
- For food crop farmers to be more efficient technically and in profit making, government and non-governmental organizations should help them in the provision of input-based adaptation strategies (e.g. multiple crop varieties) so that their production and profit can be enhanced in the face of changing climate;
- Proactive regulatory land use acts that will make food crop farmers to participate in more secured land ownership systems should be put in place for land tenants to benefit so that they can be able to invest and use sustainable adaptation strategies whose benefits come in subsequent years;
- The extension programme aspect of climate change adaptation strategies policy in the Southwestern Nigeria should focus much more on the bottom-up participatory approach so that the indigenous and the emerging adaptation strategies and technologies can be focussed in the various agro-ecologies since climate differ across ecologies;
- Government should focus on provision of functional credit facilities to help the food crop farmers in the area of climate change adaptation especially the input-

based ones and/or government should make the financial environment conducive for private players to act because government cannot do everything; and

- Institutional reforms or innovation that can make food crop farmers to relate socially with their fellow farmers especially in the same area or vicinity should be encouraged, since farmer-to-farmer extension paradigm can promote innovation faster than other form of extension methods.

Major contribution to knowledge

Despite the proliferation of research in this area, few studies have jointly analyzed efficiency and climate change adaptation. Efficiency and climate change adaptation studies had been undertaken in the past independent of each other but this study has integrated the two areas. This study determined efficiency (both profit and technical) by using climate change adaptation strategies as part of the explanatory variables (i.e. determinants of efficiency). It was shown that food crop farmers are inefficient technically and profit-wise. It shows that they are presently underutilizing their productive resources. This study elicited climate change adaptation strategies used in food crop production in Southwestern Nigeria and also determine the factors (extension contact, tenure security, access to credit and social capital) that influence their choice of use in the study area. Food crop production efficiency level can be improved as farmers combined more adaptation strategies at the present technology level in the study area.

Areas for further research:

There is need to embark on further research in the following areas;

- Effects of climate change adaptation strategies on food crop production efficiency with emphasis on economic contents of efficiency through parametric and non-parametric approaches;

- Effects of climate change adaptation strategies on each food crop (yam, cassava, maize, cocoyam) production efficiency;
- Effects of climate change adaptation strategies on fish farming or aquaculture in the swampy areas of Southwestern Nigeria;
- Climate change adaptation strategies and food crop production efficiency in different agro-ecologies of Nigeria;
- Climate change and variability coping strategies and rural livelihood along the coastal region of Southwestern Nigeria; and
- Mobilizing local resources for adaptation and its effects on value chain in cottage food crop processing industries in Southwestern Nigeria.
- Effects of climate change on agricultural produce export in Nigeria

REFERENCES

Abdulai, A. & Huffman, W. (2000). Structural adjustment and economic efficiency of rice farmers in Northern Ghana. *Economic Development and Cultural Change*, 48(3), 503-520.

Abdulai, A. & Huffman, W. E. (1998). *An Examination of Profit Inefficiency of Rice Farmers in Northern Ghana*. (Staff Paper No. 296). Iowa State University, Deparment of Economics

Adebayo, K., Dauda, T.O., Rikko, L.S., George, F.O.A., Fashola, O.S., Atungwu, et al. (2011). *Emerging and indigenous technology for climate change adaptation in the farming systems of southwest Nigeria: Issues for policy action* (ATPS Technobrief No. 27). Nairobi, Kenya: African Technology Policy Studies Network.

Adebayo, K., Dauda, T.O., Rikko, L.S., George, F.O.A., Fashola, O.S., Atungwu, J.J., Iposu, S.O., Shobowale, A.O. & Osuntade, O.B. (2011). *Emerging and indigenous technology for climate change adaptation in southwest Nigeria* (ATPS Research Paper No. 10). Nairobi, Kenya: African Technology Policy Studies Network.

Adegeye, A. J. & Dittoh, J. S. (1985). *Essentials of Agricultural Economics* (New ed.).Ibadan: Impact Publishers Nig. Ltd.

Adger, W. N.; Huq, S.; Brown, K.; Conway, D. & Hulme M. (2003). Adaptation to Climate Change in the Developing World. *Progress in Development Studies* No. 3.

Adger, W.N., Agrawala, S., Mirza, M.M.Q., Conde, C., O'Brien,K., Pulhin, J., et al. (2007). Assessment of adaptation practices, options, constraints and capacity. Climate change 2007: Impacts, Adaptation and Vulnerability. Contribution of working group II to the Fourth assessment report of the IPCC. In M.L. Parry, O.F. Canziaw, J.P. Palutikof, P.J. Vander Linden & C. E. Hanson (Eds.) (pp.717- 743). Cambridge UK: Cambridge University Press.

Agriculture and Agri-Food Canada (2001). Farm income, Financial Conditions and Directorate Government Assistance: Data book, Ottawa, Farm Income and Adaptation Policy, Agriculture and Agri-Food Canada.

Aigner, D. J. & Chu, S. F. (1968). 'On Estimating the Industry Production Function'. *American Economic Review*, 58: 826 – 839.

Aigner, D. J., Lovell, C. A. K.& Schmidt, P. (1977). 'Formulation and Estimation of Stochastic Production Function Models'. *Journal of Econometrics*, 6: 21 – 37.

Ajibefun, I. A. & Abdulkadri,A.O. (1999). An investigation of technical inefficiency of production of farmers under National Directorate of Employment in Ondo State, Nigeria. *Applied Economics Letters*, 6, 111-114.

Ajibefun, I. A. & Daramola, A.G. (2003). *Efficiency of micro-enterprise in the Nigerian economy*. (AERC Research Paper No. 134). Nairobi, Kenya: African Economic Research Consortium.

Ajibefun, I. A. (2006, August 12-18). *Linking Socio-economic and policy variables to technical efficiency of traditional agricultural production: empirical evidence from Nigeria*. Poster paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia.

Ajibefun, I. A., Battese,G.E. & Daramola, A.G. (2002). Determinants of technical efficiency in smallholder food crop farming: application of stochastic frontier production function. *Quarterly Journal of International Agriculture* 41(3), 225-240.

Ajibefun, I.A. (2007). Technical efficiency of micro-enterprises: theoretical and methodological approach to the stochastic frontier production function applied to Nigerian data". *Journal of African Economies* (Advance Access) Published June 15, 1-46.

Ajibefun, I.A; Daramola, A.G. & Falusi, A.O. (2006). Technical efficiency of small scale farmers: an application of the stochastic frontier production to rural and urban farmers in Ondo State, Nigeria. *International Economic Journal,* 20 (1), 87-107, March.

Alexander, C. & Mellor, T. V. (2005). Determinants of corn rootworm resistant corn adoption in Indiana. *AgBioForum*, 8(4), 197-204.

Ali, M. & Chaudhry, M.A. (1990). Inter-regional farm efficiency in Pakistan's Punjab: A frontier production function study. *Journal of Agricultural Economics* 41, 62-74.

Ali, M. & Flinn, J.C. (1989). Profit efficiency among Basmati rice producers in Pakistan Punjab. *American Journal of Agricultural Economics,*71, 303 – 310.

Amaza, P.S., Bila, Y. & Iheanacho, A. C. (2006). Identification of factors that influence technical efficiency of food crop production in West Africa: empirical evidence from Borno State, Nigeria. *Journal of agriculture and rural development in the tropics and subtropics,* 107(2), 139-147.

Amusa, T.A. (2010). *Contributions of women to household farming decisions among cocoa-based agroforestry households in Ekiti State, Nigeria.* Unpublished M.Sc dissertation, Dept. of Agric. Economics, University of Nigeria, Nsukka.

Arene, C. J. (1992). Rice production and factor productivity in Nigeria" *Journal of Productivity,* 33(1), 85 – 88. April – June

Arene, C. J. (1995) Measurement of resource productivity and the efficiency of labour-use among small holder rice farmers in Nigeria. *Modelling, Measurement and Control, D,* 12 (2), 1–13.

Asogwa, B. C. (2005). *An evaluation of government agricultural policies and effects on resource use in cassava production in Benue State.* Unpublished M.Sc. Thesis, Dept. of Agricultural Economics, University of Agriculture, Makurdi, Nigeria.

Asogwa, B. C., Umeh, J. C. & Ater, P. I. (2006, August 12 – 18). *Technical efficiency analysis of Nigerian cassava farmers: A guide for food security policy*. Poster Paper prepared for Presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia.

Awotoye, O. O. & Mathew, O.J. (2010). Effects of temporal changes in climate variables on crop production in tropical sub-humid South-western, Nigeria. *African Journal of*

Environmental Science and Technology, 4(8), 500-505. Retrieved August 12, 2011 from http://www.academicjournals.org/AJEST

Ayoola, G. B. (2001). *Essays on the agricultural economy: A book of readings on agricultural policy and administration in Nigeria*.1: 1-5. Ibadan: TMA Publishers.

Battese, G. E. & Coelli, T.J. (1995). A Model for technical inefficiency effect in stochastic frontier production functions for panel data. *Empirical Economics*, 20, 325 – 332.

Battese, G. E. & Corra,G.S. (1977). Estimation of a production frontier model: with application to pastoral zone of Eastern Australia. *Australian Journal of Agricultural Economics*, 21 (3), 169 – 179.

Battese, G. E. & Sarfaz, H. (1998). *Technical efficiency of cotton farmers in Vehri District of Punjab, Pakistan* (CEPA Working Paper No 8/98). Australia: University of New England, Dept. of Econometrics.

Bayard, B., Jolly, C. M. & Shannon, D. A. (2006). The adoption and management of soil conservation practices in Haiti: the case of rock walls. *Agricultural Economics Review*, 7(2), 28- 39.

Benhin, J.K.A. (2006). *Climate change and South African agriculture: impacts and adaptation options* (CEEPA Discussion Paper No. 21). Pretoria, South Africa: University of Pretoria, Centre for Environmental Economics and Policy in Africa.

Birungi, P. & Hassan, R. (2010). Poverty, property rights and land management in Uganda. *African Journal of Agricultural and Resource Economics*, 4(1), 48-69.

Boz, I., & Akbay, C. (2005). Factors influencing the adoption of maize in Kahramanmaras province of Turkey. *Agricultural Economics*, *33*, 431-440.

Bradshaw, B., Dolan, A.H. & Smit, B. (2001).Crop diversification as an adaptive response to climate and other risks in the Prairies, Guelph, Department of Geography, University of Guelph.

Breustedt, G., Muller-Scheesel, J., & Latacz-Lohmann, U. (2008). Forecasting the adoption of GM oilseed rape: Evidence from a discreet choice experiment in Germany. *Journal of Agricultural Economics*, 59(2), 237-256.

Brklacich, M., Bryant, C., Veenhof, B. & Beauchesne, A. (2000). Agricultural adaptation to climatic change: A comparative assessment of two types of farming in central Canada, in H. Millward, K. Beesley, B. Ilbery & L. Harrington (Eds.), *Agricultural and Environmental Sustainability in the New Countryside* (pp. 40-51). Winnipeg: Hignell Printing Limited.

Brklacich, M., McNabb, D., Bryant, C. & Dumanski, J. (1997). Adaptability of agriculture systems to global climate change: A Renfrew County, Ontario, Canada pilot study, in B. Ilbery, Q. Chiotti and T. Rickard (eds.), *Agricultural Restructuring and Sustainability: A geographical perspective*, Wallingford, CAB International, pp. 351-364.

Bryant, C. R., Smit, B., Brklacich, M., Johnston, T., Smithers, J., Chiotti, Q. & Singh, B. (2000). Adaptation in Canadian agriculture to climatic variability and change. *Climatic Change*, 45, 181-201.

Buba, A. D. (2004). Climate change and water problems in Chad Republic. *Journal of Arid Environment*, 3(2), 24-27.

Burton, I., Kates, R. & White, G.F. (1993).*The environment as hazard* (2nd ed.). New York: Guilford Press.

Carlson, B. (1972). *A Study of the Pure Theory of Production*. New York: Kelly and Milman.

Changnon, S.A., Changnon, D., Ray Fosse, E., Hoganson, D.C., Roth Sr., R.J. & Totsch, J.M.: (1997). Effects of recent weather extremes on the insurance industry: major implications for the atmospheric sciences, *Bulletin of the American Meteorological Society,* 78(3),425-435.

Chavanapoonphol, Y., Battese, G.E. & Chang, H.C. (2005, February 9 – 11). *The impact of rural financial services on the technical efficiency of rice farmers in the Upper North of Thailand.* Paper presented at the Annual Conference of the Australian Agricultural and Resource Economics Society at Coffs Harbour.

Chiotti, Q., Johnston, T.R.R., Smit, B. & Ebel, B. (1997). Agricultural response to climate change: A preliminary investigation of farm-level adaptation in southern Alberta. In B. Ilbery, Q. Chiotti & T. Rickard (Eds.), *Agricultural Restructuring and Sustainability: A geographical perspective* (pp. 167-183). Wallingford: CAB International.

Chiotti, Q.P. & Johnston, T. (1995). Extending the boundaries of climate change Research: A discussion on agriculture. *Journal of Rural Studies*, 11(3), 335-350.

Cline, W. (2007). *Global warming and agriculture: impact estimates by country*, Centre for Global Development and Peterson, Institute for International Economics, Washington.

Coelli, T. & Battese, G. (1996). Identification of factors which influence the technical inefficiency of Indian farmers. *Australian Journal of Agricultural Economics,* 40(2), 103 – 128.

Coelli, T. J. (1996). *A Guide to FRONTIER Version 4.1: A Computer Programme for Stochastic Frontier Production and Cost Function Estimation* (Working Paper). Armidale, Australia: University of New England, Centre for Efficiency and Productivity Analysis. Department of Econometrics.

Coelli, T., Rao, D.S.P. & Battese, G.E. (1998). *An introduction to efficiency productivity analysis.* Boston: Kluwer Academic Publishers.

Commission of the European Communities [CEC] (2009). Adapting to climate change: challenges for the European agriculture and rural areas. *Commission staff working document* accompanying the white paper- Adapting to climate change: towards a European framework for action.

Daberkow, S., & McBride, W. (2003). Farm and operator characteristics affecting awareness and adoption of precision agriculture technologies in the US. *Precision Agriculture*, 4, 163-177.

De Wit, M. & Stankiewicz, J. (2006). Changes in surface water supply across Africa with predicted climate change. *Science* 311, 1917-1921

Delcourt, D. & Van Kooten, G.C. (1995). How resilient is grain production to climatic change? Sustainable agriculture in a dryland cropping region of western Canada, *Journal of Sustainable Agriculture,* 5(3), 37-57.

deLoë, R., Kreutzwiser, R. & Mararu, L. (1999). Climate Change and the Canadian Water Sector: Impacts and adaptation, Guelph, Natural Resources Canada.

Deressa, T. (2007). *Measuring the economic impact of climate change on Ethiopian agriculture; Ricardian approach* (World Bank Policy Research Paper No.4342).World Bank, Washington DC.

Deressa, T. (2008). Analysis of perception and adaptation to climate change in the Nile Basin of Ethiopia. Post graduate student at the Centre for Environmental and Policy for Africa (CEEPA), University of Pretoria.

Deressa, T. T., Ringler, C. & Hassan, R.M. (2010). *Factors affecting the choices of coping strategies for climate extremes: the case of farmers in the Nile Basin of Ethiopia* (Final START, ACCFP Report) African Climate Change Fellowship Program (ACCFP).

Dorfman, J.H., (1996). Modeling multiple adoption decisions in a joint framework. *American Journal of Agricultural Economics* 17, 547–55.

Easterling, W.E. (1996). Adapting North American agriculture to climate change in review, *Agricultural and Forest Meteorology,* 80,1-54.

Eboh, E. C. (1998). *Social and economic research: Principles and methods,* Lagos: Academic Publications and Development Resources Ltd.

Ehirim, N. C. & Onyeka, U.P. (2002, October 20-24). *A stochastic frontier approach to technical efficiency in aquacultures in Oyo State*. Proceedings of 36th Annual Conference of Agricultural Society of Nigeria held at F. U. T. O, Owerri, 170 – 173.

Eid, H.M., El-Marsafawy, S. M. & Ouda, S.A. (2006). *Assessing the economic impacts of climate change on agriculture in Egypt: A Ricardian approach*. (CEEPA Discussion paper No. 16). Pretoria, South Africa: University of Pretoria, Centre for Environmental Economics and Policy analysis.

Ekanayake, S. A. B. (1987). Location Specificity, Settler Type and Productive Efficiency: A Study of the Mahaweli Project in Sri Lanka. *Journal of Development studies*, 23, 509 – 521.

Enete, A. A. & Onyekuru, A. N. (2011). Challenges of agricultural adaptation to climate change: empirical evidence from southeast Nigeria. *Tropicultura,* 29(4), 243-249.

Enete, A.A, Madu, I.I, Mojekwu, J.C, Onyekuru, A.N, Onwubuya, E.A. & Eze, F. (2011). *Indigenous agricultural adaptation to climate change: study of southeast Nigeria*. (ATPS Research Paper No. 6). Nairobi, Kenya, African Technology Policy Network.

Enete, A.A. & Amusa, T. A. (2010). Challenges of agricultural adaptation to climate change in Nigeria: a Synthesis from the Literature, *Field Actions Science Reports* [Online], 4, Online since 20 December, 2010. URL : http://factsreports.revues.org/678

Farrell, M.J. (1957). The measurement of productive efficiency. *Journal of the Royal statistical society*, 120, part III, series A (General), 253-281.

Fasola, T.R. (2007). Controlling the advancement of savanna into southwestern Nigeria, *Zonas Aridas* 11(1), 251-259.

Fasoranti, M.M. (2006). The influence of socio-economic variables on the technical and allocative inefficiencies of farmers in cassava-based systems in Ondo State, Nigeria. *Journal of Economics and Social Studies,* 5, 98-110.

Feder, G., Just, R., & Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change*, *33*(2), 255-298.

Fernandez-Cornejo, J., & McBride, W. (2002). *Adoption of bioengineered crops* (Agricultural Economics Report No. 810). Washington, DC: US Department of Agriculture Economic Research Service (USDA ERS).

Fernandez-Cornejo, J., Daberkow, S., & Huang, W-H. (1994). ‘The adoption of IPM techniques by vegetable growers in Florida, Michigan and Texas’. *Journal of Agricultural and Applied Economics,* 26(1):158-172.

Fernandez-Cornejo, J., Klotz-Ingram, C., & Jans, S. (2002). Farm-level effects of adopting herbicide-tolerant soybeans in the USA. *Journal of Agricultural and Applied Economics*, *34*(1), 149-163.

Fernandez-Cornejo, J., Mishra, A., Nehring, R., Hendricks, C., Southern, M., & Gregory, A. (2007). *Off-farm income, technology adoption, and farm economic performance* (Agricultural Economics Report No. 36). Washington, DC: USDA ERS.

Fishburn, P.C. (1968). “Utility theory”. *Management sciences*, 14(5), 335-378. (Theory series) (January). Retrieved June 1, 2011 from http://www.jstor.org/stable/2628674

Foltz, J. & Chang, H. (2001). *The adoption and profitability of rbST on Connecticut Dairy farms* (Research Report No. 55). Connecticut: University of Connecticut, Food Marketing Policy Center, Department of Agricultural and Resource Economics.

Food and Agriculture Organisation [FAO] (2005).*FAO Year Book*, Rome.

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.

Forsund, F. R., Lovell,C.A.K. & Schmidt, P. (1980). A survey of frontier production functions and their relationship to efficiency measurement. *Journal of Econometrics.* 13, 5 – 25.

Garnevska, E., Edwards,J.R. & Vaughan, D.R. (2006). Farm diversification opportunities in Bulgaria- the perception of farmers in the Plovdiv region- a preliminary analysis. *Journal of International Farm Management* 3(2),1-14.

Greene, W. H. (1980). ‘Maximum Likelihood Estimation of Econometric Frontier Functions’ *Journal of Econometrics*, 13 (1): 27 – 56.

Greene, W.H. (2000). Econometric analysis (4th ed). Prentice Hall, New Jersey.

Greene, W.H. (2003). Econometric analysis. (5th ed). Prentice Hall, New Jersey.

Hair, J.F., Anderson, R.E., Tatham, R.L. & Black, W.C. (1995). Multivariate data analysis with readings (4th ed.) Englewood NJ: Prentice Hall.

Hassan, R. & Nhemachena, C. (2008). Determinants of African farmers’ strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agricultural and Resource Economics,* 2(1), 83-104.

Hassan, R.M. (2008, May 31- June 6). *Implications of climate change for agricultural sector performance in Africa: Policy challenge and research agenda*. Paper presented at African Economic Research Consortium (AERC) biannual research workshop, Entebbe, Uganda.

Hassan, R.M., Kiarie, N, Mugo, N, Robin, O & Laboso, A. (1998). Adoption and performance of maize in Kenya. In Hassan, RM (ed.), Maize technology development and transfer: A GIS approach to research planning in Kenya. CAB International, London.

Hausman, J. & McFadden, D, (1984). Specification tests for the multinomial logit model. *Econometrica,* 52(5), 1219-1240.

Hausman, J. & Wise, D. (1978). ‘A conditional probit model for qualitative choice: Discrete decisions recognizing interdependence and heterogeneous preferences’. *Econometrica* 46: 403–426.

Hengeveld, G.H. & Whitewood, B. (2005). Understanding climate change 2005: a synthesis of climate change science, *Canada Environment*, Canada, Pp 31-35.

Herath, P.H.M.U. & Takeya, H. (2003). Factors determining intercropping by rubber smallholders in Sri Lanka: a logit analysis. *Agricultural Economics* 29, 159-168.

Huang, C. J. & Liu, J. T. (1994). “Estimation of a Non-neutral stochastic Frontier Production Function”. *Journal of Productivity Analysis* 4: 171 – 180.

Hucq, A., Kowalshi, J., Gutek, L. & Gray, R. (2000). Achieving understanding in agricultural GHG emission reduction. In D. Scott, B. Jones, J. Audrey, R. Gibson, P. Key, L. Mortsch and K. Warriner (Eds.), *Climate change communication*: Proceedings of an international conference, Kitchener-Waterloo, Canada, Environment Canada, pp. F3.9-F3.17.

Inter Academy Council [IAC] Report (2004). Realizing the promise and potential of African agriculture. Royal Netherlands Academy of Arts and Sciences, NL-1000 GC Amsterdam, The Netherlands.

Intergovernmental Panel on Climate Change (IPCC) (1996). The IPCC Second Assessment: Climate change 1995, Cambridge, Cambridge University Press.

Intergovernmental Panel on Climate Change [IPCC] (2001). Climate Change 2001: Impacts, Vulnerability and Adaptation. *Contribution of Working Group III to the Third Assessment Report on the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge.

Intergovernmental Panel on Climate Change [IPCC] (2007). Contribution of working group II to the fourth assessment report of IPCC- summary for policymakers.Retrieved on June 10, 2010 from http://www.ipcc.ch/pdf/assessment-report/ar4/wg2-spm.pdf.

Intergovernmental Panel on Climate Change [IPCC] (2007a). Third assessment report mitigation IPCC, Switzerland.

International Institute for Sustainable Development [IISD], (2007). Community-based adaptation to climate change Bulletin. A summary of the second International Workshop on Community-based adaptation to climate change. IISD reporting services.

Jagtap, S.S. (1995). Discovery and innovation changes in annual, seasonal and monthly rainfall in Nigeria and consequences to agriculture. *Journal of African Academic science,* 7(4), 311-426.

Johnson, .R.A. & Wichern, D.W.(1992). *Applied multivariate statistical analysis* (3rd ed.) Englewood NJ: Prentice Hall.

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.

Jondrow, J., Lovell, C. A., Materov, I. & Schmidt, P. (1982). ‘On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model’. *Journal of Econometrics,* 19: 233 –238.

Kabubo-Mariara, J & Karanja, F, (2006). The economic impact of climate change on Kenyan crop agriculture: a Ricardian approach. CEEPA Discussion Paper No. 12. Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Kaliba, A. R. M. (2004). Technical efficiency of smallholder dairy farms in Central Tanzania. *Quarterly Journal of International Agriculture*, 43 (1), 39-55.

Kalirajan, K. P. & Shand, R. T. (1985). 'Types of Education and Agricultural Productivity: A Quantitative Analysis of Tamil Nadu Rice Farming'. *Journal of International Development studies*, 21: 232 – 243.

Kalirajan, K. P. (1981a). 'An Econometric Analysis of Yield Variability in Paddy Production'. *Canadian Journal of Agricultural Economics*, 29: 283 – 294.

Kalirajan, K. P. (1981b). "The Economic Efficiency of Farmers Growing High Yielding, Irrigated Rice in India". *American Journal of Agricultural Economics*, 63, (3): 566 – 569.

Kalirajan, K.P. & Flinn, J. C. (1983). 'The measurement of farm specific technical efficiency'. *Pakistan Journal of Applied Economics*, 2: 167–80.

Kandlinkar, M & Risbey, J. (2000). Agricultural impacts of climate change: If adaptation is the answer, what is the question? Climatic change, 45, 529-539.

Karbasi, A. R., KarimKosheth, M. H. & Ashrafi, M. (2004). Technical efficiency analysis of pistachio production in Iran: Khorasan province case study. Retrieved October 10, 2006, from http://www.uq.edu.au/economics/appc2004/papers/cs7B4.pdf.

Kaschula, S. (2008). Wild foods and household food security responses to aids: evidence from South Africa. *Population and Environment* 29, 162–185.

Kassahun, M.M. (2009). *Climate change and crop agriculture in Nile Basin of Ethiopia: measuring impacts and adaptation options*. Unpublished M.Sc thesis, Dept. of Economics, School of Graduate Studies, Addis Ababa University.

Kebede, T.A. (2001). *Farm household technical efficiency: A stochastic frontier analysis (A case of rice producers in Mardi Watershed in the western development region of Nepal).* Unpublished Master's Thesis, Dept. of Economics and Social Sciences, Agricultural University of Norway.

Keelan, C., Thorne, F.S., Flanagan, P., Newman, C. & Mullins, E. (2009). Predicted willingness of Irish farmers to adopt GM technology, *AgbioForum*, 12 (3&4), 394-403.

Kelly, M. & Granich, S. (1995). Global warming and development. In S. Morse and M. Stocking (Eds.), *People and the Environment*, London, UCL Press Limited, pp. 69-107.

Khanal, R.C. (2009). Climate change and organic agriculture. *The Journal of Agriculture and Environment* 10, 100-109, Review paper.

Klassen, S. & Gilpen, J. (1998). Alberta irrigation in the old and new millennium, *Canadian Water Resources Journal*, 24(1), 61-70.

Koehler-Munro, & Goddard, (2010).Climate change and agriculture, Agriculture and Rural Development. Government of Alberta retrieved September 12, 2010 from http://www.agric.gov.ab.ca/&department/deptdocs.nsf//all/cl9706

Kondoun, T. M. (2000). *Education and technical efficiency of small-scale production: A case study of soybean farmers in Gboko L.G.A of Benue State*. Unpublished M.Sc. Thesis, Dept. of Agric. Economics, University of Agriculture, Makurdi, Nigeria.

Koutsoyiannis, A. (1977). *Theory of econometrics: an introductory exposition of econometric methods.*(2nd ed.). Hampshire: Palgrave.

Kurkalova, L. A. & Jensen, H.H. (2000).*Technical efficiency of grain production in Ukraine*. (CARD Working Paper 00-WP 250). Ames, Iowa: Centre for Agricultural and Rural Development, Iowa State University.

Kurukulasuriya, P & Mendelsohn, R, (2006c). *Crop selection: adapting to climate change in Africa* (CEEPA Discussion Paper No. 26). Pretoria, South Africa: Centre for Environmental Economics and Policy in Africa.

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

Kurukulasuriya, P. & Mendelson, R. (2006b). *Endogenous irrigation: the impact of climate change on farmers in Africa* (CEEPA Discussion Paper No. 18). Pretoria, South Africa: University of Pretoria, Centre for Environmental Economics and Policy in Africa..

Lau, L. J. & Yotopoulos, P. A. (1971). 'A Test of Relative Efficiency and Application to Indian Agriculture'. *American Economic Review.*61: 94 – 109.

Lewin, A. Y. & Lovell, C. A. K.(1990). 'Editors Introduction'. *Journal of Econometrics,* 46: 3 – 5.

Long, J.S., (1997). Regression models for categorical and limitd dependent variables: advanced quantitative techniques in the social science. Series 7. Sage, Thousand Oaks, California

Love, B., Boyd, M.S., Lyons, M.A. & Gibson, R. (1997). Testing the effectiveness of Government transfers for agricultural revenue stabilization: the case of the western Canadian grain sector, *Food Policy*, 22(2), 175-188.

Lovell*, C.A.K. (1993). 'Production Frontiers and Production* Efficiency'. Fried, C.A.K. Lovell and S.S. Schmidt (Eds) *The Measurement of Productive Efficiency*. New York: Oxford University Press.

Lusk, J. L., Abdulkadri, A.O. & Featherstone, A.M. (1999). *An examination of the empirical properties of duality between the restricted profit, unrestricted profit and production functions* Paper presented at AAEA meeting.

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.

Madukwe, M.C. (2004). "Multivariate Analysis for Agricultural Extension Research". In: Terry. A. O. (ed) *Research Methods in Agricultural Extension*. Pp 206 –236.

Mahul, O. & Vermersch, D. (2000). "Hedging crop risk with yield insurance futures and options". *European Review of Agricultural Economics*, 27(2),109-126.

Makhura, M.T., Goode, M.F. & Coetzee, G.K. (1997). *Indexing participation in the market economy through factor analysis – an implication for food security: case of Mpumalanga*. Paper for AEASA Presentation, University of Pretoria.

Marinda, P., Bangura, A. & Heidhues, F. (2006, August 12- 18). *Technical efficiency analysis of male and female-managed farms: a study of maize production in West Pokot District, Kenya*. Poster Paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia.

Marra, M., & Carlson, G. (1987). The role of farm size and resource constraints in the choice between risky technologies. *Western Journal of Agricultural Economics, 12*(2), 109-118.

Marra, M., Hubbell, B. & Carlson, G. (2001). Information quality, technology depreciation, and Bt cotton adoption in the Southeast. *Journal of agricultural and Resource Economics*, 66(4), 405-413

McCulloch, J. & Etkin, D. (1994). Proceedings of a workshop on improving responses to atmospheric extremes: the role of insurance and compensation, Toronto, Environment Canada.

Meeusen, W. & Van den Broek, J.(1977). 'Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error'. *International Economic Review,* 18: 435 – 444.

Mendelsohn, R, (2000). Measuring the effect of climate change on developing country agriculture. Two essays on climate change and agriculture: A developing country perspective. FAO economic and social development paper 145.

Mendelsohn, R. & Dinar, A. (2003). Climate, water, and agriculture. *Land Economics*, 79(3), 328-341.

Mendelsohn, R. (1998). Climate-change damages. In W.D. Nordaus, (ed.), *Economics and Policy Issues in Climate Change*, Washington, D.C., Resources for the Future.

Moonsanejad, M. G. & Mehrabi, B. (1989). Considering productivity of pistachio production factors in Rafsajan area, Book of proceeding of 1st Agricultural Economics Conference, Zabol University, Iran.

Mtika, M. (2001). The AIDS epidemic in Malawi and its threat to household food security. *Human Organization* 60,178–188.

Muga, G. & Onyango-Ouma, W (2009). Changing household composition and food security among the elderly caretakers in rural western Kenya. *Journal of Cross Cultural Gerontology* 24, 259–272.

Najafi, B. & Abdulahi, G. (1996). Considering technical efficiency of pistachio farmers in Rafsajanarea. *Canadian Journal of Agricultural Economics,* 47, 37 – 49.

Najafi, B. & Zibahi, M. (1995). Survey on technical efficiency of wheat farmers in Fars Province. *Iranian Journal of Agricultural Economics and Development,* 3 (7), 71 – 81.

National Bureau of Statistics (NBS) official website http://www.nigerianstat.gov.ng

Nchare, A. (2007). *Analysis of factors affecting technical efficiency of Arabica coffee producers in Cameroun*. (AERC Research paper 163). Nairobi, Kenya: African Economic Research Consortium.

Nhemachena, C. & Hassan, R. (2007). *Micro-level analysis of farmers' adaptation to climate change in Southern Africa* . (IFPRI Discussion paper No. 00714). Washington DC, USA: International Food Policy Research Institute (IFPRI), Environmental and Production Technology Division.

Nigerian Environmental Study/Action Team [NEST] (2003). *Climate change in Nigeria.A communication guide for reporters and educators*. Ibadan: NEST pp. 5-16.

Nnamchi, H.C. & Ozor, N. O. (2009, April 26- May 1). *Climate change and uncertainties facing farming communities in the Middle Belt Region of West Africa*. Paper presented at the 7th International Science Conference on the Human Dimensions of Global Environment Change (IHDP Open Meting 2009) held at the United Nations University, Bonn, Germany, available at http://www.openmeeting2009.org/pdf_files/pdf%20papers/Nnamchi_Ozor.pdf

Nwaru, J.C. & Onuoha, R.E. (2010). Credit use and technical change in smallholder food crop production in Imo State, Nigeria. *New York Science Journal*, 3(11), 144-151.

Nzeadibe, T.C., Egbule, C.L. Chukwuone, N. A. & Agu, V. C. (2011). *Farmers' perception of climate change governance and adaptation constraints in Niger Delta Region of Nigeria* (ATPS Research Paper No. 7). Nairobi, Kenya: African Technology Policy Studies Network.

Nzeadibe, T.C., Egbule, C.L. Chukwuone, N. A. & Agu, V. C. (2011). *Climate change awareness and adaptation in the Niger Delta Region of Nigeria* (ATPS Working Paper Series No.57). Nairobi, Kenya: African Technology Policy Studies Network.

Nzeh, E. C. & Eboh, O. R. (2011). *Technological challenges of climate change adaptation in Nigeria:Insights from Enugu State* (ATPS Working Paper Series No. 52). Nairobi, Kenya: African Technology Policy Studies Network.

Obwona, M. (2000). Determinants of technical efficiency differentials amongst small- and medium-scale farmers in Uganda: a case of tobacco growers. A final report presented at AERC Bi-annual workshop, Nairobi, Kenya.

Obwona, M. (2006). *Determinants of technical efficiency differentials amongst small-and medium-scale farmer in Uganda: A case of tobacco grower* (AERC Research Paper 152). Nairobi, Kenya: African Economic Research Consurtium. Retrieved October 10, 2006, from http://www.aercafrica.org/documents/rp152.

Odjugo, P. A. O. (2009). Quantifying the cost of climate change impact in Nigeria: Emphasis on wind and rainstorms. *Journal of Human Ecology*, 28(2), 93-101.

Odjugo, P. A. O. (2010). Regional evidence of climate change in Nigeria. *Journal of Geography and Regional Planning*, 3(6), 142-150, June 2010 Available online at http://www.academicjournals.org/JGRP

Odjugo, P. A. O. (2011). Climate change and global warming: the Nigerian perspective. *Journal of "Sustainable Development and Environmental Protection"*, 1(1), 5-17. http://www.ierdafrica.org/resources

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

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

Odjugo, P.A.O. (2010). General overview of climate change impacts in Nigeria. *Journal of Human Ecology*, 29 (1), 47-55.

Ogada, M.J., Nyangena, W. & Yesuf, M. (2010). Production risk and farm technology adoption in the rain-fed semi-arid lands of Kenya. *African Journal of Agricultural and Resource Economics*, 4(2), 159-174.

Ogundari, K. (2006, August 12-16). *Determinants of profit efficiency among small scale rice farmers in Nigeria: a profit function approach*. A Poster Paper Prepared for Presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia.

Ogundari, K. (2008). Reesource-productivity, allocative efficiency and determinants of technical efficiency of rainfed rice farmers: A guide for food security in Nigeria. *Journal of Sustainable Development in Agriculture & Environment*, 3(2), 20-33.

Ogundele, O. O. & Okoruwa, V.O. (2006). *Technical efficiency differentials in rice production technologies in Nigeria* (AERC Research Paper 154). Nairobi, Kenya: African Economic Research Consortium. Retrieved October 10, 2006, from http://www.aecrafrica.org/documents/rp154.pdf.

Ogundele, O.O. (2003). *Technology differentials and resource use efficiency in rice production in Kaduna State, Nigeria*. Unpublished Ph.D Thesis, Department of Agricultural Economics, University of Ibadan, Nigeria.

Ogunniyi, L. T. (2011). Profit efficiency among maize producers in Oyo state, Nigeria. *APRN Journal of agricultural and biological science*, 6 (11), 1-17

Oji, K. O. (2002*). Basic Principles of economics for agricultural project and policy analyses.*Nsukka: Prize Publishers.

Ojo, S. O. (2003). Productivity and technical efficiency of poultry egg production in Nigeria. *International Journal of Poultry Sciences* 2 (6), 459 – 464.

Okoruwa, V. O. & Ogundele,O.O. (2006). Technical efficiency differentials in rice production technologies in Nigeria. Retrieved June 10, 2006, from http://csae.ox.ac.uk/conferences/2006EOI-RPI/csae/okoruwa.pdf.

Okoye, C.U. (1998). Comparative analysis of factors in the adoption of traditional and recommended soil erosion control practices in Nigeria. *Soil & Tillage Research*, 45, 251-263.

Olayide, S. O. & E. Heady (1982). *Introduction to Agricultural Production Economics.* Ibadan: Ibadan University Press.

Olowofeso, O. E. & Ajibefun, I.A. (1999). 'The Maximum Likelihood Estimation of Stochastic Frontier Production Function with Technical Efficiency using Time series Data'. *Journal of Society, Engineering and Technology*, 6: 1527 – 1536.

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), 32-34.

Oren, M. N. & Alemdar, T. (2006). 'Technical Efficiency Analysis of Tobacco Farming in Southeastern Anatolia'. *Turkey Journal of Agriculture and Forestr*y, 30: 164 – 172.

Oren, M. N. & Alemdar, T. (2006). Technical efficiency analysis of tobacco farming in Southeastern Anatolia. *Turkey Journal of Agriculture and Forestr*y, 30, 164 – 172.

Otitoju, M. A. & Arene, C. J. (2010). Constraints and determinants of technical efficiency in medium-scale soybean production in Benue State, Nigeria. *African Journal of Agricultural Research*, 5(17), 2276-2280. Available online at http://www.academicjournals.org/AJAR

Otitoju, M. A. (2008). *Determinants of technical efficiency in small and medium-scale soybean production in Benue State, Nigeria.* Unpublished M.Sc dissertation submitted to the Dept. of Agricultural Economics, University of Nigeria, Nsukka.

Oyekale, A. S., Bolaji, M .B. & Olowa, O. W. (2009). Effects of climate change on crop production and vulnerability in Nigeria. *Agricultural Journals* 4(2), 77-85.

Ozor, N., Madukwe, M.C. Enete, A.A. Amaechina, E. C., Onokola, P., Eboh, E. C., Ujah, O. & Garforth, C. J. (2010). Barriers to Climate Change Adaptation among Farming Households of Southern Nigeria. *Journal of Agricultural Extension*, 14(1) June, 2010

Palatnik, R.R. & Roson, R. (2009). Climate change assessment and agriculture in general equilibrium models: alternative modelling strategies. In C. Carraro (ed.) Sustainable development series. Notado Di lavoro 67.

Parikh, A., Ali, F. & Shah, M. K. (1995). 'Measurement of Economic Efficiency in Pakistani Agriculture'. *American Journal of Agricultural Economics, 77: 675 – 685.*

Pearce, D., Cline, W., Achanta, A., Fankhauser, S., Pachauri, R., Tol, R., et al. (1996).The social costs of climate change; Greenhouse damage and benefits of control. In J. Bruce, H. Lee & E. Haites (Eds.), *Climate change 1995: Economic and Social Dimensions of climate change* (pp. 179-224). Cambridge: Cambridge University Press.

Pitt, M. & Lee, L. (1981). The measurement and sources of technical inefficiency in Indonesian weaving industry". *Journal of Development Economics.* 9, 234 – 245.

Pittock, B. & Jones, R.N. (2000). Adaptation to what and why?, *Environmental Monitoring and Assessment*, 61,9-35.

Poon, K.& Weersink, A. (2011). *Factors affecting variability in farm and off-farm income*, (Cahier de recherché/Working paper # 2011-3). RéseauSPAANetwork, Structure and Performance of Agriculture and Agri-products Industry Network.

Rahm, M., & Huffman, W. (1984). The adoption of reduced tillage: The role of human capital and other variables. *American Journal of Agricultural Economics*, *66*(4), 405-413.

Rahman, S. (2003, August). *Profit efficiency among Bangladesh rice farmer.* Contributed paper for the 25th conference of the International Association of Agricultural Economists Durban, South Africa.

Ransom, J.K.; Paudal, K. & Adhikari, K. (2003). Adoption of improved maize varieties in the hills of Nepal. *Agricultural Economics*, 29, 299-305.

Reifschneider, D. & Stevenson, R. (1999). 'Systematic Departures from the Frontier: A Framework for the Analysis of Firm Inefficiency'. *International Economic Review,* 15: 515 – 521.

Reilly, J. & Schimmelpfennig, D. (1999). Agricultural impact assessment, vulnerability, and the scope for adaptation, *Climatic Change*,43,745-788.

Reilly, J. (1995). Climate change and global agriculture: recent findings and issues. *American Journal of Agricultural Economics*,77, 727-733.

Rogers, E. (1995). *Diffusion of innovations* (4th ed.). New York: The Free Press.

Romain, W.E. & Calkins, P. (1996). Pressures to reform agricultural safety net programs: a Quebec perspective, *Canadian Journal of Agricultural Economics,44,*375-383.

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.

Schmitz, A., Just, R.E. & Furtan, H. (1994). Crop insurance in the context of Canadian and U.S. farm programs. In D.L. Hueth & W.H. Furtan (Eds.), *Economics of agricultural crop insurance: theory and evidence* (pp.45- 72). Boston: Kluwer Academic Publishers.

Schweger, C. & Hooey, C. (1991).Climate change and the future of Prairie agriculture. In J. Martin (Ed.), *Alternative futures for Prairie agricultural communities* (pp. 1-36) Edmonton, University of Alberta.

Sene, I.M.; Diop, M. & Dieng, A. (2006). *Impact of climate change on the revenues and adaptation of farmers in Senegal* (CEEPA Discussion paper No. 20). Pretoria, South Africa. Centre for Environmental Economics and Policy Analysis, University of Pretoria.

Seo, S. N. & Mendelsohn, R. (2008). Measuring impacts and adaptations to climate change: a structural Ricardian analysis of African livestock management. *Agricultural Economics,*38: 151–165.

Seo, S.N. & Mendelsohn, R. (2006). *Climate change impacts on animal husbandry in Africa: A Ricardian analysis* (CEEPA Discussion paper No. 9. Pretoria, South Africa: Centre for Environmental Economics and Policy Analysis, University of Pretoria.

Seyoum, E. T., Battese, G. E. & Flemming, E.M. (1998). Technical efficiency and productivity of maize producers in eastern Ethiopia: a case study of farmers within and outside the Sasakawa Global 2000 Project. *Agricultural Economics*, 19, 341 – 348.

Skinner,M.W., Smit,B. Dolon,A.H., Bradshaw, B. & Bryant,C.R. (2001). *Adaptation option to climate change in Canadaian Agriculture: An inventory and typology* (Occasional paper No. 25). Guelph: University of Guelph, Department. Of Geography

Smit, B. & Skinner, M.W. (2002). Adaptation options in agriculture to climate change: A typology. *Mitigation and Adaptation Strategies for Global Change,* 7, 85-114

Smit, B. (1993). Adaptation to climatic variability and change, Guelph, *Environment* Canada.

Smit, B. (1994). ‘Climate, Compensation and Adaptation’, in: J. McCulloch and D. Etkin (eds.), Proceedings of a Workshop on Improving Responses to Atmospheric Extremes: The role of insurance and compensation, Toronto, Environment Canada/The Climate Institute, pp. 229-237.

Smit, B., Burton, I., Klein, R.J.T. & Wandel, J. (2000). An anatomy of adaptation to climate change and variability, *Climatic Change*, 45, 223-251.

Smit, B., Pilifosova, O., Burton, I., Challenger, B., Huq, S., Klein, R.J.T. & Yohe, G. (2001). Adaptation to climate change in the context of sustainable development and equity. In J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken & K.S. White (Eds.), *Climate Change 2001: Impacts, Adaptation, and Vulnerability – The Contribution of Working Group II to the Third Scientific Assessment of the Intergovernmental Panel on Climate Change* (Chapter 18). Cambridge University Press, Cambridge.

Smit,B., Burton, I., Klein, R.J.T., & Street, R. (1999). The science of adaptation: A framework for assessment, mitigation and adaptation strategies for global change. 4, 199-213.

Smith, J.B. & Lenhart, S.S.(1996). Climate change adaptation policy options. *Climate Research* 6,193-201.

Smithers, J. & Smit, B. (1997). Agricultural system response to environmental stress. In B. Ilbery, Q. Chiotti and T. Rickard (Eds.), *Agricultural restructuring and sustainability: A geographical perspective* (pp. 167- 183). Wallingford: CAB International.

Solis, D., Bravo-Ureta,B. & Quiroga,R.E. (2006, August, 12-18). *Technical efficiency and adoption of soil conservation in Elsalvador and Honduras*. A contributed paper prepared for presentation the International Association of Agricultural Economists Conference, Gold Coast, Australia.

Spore (2008, August). Climate change. Special Issue August, 2008, P. 23.

Stakhiv, E. (1993). Evaluation of IPCC adaptation strategies, Fort Belvoir, Virginia, Institute for Water Resources, U.S. Army Corps of Engineers.

StataCorp (2009). Stata: Release 11. Statistical software, College station, TX: StataCorp LP

Stevenson, R. E. (1980). 'Likelihood Functions for Generalized Stochastic Frontier Estimation'. *Journal of Econometrics* 13 (1): 57 – 66.

Tandon, N. (2009). *Issues and challenges of climate change for women farmers in the Carribbean: the potentials of ICTs* (Concept paper). Networked intelligence for Development.

Taylor, T. G. & Shonkwiler ,J.S.(1986). Alternative stochastic specifications of the frontier Production: The Analysis of Agricultural Credit Programmes and Technical efficiency. *Journal of Development Economics,* 21,149 – 160.

Timmer, C. P. (1980). *Economics of a Developing World.*Hong Kong: Longman Publishers.

Tizale, C. Y. (2007). *The dynamics of soil degradation and incentives for optimal management in the Central Highlands of Ethiopia*. Unpublished Ph.D thesis, Department of Agricultural Economics, Extension and Rural Development, Faculty of Natural and Agricultural Sciences, University of Pretoria.

Tse, Y.K., (1987). A diagnostic test for the multinomial logit model. *Journal of Business and Economic Statistics* 5 (2), 283–86.

Turvey, C.G. & Baker, T.G. (1990). A farm-level financial analysis of farmers' use of futures and options under alternative farm programs. *American Journal of Agricultural Economics,* (November): 946-957.

Ukaegbu, E. O. (2010). *Assessment of constraints in dissemination of agricultural biotechnology in Abia state*. Unpublished B. Agric. Project submitted to the Dept. of Agric. Extension, University of Nigeria, Nsukka.

Van Kooten, G.C. & Arthur, L.M. (1997). 'Economic Development with Environmental Security: Policy conundrum in rural Canada', *American Journal of Agricultural Economics,* 79(5): 1508-1514.

Van Kooten, G.C. (1995). 'Climatic Change and Canada's Boreal Forest: Socio-economic issues and implications for land use', *Canadian Journal of Agricultural Economics,* 43:167-183.

Wang, H.H., Hanson, S.D., Meyers, R.J. & Black, J.R. (1998). The effects of crop yield insurance designs on farmer participation and welfare. *American Journal of Agricultural Economics,*80, 806-820.

Wiboonpongse, A. & Sriboonchitta, S. (2004, July 14-16). *The effects of production inputs, technical efficiency and other factors on Jasmine and Non-Jasmine rice yield in* *production year 1999/2000 in Thailand.* Paper presented at the Asia-Pacific Productivity Conference at Brisbane , Australia.

World Bank (2008). *World Development Report 2008.*World Bank, Washington DC.

Wu, J. & Babcock, B.A. (1998). The choice of tillage, rotation and soil testing practices: economic and environmental implications. *American Journal of Agricultural Economics* 80, 494–511.

Yotopoulos, P. A. &. Nuggent, J. B. (1973). *Economics of Development:Empirical Investigation*. New York: Harper and Row

Zoellick, R. B. (2009). A Climate Smart Future, *The Nation Newspapers.* Vintage Press Limited,Lagos, Nigeria. P. 18.

Appendix I

Department of Agric. Economics,

University of Nigeria, Nsukka

Date ---------------------------

Dear Respondent,

Request for Response to Questionnaire

I am a postgraduate student of the above named department and University, currently undertaking a research work titled ***“The Effects of Climate Change Adaptation Strategies on Food Crop Production Efficiency in Southwestern Nigeria”***

You have been selected as one of the respondents to supply the required information for this study. I therefore solicit for your cooperation to respond as objective as possible to the questions. It is purely academic work and all information supplied by you will be strictly treated in confidence.

Thank you for your patience and cooperation.

Yours faithfully,

Otitoju, M. A.

Questionnaire/ Interview Schedule

A. Location

1. State……………………………………………………………………
2. Zone……………………………………………………………………
3. Local Government Area…………………………………………….
4. Village /Town……………………………………………………………

B. Socio-economic, institutional and farm-specific characteristics of the food crop farmers

1. Name (optional)……………………………………………………………..
2. Age in years……………………………………………………………………
3. Marital Status: **Single** ☐ **Married** ☐ **Widow** ☐ **Divorced** ☐
4. Sex of the house head: **Male** ☐ **Female** ☐
5. Level of Education:
   i. Never attended school ☐ ii. Attended primary school ☐
   iii. Attended secondary school ☐ iv. Attended any higher institution ☐
6. How many years did you totally spend in school…………………………
7. Number of people in your farming household…………………………….
8. What is the average distance to your farm(s) in kilometers from your homestead?………………..
9. Do you belong to any civil, local and farm association(s): Yes ☐ No ☐ If yes, how many………………………….
10. (a). Are you aware of climate change? Yes ☐ No ☐ If yes, in what form(s)?
    Higher temperature ☐ Lower temperature ☐ Increased rainfall ☐
    Decreased rainfall ☐ Delayed/Erratic rainfall pattern ☐
    (b). For how many years have you been aware of climate change…………………………
11. Do you have access to agric. extension services? Yes ☐ No ☐ If yes, how many visit(s) in the cropping season…………………………..
12. Do you have access to credit facilities? Yes ☐ No ☐ If yes, is it

formal ☐ informal ☐ State the volume of the accessed credit in naira……………………….. how much was the interest paid on the loan in naira……………………

13. Which of these forms of land ownership structure did you operate in your food crop farming? Inherited ☐ leasehold ☐ crop share ☐ If leasehold, state the rent paid in the cropping season in naira……………………… If inherited, do you have the right to transfer it to your children? Yes ☐ No ☐
14. How many relatives outside your household were involved in farming discussion with you in the last farming season?..

C. Farming systems practice by food crop farmers

Which of these farming systems did you practise?

a. Monocropping ☐ b. Mixed cropping ☐ c.Shifting cultivation ☐

d. Strip cropping ☐ e. Mixed farming ☐ f. Crop rotation ☐

If there is (are) other(s), specify ……………………………………, …………………, ………………………………….., …………………………………

D. Inputs, outputs, and type of food crops grown by the farmers

(i). What food crop(s) did you grow in the last cropping season? Also indicate the farm size in hectare(s), the yield or output in Kilogramme (kg), and the corresponding revenue generated in naira. Please fill in the appropriate crops combination.

S/No	Food crop	Farm size in hectare(s)	Output in kg		Revenue in Naira
1.	Cassava (sole)				
2.	Yam (sole)				
3.	Maize (sole)				
4.	Yam + Cassava		Yam		
			Cassava		
5.	Yam + Cassava + Maize		Yam		
			Cassava		
			Maize		
6.	Yam + Maize		Yam		
			Maize		
7.	Cassava+ Cocoyam		Cassava		
			Cocoyam		
8.	Cassava + Maize		Cassava		
			Maize		

If different from the above stated food crops, please specify below;

Food crop	**Farm size in hectare (s)**	**Output in Kg**	**Revenue in Naira**

(ii). What was the labour used and the cost spent on each of the following farm operations/ activities in food crop production?

Farm operation	**Family labour**	**Exchange labour**		**Hired labour**	
	Quantity in Mandays	**Quantity in Mandays**	**Amount spent in Naira**	**Quantity in Mandays**	**Amount spent in Naira**
Land clearing					
Cultivation					
Planting					
Staking					
Weeding					
Mulching					
Fertilizer application					
Organic manure application					
Herbicides application					
Harvesting					

How much was a labourer paid per day in naira………………………………..

(iii). State the amount spent and the quantity used of the following inputs in food crop production in the cropping season

Input	**Quantity used in Kg or litres**	**Amount spent in naira**
Fertilizer (Kg)		
Seeds (Kg)		
Pesticides (Litres)		
Herbicides (Litres)		
Hiring of tractor(s)		

(iv).What were the implements used in the food crop production and when did you purchase them, how much did you buy each and how much will you dispose them now?

S/No.	Implements	Quantity in Number	Year of purchase	Amount Purchased in Naira	Disposing Amount in Naira
1.	Cutlasses				
2.	Hoes				
3.	Knapsack sprayer (s)				
4.	Mattock (s)				
5.	Digger				
6.	Watering can (s)				
7.	Shovel/ spade				
8.	Wheel barrow (s)				
9.					
10.					

E. Climate change adaptation strategies used by the farmers in food crop production

(i). Which of the following practices did you intensify to cope with climate change in the last cropping season?

a. Multiple crop type/ varieties Yes ☐ No ☐ If yes, state the crop and the number of the variety (ies)

(1). Yam ………………………

(2). Cassava ……………………

(3). Maize ……………………

(4). Cocoyam ……………………

b. Land fragmentation Yes ☐ No ☐ If yes, how many fragments or plots…………………………………………………….

c. Use of alternative fallow and tillage practices Yes ☐ No ☐

If yes, what tillage practice(s)…………………………………………..,

…………………………………., ………………………………………

d. Multiple planting dates Yes ☐ No ☐ If yes, how many …………………………………………………………

e. Irrigation practice Yes ☐ No ☐ If yes, what type………………………………………..

f. Crop diversification Yes ☐ No ☐ If yes, how many crops (in number)?

……………………………………………………

g. Off-farm employment Yes ☐ No ☐ If yes, state them…………………………………………………………………..and what is the estimated off-farm income in Naira ?
…………………………………………

h. Mulching Yes ☐ No ☐

i. Cover cropping Yes ☐ No ☐ If yes, how many cover

crop(s) planted in number……………………………………….

j. (i). Fertilizer application Yes ☐ No ☐ If yes, how many

kilogrammes ……………….or how many bag(s) (1 bag= 50kg)……………………..

(ii). Organic manure Yes ☐ No ☐

k. Planting of trees Yes ☐ No ☐ If yes, how many trees
in number……………………………………………………………………

l. Shading/ sheltering Yes ☐ No ☐

m. Change in food crop farmland Yes ☐ No ☐ If yes, from

what hectare(s)………………… to what hectare(s)……………………………

n. If there is (are) other(s), please specify……………………………………………………………………
…………………………………………………..

(ii). State the level of intensity of the practice used by ticking the appropriate box;

S/No	Practices	HI	MI	N
1.	Multiple crop types/varieties			
2.	Land fragmentation			
3.	Use of alternative fallow/tillage practices			
4.	Multiple planting dates			
5.	Irrigation practice			
6.	Crop diversification			
7.	Off-farm employment			
8.	Mulching			
9.	Cover cropping			
10.	Fertilizer application			
11.	Organic manure application			
12.	Planting trees			
13.	Shading/sheltering			
14.	Change in food crop farmland size			

Note: HI stands for highly intensified; MI stands for moderately intensified; and N stands for no intensification.

F. **Constraints on climate change adaptation in food crop production in Southwestern Nigeria**

S/No	Constraints militating against food crop farmers in climate change adaptation strategies	VH	H	L	VL
1.	Illiteracy of the food crop farmer				
2.	Lack of /inadequate extension programmes directed to meet the climate change adaptation strategies in food crop production				
3.	Poor access to climate change adaptation strategies information by food crop farmers				
4.	Limited Government irresponsiveness to climate risk management				
5.	Far distance of household food crop farms to their homesteads				
6.	Lack of /or inadequate access to weather forecast technologies				
7.	Lack of /or inadequate access to supporting institutional facilities e.g, cooperative, adult education programme.				

8.	Tedious nature of climate change adaptation strategies.				
9.	High cost of improved crop varieties				
10.	Poor agricultural extension service delivery				
11.	Poor information on early warning systems				
12.	Traditional beliefs/ practices e.g. on the commencement of farming season, crop festival period, etc				
13.	Non-availability of farm labour				
14.	Inadequate knowledge of how to cope or build resilience				
15.	Poor access to and control of land.				
16.	High cost of fertilizers and other inputs				
17.	Lack of /or inadequate awareness and access about NGOs programme on climate change adaptation.				
18.	High cost of irrigation facilities				
19.	High cost of farmland				
20.	Inherited system of land ownership				
21..	Neighborhood norms, customs, culture, and traditional belief against adaptations				
22.	Involvement of the food crop farmers in some off farm jobs, e.g. trading, artisans etc.				
23.	Insufficient knowledge of credit source to support farm work.				
24.	Religious belief of the farming household				
25.	Non-availability of storage facilities				
26.	Lack of/ or inadequate government policies to empower food crop farmers				
27.	Small scale production of some of the food crop farming households.				
28.	lack of access to weather and climate forecasts information				
29.	Lack of /or inadequate collateral security required to secure loan to support food crop farming operations				

Note: VH stands for very high; H stands for high; L stands for low; and VL stands for Very Low

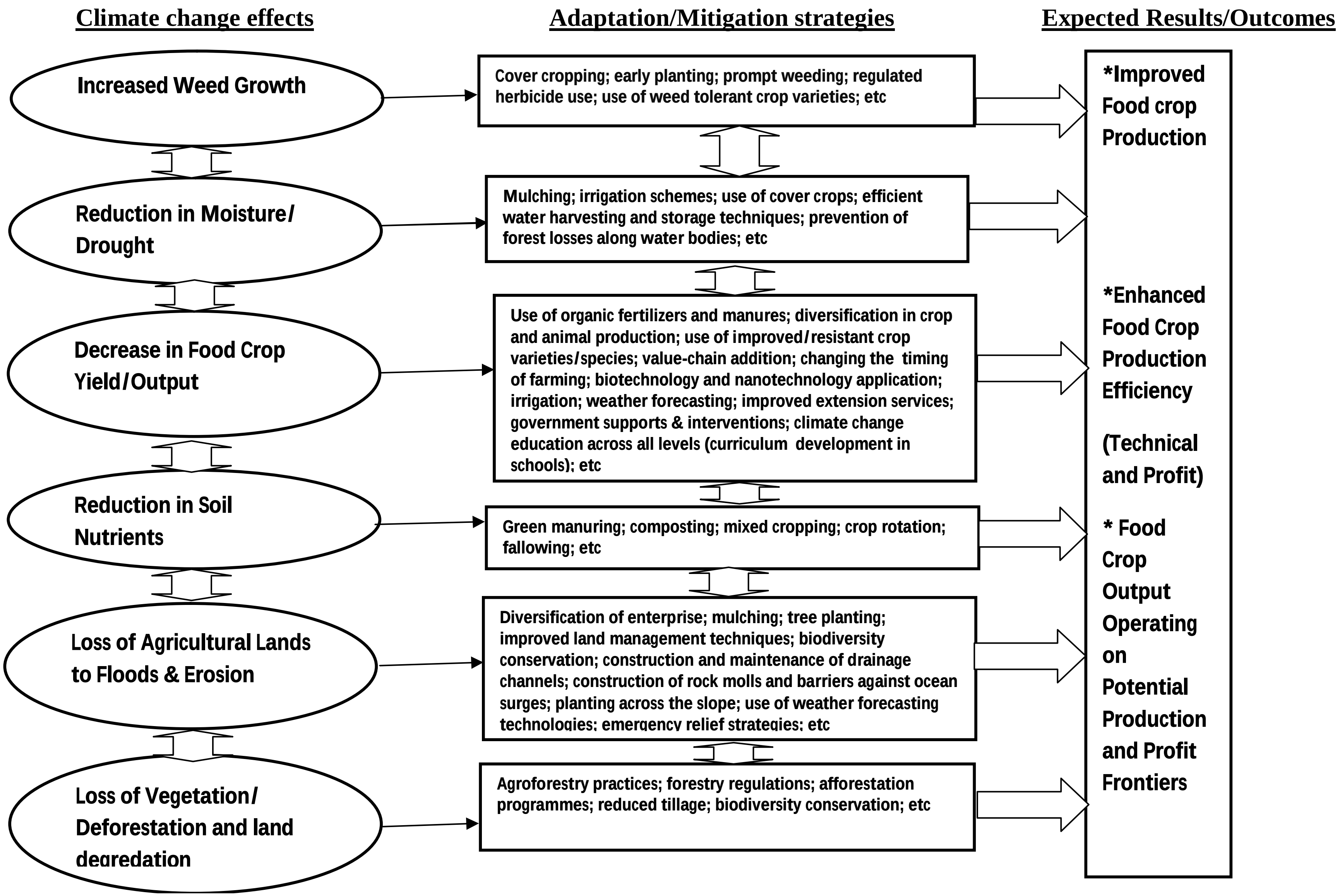

Fig. 2.3: A conceptual framework of the effects of climate change adaptation strategies on food crop production efficiency

Source: Adapted from Ozor *et al.*, 2010