UNIVERSITI PUTRA MALAYSIA

ECONOMIC IMPACT OF CLIMATE CHANGE ON MAIZE PRODUCTIVITY IN NORTHERN NIGERIA

KASIMU IBRAHIM

FPAS 2015 9

ECONOMIC IMPACT OF CLIMATE CHANGE ON MAIZE PRODUCTIVITY IN NORTHERN NIGERIA

By

KASIMU IBRAHIM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Doctor of Philosophy

May 2015

Abstract of thesis presented to Senate of Universiti Putra Malaysia in Fulfillment of the requirement for the degree of Doctor of Philosophy

ECONOMIC IMPACT OF CLIMATE CHANGE ON MAIZE PRODUCTIVITY IN NORTHERN NIGERIA

By

KASIMU IBRAHIM

May, 2015

Chairman: Professor Mad Nasir Shamsudin, PhD

Faculty: Environmental Studies

In recent years, climate change has become a more serious issue than any other environmental problem. One of the main concerns is the risk it poses to food production, especially in developing countries, where a large percentage of the population relied heavily on agriculture for survival. Irrational allocation of resources also contributed to the decline of agricultural productivity in Africa. In Nigeria, few researches focused on assessing the economic impact of climate change and ways of improving productive efficiency of maize. Having established these problems, the main goals of this study are to estimate the economic impact of climate change on net revenue from maize in northern Nigeria and also to identify the role of socioeconomic factors in cushioning the impact. Furthermore, this research aimed to measure the technical efficiency of maize production and identify its determinants.

As part of solution to the problems results of the study are intended to inform farmers, researchers and policy makers, on the economic impact of climate change on net revenue and technical efficiency of the respondents in the study area. Climate data for the study mainly includes temperature and rainfall. Data on net revenue, input use, cost of production, yield and farm specific factors were collected through respondent's survey. The main methodologies used in the analysis of the study are the Ricardian and the stochastic frontier approaches. Results of the study obtained through Mann-Kendall, Ricardian, stochastic frontier and Tobit analyses revealed evidence of climate change. Although the impact was mixed, temperature played a more important role in determining farm net revenue, as against rainfall during the crop growing season. Furthermore, market distance, farm size and farm power were the factors that significantly determined net revenue. On the technical efficiency of farms, the inputs tested were found to significantly increase maize productivity. Findings showed that education, credit, household size, age and gender contributed significantly in reducing technical inefficiency of the respondents.

The conclusion of the study was that climate change had a mix impact on revenue from maize production. In addition, certain socioeconomic factors could be used by farms to adapt to climate change. Projections based on the analyses of the study showed that future climate change will be harmful to net revenue. Although the respondents achieved high

level of technical efficiency findings of the study revealed that technical inefficiency exist among maize farms. All inputs tested could be used to increase productivity, but increase in the supply of labor may lead to a more significant rise in productivity. Similarly, factors such as education, credit, age, household size and gender could be explored to improve technical efficiency. To comprehensively address the problems of climate change and inefficient resource use, there is the need to focus attention on assessing the impacts of climate change and technical efficiency, two problems that previous studies have not addressed properly. The policy implications of these results, if carefully evaluated are expected to serve as a framework for developing climate change adaptation and efficient resource utilization options in the study area.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia untuk memunuhi keperluan untuk ijazah Doctor Falsafah

KESAN ECONOMI PERUBAHAN IKLIM TERNADAP PRODUKTIVITI JAGONG DI NIGERIA UTARA

Oleh

KASIMU IBRAHIM

May 2015

Pengurusi: Professor Mad Nasir Shamsudin, PhD

Faculti: Pengajian Alam Sekitar

Dalam tahun-tahun kebelakangan ini, perubahan iklim telah menjadi isu yang lebih serius daripada apa masalah alam sekitar yang lain. Salah satu kebimbangan utama adalah risiko yang ditimbulkan olehnya kepada pengeluaran makanan terutamanya di negara membangun, di mana sebahagian besar daripada penduduk amat bergantung kepada pertanian untuk kelangsungan hidup. Isu pengagihan sumber yang tidak rasional secara negatif mempengaruhi kecekapan teknikal pengeluaran pertanian juga dikenal pasti sebagai salah satu faktor utama yang menyumbang kepada penurunan produktiviti pertanian di Afrika. Di Nigeria, beberapa kajian memberi tumpuan kepada penilaian kesan ekonomi perubahan iklim dan juga bagaimana untuk meningkatkan kecekapan pengeluaran jagung. Melihat kepada permasalahan ini, matlamat utama kajian ini adalah untuk menentukan kesan ekonomi perubahan iklim ke atas hasil bersih daripada jagung di Utara Nigeria dan untuk menentukan peranan faktor sosio-ekonomi dalam menampan impak yang terhasil. Di samping itu, kajian ini juga bertujuan untuk mengukur kecekapan teknikal pengeluaran jagung dan penentukurannya.

Hasil kajian adalah bertujuan untuk memaklumkan kepada petani, penyelidik dan pembuat dasar, mengenai kesan ekonomi perubahan iklim ke atas pendapatan bersih dan kecekapan teknikal daripada responden di kawasan kajian. Data untuk kajian ini dikumpulkan melalui kaji selidik responden di mana maklumat mengenai pendapatan bersih, penggunaan input, kos pengeluaran hasil ladang dan faktor-faktor khusus telah diperolehi. Model Ricardian, *stochastic frontier* dan model Tobit telah digunakan untuk penganalisaan data. Hasil kajian menunjukkan bahawa walaupun perubahan iklim mempunyai kesan yang pelbagai kepada hasil bersih, suhu memainkan peranan yang lebih penting sebagai penentu pendapatan bersih ladang, berbanding hujan, terutamanya semasa musim penanaman. Tambahan pula, pasaran, saiz ladang dan tenaga ladang merupakan faktor yang signifikandalam menentukan pendapatan bersih. Dari segi kecekapan teknikal ladang, semua input yang diuji didapati meningkatkan produktiviti jagung dengan signifikan. Pendidikan, kredit, saiz isi rumah, umur dan jantina telah didapati boleh mengurangkan ketidakcekapan teknikal di kalangan responden.

Kesimpulan daripada kajian ini adalah perubahan iklim mempunyai kesan yang pelbagai kepada hasil bersih pengeluaran jagung di kawasan itu dan beberapa faktor sosioekonomi boleh digunakan sebagai pilihan penyesuaian ladang untuk mengurangkan impak yang terhasil. Unjuran analisis menunjukkan bahawa perubahan iklim masa depan akan menjadi ancaman kepada pendapatan bersih. Walaupun responden berjaya mencapai tahap tinggi kecekapan teknikal, kajian menunjukkan bahawa ketidakcekapan teknikal wujud di kalangan ladang jagung. Kesemua input boleh berupaya meningkatkan produktiviti tetapi peningkatan tenaga kerja akan memberikan peningkatan yang lebih ketara dalam produktiviti. Faktor-faktor seperti pendidikan, kredit, umur, saiz isi rumah dan jantina boleh diterokai untuk meningkatkan kecekapan teknikal. Untuk menangani masalah perubahan iklim dan penggunaan sumber yang tidak cekap secara komprehensif, adalah perlu untuk menumpukan perhatian jangkaan kesan perubahan iklim dan kecekapan teknikal, dua ancaman yang tidak ditangani dalam kajian-kajian sebelum ini.

ACKNOWLEDGEMENTS

I begin by thanking and praising Allah (SWT) for sparing my life and making it possible for me to undertake this research. The task of accomplishing this study comes with many challenges, however, the invaluable support of the members of my supervisory committee made it possible to overcome these challenges. I would like to express my profound gratitude to the entire members of the committee Prof. Datuk Mad Nasir Shamsudin, Assoc. Prof. Alias B. Radam and Assoc. Prof. Rusli Yacob for their intellectual contributions. Their guidance, constructive critisms, suggestions and scholarship, immensely contributed towards the success of the research. I acknowledged with special gratitude the attention and assistance given to me by the Chairman of the committee Prof. Nasir Mad Shamsudin throughout the period of my study despite his tight schedules.

I am indebted to fellow members of my Laboratory notably Adam Shehu Usman whose support and contributions provided me with the much needed impetus during the period of the study. The entire Staff of the Faculty of environmental studies were kind and helpful, i sincerely appreciated their support. It is ethical to acknowledge the enormous contribution made by the enumerators who conducted the field survey most especially Jabir Abubakar, Jaafar Kasim, Sani Lawali and Anas Abubakar who supervised the enumeration. Special recognition is also due to Dr. Umar Aliyu of Geograhy Department, Usumanu Dan Fodio University, Sokoto, Nigeria; a valuable data for the study was provided by him. Finally, I would like to express my sincere appreciation to members of my family especially my wives Balkisu Abubakar and Aisha Jibril for their sacrifice and efforts. Your love and patience was a source of inspiration for me. My children whom i missed in the course of the study are also worthy of mention, i benefitted immensely from your prayers and encouragement. May Allah (SWT) reward you abundantly.

This thesis was submitted to the senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Mad Nasir Shamsudin, PhD
Professor
Faculty of Environmental Studies
Universiti Putra Malaysia
(Chairman)

Alias b. Radam, PhD
Associate Professor
Faculty of Economics and Management
Universiti Putra Malaysia
(Member)

Rusli Yacob, PhD
Associate Professor
Faculty of Environmental Studies
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: ________________________ Date: _______________________

Name and Matric. No.: Kasimu Ibrahim GS30995

Declaration by Members of Supervisory Committee

This is to confirm that

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: _________________________

Name of Member Supervisory Committee: _________________________

Signature: _________________________

Name of Member Supervisory Committee: _________________________

Signature: _________________________

Name of Member Supervisory Committee: _________________________

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AE	Allocative Efficiency
BNRCC	Building Nigeria Response to Climate Change
CERES	Crop Environment Resource Synthesis
CGE	Computable General Equilibrium
CO2	Carbon dioxide
COLS	Corrected Ordinary Least Square
CROPWAT	Crop Water Requirements
DEA	Data Envelopment Analysis
DFI	Debreu-Ferrell Input
DFO	Debreu-Ferrell Output
DMU's	Decision Making Units
DSSAT	The decision Support System for Agro technology Transfer
EE	Economic Efficiency
EPIC	Erosion Productivity Impact Calculator
EU	European Union
FAO	Food and Agricultural Organization
FARM	Future Agricultural Resource Model
FGN	Federal Government of Nigeria
FME	Federal Ministry for Environment
GCM's	Global Circulation Models
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIS	Geographic Information System
IBSNAT	International Benchmark Sites Network for Agro technology Transfer
ICASA	International Consortium for Agricultural Systems Applications
IPCC	Intergovernmental Panel on Climate Change
LGA's	Local governments Areas
MLE	Maximum Likelihood Estimate
MOLS	Modified Ordinary Least Squares
NBS	National Bureau for Statistics
NIMET	Nigeria Meteorological Agency
SDEA	Stochastic Data Envelopment Analysis
SFA	Stochastic Frontier Analysis
TE	Technical Efficiency
UNDP	United Nations Development Program

UNFCC	United Nations Framework Convention on Climate Change
USDA	United States Department for Agriculture
USD	United States Dollar

CHAPTER 1

INTRODUCTION

1.1 Background

Historically, science has shown that the world climate has been dynamic for millions of years. However, climate change in the past two centuries was unprecedented. The current changes in climate coupled with low farm output were identified as the major impediments to agriculture in Nigeria. This research was conducted to study the economic impact of climate change on net revenue and technical efficiency of maize productivity in northern Nigeria. The analysis was intended to improve on the existing literature, with regards to these two issues, in the context of northern Nigeria. Climate change is recognized by today's world as the most important environmental problem affecting humanity. It refers to a serious and continuous change in weather pattern. It is largely attributed to the emission of greenhouse gases such as carbon dioxide, methane, nitrous oxide and water vapor by humans. These gases are mainly produced by the transport, agriculture, manufacturing and energy sectors of the economy.

The scientific community largely believed that the earth climate continuously changed for millions of years. However, evidence has shown that anthropogenic activities from industrial revolution in the past two centuries were largely responsible for the recent rise in the concentration of greenhouse gases above usual limits. This, according to the fourth assessment report of the Intergovernmental Panel on Climate Change IPCC (2007) led to changes in the frequency and intensity of climate; resulting in extreme and violent weather events. The extreme weather manifested as warmer temperatures, heavy rainfall, drought, floods and cyclones. The aggregate shift in weather pattern is known as the climate change; the impact of which together with rising world population poses a serious threat to the vital sectors of the world economy. The economic sectors most vulnerable to climate change are mainly water supply, ecosystems, coastal habitats, industries, health and agriculture.

With the hindsight that climate change phenomenon is global in nature and its impact economy wide; it should be understood that agricultural sector in all countries of the world are exceptionally vulnerable, due to their dependence on natural climate. Agriculture is the world's oldest economic activity. It refers to the production, processing, promotion and the distribution of agricultural products, including forestry, fruit and vegetable cultivation, poultry and beekeeping. Agriculture provides food and raw materials to the entire world population. It is the backbone of the economy of a given country. The sector serves as the major source of employment to over 70% of the economically active world rural populace. Furthermore, it accounts for 3% of World GDP (World Bank 2012). Similarly, agriculture provides food security and a source of foreign exchange and savings. It is also the main supplier of industrial raw materials and source economic development in many countries.

Having established the importance of agriculture to the world; it is pertinent to discuss the role of agriculture to the Nigeria's economy. In Nigeria, despite the rapid growth of oil industry, agriculture still remained one of the most viable sectors of the economy.

The agricultural sector contributed 33% to GDP in 2013 based on the rebased GDP figures (NBS 2014). About 80% of the domestic food in the country, especially from crops and forestry is produced by small scale farmers. The fishery and livestock products are supplemented by imports. Agriculture, in addition to providing raw materials to the manufacturing industries, also serves as a source of foreign exchange earnings as well as economic development. It provide employment for about 80% of the Nigeria's rural poor population (NBS 2014). Despite the economic importance of agriculture in Nigeria, agricultural practices are still carried out using low level technology. Inputs use is inefficient and average production per hectare is 1.4 tons, much lower than world average (4 tons/ha). Currently, two important factors were identified as threats to agricultural growth and development in Nigeria; these are climate change and poor farm output due to inefficient resource use (Ajebefun, 2002; Aye & Mungatana 2010; Bosello et al., 2013; Hassan et al., 2012; Ogundele & Okoruwa 2006; Placid, 2000). Figure 1.1 below represents Nigeria's sectoral contribution to GDP in 2013.

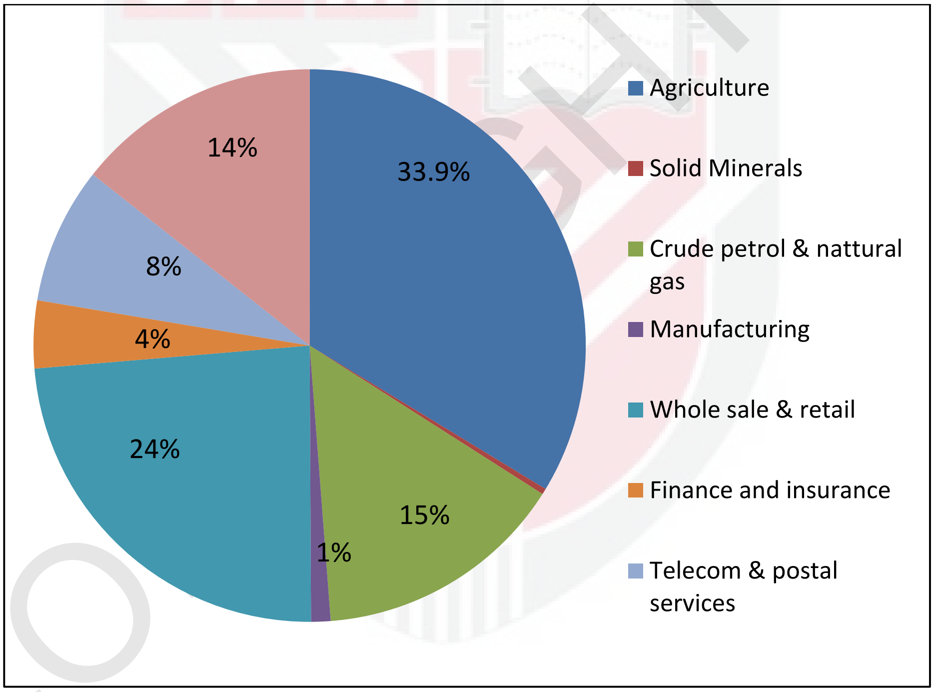

Figure 1.1: Nigeria's Percentage Share of GDP 2013 (NBS 2014)

In the last paragraph, the importance of agriculture to the Nigerian economy was highlighted; in this part global impact of climate change will be outlined. Despite uncertainties on the total economic impact of climate change on the world economy, several bodies such as IPCC showed that by the end of the 21st century, huge economic losses will be incurred due to climate change across the globe. Similarly, facts from scientific studies showed impact on agriculture in many regions of the world. Worldwide impact was forecasted to reduce grain production by 20% to 30% (Darwin et al., 1995). Global welfare changes in agriculture will result to a loss of sixty one billion USD (Reilly et al., 1996). Significant negative impacts were also predicted across the globe (Fischer & Van Velthuizen 1996; Rosenzweig and Parry 1994; Tsigas et al., 1997; Reilly 1999; Kurukulasuriya et al., 2006; Mendelsohn et al., 1994; Kurukulasuriya & Rosenthal 2003). A common prediction of the impact of climate change across the globe made by several studies is the reduction in the magnitude of future food production (IPCC 1996; Bindi and Olesen 2011; Kurukulasuriya & Rosenthal 2003).The warming scenario predicted by scientist will lead to variation of agricultural impacts across regional and local divides. However, emerging facts predicted worst impact for tropical regions (Mendelsohn, 2000; Kurakulasuriya & Rosenthal 2003). One estimate put losses in agricultural production from developed countries at 2% - 4% and developing countries will lose an estimated 14% -16% of their total production. Table 1.1 shows the regional impact of climate change on agriculture.

Table 1.1: Regional impact of climate change on agriculture

Region	Impact (% of GDP)	Yield reduction (%)
World	10	-
Developed countries	2 - 4	-
Developing countries	14-16	-
Africa	10	50
Asia	9	30
Australia New Zealand	-	30
Europe	4	10
United States	3.6	-

Source; IPCC 2007

In addition, more evidence of the impacts of climate change on world agriculture is emerging from growing body of literature. It was predicted that a 2.5 ^{0}C (36.5 ^{0}F) rise in temperature will hamper crop yields (Amiraslany, 2010). This coupled with growing human population will result in higher food prices. Although, this trend will have small impact on global revenue; more impact is forecasted for developing countries. A considerable reduction in rainfall was also forecasted in many parts of the world. This will make crop yields even more vulnerable. Impact of climate change will not only affect agricultural productivity, but also worldwide supply and demand of agricultural produce, as well as farm prices and revenue. The climate in Africa is mostly dry, characterized by short rainy season. Like other parts of the world the trend of temperature is increasing and there is uncertainty on the future trend of rainfall. However, high population pressure on natural resources, extreme poverty, heavy reliance on agriculture excercebated by marginal climate makes African region the most vulnerable to climate change (Kurukulasuriya et al., 2006: Matthews et al., 2007). In West African Sahel alone an estimated 80% of the population is involved in agriculture and livestock farming; these sectors contributed about 35% to GDP in these countries. The total economic impact of climate change on agriculture in these countries is put at 10% of their GDP (Kurukulasuriya & Rosenthal 2013). The crucial role played by agriculture in the socio economic development of many developing countries including Nigeria justifies the concern on the negative impact of climate change.

The points above strive to establish evidence of negative impact of climate change on the global economy; the situation is not different in Nigeria. Findings from many studies showed evidence of rise in temperature and changes in the intensity of rainfall across all regions (Aaron, 2011; BNRCC 2011; FME 2003; 2012; Hassan et al., 2012; Kalmalkar et al., 2010; NIMET 2014). It was forecasted that temperature will rise by 1.5 ^{0}C to 2.5 ^{0}C (34.7 ^{0}F – 36.5 ^{0}F) in the 21st century; and there will be a general slight increase in rainfall across different parts of the country. Projection from these studies showed that like in many other countries of Africa, the agricultural sector in Nigeria will also be susceptible to the impact of climate change. Estimate of damage in Nigeria is projected to reach up to 1.5% to 3% of GDP each year by 2030; it will also lower crop yield by 5% to 25% by 2050 (Hassan et al., 2012; Bello et al., 2012). Massive reliance on agriculture by the citizens, lack of institutional capacity to adapt and the geographical location of Nigeria makes it more vulnerable to climate change. Despite these harsh forecasts on the most important sector of the Nigerian economy; there is still lack of sufficient empirical studies that assessed economic impact of climate change on agriculture.

To provide a clear picture of the situation, it is to be noted that researches that conducted the assessment of the economic impact of climate change on agriculture in Nigeria using various approaches are quiet few. Ricardian method was however used by Ajetomobi et al., (2010); Odozi et al., (2013); Bosello et al., (2013); Fonta et al., (2011) to analyze economic impact of climate change on agriculture. A common finding of these studies revealed that climate change will be harmful to agriculture in Nigeria. The two most important elements of climate that were observed to affect agriculture in Nigeria are temperature and rainfall. The vulnerability of impact is contingent on wide range of local environmental and management factors in various agro ecological zones. However, the few studies conducted mainly, concentrated on the southern part of the country and their focus was not on cereal crops. Generally, under the current situation, literature on the impact of climate change on farm revenue is scanty. Specifically, little is known about how maize farms behaved under changing climate in northern Nigeria. It is therefore difficult to trace a study that measures the impact across northern Nigeria. The few studies conducted were limited to small areas with no variation in climate; as a result a clear picture of the impact cannot be obtained. This justified that measuring the impact of climate change on agriculture over wide range of climate is becoming an increasingly important aspect of assessing climate change impact in Nigeria.

Having enunciated the gap in knowledge on the impact of climate change in Nigeria, what follows next is a synopsis of the Ricardian method. Ricardian method is one of the potential techniques for measuring the economic impact of climate change on agriculture. It was based on the perceptions that land values match the output of land in a competitive environment. One of the major assumptions of the technique is the direct relationship between climate and farm values. Ricardian method is a recent technique that is widely applied to assess the impact of climate on land values or net farm revenue. The impact is measured by conducting a regression of farm revenue on climatic variables. The method assumes farmers change their use of inputs and outputs continuously, to suit the immediate environment and as a result adaptation options are implicitly taken. With this assumption, adaptation options are considered as a black box, because the modifications are not explicitly modeled (Mendelsohn & Dinar 2009). To use the Ricardian technique, inputs such as labor, capital and crop choices are not included in the regression because they are endogenous factors. Similarly, accurate measurement of variables, large sample size and wider variation in relevant variables especially climate are important considerations for accuracy in the Ricardian technique. Mendelsohn et al., (1994) first applied the method to measure land values in US. Mendelsohn and Kurukulasuriya (2008) also used the technique as the methodology for the analysis of a multicounty study, which considered the impact of climate change on crops and livestock in Africa.

So far the description of the problem setting concentrated mainly on the issue of climate change. However, another important problem of agriculture in Nigeria as highlighted earlier is low resource use efficiency. Efficiency of a farm (production unit) can be measured either with respect to its normatively desired performance or with the performance of another farm. Thus, measures of efficiency are essentially computed by comparing observed performance with some specified standard notion of performance. The “production frontier” serves as one such standard in the case of technical efficiency. Technical efficiency can be defined as the ability and willingness of a production unit to obtain the maximum possible output with a specified endowment of inputs (represented by a frontier production function), given the surrounding technology and environmental conditions. Farrell (1957) carried out the first empirical study to measure technical efficiency for a cross-section of production units by using a deterministic/non-parametric frontier approach.

The measure above assumes that the production function of the fully efficient unit is known in some manner. Since this bench mark of frontier production function is never known in practice, Farrell suggests that it can be estimated from sample data using either a non-parametric piecewise linear technology or by a parametric function such as the Cobb-Douglas form. A potential advantage of the stochastic production frontier approach is that random variations in catch can be accommodated, so that the measure is more consistent with the potential harvest under “normal” working conditions. A disadvantage of the technique is that although it can model multiple output technologies, doing so is somewhat more complicated; for it requires stochastic multiple output distance functions and raises problems for outputs that take zero values (Paul, Johnson & Frengley, 2000). An implicit assumption of production functions is that all firms are producing in a technically efficient manner, and the representative (average) firm therefore defines the frontier.

To address the concern for low agricultural output in Nigeria, the issue of resource use efficiency should be considered. At this point, it is important to note that although maize is important as a food and industrial crop in Nigeria and despite challenges posed by the threat of low output, few studies that analyzed technical efficiency of resource use examined maize in their assessments. Studies that estimated the technical efficiency of maize farms in Nigeria using the stochastic frontier model include (Aye & Mungatana 2010; Etim & Okon 2013; Ogunniyi 2011; Ogunniyi 2012; Oluwatayo & Adesoji 2008; Sadiq 2013). Findings of these studies revealed that substantial amount of yield and revenue from maize is lost due to inefficient utilization of farm inputs. Despite this gloomy picture, the focus was not on maize; the few studies that estimated the technical efficiency of maize based their assessments mostly in the southern part of the country mostly, within one agro ecological zone; this makes it difficult to generalize their conclusions to countrywide. Therefore, empirical findings of studies on economic impact of climate change as well as technical efficiency of maize in northern Nigeria is lacking and the scanty information cannot be generalized to countrywide level. This study is an attempt to provide a deep assessment of the economic impact of climate change on maize revenue as well as the technical efficiency of maize farmers in northern Nigeria. This effort is aimed at providing a clear picture of the situation with respect to the maize industry.

Having provided basis for the current research in the preceding part, it should be clearly understood that the study is necessary in order to provide more insights on the magnitude of the impact of climate change on revenue. In addition, the study is vital for an in-depth assessment of the technical efficiency level of maize farmers in northern Nigeria with a view to improve the growth and productivity of the industry. This effort is essential for national planning and policy formulation to creating necessary measures that will lessen the impact of climate change and raise farm output. This study to date is among the few analyses that simultaneously evaluate economic impact of climate change and technical efficiency of maize productivity covering 3 out of the 4 agro ecological zones in northern Nigeria; it is an effort to fill the existing gaps in literature. Findings of the study are likely to be beneficial to farmers, researchers as well as the policy makers in improving their knowledge of climate change impact on revenue. It will also provide a picture of the technical efficiency of maize production. These efforts are important for developing climate change adaptation framework and resource use policy that will increase farm resilience and output; an indispensable pre-requisite for Nigeria's sustainable growth and development.

1.2 Problem Statement

To provide a clear understanding of the situation, before stating the main problem of the study, it is important to begin by highlighting the major constraints to maize production in northern Nigeria.

a) Soil Fertility

Maize production in the Savannas is faced with several constraints which limit its output. A combination of poor soil fertility, drought and *Striga hermonthica* infestation leads to an on-farm yield reduction by over 70% even with the use of high-yielding varieties. Land-use intensification resulting from high population pressure especially in the Northern Guinea Savanna has resulted in serious land degradation and nutrient depletion (Oikeh et al., 2003). Soils in the region are deficient in nitrogen; this most often affects maize yield (Carsky & Iwuafor, 1997). High cost of inputs, inappropriate application methods and low supply, limits the use of nitrogen fertilizers. The problem of poor soil fertility in the Guinea Savanna is exacerbated by occasional drought at various stages of crop growth. For maize, drought incidence at the flowering and grain-filling stages can lead to serious yield reduction.

b) Weeds

Findings of research studies and farmers experience in the Northern Guinea and Sudan Savannas of Nigeria revealed that Striga infestation has remained a serious pest affecting millet, sorghum, maize, and upland rice (Showemimo et al., 2002) . In northern Nigeria, almost all farms grown with maize and sorghum were reported to be infested (Dugje et al., 2009). It was estimated that 10% to 100% of grain of these cereal crops is lost to Striga infestation. In addition to damage due to this parasitic weed, substantial losses are incurred as a result of competition with other weeds.

c) Resource Use Efficiency

In view of the importance of maize as a major staple food in Nigeria, the current low level of maize output which at present stood at 8 million tons is a source of concern for policy makers and farmers. Under this situation, the demand for the commodity is always short of supply, resulting into shortages and price increase. The situation is more worrisome because of the fact that Nigeria's average yield which stood at 1.4 tons/ha is far lower than world average yield of 4.3 tons/ha. It is even lower than some African countries such as South Africa. Several efforts made by the government in Nigeria to tackle the problem of low output, such as the use of enhanced production technology like the use of fertilizer, improved seeds, chemicals and improved farm production practices failed to yield the desirable results. Findings from several studies began to point towards production inefficiency. Low input use efficiency was identified as one of the major constraint to maize output in Nigeria.

d) Climate Change

It is now widely agreed that climate change constitute one of the greatest threat to the world economy. The sub Saharan Africa was projected to be more vulnerable to climate change as a result of decline in rainfall, rise in temperature, extreme weather events and floods; this has serious negative implications for agriculture. In Nigeria and most especially northern Nigeria agriculture is heavily dependent on climate. Evidence of impact of climate change on agriculture in Nigeria showed that crop yield that is highly dependent on climate is declining leading to serious reduction in farm revenue (Bello et al., 2012; Farauta et al., 2011). Maize an important cereal crop grown in northern Nigeria and highly dependent on climate is one of the crops projected to be affected by climate change in Nigeria and all parts of Sub Saharan Africa (Cairns et al., 2013).

Having accentuated the current situation, with regards to maize production in northern Nigeria, the enormity of the problem could be appreciated considering the role of maize to Nigeria's economy. Maize contributed about 6.95 % to crop production GDP in 2012 (NBS 2012). Akimwumi (2014) reported that output from maize was 10.28 million metric tons and provided revenue of ₦259 billion (1.2 billion USD). In 2010 about 7003 tons were imported to supplement local demand. Problem of the study could therefore be stated as; decline in farm revenue as a result of climate change as well as low level of farm output due to inefficient use of inputs were among the major problems of maize production in northern Nigeria (Ajebefun, 2002; Aye & Mungatana 2010; Bosello et al., 2013; Hassan et al., 2012; Ogundele & Okoruwa 2006; Placid, 2000). Findings from several studies have consistently drawn the attention of the world on the impacts and consequences of the world climate. The susceptibility of maize crop to climate change heightens the concern for the impact in Nigeria. Rising average temperature, uncertainty in the trend of rainfall with mixed impact especially in northern Nigeria, increased incidence of drought and floods as well as desertification and reduction in the country's land under forest cover are few but strong evidences of climate change (Farauta, et al., 2011; Oluwunmi, 2009; Anuforom, 2010). Similarly a number of studies Ogunniyi (2011); Sadiq et al., (2013); Aye and Mungatana (2010); Olatomide and Omowumi (2010) and Etim and Okon (2013) linked the low output of maize farms in northern Nigeria to the inefficient use of inputs.

1.3 Research Question

The central question that guided this study is how the impact of climate change affects net revenue from maize production and the factors that contribute to technical efficiency of maize production in northern Nigeria?

1.3 Research Hypothesis

Based on the review of literature, five major hypotheses will guide the study

Null hypothesis H_0:

a) Revenue from maize do not exhibit high rate of decline as a result of climate change
b) Revenue from maize does not decline as a result of marginal rise in temperature and precipitation
c) Revenue from maize production does not vary as a result of change in climatic scenario
d) Use of farm inputs does not contribute to technical inefficiency of maize production in northern Nigeria

.

Alternative Hypothesis H_1:

a) Revenue from maize exhibit high rate of decline as a result of climate change
b) Revenue from maize declines as a result of marginal rise in temperature and precipitation
c) Revenue from maize varies due to change in climatic scenario
d) Use of farm inputs contribute to technical inefficiency of maize farms in northern Nigeria

1.4 Study Objectives

The general objective of this study is to analyze the relationship between climate change and net revenue and also to determine the technical efficiency of maize farms in northern Nigeria.
More specifically the study has the following objectives:

a) To measure the impacts of climate change on revenue from maize production in northern Nigeria
b) To estimate the impact of marginal change in climate on maize net revenue
c) To estimate the impact on net revenue from maize under different climatic scenarios
d) To evaluate the technical efficiency of maize farms
e) To analyze the determinants of technical efficiency of maize farms

1.5 Significance of the Study

Picture of the emerging threat of climate change on agriculture makes it evident that the economic impact assessment will continue to be a critical component of climate change mitigation and adaptation policies. In Nigeria, although few studies considered the assessment of the economic impact of climate change on agriculture Ajetomobi et al., (2011); Odozi et al., (2013); Bosello et al., (2013); Fonta (2011) most of the studies did not focus on cereal crops, which provide the main sources of food in Nigeria. In addition the few studies concentrated only on the southern part of the country. Their assessments are therefore based on areas with uniform climates; this provides a sketchy picture of the impact. Similarly literature from previous studies is nearly silent on the vulnerability of farm revenue to climate change in Nigeria. To provide a comprehensive picture of the situation, an in depth assessment of the impact across northern Nigeria is vital. The current study, which is one the few regional scale studies that cut across agro ecological zones in northern Nigeria, attempted to bridge these gaps, by undertaking to assess the economic impact of climate change on maize revenue.

The study made at least four significant contributions through evaluating economic impact of climate change on maize. First the study contributed to the expanding body of knowledge by assessing the impact of climate change on revenue from maize production. Through deep assessment on how climate change impact affects farm revenue, it is possible to understand more clearly the relationship between farm revenue and climate change; this is expected to provide the best option to tackle the problem. Secondly, lack of sufficient information on the impact of climate change on maize in Nigeria showed that there is wide dearth of knowledge on the subject. The study contributed towards bridging this gap. Another contribution made by the study is providing a picture of how farm revenue from maize production will change with future climate. The ultimate issue underlying this research is how farm adaptation will reduce the impact of climate change. It is anticipated that the study may identify ways through which farm adaptations will contribute in reducing the impact of climate change on farm revenue in the study area. Lastly, the findings of the study are expected to provide adequate knowledge that will serve as a baseline as well as a guide to farmers and policy makers in the area of climate change impact on maize.

Similarly, one additional problem that affects agriculture in Nigeria as identified by previous research effort is low level of farm output. Substantial amount of produce and revenue are lost due to inefficient utilization of farm inputs. Research on technical efficiency of agricultural production in Nigeria is scanty; the few studies conducted do not cover the entire country and considered only few selected crops. As a result insufficient information on the technical efficiency of maize production existed. To raise output, it is necessary to close this knowledge dearth. This study provided a comprehensive assessment of the technical efficiency of maize farmers across many geographical areas in northern Nigeria; to date it is one of the few studies that conducted a regional scale analysis of the technical efficiency of maize production in northern Nigeria. The study is expected to be invaluable in raising the level of technical efficiency of farmers in northern Nigeria by making the following contributions. Findings of the study are anticipated to provide a clear image of the level of technical efficiency of the respondents engage in maize production in the area. Findings of the study are also hoped to provide insight on vital inputs to raise the level of maize output. In addition, socioeconomic factors that contributed to technical efficiency were determined with a view to making improvements. Lastly findings of the study analyzed the level of technical efficiency of the respondents from each agro ecological zone in the area. This is expected to assist the respondents from all the agro ecological zones in improving resource use efficiency.

1.6 Organization of the Thesis

This thesis consists of five chapters which were organized as follows. In chapter one, a brief background of the study was provided; in this part the main problem setting of the research which is climate change was exhaustively described. In the next part, attempt to link the problem with agriculture was made, the importance of agriculture to the world economy and Nigeria was also highlighted. Having done this, the study attempted to give an account of the world wide impact of climate change on agriculture. The focus was then narrowed to the impact of climate change on agriculture in Nigeria. In the section that follows, the problem of the study was identified and stated; this was followed by the identification of the research questions and the study hypothesis. Following the hypothesis is the study objectives; in this part the general and the specific objectives of the research were stated. Lastly, the chapter concluded by a brief description of the significance of the study.

Chapter two was arranged as follows; firstly, an account of the impact of climate change on agriculture was provided under this a brief outline of the Kyoto protocol was made. This was followed by description of the potential methods of measuring the economic impact of climate change on agriculture. Next, the theoretical framework of the study was laid. Under the theoretical framework a detailed analysis of structural Ricardian model was made and the strengths and weaknesses were exposed; this was followed by the specification of the Ricardian model. In the next section, a critical analysis of previous studies that considered the Ricardian methodology was made. In the second part of the chapter, theories of technical efficiency were treated, estimation techniques for both the efficiency and inefficiency effects model were reviewed. Under the same section; merits and demerits of the stochastic frontier approach were examined. Next, potential approaches to measuring technical efficiency were considered. An overview was made of previous studies that measures technical efficiency, this was followed by an overview of previous stochastic frontier analysis and lastly, studies that considered two-step analysis were reviewed.

Chapter three treated the methodology of the study and was structured as follows; in the first part, the area of study was described; this section focused on the description of the geography of the area, its climate and agriculture. Description of the models of study and justification for their application as tools of analysis was also considered in this part. A detailed description of the study variables follows in the next section; under this part both the dependent and independent variables were explained and their measurement briefly described. In the last section of the chapter, the study design and methods were considered under which the procedure for sampling, data collection and data analysis as well as estimation procedure and econometric estimation were discussed.

Presentation, interpretation and the implications of the results were treated in chapter four; the chapter was divided into two main sections. In section one results of the analyses for the study was presented; it began with the results of the descriptive statistics for the study, followed by the Mann-Kendall test. Result of the Ricardian analysis was later presented. It comprised of the result for the marginal impact analysis and analysis of future climate change scenario. Ricardian analysis for small and large farms was also treated. Next section considered the result of the stochastic frontier analysis; this was followed by the results of the Tobit analysis. The result presentation section limits itself to the introduction of the results. In the second part of the chapter the results were thoroughly and critically discussed, providing detailed interpretation and the implications for the results. The chapter concluded by providing a general overview of the findings and implication for the study.

The last chapter of the study was chapter five. The main highlights of the chapter included a general summary of the major findings of the study, where a brief account of the problem of study, the objectives of the study, methodology and results of the study were made; in the same section the implication and major contribution of the study were elucidated. The general implication for the study was also presented in this part. The meaning, implications and the consequences of the result were also illustrated. Limitations of the study were later presented and expectations for future research were recommended based on the findings of the study. Lastly the chapter ended with a concise but comprehensive conclusion of the analyses for the study.

REFERENCES

Aaron, S. (2011). Climate Change Adaptation and Conflict in Nigeria (No. 274). United States Institute of Peace.

Abatania, L. N., Hailu, A., & Mugera, A. W. (2012). Analysis of farm household technical efficiency in northern Ghana using bootstrap DEA. In Proceedings of the 56th Annual Conference of the Australian Agricultural and Research Economics Society. Framantle, WA.

Adams, R. M., Hurd, B. H., Lenhart, S., & Leary, N. (1998). Effects of global climate change on agriculture: an interpretative review. *Climate Research*, 11(1), 19–30.

Adams, R. M., Rosenzweig, C., Peart, R. M., Ritchie, J. T., McCarl, B. A., Glyer, J. D. Allen, L. H. (1990). Global climate change and US agriculture. *Nature* 345, 219-224.

Afriat, S. N. (1972). Efficiency estimation of production functions. *International Economic Review*, 13(3), 568–598.

Aigner, D. J., & Chu, S.-F. (1968). on estimating the industry production function. *The American Economic Review*, 58(4), 826–839.

Aigner, D., Lovell, C. A., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, 6(1), 21–37.

Ajetomobi, J. O. & Abiodun, A. (2010). Climate change impacts on cowpea productivity in Nigeria. *African Journal of Food, Agriculture, Nutrition and Development*, 10 (3), 2258-2271.

Ajetomobi, J. O., Abiodun, A., & Hassan, R. (2011). Impacts of climate change on rice agriculture in Nigeria. *Tropical and Subtropical Agroecosystems*, 14(2), 613–622.

Ajibefun, I. A. (2002). *Analysis of policy issues in technical efficiency of small scale farmers using the stochastic frontier production function: With application to Nigerian Farmers.* In International Farm Management Association Congress, Wageningen; Netherlands, 7 - 12 July, 2002 Retrieved from http://ageconsearch.umn.edu/bitstream/7015/2/cp02aj01.pdf. [Accessed 28 October 2014].

Akiwumi, A. (2014, November 7). Rice, maize, others contribute ₦778 billion to revenue. Business and Finance Edition. *National Mirror*, Abuja, Nigeria. Retrieved from http;//nationalmirroronline.net. [Accessed 24 May, 2015].

Al-hassan Seidu. (2012). Technical Efficiency in Smallholder Paddy Farms in Ghana: an Analysis Based on Different Farming Systems and Gender. *Journal of Economics and Sustainable Development*, 3(5), 91–105.

Ali, M., & Chaudhry, M. A. (1990). Inter-regional farm efficiency in Pakistan's Punjab: a frontier Production function study. Journal of Agricultural Economics, 41(1), 62–74.

Ali, M., & Flinn, J. C. (1989). Profit efficiency among Basmati rice producers in Pakistan Punjab. *American Journal of Agricultural Economics*, 71(2), 303–310.

Al-Sharafat, A. (2013). Technical Efficiency of Dairy Farms: A Stochastic Frontier Application on Dairy Farms in Jordan. *Journal of Agricultural Science*, 5(3), 45-53.

Amaza, P. S., & Maurice, D. C. (2008). *Identification of factors that influence technical efficiency in rice-based production systems in Nigeria. Rice Policy and Food Security in Sub-Saharan Africa*. Proceedings of workshop held on 7-9 November, Cotonou, Benin.

Amiraslany, A. (2010). *The impact of climate change on Canadian agriculture: a Ricardian approach.* Doctoral Thesis, University of Saskatchewan, Canada.

Anuforom, A. C. (2010). *Demonstration and assessment of climate change in Nigeria and development of adaptation strategies in the key socio-economic sectors: meteorological approach.* In A Paper presented at the National Stakeholders Workshop on Developing National Adaptation Strategies and Plan of Action for Nigeria, Abuja, Nigeria 22nd, March 2010.

Aregheore, E. M. (2009). Country pasture/forage resource profile—Nigeria. Rome, Italy: FAO.

Ater, P. I., & Aye, G. C. (2012). Economic impact of climate change on Nigerian maize sector: a Ricardian analysis. *Environmental Impact*, 162, 231–239.

Ayaz, S., Hussain, Z., & Sial, M. H. (2010). Role of credit on production efficiency of farming sector in Pakistan (a data envelopment analysis). *Engineering and Technology*, (66), 1042–1047.

Aye, G. C., & Mungatana, E. D. (2010). Technical efficiency of traditional and hybrid maize farmers in Nigeria: Comparison of alternative approaches. *African Journal of Agricultural Research.* 5(21), 2909-2917.

Babatunde, R. O., Fakayode, S. B., & Obafemi, A. A. (2008). Fadama maize production in Nigeria: Casa study from Kwara State. *Research Journal of Agriculture and Biological Sciences*, 4(5), 340–345.

Bailey, D., Biswas, B., Kumbhakar, S. C., & Schulthies, B. K. (1989). An analysis of technical, allocative, and scale inefficiency: the case of Ecuadorian dairy farms. *Western Journal of Agricultural Economics*, 14(1), 30–37.

Battese, G. E., & Coelli, T. J. (1988). Prediction of firm-level technical efficiencies with a generalized frontier production functions and panel data. *Journal of Econometrics*, 38(3), 387–399.

Battese, G. E., Coelli, T. J., & Colby, T. C. (1989). *Estimation of frontier production functions and the efficiencies of Indian farms using panel data from ICRISAT's village level studies*. Department of Econometrics, New England, University of New England Press.

Battese, G. E., & Coelli, T. J. (1992). Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India. *Journal of Productivity Analysis* 3, 153-169.

Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*, 20(2), 325–332.

Bauer, P. W. (1990). Recent developments in the econometric estimation of frontiers. *Journal of Econometrics*, 46(1), 39–56.

Belbase, K., & Grabowski, R. (1985). Technical efficiency in Nepalese agriculture. *The Journal of Developing Areas*, 19(4), 515–526.

Bello, O. B., Ganiyu, O. T., Wahab, M. K. A., Afolabi, M. S., Oluleye, F., Ige, S. A., & Mahmud, J. (2012). Evidence of Climate change impacts on agriculture and food security in Nigeria. *International Journal of Agriculture and Forestry*, 2(2), 49–55.

Bindi, M., & Olesen, J. E. (2000). Agriculture." In M. L. Parry ed. Assessment of Potential Effects and Adaptations for Climate Change in Europe: The Europe ACACIA Project. Jackson Environment Institute, University of East Anglia.

Bosello, F., Campagnolo, L., & Eboli, F. (2013). Climate change and adaptation: The case of Nigerian agriculture. Social Science Research Network, 35. Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2255920 [Accessed November 16 2013].

Bravo-Ureta, B. E., & Rieger, L. (1990). Alternative production frontier methodologies and dairy farm efficiency. *Journal of Agricultural Economics*, 41(2), 215–226.

Bravo-Ureta, B. E., & Pinheiro, A. E. (1993). Efficiency analysis of developing country agriculture: a review of the frontier function literature. *Agricultural and Resource Economics Review*, 22(1), 88–101.

Bravo-Ureta, B. E., & Evenson, R. E. (1994). Efficiency in agricultural production: the case of peasant farmers in Eastern Paraguay. *Agricultural Economics*, 10(1), 27–37.

Building Nigeria's Response to Climate Change Project. (2011). Climate Change Scenarios for Nigeria: Understanding Biophysical Impacts Series A Final Edition. Ibadan, Nigeria.

Cairns, J. E., Hellin, J., Sonder, K., Araus, J. L., MacRobert, J. F., Thierfelder, C., & Prasanna, B. M. (2013). Adapting maize production to climate change in sub-Saharan Africa. Food Security, 5(3), 345–360.

Carsky, R. J., & Iwuafor, E. N. O. (1997). *Contribution of soil fertility research and maintenance to improved maize production and productivity in sub-Saharan Africa*. In Strategy for sustainable maize production in West and Central Africa. Proc. Regional Maize Workshop, IITA-Cotonou, Benin Republic. 29 May - 2 June 1997.

Cazals, C., Florens, J.-P., & Simar, L. (2002). Nonparametric frontier estimation: a robust approach. *Journal of Econometrics*, 106(1), 1–25.

Chang, C. C. (2002). The potential impact of climate change on Taiwan's agriculture. *Agricultural Economics*, 27(1), 51–64.

Chaouche, K., Neppel, L., Dieulin, C., Pujol, N., Ladouche, B., Martin, E. Caballero, Y. (2010). Analyses of precipitation, temperature and evapotranspiration in a French Mediterranean region in the context of climate change. *Comptes Rendus Geoscience*, 342(3), 234–243.

Charles, Nhemachina., Rashid Hassan and Pradeep Kurukulasuriya. (2010). Measuring the Economic Impact of Climate Change on African Agricultural Systems. *Climate Change Economics*, 1(1), 33–55.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2(6), 429–444.

Charnes, A., Cooper, W. W., Wei, Q. L., & Huang, Z. M. (1989). Cone ratio data envelopment analysis and multi-objective programming. *International Journal of Systems Science*, 20(7), 1099–1118.

Christine Kawuma Menya. (2005). Rainfall Variation Due to Climate Change: An Intertemporal investigations into its impact on subsistsnce net revenue.

Cline, W. R. (1996). The impact of global warming of agriculture: comment. *The American Economic Review*, 86(5), 1309–1311.

Coelli, T. J. (1996). A guide to FRONTIER version 4.1: A computer program for stochastic frontier production and cost function estimation. CEPA Working papers. Retrieved from http://www.ucema.edu.ar/u/dl/CURSOS/Topicos_de_Econometria_Aplicada_-_MAE/FRONTIER41_GUIDE.DOC. [Accessed June 16 2013].

Cornwell, C., Schmidt, P., & Sickles, R. C. (1990). Production frontiers with cross-sectional and time-series variation in efficiency levels. Journal of Econometrics, 46(1), 185–200.

Council for Agricultural Science and Technology. (2009). Preparing U.S. agriculture for global climate change. (No. Task Force Report 119). Ames, Iowa USA.

D'Eça, A. P. P. M. (1992). *An econometric analysis of farm level efficiency of small farms in the Dominican Republic.* Connecticut: University of Connecticut press.

Darwin, R., Tsigas, M. E., Lewandrowski, J., & Raneses, A. (1995). World agriculture and climate change: Economic adaptations (Agricultural Economics No. 703). Washington D.C.: United States Department of Agriculture, Economic Research Service. Retrieved from http://ideas.repec.org/p/ags/uerser/33933.html.[Accessed October 28, 2014].

Darwin, R., Tsigas, M., Lewandrowski, J., & Raneses, A. (1996). Land use and cover in ecological economics. *Ecological Economics*, 17(3), 157–181.

Darwin, R. (1999). A farmer's view of the Ricardian approach to measuring agricultural effects of climatic change. *Climatic Change*, 41(3-4), 371–411.

Darwin, R. (1999). The impact of global warming on agriculture: A Ricardian analysis: Comment. *The American Economic Review*, 89(4), 1049–1052.

David, J., Lionel, H., & Eric, R. (2012). *Determinants of technical efficiency in beef cattle production in Kenya.* Presented at the the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguacu, Brazil.18-24 August 2012.

Dawson, P. J., Lingard, J., & Woodford, C. H. (1991). A generalized measure of farm-specific technical efficiency. *American Journal of Agricultural Economics*, 73(4), 1098–1104.

Debreu, G. (1951). The coefficient of resource utilization. Econometrica: *Journal of the Econometric Society*, 273–292.

Del Río, S., Herrero, L., Pinto-Gomes, C., & Penas, A. (2011). Spatial analysis of mean temperature trends in Spain over the period 1961–2006. *Global and Planetary Change*, 78(1), 65–75.

Deressa, T. T., & Hassan, R. M. (2009). Economic impact of climate change on crop production in Ethiopia: evidence from cross-section measures. *Journal of African Economies*, ejp002, 1-26.

Deschenes, O., & Greenstone, M. (2007). The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather. *The American Economic Review*, 354–385.

Dlamini, S. I., Masuku, M. B., & Rugambisa, J. I. (2012). Technical efficiency of maize production in Swaziland: A stochastic frontier approach. *African Journal of Agricultural Research*, 7(42), 5628–5636.

Dugje, I. Y., Omoigui, L. O., Ekeleme, F., Kamara, A. Y., & Ajeigbe, H. (2009). Farmers' guide to cowpea production in West Africa. IITA, Ibadan, Nigeria.

Eid, H. M., El-Marsafawy, S. M., & Ouda, S. A. (2007). Assessing the economic impacts of climate change on agriculture in Egypt: a Ricardian approach. World Bank. Retrieved from http://ceepa.co.za/docs/cdp16.pdf

Ekanayake, S. A. B., & Jayasuriya, S. K. (1987). Measurement of firm-specific technical efficiency: a comparison of methods. *Journal of Agricultural Economics,* 38(1), 115–122.

Ekayanake, S. A. B. (1987). Location specificity, settler type and productive efficiency: A study of the Mahaweli project in Sri Lanka. *The Journal of Development Studies*, 23(4), 509–521.

Enwerem, V. A., & Ohajianya, D. O. (2013). Farm Size and Technical Efficiency of Rice Farmers in Imo State, Nigeria. *Greener Journal of Agricultural Sciences*, 3(2), 128–136.

Etim, N. A., & Okon, S. (2013). Sources of Technical Efficiency among Subsistence Maize Farmers in Uyo, Nigeria. *Journal of Agricultural and Food Sciences*, 1(4), 48–53.

Fan, S. (1991). Effects of technological change and institutional reform on production growth in Chinese agriculture. *American Journal of Agricultural Economics*, 73(2), 266–275.

Farauta, B. K., Egbale, C. L., Idrissa, Y. C., & Agu, V. C. (2011a). Climate Change and Adaptation Measures in Northern Nigeria: Empirical Situation and Policy Implications (No. 62). Nairobi, Kenya: African Technology Policy Studies Network.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society.* Series A (General), 253–290.

Federal Ministry of Environment ,Nigeria (2003). Nigeria's First National Communication Under the United Nation Framework Convention on Climate Change. Federal Republic of Nigeria.

Federal Ministry of Environment, Nigeria (2012). Nigeria's Path to Sustainalble Development through Green Economy (Coutry Report to the Rio+20). Rio de janeiro ,Brazil: United Nations.

Ferrier, G. D., & Hirschberg, J. G. (1997). Bootstrapping confidence intervals for linear programming efficiency scores: With an illustration using Italian banking data. *Journal of Productivity Analysis,* 8(1), 19–33.

Fischer, G., & van Velthuizen, H. (1996). Climate Change and Global Agriculture Potential Project:A Case Study of Kenya. Retrieved from http://www.citeulike.org/group/13619/article/7673038. [Accessed 28 October 28, 2014].

Fleischer, A., Lichtman, I., & Mendelsohn, R. (2008). Climate change, irrigation, and Israeli agriculture: Will warming be harmful? *Ecological Economics*, 65(3), 508–515.

Fonta, W., Ichoku, H., & Urama, N. (2011). Climate Change and Plantation Agriculture: A Ricardian Analysis of Farmlands in Nigeria. *Journal of Economics and Sustainable Development,* 2(4), 63–75.

Food and Agricultural Organisation. (2007). FAO 2007 Food Outlook. Rome Italy.

Food and Agricultural Organisation. (2010). FAOSTAT Database on Agriculture. Rome, Italy.

Food and Agricultural Organisation. (2011). Women in Agriculture Closing the Gender Gap for Development. Rome, Italy.

Gabrielsen, A. (1975). On estimating efficient production functions. Working Paper No. A-85. Bergen: Christian Michelsen Institute.

Gbetibouo, G. A., & Hassan, R. M. (2005). Measuring the economic impact of climate change on major South African field crops: a Ricardian approach. *Global and Planetary Change*, 47(2), 143–152.

Gonçalves, R. M. L., Vieira, W. da C., Lima, J. E. de, & Gomes, S. T. (2008). Analysis of technical efficiency of milk-producing farms in Minas Gerais. *Economia Aplicada*, 12(2), 321–335.

Greene, W. H. (1980). Maximum likelihood estimation of econometric frontier functions. *Journal of Econometrics*, 13(1), 27–56.

Greene, W. H. (1997). *Frontier production functions*. Handbook of Applied Econometrics, 2, 81–166.

Grosskopf, S. (1996). Statistical inference and nonparametric efficiency: A selective survey. *Journal of Productivity Analysis*, 7(2-3), 161–176.

Guerene, Arantxa, Margarita Ruiz Ramos, Carlos H. Diaz-Ambrona Jose R. Conde and M. Ines Minguez. (2001). Assessment of climate change and agriculture in Spain using climate models. *Agronomy Journal*, 93, 237–49.

Hallam, D., & Machado, F. (1996). Efficiency analysis with panel data: A study of Portuguese dairy farms. *European Review of Agricultural Economics*, 23(1), 79–93.

Hassan, R. M. (2010). Implications of climate change for agricultural sector performance in Africa: policy challenges and research agenda. *Journal of African Economies*, 19 (2), 77-105. Retrieved from http://jae.oxfordjournals.org/content/19/suppl_2/ii77.short. [Accessed June 16 2014.

Hassan, S. M., Ikuenobe, C. E., Jalloh, A., Nelson, G., & Thomas, T. S. (2012). West African Agriculture and Climate Change: A COMPREHENSIVE ANALYSIS — NIGERIA. International Food Policy Research Institute Washington, DC, USA.

Herrero, I., & Pascoe, S. (2002). Estimation of technical efficiency: a review of some of the stochastic frontier and DEA software. Computers in Higher Education Economics Review, 15(1).

Huang, C. J., & Bagi, F. S. (1984). Technical efficiency on individual farms in northwest India. *Southern Economic Journal*, 51(1), 108-115.

Ibrahim, H. Y., & Omotesho, O. A. (2013). Determinant of technical efficiency in vegeTable production under Fadama in Northern Guinea Savannah, Nigeria. *Journal of Agricultural Technology,* 9(6), 1367–1379.

Idris, M. N. D., Siwar, C., & Talib, B. (2013). Determinants of technical efficiency on pineapple farming. *American Journal of Applied Sciences*, 10(4). 426 - 432.

Iglesias A., C. Rosenzweig and D. Pereira. (1999). Predictions spatial impacts of climate change in agriculture in Spain. *Global Environmental Change*, 10, 69–80.

Iglesias Ana. and Luis Garrote. (2007). *Projections of economic impacts of climate change in sectors of Europe based on bottom up analysis*. Seville Spain.

Iken, J. E., & Amusa, N. A. (2004). Maize research and production in Nigeria. *African Journal of Biotechnology,* 3(6), 302–307.

Intergovernmental Panel on Climate Change. (1996). *Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analyses* Contribution of Working Group II to the IPCC Second Assessment Report. Cambridge, UK: Cambridge University Press.

IPCC (2007). 27th Session of the Intergovernmental Panel on Climate Change. In Fourth Assessment Report. Valencia, Spain.

Isyanto, A. Y., Semaoen, M. I., & Hanani, N. (2013). Measurement of Farm Level Efficiency of Beef Cattle Fattening in West Java Province, *Indonesia. Journal of Economics and Sustainable Development*, 4(10), 100–104.

Johnson, G. L. (1967). *A note on non-conventional inputs and conventional productivity functions. Agriculture in Economic Development,* New York: McGraw-Hill.

Jondrow, J., Knox Lovell, C. A., Materov, I. S., & Schmidt, P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function model. *Journal of Econometrics,* 19(2), 233–238.

Jorgenson, D. W., Goettle, R. J., Hurd, B. H., Smith, J. B., Chestnut, L. G., & Mills, D. M. (2004). US market consequences of global climate change. Retrieved from http://agecon.nmsu.edu/bhurd/HurdHome/HURD/pdf. [Accessed August 11 2014.]

Kabubo-Mariara, J., & Karanja, F. K. (2007). The economic impact of climate change on Kenyan crop agriculture: A Ricardian approach. *Global and Planetary Change*, 57(3), 319–330.

Kabwe, S. (2012). *Factrors affecting efficiency of smallholder cotton producers in Zambia.* M.sc. Dissertation, University of Zambia.

Kaiser, H. M., Riha, S. J., Wilks, D. S., Rossiter, D. G., & Sampath, R. (1993). A farm-level analysis of economic and agronomic impacts of gradual climate warming. *American Journal of Agricultural Economics*, 75(2), 387–398.

Kalirajan, K. (1981). An econometric analysis of yield variability in paddy production. *Canadian Journal of Agricultural Economics/Revue Canadienne D'agroeconomie*, 29(3), 283–294.

Kalirajan, K. P., & Flinn, J. C. (1983). The measurement of farm specific technical efficiency. *Pakistan Journal of Applied Economics,* 2(2), 167–180.

Kalirajan, K. (1984). Farm-specific technical efficiencies and development policies. *Journal of Economic Studies,* 11(3), 3–13.

Kalirajan, K. P., & Shand, R. T. (1985). Types of education and agricultural productivity: a quantitative analysis of Tamil Nadu rice farming. *The Journal of Development Studies,* 21(2), 232–243.

Kalirajan, K. P., & Shand, R. T. (1986). *Estimating location-specific and firm-specific technical efficiency: an analysis of Malaysian agriculture*. Australian National University: National Centre for Development Studies.

Kalirajan, K. P. (1990). On measuring economic efficiency. *Journal of Applied Econometrics*, 5(1), 75–85.

Kalijaran, K. P. (1991). A note on Nonconventional Inputs and Conventional Productivity Function. In: Kalijaran 1991 the Importance of Efficienct Use in the Adoption of Technology; A Micro Panel Data Analysis. *Journal of Productivity Analysis*, 2, 113–126.

Kalirajan, K. P. (1991). The importance of efficient use in the adoption of technology: a micro panel data analysis. *Journal of Productivity Analysis*, 2(2), 113–126.

Karabulut, M., Gürbüz, M., & Korkmaz, H. (2008). Precipitation and Temperature Trend Analyses in Samsun. *J. Int. Environmental Application & Science*, 3(5), 399–408.

Karmalkar, A., McSweeney, C., New, M., & Lizcano, G. (2010). UNDP Country Profile: Nigeria. United Nations Development Program. Retrieved from http://country-profiles.geog.ox.ac.uk General Climate.[Accessed 20 October 2014].

Karmeshu, N. (2012). Trend Detection in Annual Temperature & Precipitation using the Mann Kendall Test–A Case Study to Assess Climate Change on Select States in the NorthEastern United States. Retrieved from http://repository.upenn.edu/mes_capstones/47/. [Accessed 25 October 2014].

Khai, H. V., & Yabe, M. (2011). Technical efficiency analysis of rice production in Vietnam. *Journal of ISSAAS*, 17(1), 135–146.

Khan, M. H., & Maki, D. R. (1979). Effects of farm size on economic efficiency: The case of Pakistan. *American Journal of Agricultural Economics*, 61(1), 64–69.

Kneip, A., & Simar, L. (1996). A general framework for frontier estimation with panel data. *Journal of Productivity Analysis*, 7(2-3), 187–212.

Koopmans, T. C. (1951). Analysis of production as an efficient combination of activities. *Activity Analysis of Production and Allocation*, 13, 33–37.

Kopp, R. J., & Smith, V. K. (1980). Frontier production function estimates for steam electric generation: A comparative analysis. *Southern Economic Journal*, 1049–1059.

Kumar, K. S. K., (1998). *Modeling and analysis of climate change impacts on Indian agriculture*. PhD Thesis Indira Gandhi Institute of Development Research, Mumbai, India.

Kumar, K. S K., & Parikh, J. (2001). Indian agriculture and climate sensitivity. *Global Environmental Change*, 11(2), 147–154.

Kumbhakar, S. C. (1987). The specification of technical and allocative inefficiency in stochastic production and profit frontiers. *Journal of Econometrics*, 34(3), 335–348.

Kumbhakar, S. C., Ghosh, S., & McGuckin, J. T. (1991). A generalized production frontier approach for estimating determinants of inefficiency in US dairy farms. *Journal of Business & Economic Statistics*, 9(3), 279–286.

Kumbhakar, S. C., & Lovell, C. K. (2003). *Stochastic frontier analysis*. Cambridge: Cambridge University Press.

Kurukulasuriya, P., & Rosenthal, S. (2003). Climate change and agriculture. World Bank Environment Department Paper, (91). Retrieved from http://www.c-ciarn.uoguelph.ca/updates_archived/World_Bank_Paper.pdf. [Accessed 28 October 2014].

Kurukulasuriya, P., Mendelsohn, R., Hassan, R., Benhin, J., Deressa, T., Diop, M., … Jain, S. (2006). Will African agriculture survive climate change? *The World Bank Economic Review*, 20(3), 367–388.

Kurukulasuriya, P., & Ajwad, M. I. (2007). Application of the Ricardian technique to estimate the impact of climate change on smallholder farming in Sri Lanka. *Climatic Change*, 81(1), 39–59.

Kurukulasuriya, P. and R. Mendelsohn. (2008). A Ricardian analysis of the impact of climate change on African cropland. *African Journal of Agriculture and Resource Economics,* 2, 1–23.

Kuwornu, J. K., Amoah, E., & Seini, W. (2013). Technical Efficiency Analysis of Maize Farmers in the Eastern Region of Ghana. *Journal of Social & Development Sciences*, 4(2).

Kwarteng, J. A., & Towler, M. J. (1995). *West African Agriculture: A textbook for Schools and Colleges*. London: Macmillan Ltd.

Lambarraa, F., & Kallas, Z. (2009). *Subsidies and technical efficiency: An application of stochastic frontier and Random-effect Tobit models to LFA Spanish olive farms.* A paper presented at the 13th EAAE Seminar A resilient European food industry and food chain in a challenging World, Chania, Crate, Greece 3-6 September, 2009.

Lang, G. (2001). Global Warming and German Agriculture Impact Estimations Using a Restricted Profit Function. *Environmental and Resource Economics*, 19(2), 97–112.

Latruffe, L., Balcombe, K., Davidova, S., & Zawalinska, K. (2004). Determinants of technical efficiency of crop and livestock farms in Poland. *Applied Economics*, 36(12), 1255–1263.

Li, X., Takahashi, T., Suzuki, N., & Kaiser, H. M. (2011). The impact of climate change on maize yields in the United States and China. *Agricultural Systems* 104(4), 348-353.

Liu, H., Li, X., Fischer, G., & Sun, L. (2004). Study on the impacts of climate change on China's agriculture. *Climatic Change*, 65(1-2), 125–148.

Liu, W.-B., Wongchai, A., & Peng, K.-C. (2014). Adopting Super-efficiency and Tobit Model on Analyzing the Efficiency of Teacher's Colleges in Thailand. .*International Journal on New Trends in Education.*

Loikkanen, H. A., & Susiluoto, I. (2002). *An evaluation of economic efficiency of Finnish regions by DEA and Tobit models*. Paper prepared for the 42nd Congress for the European Regional Science Association, Dartmund Germany, 27-31 August 2002.

Lovell, C. K. (1993). *Production frontiers and productive efficiency*. Oxford: Oxford University Press.

Maddison, D. (2000). A hedonoic analysis of agricultural land prices in England and Wales. *European Review of Agricultural Economics*, 27(4), 519–532.

Mahdi, N., Sghaier, M., & Bachta, M. S. (2010). Technical efficiency of water use in the irrigated private schemes in Smar watershed, South-Eastern Tunisia. Options Méditerranéennes, 289–300.

Mailena, L., Shamsudin, M. N., Radam, A., & Mohamed, Z. (2014). Efficiency of Rice Farms and its Determinants: Application of Stochastic Frontier Analysis. *Trends in Applied Sciences Research,* 9(7).

Matthews, R., Bakam, I., & Muhammed, S. (2007). *Global climate change: climates of the future, choices for the present.* In Keynote paper presented at African Technology Policy Studies Conference—Science, Technology and Climate Change Adaptation in Africa. Johannesburg; South Africa, 19-22 November 2007. Retrieved from http://www.macaulay.ac.uk/images/ATPS%20paper_RBM.pdf

Mavromatis, T. and P.D. Jones. (1998). Comparism of climate change scenerio construction methodologies for impact assessment studies. *Agricultural Forest and Meteorology*, 91, 51–67.

Meeusen, W., & Van den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review*, 18(2) 435–444.

Mendelsohn, R., Nordhaus, W. D., & Shaw, D. (1994). The impact of global warming on agriculture: a Ricardian analysis. *The American Economic Review*, 84(2) 753–771.

Mendelsohn, R., Nordhaus, W., & Shaw, D. (1996). Climate impacts on aggregate farm value: accounting for adaptation. Agricultural and Forest Meteorology, 80(1), 55–66.

Mendelsohn, R., & Dinar, A. (1999). Climate change, agriculture, and developing countries: does adaptation matter? *The World Bank Research Observer*, 14(2), 277–293.

Mendelsohn, R., & Nordhaus, W. (1999). The impact of global warming on agriculture: A Ricardian analysis: Reply. *The American Economic Review*, 89(4), 1046–1048.

Mendelsohn, R., Dinar, A., & Dalfelt, A. (2000). Climate change impacts on African agriculture. Preliminary Analysis Prepared for the World Bank, Washington, District of Columbia, 25.

Mendelsohn, R. (2000). Efficient adaptation to climate change. *Climatic Change*, 45(3-4), 583–600.

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

Mendelsohn, R., Dinar, A., & Williams, L. (2006). The distributional impact of climate change on rich and poor countries. *Environment and Development Economics*, 11(02), 159–178.

Mendelsohn, R., & Kurukulasuriya, P. (2008). A Ricardian analysis of the impact of climate change on African cropland. *African Journal of Agriculture and Resource Economics*, 2, 1–23.

Mendelsohn, R. O., & Dinar, A. (2009). *Climate change and agriculture: an economic analysis of global impacts, adaptation and distributional effects*. Cheltenham: Edward Elgar Publishing.

Mendelsohn, R., Arellano-Gonzalez, J., & Christensen, P. (2010). A Ricardian analysis of Mexican farms. *Environment and Development Economics*, 15(2), 153-171.

Molua, E. L. (2002). Policy Options. *Environment and Development Economics*, 7, 529–545.

Molua, E. L., & Lambi, C. (2006). The economic impact of climate change on agriculture in Cameroon. Policy Research Working Paper, 4364.

Molua, E. L., & Lambi, C. M. (2007). The economic impact of climate change on agriculture in Cameroon.Volume 1 of 1 World Bank, Development Research Group, Sustainable Rural and Urban Development Team. Retrieved from http://search.mywebsearch.com/mywebsearch/GGmain.jhtml?[Accessed June 16 2007].

Msuya, E. E., Hisano, S., & Nariu, T. (2008). Explaining productivity variation among smallholder maize farmers in Tanzania. Retrieved from http://mpra.ub.uni-muenchen.de/14626/. [Accessed February 13, 2014]

Muchena, P. (1994). Implications of climate change for maize yields in Zimbabwe. Implications of Climate Change for International Agriculture: *Crop Modeling Study*, 1–9.

National Agricultural Extension Research Liaison Services (2013). Agricultural Performance Survey 2013 Wet Season.

National Bereau for Statistics, Federal Republic of Nigeria (2007). Annual Abstract of Statistics. Abuja, Nigeria.

National Bereau for Statistics, Federal Republic of Nigeria (2009). Annual Abstract of Statistics. Abuja, Nigeria.

National Bereau for Statistics, Federal Republic of Nigeria (2010). Annual Abstract of Statistics. Abuja, Nigeria.

National Bereau for Statistics, Federal Republic of Nigeria (2011). Nigeria's GDP in Third Quarter. Abuja, Nigeria.

National Bereau of Statistics, Federal Republic of Nigeria (2012). Gross Domestic Product for Nigeria. Abuja, Nigeria.

National Bureau for Statistics. Federal Republic of Nigeria (2014). Nigeria Rebased Nominal GDP IN 2013. Abuja, Nigeria.

Nelson, G. C., Rosegrant, M. W., Koo, J., Robertson, R., Sulser, T., Zhu, T., others. (2009). Climate change: Impact on agriculture and costs of adaptation (Vol. 21). Intl Food Policy Res Inst.

Nhemachena, C., Hassan, R., & Chakwizira, J. (2010a). *Economic impacts of climate change on agriculture and implications for food security in Southern Africa.* In Climate Change and Security," the 250th Anniversary Conference organized for The Royal Norwegian Society of Sciences and Letters. Trondheim, Norway 21-24 June.

Nhemachena, C., Hassan, R., & Kurukulasuriya, P. (2010b). Measuring the economic impact of climate change on African agricultural production systems. *Climate Change Economics*, 1(01), 33–55.

Nigeria Meteorological Agency. (2012). Meteorological Data for Northern Nigeria from 1970 -2011. Abuja, Nigeria.

Nigeria Meteorological Agency. (2014). Seasonal Rainfall Prediction. Abuja, Nigeria: Nigeria Meteorological Agency.

Ninth Conference of the Parties to UNFCCC. (2003). Presented at the United Nations Framework Convention on Climate Change, Milan, Italy.

Nya, E. J., Okorie, N. U., & Eka, M. J. (2010). An economic analysis of Talinum triangulare (Jacq.) production/farming in Southern Nigeria. *Trends in Agricultural Economics*, 3(2), 147–157.

Obidi, N. C. (2011). *Economic Efficiency of Maize Production in Northern Nigeria: The Analyses of Technical and Allocative Efficiencies Using Stochastic Frontier Models.* Germany: Lap Lambert Publishing.

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

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

Odozi, J. C., Awoyemi, T. T., Omonona, B. T., & Oluwatayo, I. B. (2013). Economic impact of climate change on Nigeria's agriculture: a conceptual framework. *African Journal of Economic and Sustainable Development*, 2(2), 139–156.

Ogundele, O. O., & Okoruwa, V. (2006). Technical efficiency differentials in rice production technologies in Nigeria. African Economic Research Consortium. Retrieved from http://core.kmi.open.ac.uk/download/pdf/6562544.pdf. [Accessed 28 October 2014].

Ogunniyi, L. T. (2011). Profit efficiency among maize producers in Oyo State, Nigeria. *Journal of Agricultural & Biological Science*, 6(11).

Ogunniyi, L. T. (2012). Fertilizer Use Efficiency of Maize Producers in Ogun State of Nigeria. *The Pacific Journal of Science and Technology*, 13(2).

Oguntunde, P. G., Abiodun, B. J., & Lischeid, G. (2011). Rainfall trends in Nigeria, 1901–2000. *Journal of Hydrology*, 411(3), 207–218.

Oikeh, S. O., Carsky, R. J., Kling, J. G., Chude, V. O., & Horst, W. J. (2003). Differential N uptake by maize cultivars and soil nitrate dynamics under N fertilization in West Africa. Agriculture, *Ecosystems & Environment*, 100(2), 181–191.

Olesen, O. B., & Petersen, N. C. (1995). Chance constrained efficiency evaluation. Management Science, 41(3), 442–457.

Olofintoye, O., Adeyemo, J., & Otieno, F. (2012). Impact of Regional Climate Change on Freshwater Resources and Operation of the Vanderkloof Dam System in South Africa. Global warming–impacts and future perspective, 165.

Olomola, A. S. (2007). Competitive Commercial Agriculture in Sub Saharan Africa: Nigerian Case Study. CIDA/ World Bank.

Olowa, O. W., & Olowa, O. A. (2010). Sources of Technical Efficiency among Smallholder Maize Farmers in Osun State of Nigeria. *Research Journal of Applied Sciences*, 5(2), 115–122.

Oluwatayo, I. B., Sekumade, A. B., & Adesoji, S. A. (2008). Resource use efficiency of maize farmers in rural Nigeria: Evidence from Ekiti State. *World Journal of Agricultural Sciences*, 4(1), 91–99.

Oluwunmi, A. (2009). Considerations in Nigeria's Agricultural Policy: Strategies and Progress (No. 4). Abuja, Nigeria: Federal Ministry of Environment.

Onoja, A. O., & Achike,, A. I. (2008). *Technical Efficiency of Rice Production Under Small Scale Farmer- Managed Irrigation Schemes and Rained-Fed Systems in Kogi State, Nigeria.* In: E. A. Aiyedun, P. O. Idisi andJ. N. Nmadu (eds). In Proceedings of the 10th Annual conference of the Nigerian Association of Agricultural Economists (pp. 242–252). University of Abuja, Nigeria.

Onyeji, S. C., & Fischer, G. (1994). An economic analysis of potential impacts of climate change in Egypt. *Global Environmental Change*, 4(4), 281–299.

Ouedraogo, M., Some, L., & Dembele, Y. (2006). Economic impact assessment of climate change on agriculture in Burkina Faso: A Ricardian Approach. Centre for Environmental Economics and Policy in Africa (CEEPA), University of Pretoria. Retrieved from http://ceepa.co.za/docs/CDPNo24.pdf. [Accessed July 17, 2014.

Parikh, A., & Shah, K. (1994). Measurement of technical efficiency in the North-West frontier Province of Pakistan. Journal of Agricultural Economics, 45(1), 132–138.

Parikh, A., Ali, F., & Shah, M. K. (1995). Measurement of economic efficiency in Pakistani agriculture. *American Journal of Agricultural Economics*, 77(3), 675–685.

Passel, S. van, Massetti, E., & Mendelsohn, R. (2012). A Ricardian analysis of the impact of climate change on European agriculture. CMCC Research Paper, (RP0164). Retrieved from http://www.cabdirect.org/abstracts/20133144151.html. [Accessed June 3, 2014].

Paul, C. J. M., Johnston, W. E., & Frengley, G. A. (2000). Efficiency in New Zealand sheep and beef farming: The impacts of regulatory reform. *Review of Economics and Statistics,* 82(2), 325–337.

Phillips, J. M., & Marble, R. P. (1986). Farmer education and efficiency: a frontier production function approach. *Economics of Education Review*, 5(3), 257–264.

Pitt, M. M., & Lee, L.-F. (1981). The measurement and sources of technical inefficiency in the Indonesian weaving industry. *Journal of Development Economics*, 9(1), 43–64.

Placid, N. C. (2000). Nigeria's Agriculture and the Challenges in the 21st Century. *Agro Science*, 1.

Polsky, C. (2004). Putting space and time in Ricardian climate change impact studies: Agriculture in the US Great Plains, 1969–1992. *Annals of the Association of American Geographers,* 94(3), 549–564.

Porcelli, F. (2009). Measurement of Technical Efficiency: A brief survey on parametric and non-parametric techniques. Citeseer.

Radam, A., & Shamsudin, M. N. (2001). Production frontier and technical efficiency: The case of paddy farms in Malaysia. *The Asian Economic Review*, 43(2), 315–323.

Rakipova, A. N., Gillespie, J. M., & Franke, D. E. (2003). Determinants of technical efficiency in Louisiana beef cattle production. *Journal of American Society of Farm Managers and Rural Appraisers* (ASFMRA), 99–107.

Rawlins, G. (1985). Measuring the Impact of I.R.D.P. upon the Technical Efficiency Level of Jamaican Peasant Frmers. *Social and Economic Studies,* 34(2), 71–96.

Ray, S. C. (1985). Measurement and test of efficiency of farms in linear programming models: a study of West Bengal farms*. *Oxford Bulletin of Economics and Statistics,* 47(4), 371–386.

Reilly, J.M., Hohmann, N., & Kane, S. (1996). Climate Change and Agricultural Trade: Who Benefits, Who Loses? In Climate Change and World Food Security (pp. 161–180). Springer. Retrieved from http://link.springer.com/chapter/10.1007/978-3-642-61086-8_6.[Accessed 28 October 2014].

Reilly, J.M. (1999). What does climate change mean for agriculture in developing countries? A comment on Mendelsohn and Dinar. The World Bank Research Observer, 295–305.

Reilly, J. M., Tubiello, F., McCarl, B. A., & Melillo, J. (2001). Climate change and agriculture in the United States. Climate Change Impacts on the United States: US

National Assessment of the Potential Consequences of Climate Variability and Change: Foundation, 379–403.

Reilly, J.M., Tubiello, F., McCarl, B., Abler, D., Darwin, R., Fuglie, K. others. (2003). US agriculture and climate change: new results. *Climatic Change*, 57(1-2), 43–67.

Reinsborough, M. J. (2003). A Ricardian model of climate change in Canada. *Canadian Journal of Economics/Revue Canadienne D'économique,* 36(1), 21–40.

Richmond, J. (1974). Estimating the efficiency of production. *International Economic Review*, 15(2), 515–521.

Rosegrant, M. W., Msangi, S., Ringler, C., Sulser, T. B., Zhu, T., & Cline, S. A. (2008). *International model for policy analysis of agricultural commodities and trade (IMPACT): Model description*. Washington, DC: International Food Policy Research Institute.

Rosenberg, N. J. (1992). Adaptation of agriculture to climate change. *Climatic Change*, 21(4), 385–405.

Rosenzweig C., A. Iglesias and M.L. Parry. (1994). Potential impacts of climate change on World food supply. *Nature* 367 (6459), 133-138.

Rosenzweig,C. and Iglesias A. (1998). *The use of crop models for international climate change impact assessment* (G.Y. Tsuji,G. Hoogenboom and P.K. Thornton.). Dordrecht the Netherlands: Kluwer Academic Publishers.

Sadiq, M. S., Yakasai, M. T., Ahmad, M. M., Lapkene, T. Y., & Abubakar, M. (2013). Profitability and Production Efficiency of Small-Scale Maize Production in Niger State, Nigeria. IOSR *Journal of Applied Physics*, 3, 19–23.

Salau, S. A., Adewumi, M. O., & Omotesho, O. A. (2012). Technical Efficiency and its Determinants at Different Levels of Intensification Among Maize-Based Farming Households in Southern Guinea Savanna of Nigeria. *Ethiopian Journal of Environmental Studies and Management*, 5(2), 195–206.

Sands, R. D., & Edmonds, J. A. (2004). Economic analysis of field crops and land use with climate change. *Climate Change Impacts for the Conterminous USA*: An Integrated Assessment Paper (7) 1-25.

Sanghi, A., Alves, D., Evenson, R., & Mendelsohn, R. (1997). Global warming impacts on Brazilian agriculture: estimates of the Ricardian model. *Economía Aplicada*, 1(1), 7–33.

Scheraga, J. D., Leary, N. A., Goettle, R. J., Jorgenson, D. W., & Wilcoxen, P. J. (1993). Macroeconomic modeling and the assessment of climate change impacts. Ed. Y. Kaya, N. Nakicenovic, WD Nordhaus and FL, Toth, Costs, Impacts and Benefits of CO, 2.

Schmidt, P., & Sickles, R. C. (1984). Production frontiers and panel data. *Journal of Business & Economic Statistics*, 2(4), 367–374.

Sene, I. M., Diop, M., & Dieng, A. (2006). Impacts of climate change on net revenues and adaptation of farmers in Senegal. CEEPA Discussion Paper 20, University of Pretoria, South Africa. Retrieved from http://ceepa.co.za/docs/CDPNo20.pdf. [Accessed July 17, 2014].

Sengupta, J. K. (1990). Transformations in stochastic DEA models. *Journal of Econometrics*, 46(1), 109–123.

Seo, S. N., & Mendelsohn, R. (2008). A Ricardian analysis of the impact of climate change on South American farms. Chilean *Journal of Agricultural Research*, 68(1), 69–79.

Seo, S. N., Mendelsohn, R., Dinar, A., Hassan, R., & Kurukulasuriya, P. (2009). A Ricardian analysis of the distribution of climate change impacts on agriculture across agro-ecological zones in Africa. *Environmental and Resource Economics*, 43(3), 313–332.

Shafiq, M., & Rehman, T. (2000). The extent of resource use inefficiencies in cotton production in Pakistan's Punjab: An application of Data Envelopment Analysis. *Agricultural Economics*, 22(3), 321–330.

Shanmugam, K. R., & Venkataramani, A. (2006). Technical efficiency in agricultural production and its determinants: An exploratory study at the district level (Working paper No. 22513 Australia: East Asian Bureau of Economic Research. Retrieved from http://ideas.repec.org/p/eab/macroe/22513.html. [Accessed February 13, 2014].

Shapiro, K. H., & Müller, J. (1977). Sources of technical efficiency: the roles of modernization and information. *Economic Development and Cultural Change*, 293–310.

Shapiro, K. H. (1983). Efficiency differentials in peasant agriculture and their implications for development policies. *The Journal of Development Studies*, 19(2), 179–190.

Sharma, K. R., Leung, P., & Zaleski, H. M. (1999). Technical, allocative and economic efficiencies in swine production in Hawaii: a comparison of parametric and nonparametric approaches. *Agricultural Economics*, 20(1), 23–35.

Sharpley, A. N., Williams, J. R., & others. (1990). EPIC-erosion/productivity impact calculator: 1. Model documentation. Technical Bulletin-United States Department of Agriculture, (1768 Pt 1).

Showemimo, F. A., Kimbeng, C. A., & Alabi, S. O. (2002). Genotypic response of sorghum cultivars to nitrogen fertilization in the control of Striga hermonthica. *Crop Protection*, 21(9), 867–870.

Sibiko, K. W. (2013). Determinants of common bean productivity and efficiency: a case of smallholder farmers in Eastern Uganda. *Current Research Journal of Economic Theory,* 5(3), 44-55.

Simar, L., & Wilson, P. W. (1998). Sensitivity analysis of efficiency scores: How to bootstrap in nonparametric frontier models. *Management Science*, 44(1), 49–61.

Sofoluwe, N. A., Tijani, A. A., & Baruwa, O. I. (2011). Farmers' perception and adaptation to climate change in Osun State, Nigeria. *African Journal of Agricultural Research*, 6(20), 4789–4794.

Squires, D., & Tabor, S. (1991). Technical efficiency and future production gains in Indonesian agriculture. *The Developing Economies*, 29(3), 258–270.

Stevenson, R. E. (1980). Likelihood functions for generalized stochastic frontier estimation. *Journal of Econometrics*, 13(1), 57–66.

Taylor, T. G., & Scott Shonkwiler, J. (1986). Alternative stochastic specifications of the frontier production function in the analysis of agricultural credit programs and technical efficiency. *Journal of Development Economics*, 21(1), 149–160.

Taylor, T. G., Drummond, H. E., & Gomes, A. T. (1986). Agricultural credit programs and production efficiency: an analysis of traditional farming in SouthEastern Minas Gerais, Brazil. *American Journal of Agricultural Economics*, 68(1), 110–119.

Thompson, R. G., Langemeier, L. N., Lee, C.-T., Lee, E., & Thrall, R. M. (1990). The role of multiplier bounds in efficiency analysis with application to Kansas farming. *Journal of Econometrics*, 46(1), 93–108.

Timmer, C. P. (1971). Using a probabilistic frontier production function to measure technical efficiency. *Journal of Political Economy*, 79 (4), 776–94.

Tsigas, M. E., Frisvold, G. B., & Kuhn, B. (1997). Global climate change and agriculture. Global Trade Analysis: Modeling and Applications, 280–304.

Tzouvelekas, V., Pantzios, C. J., & Fotopoulos, C. (2001). Technical efficiency of alternative farming systems: the case of Greek organic and conventional olive-growing farms. *Food Policy*, 26 (6), 549–569.

United Nations Development Program. (2010). Climate Change Country Profiles, Nigeria (No. 91) (pp. 157–166). New york: United Nations Development Program. Retrieved from http://country-profiles.geog.ox.ac.uk/UNDPCCCP_documentation.pdf. [Accessed June 16 2014].

United Nations Framework Convention on Climate Change (1997). Kyoto Protocol.

United States Department of Agriculture USDA. (2007). Crop Simulation Models. USDA.

Wadud, A., & White, B. (2000). Farm household efficiency in Bangladesh: a comparison of stochastic frontier and DEA methods. *Applied Economics*, 32(13), 1665–1673.

Wang, J., Mendelsohn, R., Dinar, A., Huang, J., Rozelle, S., & Zhang, L. (2009). The impact of climate change on China's agriculture. *Agricultural Economics*, 40(3), 323–337.

Winsten, C. B. (1957). Discussion on Mr. Farrell's paper. Journal of the Royal Statistical Society, 120, 282–284.

Winters, P., Murgai, R., Sadoulet, E., de Janvry, A., & Frisvold, G. (1998). Economic and welfare impacts of climate change on developing countries. *Environmental and Resource Economics*, 12(1), 1–24.

Wooldridge, J. M. (2005). Simple solutions to the initial conditions problem in dynamic, nonlinear panel data models with unobserved heterogeneity. *Journal of Applied Econometrics*, 20(1), 39–54.

World Bank (2008). World Bank World Development Report 2008.Washington D.C. World Bank 2008. Washington D,C World Bank.

World Bank (2012). World Development Indicators 2012. World Bank Publications. Retrieved from http://books.google.com.my/books? [accessed August 12, 2014].

Yates, D. N., & Strzepek, K. M. (1998). Modeling the Nile Basin under climatic change. *Journal of Hydrologic Engineering*, 3(2), 98-108.

Zainal, Z., Shamsudin, M. N., Mohamed, Z. A., & Adam, S. U. (2012). Economic Impact of Climate Change on the Malaysian Palm Oil Production. *Trends in Applied Sciences Research*, 7(10), 872-880.

Zalkuwi, J. W., Dia, Y. Z., & Dia, Z. (2010). Analysis of Economic Efficiency of Maize Production in Ganye local Government Area Adamawa state, Nigeria (No. 2). Adamawa State Nigeria: Adamawa State University. Retrieved from http://www.sciencepub.net/report/report0207/01_3183report0207_1_9.pdf.[Accessed February 15 2014].

Zhang, X., Vincent, L. A., Hogg, W. D., & Niitsoo, A. (2000). Temperature and precipitation trends in Canada during the 20th century. *Atmosphere-Ocean*, 38(3), 395–429.

LIST OF PUBLICATIONS

Economic Impact of Climate Change on Maize Production in Northern Nigeria *Trends in Applied Sciences Research,* 9(9): 522-533.

Technical Efficiency in Maize Production and its Determinants: A Survey of Farms across Agro ecological Zones in Northern Nigeria *Trends in Agricultural Economics*, 7(2): 57-68.

Rainfall Trend Detection in Northern Nigeria over the Period of 1970-2012 *Journal of Environment and Science,* 5(2): 94-99.