EVALUATION OF TECHNICAL, ALLOCATIVE AND ECONOMIC EFFICIENCY OF RICE PRODUCERS: A CASE STUDY IN CENTRAL RIVER REGION NORTH & SOUTH OF THE GAMBIA

By

BAKARY KADDY. SULAYMAN. SANYANG (BSc. Agriculture)

A Thesis Submitted to the Department of Agricultural Economics, Agribusiness and Extension,

Kwame Nkrumah University of Science and Technology

In Partial Fulfillment of the Requirements for the Degree

Of

MASTER OF PHILOSOPHY IN AGRICULTURAL ECONOMICS

Faculty of Agriculture

College of Agriculture and Natural Resources

NOVEMBER, 2014

DECLARATION

I, Bakary Kaddy Sulayman Sanyang, do hereby declare that this submission is entirely my own work towards the MPhil. (Agricultural Economics) and that, to the best of my knowledge, it contains no materials previously published by another person or material which has been accepted for the award of any other degree of the University except where due acknowledgement has been made in the text.

BAKARY KADDY. SULAYMAN SANYANG (PG7002512)		....
(Student's Name & ID)	(Signature)	(Date)

Certified by:

Dr. GYIELE K. NURAH (Major Supervisor)	....	....
	(Signature)	(Date)
Dr. ROBERT AIDOO (Co-Supervisor)	....	....
	(Signature)	(Date)
Dr. DADSON AWUNYO-VITOR	....	....
(Head of Department)	(Signature)	(Date)

DEDICATION

This research work is dedicated to my wife Fatoumata M.S Jassey, my two daughters Mbafatou Sanyang & Mama Sanyang and my son Bakary Kaddy Sanyang Jr for their everlasting understanding, love, care and emotional support. I also dedicate it to my sweet mother, Kaddy Sabally loving father Sulayman (Sako) Sanyang and caring Uncle Babanding M.S Sabally for their struggle and toiling in bring me to this level.

ACKNOWLEDGEMENTS

My ultimate gratitude goes to Almighty Allah for his mercies and protection bestowed upon me during my academic and research work. My profound gratitude goes to my major supervisor Dr. Gyiele Nurah for his constructive criticisms, diverse and scholarly contribution to the timely completion of this study. I am also grateful to my two co-supervisors Dr Robert Aidoo Department Agricultural Economics, Agribusiness and extension and Dr. Aminou Arouna of Policy and Impact Assessment Program of Africa Rice Center (Africa Rice) for their guidance, kindness, patience and the much time they dedicated to me just to ensure that the work is professionally done. To Mr. Ifidon and the entire PSTAD staff, I am indebted to your institution for the financial support granted to me, which was timely for without which I would not have achieved my MPhil study; I say a big thank you. I am as well indebted to Mr. Fafanding Fatajo Project Coordinator FISCA for his instrumental role in me achieving the scholarship for my study.

My sincere gratitude also goes to Africa Rice Center for the support the Policy and Impact Assessment Program rendered to me during my data collection and analysis. To my friend Mr. Bakary O. Camara the head of the socioeconomic unit of NARI and to his colleagues at the office and the baseline survey data collectors in the two hubs and the late Director General of NARI Dr. Babu Jobe for the conducive environment they provided me with during my data collection. I also owe a debt of immense gratitude for the assistance offered to me by the former Director General of the Department of Agriculture of The Gambia, Mr. Musa Humma and his entire staff. I appreciate the

advice and encouragement of my good friend, my mentor Mr. Ousman Jammeh Permanent Secretary 1 of the Ministry of Agriculture. My sincere gratitude goes to Mr. Aba G. Sankareh, Deputy Director Planning Services Unit and his entire staff for their support during my data collection.

My profound appreciation is extended to Dr J.A Bakang the former Head of the Department of Agricultural Economics, Agribusiness and extension for his relentless support during the course of my study. Similar sentiments are extended to the current Head of Department Dr Dadson A. Vitor, for his guidance and support.

Special gratitude goes to the lecturers and colleague students of the Department of Agricultural Economics, Agribusiness and extension for their encouragement and constructive criticisms during my seminar presentations. I appreciate all the efforts and facilitations you made which ensured that my study became a success. To my Aunty Mbafatou Sanyang, thank you for being there for my family in my absence; to my aunt's Luntang Sabally, Aja Fulo Sabally and all my siblings, I thank you for your dedication and company to my family.

To Emmanuel Donkor, Mamma Sawaneh, Aristide Akpa and Rico Amoussouhoui for their technical backstopping during my data analysis and all of you who were instrumental in my studies, thank you and May the Allah Almighty continue blessing you for your support.

ABSRACT

There is a well-established growing demand for rice in the Gambia as a major staple. Prevailing prices in the global and local markets influence the ability of households to purchase rice. Demands for rice outweigh local production as only a fraction is met by domestic production. This study investigates the, technical, allocative and economic efficiency of rice farmers in the Central River Region North and Central River Region South of the Gambia. Primary data was collected for the 2013 cropping season from a sample of 200 rice farmers; 80 were selected from the North and 120 from south, but ended up using 192 completed questionnaires for analysis. A Parametric Stochastic Frontier Production Function was used to assess technical, allocative and economic efficiency of rice producers in the study area. A Cobb-Douglas frontier production function which has self-dual characteristics was used to derive technical efficiency scores for the rice producers. Constraints reported by farmers were analyzed using Kendall's coefficient of concordance to test for the degree of agreement in ranking. The results of the study revealed that farm size, labour and fertilizer have a significant effect on increasing farmer's efficiency. Results have revealed that there is a significant level of inefficiency among rice producers as illustrated by the coefficients. Technical efficiency estimates range from 0.90 percent to 93.30 percent with a mean efficiency of 65.03 percent, while Allocative efficiency estimates range from 1.10 percent to 93.50 percent with a mean of 67.47 percent. The mean economic efficiency

was found to be 47.76 percent. This suggests that there is considerable room for improvement in increasing rice productivity through better use of available resources and existing technology. The study also showed that increase in farmer's subscription to cooperative membership, improved rice variety adoption and the improvement of irrigation facilities may reduce overall inefficiency among rice farmers in the study area. Constraints faced by rice farmers were ranked based on abiotic, biotic and socioeconomic factors. The study revealed that a soil related factor (salinity) was ranked as the most important abiotic factor, diseases were ranked as the most important biotic factor and limited land size and its related tenure issues were considered to be the most important socioeconomic constraint. This study therefore recommends that policies that would improve access to fertilizer, irrigation schemes, improved rice varieties and formation of farmer's cooperatives should be pursued.

TABLE OF CONTENTS

LIST OF TABLES PAGES

LIST OF FIGURES PAGES

LIST OF ACRONYMS

AE	Allocative Efficiency
AGRA	Alliance for Green Revolution in Africa
ANR	Agriculture and Natural Resources Sector
CAADP	Comprehensive African Agricultural Development Programme
CARD	Coalition for Africa Rice Development
CFSVA	Comprehensive Food Security and Vulnerability Analysis
DEA	Data Envelope Approach
DMU	Decision Making Unit
DOA	Department of Agriculture
EE	Economic Efficiency
FAO	Food and Agricultural Organisation
FMRIP	Farmer Manage Rice Irrigation Project
GBoS	Gambia Bureau of Statistics
GDP	Gross Domestic Products
GNAIP	Gambia National Agricultural Investment Plan
HYV	High Yielding Varieties
JICA	Japan International Cooperation Agency

MOA	Ministry of Agriculture
NARI	National Agricultural Research Institute
NASS	National Agricultural Sample Survey
NERICA	New Rice for Africa
PAGE	Programme for Accelerated Growth and Employment
PF	Production Frontier
SFA	Stochastic Frontier Approach
SFPF	Stochastic Frontier Production Function
SSA	Sub Saharan Africa
TE	Technical Efficiency
WARDA	West Africa Rice Development Association
WB	World Bank
WFP	World Food Programme

CHAPTER ONE

1.0. INTRODUCTION

1.1 Background of the study

The main drivers of economic growth for the Gambia remain the agricultural sector and the tourism industry. The agricultural sector accounted for about 30% of Gross Domestic Product in 2010 and it provides employment to 75 percent of the country's population and meets about 50 percent of the national food requirements (PAGE, 2011). Agriculture is also the sole means of income generation for the majority of rural households below the poverty line. The agricultural sector is regarded as the prime sector for investments to raise income, improve food security and reduce poverty.

Rice (*Oriza sativa*) is the prime source of food for nearly half of the world's population, especially in Asia and Africa, including the Gambia. Kumar *et al*. (2008) noted that since 1973, West Africa's demand for rice has grown at an annual rate of 6% driven by population growth of 2.9 %.

The Gambia is classified as a Least Developed, Low Income Food Deficit Country and its ranked 172 out of 187 countries according to the 2014 Human Development Index (UNDP, 2014). About a third of the populations are living below the US$1.25 per day poverty line and the economy is relatively undiversified with economic growth averaging 5-6 percent of GDP in 2006-2012 period (UNDP, 2014).

Africa depends to a large extend on imports and in 2008, Africa imports accounted for 32% of the rice traded globally, most of it from Asia. The growing demand of rice provides a strong impetus to continue to improve growth and efficiency of local rice production, but also to develop policies to control large imports that can impede the development of domestic rice sector (AfricaRice, 2011). Demand for rice from less advantaged areas in Africa is certain to increase, replacing much of the coarse grains such as sorghum (*Sorghum vulgare* L.) and millet (*Pennisetum glaucum* L.) as the major source of dietary calories (Ceesay, 2004).

Rice is the most preferred staple food in the Gambia and therefore considered as the most critical crop that determines Gambia's food self-sufficiency, with an average annual population growth rate of 3.1%. An increase in rice production has become vital to both matching the rising caloric demand for this staple and to contributing to the income of the rural poor. Gambia's annual requirements for rice (major staple food) are in the range of 180,000 to 227,000 metric tons (MT) and presently only 13% is met through local production (29, 510 metric tons) (NASS, 2013). One way of solving the problem of food shortage being created by the widening gap between food output growth and population growth is through increasing agricultural productivity. For these reasons the government of the Gambia is keen to increase rice productivity and production.

Although rice production in the Gambia has shown significant increase over the years, there has been a considerable lag between production and demand level with imports making up the shortfall. As per the Gambian Agricultural and Natural

Resources Sector (ANR) Policy document, the specific objective of agricultural sector is the attainment of self-sufficiency in basic food commodities with particular reference to those food commodities which consume considerable shares of the Gambia's foreign exchange and which can be produced locally (Gambia, 2009).

The Government of the Republic of the Gambia decided to prioritize agriculture in the quest to try and boost the livelihoods of its people. The Government has continued to support agriculture basically at increasing productivity of land and therefore has promoted packages of improved practices, which included development of high yielding varieties, improved management, and provision of subsidized inputs and extension services as well as through provision of markets for the farm produce. Provision of credit facilities with easy repayment terms were instituted to make farmers more productive.

Recently, the Gambia government in collaboration with the Africa Rice Centre (AfricaRice) introduced high yielding rice varieties bred for Africa called the New Rice for Africa (NERICA). The NERICA varieties were first introduced in the Gambia through the participatory varietal selection in 1998. Since the development of NERICA, considerable efforts have been made by National Agricultural Research Institute (NARI), Department of Agriculture (DOA) and Donor agencies to widely disseminate them across the Gambia. At present the NERICA varieties have spread across all agricultural regions of the country (Dibba *et al*, 2012) with fertilizer and irrigation support to farmers.

Among all the several efforts geared towards increasing rice productivity, the development and dissemination of improved rice varieties appear to be most prominent. In light of boosting production and productivity of rice; improved rice varieties were disseminated to different ecologies throughout the Gambia. Over the years government has embarked on several projects which provide subsidized inputs to rice producers so as to make them productive and food secure.

1.2 Problem statement

Rice is the most important staple food crop in The Gambia with a total annual consumption in 2009 estimated at 102, 000 metric tons (FAO, 2012). As the main staple food of the Gambia, rice is consumed at least twice a day in most households in the country. The crop is grown in all ecologies in the six agricultural regions of the country and serves as the source of livelihood for over 70% of the farming households in the country. Due to its critical role in employment generation and contribution to household food and income security in the Gambia, the central government has prioritized the crop and supported farmers over the years with improved varieties and subsidized fertilizers to ensure increased production and productivity.

Despite efforts at increasing rice productivity through the cultivation of improved rice varieties in all the regions of the country, yields of rice in the Gambia have remained lower than expected. Under control research in both ecologies by the National Agricultural Research Institute (NARI), actual yield[1] of rice in upland ecology

[1] Actual Yield is the yield realisable at farmer field level.

ranges from 0.6 – 2.5 Mt/Ha with an average yield of 1.6 Mt/Ha. It has a potential yield[2] ranging from 3 – 6 Mt/Ha with an average of 4.5Mt/Ha (NARI, 2013). The actual yields reported from the lowland ecology ranges from 4 – 7.5 Mt/Ha with an average of 5Mt/Ha. But the reported potential yields range from 7.5 – 11 Mt/Ha with an average of 9.2 Mt/Ha (NARI, 2013). As a result of the low productivity in the rice sector, the country is not self-sufficient in rice production. Locally produced rice meets less than half of the total demand; hence, the remaining is obtained through importation which takes a huge chunk of the nation's foreign capital reserve.

Low productivity in the Gambia's rice sector, which has warranted the massive unsustainable levels of rice imports, could be attributed to constraints farmers face, including environmental factors, technological constraints and poor management practices. Environmental factors responsible for low yields in rice productivity include the steady decline in rainfall which led to critical drought condition; and acidity and salinity leading to low productivity. Depletion of soil fertility, along with poor management of weeds, pest and diseases, is a major biophysical cause for the low per capita rice production in the Gambia. Over decades, large quantities of nutrients from the soil have been removed without using sufficient quantities of manure and fertilizer to replenish the soil. Also inappropriate fertilizers are used in many areas because there is lack of soil testing. The identified constraints are likely to affect farmer's production levels and their overall efficiency in rice cultivation.

---

[2] Potential Yield can be the maximum yield obtained with good agricultural practices in an experimental plot.

The challenge of poor yields in the rice sector is likely to persist if better understanding of the factors that underpin farmers' level of (in)efficiency are not explored through empirical research. Consequently, this study has been undertaken to evaluate economic efficiency of rice producers and investigate the sources of inefficiency in rice production as one way of determining factors responsible for low productivity in rice production and provide appropriate policies to address these numerous constraint

1.3. Research Questions

The following research questions were addressed in the study:

- What are the factors that determine rice yield levels in the Gambia?
- What is the level of technical, allocative and economic efficiency of rice producers?
- What are the factors that influence the efficiency levels of rice producers?
- What constraints do rice farmers face in the Gambia?

1.4. Objectives of the study

1.4.1. Main objective

The overall objective of this study is to evaluate technical, allocative and economic efficiency of rice producers in Central River Region North and South of the Gambia.

1.4.2. Specific objectives of the study

The study addressed the following specific objectives:

1. To determine the factors that influence rice yield in the Gambia.

2. To determine the level of Technical, Allocative and Economic Efficiency of rice producers in the Gambia

3. To evaluate the main determinants of efficiency among rice producers in the Gambia.

4. To identify the major constraints faced by rice producers in the Gambia

1.5. Hypotheses

The following null hypothesis would be validated:

1) Yield of rice is positively affected by fertilizer, land size, labour and seed.

2) Farmers are both technically and allocativelly inefficient in the production of rice.

3) Economic efficiency is positively affected by socio-economic factors.

1.6. Justification

The researcher was motivated to identify whether rice farmers utilize full capacity in their production processes or not, and to find ways of improving their productivity, in case they were less efficient.

This study is designed to help find solutions which would promote increases in rice productivity as well as overall output. Therefore, this study will have important benefits to the researcher, rice producers, policy makers in government and to contribution to the body of knowledge in production economics and finally to come up with policy proposals to address the constraints.

Identifying inefficiency in rice production helps rice producers to use their inputs efficiently thereby helping in minimizing the already scarce resources in the country. It is important that farmers use resources efficiently to achieve the maximum yield. That is, if rice farmers can increase productivity with the same input quantities under efficient allocation and management of resources at the farm level; this will have great implication for overall national development and food security.

Additionally, results of this study will help policy makers to design policies to target interventions according to the identified needs and constraints of rice producers. Moreover, the results from this study will contribute to the already existing body of knowledge in production economics and efficiency studies in particular. The efforts here could provoke efficiency studies on other crops in the Gambia.

As it was also reviewed that rice productivity in farmers' fields are often below what will be possible with improved management (potential yield). A good understanding can enable us to identify progress in farmers' fields and also help us identify the extent to which increased cost can be justified to raise yields or reduce yield losses. Identifying the productivity gaps also enables the major yield-limiting factors (e.g. drought, flooding, fertilizer deficiencies, extreme temperature) and yield reducing factors (e.g. pests, diseases) to be identified.

Productivity gaps occur in low-input systems with poor water control and relatively low-input management, but often also in high-input systems with good water control that allows for more precise management. Rice growth and development can be severely disrupted by drought or floods. Absence or late availability of critical inputs may also undermine farmers' ability to make management decision and undertake farm operations on time.

The importance of conducting efficiency analysis in determining farm level efficiency has also been shown in literature. The papers reviewed are dated as far back as 1957 and as recent as 2011. In all these papers what is apparent is that for a group of farmers it is extremely important to identify the sources of their inefficiency as well as the major determinants of such inefficiencies so as to recommend the most appropriate policy to address such problems.

1.7. Organization of study

The study is divided into five chapters. Chapter One provides the background, problem statement, objectives of the study and justification of the study.

Chapter Two presents the Literature Review. The methodology is described in Chapter Three. In particular, it describes the choice and location of the study area, sampling procedure and analytical technics, theoretical framework and empirical model.

The descriptive and empirical results are discussion and presented in Chapter Four and the final Chapter covers summery of the findings, conclusions and recommendations.

CHAPTER TWO

2.0. LITERATURE REVIEW

This chapter begins with a review of literature on the importance of rice production and consumption trends, as well as rice productivity and factors that influence production in the Gambia. This is followed by the efficiency definition, concept and approaches to measuring efficiency. Literature was also reviewed on empirical studies on efficiency, factors that influence efficiency and empirical review of studies on efficiency in rice production. It concludes with constraints on rice production and a conclusion of the chapter.

2.1. Importance of rice in the Gambia

Rice is the leading provider of food calories in West Africa, and it is now the second largest source of food energy in Sub Saharan Africa (SSA) as a whole. The increasing role of rice in the food basket of SSA consumers has made rice a political crop, in the sense that its price and accessibility influences social stability (Seck *et al*., 2012).

Rice is often considered one of the most protected commodities in the world and only about 7% of global rice production is traded on the international market. In this distorted market, the major producing countries may close their borders to trade during periods of perceived supply shortage, as happened in 2007 and 2008.

Rice availability and prices impact directly on the welfare of the poorest consumers in the region; many of whom are resource poor farmers who depend on rice as both staple food and a source of income. It is therefore not surprising that rice is a major component of the food security and poverty alleviation strategies of many SSA countries. Against this background, any improvement in rice productivity will contribute significantly to achieving a higher level of regional and household food security, while responding to the needs of the poorest consumers by enhancing their diet both quantitatively and qualitatively and by providing additional income opportunities (Seck *et al*., 2012).

In the Gambia rice has been cultivated for several hundreds of years by every agricultural farm household. Since the introduction of rice, it has established itself as one of the most important food crop in the country. Currently it is the most important staple food crop and source of calories in terms of consumption which is eaten at least twice daily by most household in the country. It has achieved some economic benefits to farmers who grow it but not as groundnut where its production is one of the main sources of employment and income for a large number of farmers in the country.

With an average per capita consumption of about 117kg (Ceesay, 2004), rice is synonymous with food contributing a larger portion of the total food intake than any other cereal. In rural areas, rice provides about 75 percent of total calorie intake and about 45 percent of protein intake (Jaiteh, 2003). Therefore, any agricultural development strategy aimed at self-sufficiency in food - without taking into account the importance of rice - will be an insufficient development strategy. Many private agencies, foundations, national and several international agencies have sponsored action programmes to alleviate poverty and food insecurity through rice production.

Rice is grown throughout the Gambia by resource poor rural farmers and landless agricultural labourers on small farms ranging mostly from 0.5 to 0.75 ha averaging about 1 ha (Jaiteh, 2003). However, most of the poor and poorly fed Gambians live in areas where rice can be grown comparatively cheaper. Rice feeds most of the people of the Gambia than any other crop; about 66% of household income is spent on food and about 30.9% of food expenditure is on cereals and cereal products, of which 82.3% is on rice (Jaiteh, 2003).

It is the principal dietary item providing more than 40% of the nation's food need (Ceesay, 2004); in periods of acute food shortage rice is used by donor agencies as food for crisis mitigation. Annual production of rice accounts for less than one quarter of domestic requirements, this huge deficit is made up of costly imports. Over the years the Government has made increasing rice output a major policy objective in order to conserve foreign exchange earnings through import substitution.

2.2. Rice production and consumption trends in the Gambia

According to FAOSTAT, (2012) rice area cultivated annually in the Gambia averages about 32, 214 hectares. Total annual rice production is currently over, 54, 219 metric tonnes. Average yield of rice are moderate when expressed per unit of land area averaging less than 2 t/ha (FAOSTAT, 2012).

Productivity trend indicated in Figure 2.1 have shown decreasing productivity in spite of government investment in the Gambia rice sector, but have only shown little improvement since 2007. This productivity has dropped from 12, 168 tonnes in 2011 to as low as 8, 526 tonnes. The goal of self-sufficiency in food production at the national level remain a long term target couple with the ever population growth rate.

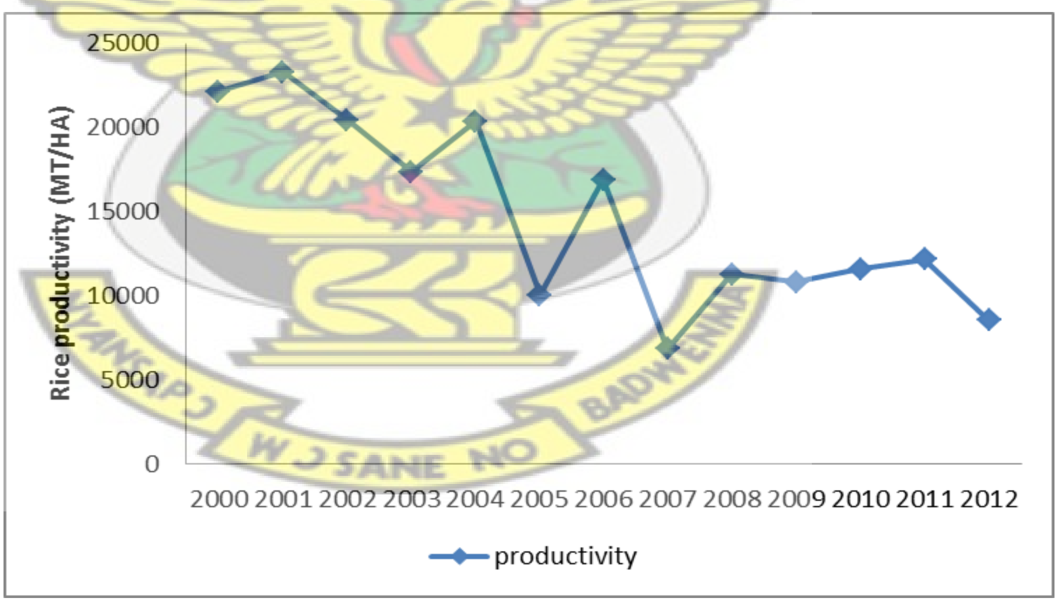


Figure 2.1: Rice productivity in the Gambia (2000-2012)
Source: FAOSTAT (2012)

Figure 2.2 shows no systematic trend in rice production. Rice production picks up in 2007 from 11, 395 Mt to about 99, 890 Mt in 2010 when it drops to 51, 136 Mt and up a bit to 54, 219 Mt in 2011 and 2012 respectively. This has led to continuous importation of rice to meet the local demand.

The area cultivated has been fluctuating from the year 2000-2007, when the total land area cultivated was about 16, 608 hectares, but three years later it went up to 86, 150 hectares in 2010 and a year later in 2011 it dropped to 42, 026 hectares but went up again in 2012 to 63, 592 hectares.

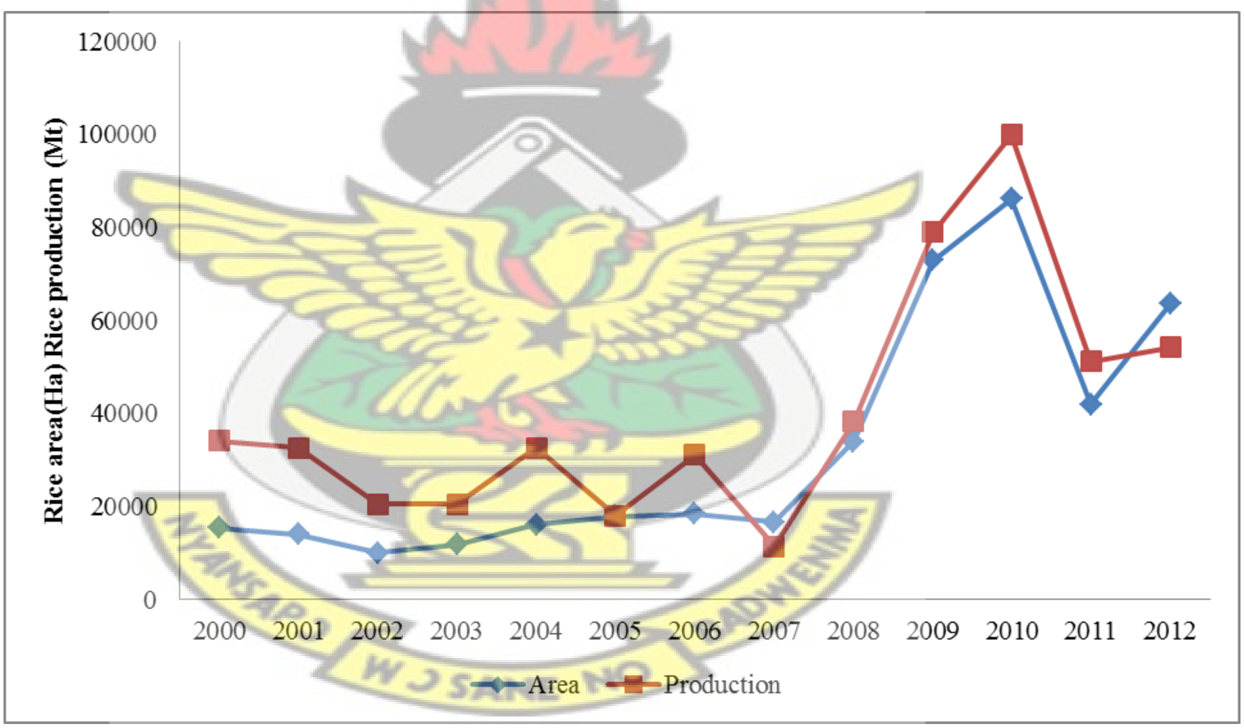


Figure 2.2: Area and Production of Rice (2000-2012)

Source: FAOSTAT (2012)

2.3. Rice yield and its determinants

2.3.1. Rice productivity

Becker *et al*. (2003) reported that average on farm yields of irrigated lowland rice in different agro ecological zones in West Africa range from 3.4 t/ha to 5.4 t/ha, and potentials yield range from 6.9 t/ha to 9.8 t/ha. The potential yield is highest in the Sahel zone (Senegal) and lowest in humid forest zone (Cote d'Ivoire).

Becker and Johnson (1999) conducted survey in irrigated systems of the forest zone of Cote d'Ivoire. They reported an average yield of 3.2 t/ha under partial irrigation and 4.2 t/ha in fully irrigated systems.

Potential yields of irrigated lowland rice in Madagascar are estimated at about 11.4-14.9 t/ha (Sheehy *et al*., 2004), while upland rice yields ranges from 2.6 t/ha to 9.9 t/ha (Tsujimoto *et al*., 2009), which suggests yield gaps ranges from 1.5 t/ha to 12.3 t/ha. Trials managed by researchers achieved more than 11 t/ha in Egypt and Kenya, and more than 9 t/ha in Mozambique (Menete *at al*., 2008). Thus, potential rice yields in Egypt, Kenya and Madagascar seem to be higher than those in West Africa.

Studies in West Africa show average farm yields for rainfed lowland rice range from 1.0 t/ha to 2.2 t/ha (Becker and Johnson, 2001). Given that potential yields of rainfed lowland rice are assumed to be similar to those of irrigated low-land rice, the yield gaps are 4.8-7.6 t/ha (Becker *et al*., 2003).

Rice yield measurements for rainfall upland rice, including intensive and extensive systems in West Africa, showed a range in farmers' fields of 0.8-1.6 t/ha (Becker and Johnson, 2001). While potential yields have not been estimated for upland rice in Africa, trials managed by researchers have given rice yields of 4.0-5.6 t/ha with nutrient input and also with supplementary irrigation in two of five studies in West Africa (Saito and Futakuchi, 2009). Thus, productivity gap also appears to be higher under rain-fed upland conditions, but not as large as those under irrigated and rain-fed lowland conditions. Becker and Johnson (2001) showed that increased cropping intensity and reduced fallow duration in West Africa were associated with yield reduction: intensification-induced yield loss was about 25% (a drop from an average of 1.5 t/ha to 1.1 t/ha) and was mainly related to increased weed infestation and declining soil quality.

Growth-limiting factors such as limited water, low plant available nitrogen and phosphorus result in yield levels that are commonly 20 to 50% below potential yield (Penning de Vries and Rabbinge, 1995). Continuous cropping in upland rice without adequate nutrient addition results in depletion of nutrients from the soil and frequently requires fertilizer inputs to improve yields. Response of upland rice to nitrogen fertilizer has long been recognized (Ceesay, 2004).

Rice is grown in diverse environments in Africa, and this is reflected in farmers' yields[3]. This ranges from less than 1 t/ha in low input, rain-fed systems to more than 9 t/ha in high input, irrigated systems (Seck *et al.*, 2012).

Average rice yield in Africa of 2.15 t/ha; (USDA, 2013) is low compared with other continents, this is to a large extend as a result of the fact that rice cropping in sub-Saharan Africa is predominantly rain-fed (Diagne *et al.*, 2012).

2.3.2 Determinants of rice productivity

2.3.2.1. Fertilizer

The only two countries in Africa with a significant rice area and considerable total fertilizer consumption are Egypt and Nigeria; they reported a total fertilizer consumption of 2.0 and 0.5 million Mt respectively in 2008. The yield rice farmers obtain from a particular field will depends on the quantities of nutrients that are taken up by the plant during the growing cycle, either from the soil indigenous nutrient or from external inputs, such as mineral fertilizer, and whether this nutrient uptake is balance.

Recommended Nitrogen for lowland rice usually ranges from 60 kg/ha to 120 kg/ha, applied in 2-3 splits at planting, early tillering and panicles initiation and additional split at booting can be beneficial in very high yielding system (Woperies-Pura *et al*, 2002).

[3] Rice Yield are obtained by dividing total rice production by total rice area of the household

Upper rates in wet season under irrigated conditions are 90-120 kg Nitrogen/ha. Very high nitrogen of up to 150 kg/ha can be recommended in irrigated rice during the dry season, if higher solar radiation enables potential grain yield of up to 12 t/ha (Haefele and Woperies, 2004).

Application of Urea super granules is promoted in some irrigated systems (Fofana *et al*, 2010). Phosphorus is recommended especially if higher yields are targeted. The incorporation of phosphorus during land preparation or surface application up to 20 days after transplanting is good practice for flooded rice crop (Haefele et al, 2013). Potassium fertilizer should be applied along with nitrogen and phosphorus on poor soil, if higher yields are targeted, and especially if two crops are grown per year regularly. The amount of potassium that needs to be applied also depends on potassium inputs from the irrigated water and from dust depositions (Haefele et al, 2013).

2.3.2.2. Land size

Across the continent, the most fertile and productive lands for rice are found in the flood plains and inland valleys, and the potential to expand rice harvested area in sub-Saharan Africa is huge (Woperies *et al*, 2013).

Smallholder farmers in sub-Saharan Africa generally obtain production levels that are far below what would be possible under favourable conditions. Africa, where nutrient impoverished granites, basement sediments and sand cover about 90% of the land surface (Smaling, 2005). Low soil fertility and the often unfavourable climate create intense pressure on land, even at relatively low population densities.

Since the early 1990s there has been growing concern about the fertility of soils and, consequently, the sustainability of land use in Africa. Many studies suggest that soils are rapidly degrading, for example, Sanchez et al. (1997) stated that soil fertility depletion in smallholder farms is the fundamental biophysical root cause for declining per capital food production in sub-Saharan Africa.

Land plays an important role in farming. The size of the farm is based on the size of land used by the household for rice production. Most of the farmers have limited access to enough land. Raghbendra *et al.*, (2005) reported a negative relationship of the number of plots on efficiency. This implies land fragmentation (as measured by number of plots per Ha) have a negative impact on yields. Access to land is by far the most important variable, explaining the differentiation in output. Barners (2008) found the relationship between land holding size and efficiency to be positive.

2.3.2.3. Seed

Seeds are the backbone of agricultural production. Despite this importance, however, rice farmers in Africa lack assured access to sufficient, good quality seed of preferred varieties in time for showing. In the 1970s and the 1980s, public sector seed programmes in sub-Saharan Africa generally promoted the dissemination of improved rice varieties. With the structural reforms of 1990s, the seed sector was liberalised, though the private sector has only partly replaced the public sector in providing seed to farmers. With the growing awareness that promoting rice production in Africa is crucial for economic growth, food security and social stability, ‘seed’ is firmly back on the agenda of many government and technical and financial rice development partners. This becomes particularly evident after the 2008 food crisis, which was manifested as a ‘rice crises’ in many African countries (Viatte *et al*., 2009).

Rice seed sector development in Africa needs to address issues of availability, accessibility, seed quality, varietal quality and purity and resilience to effectively contribute to increasing productivity and sustainability of rice seed system in Africa (Remington *et al*, 2002)

To increase rice production in sub-Saharan Africa, well-coordinated rice breeding efforts, functional national varietal release systems, and regional efforts to facilitate seed trade across borders are essential (Kumashiro *et al*, 2013).

Small-scale farmers who practice subsistence farming do not buy certified seeds, but they use recycled seeds that are stored after every harvest, while others buy recycled seeds from their fellow farmers. This practice affects the crop output every year in terms of quantity as well as quality (Douglas, 2008).

2.3.2.4. Labour

Availability of labour at critical times is often a major constraint, and this situation is aggravated by the effects of the HIV/AIDS pandemic Rickman *et al*, (2013). Delay during harvesting, threshing and drying cause losses in both grain quality and quantity.

Due to labour shortage, many farmers have shifted from transplanting to direct seeding or were already direct seeding usually manual broadcasting. The majority of lowland rice farmers in SSA level their land by moving soil from higher to lower portions of the field using a hand hoe. In large fields, farmers sub divide the land into more manageable sizes. This practice tends to reduce the area available for planting because of the space taken up by bunds Rickman *et al*, (2013).

More than 70% of the rice in Africa is harvested by hand using sickle, knife or machete. This requires a lot of labour, mostly provided by women in rain-fed upland and rain-fed lowland areas, and by men in irrigated environment. Hand harvesting is fraught with problems, including the time required that could be used in other activities and delay in harvesting, leads to both quantitative and qualitative losses. (Rickman *et al*, 2013).

Larger farms will hire labour only until the marginal product of labour is equal to this minimum wage. Thus, there will be unemployed labour and the opportunity cost of employing family labour will be low on small-scale farms (Verma and Bromley, 1987).

Carter and Wiebe (1990) argue that small-scale hyper productivity is eventually overwhelmed by capital constraints-as farm size increases; it becomes less easy to substitute family labour for hired labour and other purchased inputs

2.4. Efficiency in rice production

2.4.1. Efficiency definition

Farrell, (1957) identified three types of efficiency: technical efficiency, allocative efficiency (referred to by Farrell as 'price efficiency'), and economic efficiency (referred to by Farrell as 'overall efficiency'). Technical efficiency[4] (TE) refers to the ability of a Decision Making Unit (DMU) to produce the maximum feasible output from a given bundle of inputs, or the minimum feasible amounts of inputs to produce a given level of output. The former definition is referred to as output-oriented TE, while the latter definition is referred to as input-oriented TE. Allocative efficiency[5] (AE) refers to the ability of a technically efficient DMU to use inputs in proportions that minimize production costs given input prices. Allocative efficiency is calculated as the ratio of the minimum costs required by the DMU to produce a given level of outputs and the actual costs of the DMU adjusted for TE. Economic efficiency (EE) is the product of both TE and AE (Farrell, 1957). Thus, a DMU is economically efficient if it is both

[4] A firm is said to be technical efficient in its production when it produces maximum quantity of output from a given set of input resource.

[5] Allocative Efficiency is the firm's ability to use inputs in optimal proportions given their respective prices and production technology

technically and allocative efficient. Economic efficiency is calculated as the ratio of the minimum feasible costs and the actual observed costs for a DMU.

2.4.2. Concept of efficiency

In microeconomic theory, a production function is viewed as a technical relationship which depicts transformation of inputs into output (Battese & Coelli, 1992). It is also defined in terms of maximum output that is attainable from a given set of inputs. Maximum output attainable in a production process is what gives rise to certain concerns in economic theory which includes efficiency with which economic agents produce such outputs. To measure this efficiency, a production frontier function is derived which depicts the maximum output as a function of input set. In the same line of thought, a cost frontier function depicts the minimum cost as a function of input prices and output (Coelli, Rao, O'Donnell & Battese, 2005). The term efficiency therefore becomes a relative measure of a firm's ability to utilise inputs in a production process in comparison with other firms in the same industry. It is relative in the sense that comparisons of efficiency scores are made relative to the best performing firm in the same industry. Similar assertions can be made with regard to cost efficiency. In economics and other fields a firm's efficiency can be viewed in terms of technical efficiency, allocative efficiency and economic efficiency.

Farrell (1957) is one of the earliest researchers to use and measure efficiency and did this by comparing the firm's observed and optimal values of outputs and inputs. Farrell (1957) actually extended the works of Debreu (1951) and Koopmans (1951) who earlier on had begun discussions on productivity and efficiency measurements in economic literature. Farrell demonstrated efficiency measurement using the input oriented approach where a firm was using two inputs, namely, capital (K) and labour (L) to produce output (Y).

In order to be economically efficient, a firm must first be technically efficient and this is just one component of overall economic efficiency. Profit maximization requires a firm to produce the maximum output given the level of inputs employed (i.e. be technically efficient), use the right mix of inputs in light of the relative price of each input (i.e. be input allocative efficient) and produce the right mix of outputs given the set of prices (i.e. be output allocative efficient) (Kumbhaker and Lovell 2000). These concepts can be illustrated graphically using a simple example of a two input (x_1, x_2)-two output (y_1, y_2) production process (Figure 2.3) below. Efficiency can be considered in terms of the optimal combination of inputs to achieve a given level of output (an input-orientation), or the optimal output that could be produced given a set of inputs (an output-orientation).

In Figure 2.3 (a), the firm is producing a given level of output (y_1^*, y_2^*) using an input combination defined by point **A**. The same level of output could have been produced by radially contracting the use of both inputs back to point **B,** which lies on the isoquant associated with the minimum level of inputs required to produce (y_1^*, y_2^*) (i.e. Iso (y_1^*, y_2^*)). The input-oriented level of technical efficiency ($TE_I(y,x)$) is defined by OB/OA. However, the least-cost combination of inputs that produces (y_1^*, y_2^*) is given by point **C** (i.e. the point where the marginal rate of technical substitution is equal to the input price ratio w_2/w_1). To achieve the same level of cost (i.e. expenditure on inputs), the inputs would need to be further contracted to point **D**. The cost efficiency (CE(y,x,w)) is therefore defined by OD/OA. The input allocative efficiency (AE_I(y,w,w)) is subsequently given by CE(y,x,w)/TE_I(y,x), or OD/OB in Figure 2.3 (a) (Kumbhaker and Lovell 2000).

The production possibility frontier for a given set of inputs is illustrated in Figure 2.3 (b) (i.e. an output-orientation). If the inputs employed by the firm were used efficiently, the output of the firm, producing at point **A**, can be expanded radially to point **B**. Hence, the output oriented measure of technical efficiency (TE_O(y,x)), can be given by OA/OB. This is only equivalent to the input-oriented measure of technical efficiency under conditions of constant returns to scale. While point B is technically efficient, in the sense that it lies on the production possibility frontier, higher revenue could be achieved by producing at point **C** (the point where the marginal rate of transformation is equal to the price ratio p_2/p_1). In this case, more of y_1 should be produced and less of y_2 in order to maximise revenue. To achieve the same level of revenue as at point **C** while maintaining the same input and output combination, output of the firm would need to be expanded to point **D**. Hence, the revenue efficiency (RE(y,x,p)) is given by OA/OD. Output allocative efficiency (AE_O(y,w,w)) is given by RE(y,x,w)/TE_I(y,x), or OB/OD in Figure 2.3(b) (Kumbhaker and Lovell 2000).

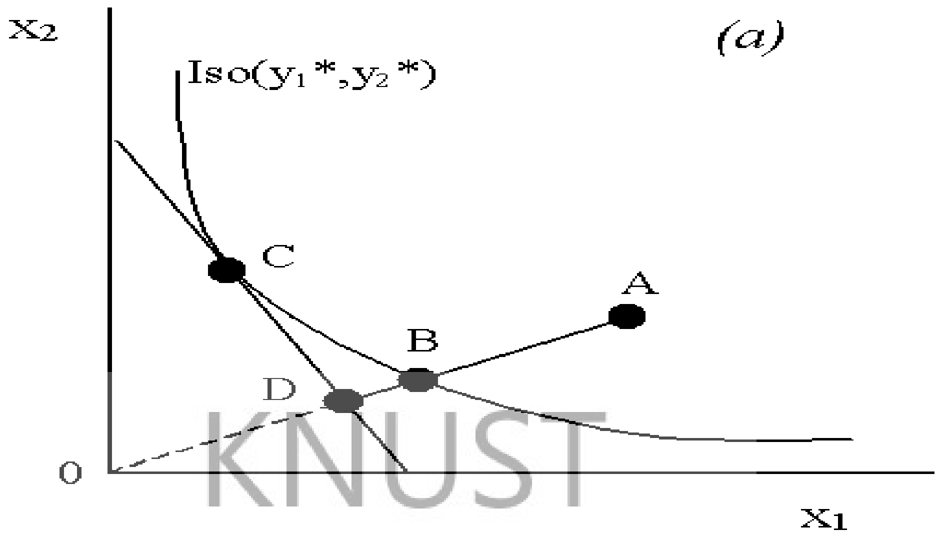


Figure 2.3: (a) input oriented efficiency measure

Source: Kumbhaker and Lovell 2000

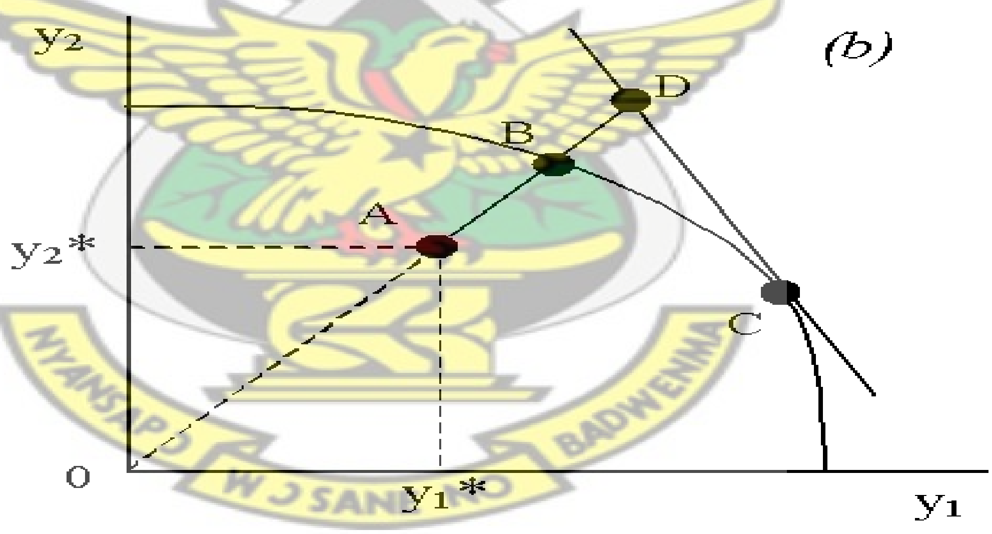


Figure 2.3: (b) output oriented efficiency measures

Source: Kumbhaker and Lovell 2000

2.4.3. Approaches to measuring efficiency

The two main approaches to measuring efficiency that have been discussed in literature include the average production functions and the frontier approach. The average production function approach measures efficiency by first constructing productivity of inputs and then constructing an efficiency index. This method was deemed unsatisfactory by most economists as such functions were incapable of providing information on efficiency because they attributed differences from the estimated function to symmetric random disturbances (Pitt & Lee, 1981). Moreover, such functions are seen as average functions because they estimate the mean and not the maximum output. With so many flaws in this method, it led to the development of a new method, the frontier approach which had better and well founded conceptual basis for measuring efficiency (Aigner, *et al*. 1977; Meeusen and van den Broeck, 1977).

The frontier approach to efficiency measurement can be divided into parametric and non-parametric (Farell, 1957). Non-parametric methods, as originally conceived by Farell (1957), used the unit input output space to create a frontier isoquant within the production possibility set (Khanna, 2006). The frontier was determined by a single or a convex combination of efficient units which were then compared against inefficient units to calculate the extent of inefficiency. This method was later applied to the multiple input output case (Murillo-Zamorano, 2004).

In comparison to the non-parametric approach, the parametric approach has an advantage owing to its ability to express frontier technology in simple mathematical form as well as the ability to encompass non-constant returns to scale. The major flaw of the parametric approach is that sometimes unwarranted functional/structures may be imposed on the frontier. And when this is the case, it imposes a limitation on the number of observations that can be technically efficient. The parametric approach is divided into deterministic and stochastic frontiers. In essence, the difference between deterministic and stochastic methods lies in the treatment of the error term.

In deterministic methods, the error is implicitly assumed and makes no distinction between unobserved variables that lie outside the control of the agent and those that lie within it. Stochastic models decompose the error term into purely statistical noise (that lies outside the control of the production agent), and inefficiency (a one-sided error term). Stochastic parametric methods employ only econometric techniques such as Maximum Likelihood Methods or Corrected Ordinary Least Squares that is used to estimate rather than calculate the efficiency frontier (Kumbhakar and Lovell, 2000).

Non-parametric methods such as the Data Envelope Analysis (DEA) rely on mathematical programming applied to sample observations to construct a production frontier which are used to calculate efficiency scores. The advantage of the DEA method lies in its flexibility as it requires no specification of a functional form. However, it is entirely data driven and extremely sensitive to outliers. Also, it does not allow the estimation of shadow prices nor does it allow testing of hypotheses (Khanna, 2006).

Among the advantages of stochastic frontier models are that they control random unobserved heterogeneity among firms. The statistical significance of variables determining efficiency can be verified using statistical tests and that the firm specific inefficiency is not measured in relation to the best performing firm as it is done in non-parametric approaches. The main disadvantages are that in stochastic frontier there is the need to make distributional assumptions for the two components plus the independence assumptions between the regressors and the error term.

Two known approaches are used in the estimation of efficiency models. These are the *one step* and the *two step* procedure. Efficiency estimation in the one step procedure estimates all parameters in just one step where inefficiency effects are defined as a function of the firm's specific factors but are incorporated directly in the maximum likelihood estimation. In other words, both the frontier model and the efficiency models are simultaneously estimated. In the two step procedure, the PF is first derived after which TE of each firm is derived. The TE estimated are then regressed against a set of variables which are hypothesised to influence the firms' efficiency. The two step procedure was proposed by Battese and Coelli (1995), in their model for measuring technical inefficiency effects in stochastic frontier production function (SFPF) for Panel Data.

2.5. Empirical literature on efficiency

2.5.1. Review of empirical literature on efficiency

Although the field of production economics has been extensively studied, it was the pioneering works of Farrell (1957) which led to serious considerations of the possibility of estimating frontier production functions with a view of harmonising and bridging the gap between theory and empirical works (Aigner, *et al*., 1977). However, Farrell's works only resulted in the estimation of average production functions (Aigner, *et al*., 1977). One major flaw of average functions was that they are incapable of providing information on efficiency because they attribute differences from the estimated function to symmetric random disturbances (Pitt & Lee, 1981). Other efforts to estimate frontier production functions were done by Aigner and Chu (1968); Afriat (1972); Richmond (1974) and Pitt & Lee, (1981). Thus, Farrell (1957), Aigner and Chu (1968), Afriat (1972) and Richmond (1974) all estimated their frontier using linear and quadratic programming techniques. The initial proposed model was of the form:

$$y_i = f(x_i;\beta) \qquad (2.1)$$

Where; y_i is the maximum possible output obtained from x_i; x_i is a non-stochastic vector of inputs, and β is the unknown vector of parameter to be estimated.

Thus, equation (2.1) postulates that for a given i^{th} firm the maximum possible output is a function of input vectors. Through the application of appropriate mathematical programming techniques based on a cross sectional sample, Aigner and Chu (1968) suggested the estimation of the β parameters through:

$$\sum_{i=1}^{n}\left[y_i - f(x_i;\beta)\right] \qquad (2.2)$$

subject to

$$y_i \leq f(x_i\beta)$$

If $f(x_i\beta)$ is linear in β, and

$$\sum_{i=1}^{n}\left[y_i - f(x_i;\beta)\right]^2 \qquad (2.3)$$

subject to;

$$y_i \leq f(x_i\beta) \qquad (2.4)$$

which is a quadratic programming problem if $f(x_i;\beta)$ is also linear in β. However, their approach to frontier estimation could not succeed because the method did not allow for random shocks in the production process, which are outside the firm's control. As a result, maximum possible output determined from a given input was exaggerated because the frontier was determined only from a few extreme measured observations as the approach was extremely sensitive to outliers (Pitt & Lee, 1981).

Attempts to correct the flaws in Farrell's model were made by Timmer (1971) who eliminated a certain percentage of the total observations (Pitt & Lee, 1981). However, the selection procedure used by Timmer (1971) on the percentage of the total observations to be eliminated was arbitrary and that was not based on statistical theory (Pitt & Lee, 1981).

2.5.2. Determinants of efficiency

2.5.2.1 Age

Age of farmer is expected to influence efficiency in any direction depending on the education level and experience. Age contribute positively if the level of farmer's education and experience in farming is high, and negatively, if the level of education and experience of farmers is low.

Tiamiyu (2010) points out that there is significant but negative relationship between age and efficiency indices. This is expected where younger farmers are more educated, and thus more successful in gathering information about new technology, which in turn will improve their efficiency

A farmer's age which is believed can serve as proxy for farming experience also influences efficiency. This is so since farming experience increases with an increase in age. Coelli (1996) pointed out that the age of the farmer could have a positive or negative effect upon the size of the inefficiency effects. He concludes that older farmers tend to have had more farming experience and hence less inefficiency.

Galawat and Yabe (2011) found age to have a negative and statistically significant connection with *TE* only. This finding could suggest that an increase in age leads to technical inefficiency of farmers. One of the possible explanations to this situation was reasoned by Shehu *et al*. (2007) who stated that the general ability to supervise farming activities decreases as farmers advance in age. These results are consistent with the findings of Bravo–Ureta and Evenson (1994). Younger farmers are likely to have formal education, and therefore might be more successful in gathering information and understanding new practices, which in turn will improve their efficiencies.

2.5.2.2. Gender

The FAO estimates that, in Sub-Saharan Africa as a whole, 31 percent of rural households are headed by women, mainly because of the tendency of men to migrate to cities in search of wage labour. Despite this substantial role, women have less access to land than men. When women do own land, the land holding tends to be smaller and located at marginal areas. Rural women also have less access to credit than men, which limits their ability to purchase seeds, fertilizer and other inputs needed to adopt new farming techniques (FAO, 2002).

The roles of women in agriculture are well documented in Norton and Alwang (1993). Women have dual roles where they not only manage the affairs of the household but also the farm. Women are more efficient in making decision in selecting inputs in relation with market price compared to men. However, overall, men are more economically efficient in more labour intensive work like felling trees, ploughing, and so on.

Dolisca and Jolly (2008) studying the situation in Haiti have revealed that being a male farmer increases technical inefficiency. After land preparations women normally carry out the remaining activities involved in the production process at the farm and this is more evident in the Gambia rice sector. Adesina and Djato, (1996) argue that men and women farmers are both efficient in resource use.

2.5.2.3. Education

Education enhances a farmer's ability to seek and make good use of information about production inputs, and therefore, expected to influence efficiency positively. Education plays a great role in adoption of most new technologies that normally calls for better management including consistent record keeping and proper use of the various inputs in maize production (Cheryl *et al*, 2003).

Some empirical studies such as Owour and Shem (2009) have shown a negative relationship between education and technical efficiency of farmers. One possible explanation is that technical skills in agricultural activities, especially in developing countries are more influenced by "hands on" training in modern agricultural methods than just formal schooling. Another school of thought has it that technical inefficiency tends to increase after 5 years of schooling. This could probably be explained by the fact that high education attenuates the desire for farming and therefore, the farmer probably concentrates on salaried employment instead (Kibaara, 2005).

Other studies show that education enhances the managerial and technical skills of farmers. According to Battese and Coelli (1995) education is hypothesized to increase the farmers' ability to utilize existing technologies and attain higher efficiency levels. Accesses to better education enable farmers to manage resources in order to sustain the environment and produce at optimum levels. Educated farmers easily adopt improved farming technology and therefore should have higher efficiency scores than farmers with low level of education (Seyoum *et al.*, 1998).

2.5.2.4. Household size

In a village setting household size sometimes is known to be a source of farm and off-farm income generating activities (Sentumbwe, 2007). The size of farmers' household is another factor that influences the efficiency of farmers. Abdulai and Eberlin (2001) pointed out that although large household size puts extra pressure on farm income for food and clothing, they at times ensure availability of enough family labour for farming activities to be performed on time.

Amos (2007) revealed in his study that family size have a positive and significant effect on technical efficiency among cocoa producing households in Nigeria. A study carried out by Jema (2006) also indicated a positive and significant effect of family size among small-scale vegetable farming households in Ethiopia. Farmers with surplus labour force are likely to use the rest of the family labour, and hence operate inefficiently or farmers with bigger household size would have to allocate more financial resources to health, education and so on for members of the household and thus affect production (Nchare, 2007).

2.5.2.5. Cooperative membership

A positive relationship between *TE* and *EE* was reported by Galawat and Yabe (2011). This according to them implies that farmers who joined cooperatives or associations, or formed an organization, tend to be more efficient than farmers who do not. Membership in farmers organizations/cooperatives allow the farmers to have the opportunities of sharing information with other farmers especially on 'how to use' knowledge on modern rice production practices by interacting with other farmers.

Access to extension agents is expected to increase the efficiency of rice farmers, if farmers learn from the services provide by extension agents. Membership of cooperative can easily facilitate access to extension services. A farmer's regular contact with extension workers facilitates the practical use of modern technologies and adoption of agronomic norms of production.

Owusu and Donkor, (2012) found out that coefficienct of membership of farmer based organization is statistically significant at 5% level in both Tobit models specified for the areas cultivated under improved cassava varieties. The result thus indicated that membership of farmer based organization significantly increases the likelihood of farmers to adopt and increase the area under cultivation of the improved cassava varieties.

Farmers' organisations play an important role in organising members into input cooperatives and seeking access to other financial development agencies. This is an important factor affecting technical efficiency. With availability of finance much can be done to improve crop production. Since inputs are expensive they can form a group and buy in bulk as it becomes cheaper compared to individual purchases. They can also have access to extension officers as they are able to help a group of farmers and not individuals (Douglas, 2008).

2.5.2.6. Irrigation

The findings of Galawat and Yabe (2011) in their study revealed irrigation as the only variable that has uniformly the same sign and is statistically significant in all three efficiency equations. Poor infrastructure like in irrigation has proven to have positive effects on a farmer's inefficiency. They in fact revealed that most of the farmers have limited or no supply of proper water supply because no irrigation system is available. Most of the farmers interviewed lamented on the unavailability of proper irrigation system, as they believed it can help to improve rice yield and efficiency.

There is scope to increase the area under irrigation in many countries through expansion or rehabilitation of irrigation structures. This is especially important in countries like Mali and Senegal, where farm size per household in irrigated system has been declining since the 1970s because of population growth and lack of new land that has been developed for irrigation and reaches critical low levels (SWAC/OECD, 2011).

With irrigation, farmers will reduce rice production risks and will be able to lift their rice firms to a higher production efficiency level through intensification. It will also open up possibilities to grow two or even three rice crop per year depending on the prevailing climate (Woperies *et al*, 2013).

2.5.2.7. Credit

Access to credit improves liquidity and enhances use of agricultural inputs in production as it is often claimed in development theory. It also provides farmers with additional source of investment in new ideas and therefore expected to be positively related to efficiency. However, there could be some exceptions. For example, Tiamiyu, (2010) points out that access to credit has negative but significant influence on the technical and economic efficiency. This implies that credit use significantly reduce rice farmers' technical and economic efficiency. The reason may be due to wrong use of credit.

Access to credit from formal and informal institutions is important for agricultural productivity; many poor rural farmers heavily rely on informal credit institutions to cope with food insecurity and its effects as well as to finance the purchase of farm inputs (Buchenrieder, 2004).

The availability of credit will enable farmers to purchase inputs in a timely manner and hence is supposed to increase efficiency. Abdulai and Eberlin (2001) pointed out that, access to formal credit contribute positively to production efficiency.

2.5.2.8. Training

Galawat and Yabe (2011) found training to be significant in explaining TE, which indicates that training is directly related to productivity. Therefore, farmers who went to or attended farm–related training are more technically efficient than farmers who do not. A study done by Sentumbwe (2007) indicated that farmers who had got training in better agricultural practices were more technically efficient than those that had not participated. Another study by Glenville (2000) also indicated that farmers who had got training in better agricultural practices were more technically efficient than those that had not participated.

Douglas (2008) found that membership to Agricultural Productivity Enhancement Program was found to be positively related and significantly affecting technical efficiency at 1% level. This implied that there was a positive contribution of training on maize farmers' production efficiency.

2.5.2.9. Varieties

There were significant positive effects on rice yields through NERICA adoption in Benin and the Gambia (Dibba *et al.*, 2012). Therefore, the role of research and Agricultural Department in introducing new technology to farmers should be emphasized here. Productivity gains stemming from technological innovation remain of critical importance in agriculture despite the role that higher efficiency levels can have on output.

Ogundele and Okoruwa (2006) estimated a stochastic production frontier (SPF) to determine the technical efficiency differential in rice production in Nigeria. They found that farmers cultivating traditional rice and improved varieties shared relatively the same socio-economic characteristics except for farming experience and the number of extension visits. In terms of efficiency, the distribution was highly skewed with over

75% and 60% of the farmers having their technical efficiency above 90% in the traditional and improved technology groups, respectively.

The roles of agricultural technology change in reducing rural poverty and fostering overall economic development have been widely documented in the economic literature (Becerril and Abdoulai, 2010). Agricultural technology opens great opportunities for increasing food crop production and reducing the crop vulnerability in developing countries; therefore it has the potential to improve farm efficiency and provide external benefit such as resource conservation (Moreno and Sunding, 2005).

2.5.3. Empirical comparative studies

Several efficiency studies have been conducted by other researchers worldwide. Battese and Coelli (1995), in their study of Technical Inefficiency Effects in a Stochastic Frontier Production Function using panel data concluded that the inefficiency effects were stochastic and depended on the farmer specific variables as well as the time of observation. Farmer-specific variables herein refer to inputs used in the production process such as labour and capital which are associated with each firm. They used a linearised version of the logarithm of Cobb-Douglas production function where different input variables accounted for different effects. For instance, they used age, schooling, years in production, among others, to account for technical change and time varying effects.

Similarly, Battese and Coelli (1992) effectively demonstrated the importance of frontier production function in predicting technical inefficiency of individual firms in an industry. They demonstrated this using panel data of 38 farms in India for which firm effects were an exponential function of time, and concluded that technical inefficiencies of the farmers were not time invariant when the year of observation was excluded from the stochastic frontier. The opposite was true when year of observation was included in the stochastic frontier.

Comparisons have also been made between the traditional (average) Cobb-Douglas function and the generalised frontier model and the results have shown that generalized frontier models are more suitable models in the study of technical inefficiencies. For example, a study by Battese and Coelli (1988) on the prediction of firm level technical efficiencies revealed that the traditional Cobb-Douglas production function was not a suitable model for prediction. They applied a stochastic frontier production function to the dairy industry of New South Wales and Victoria. They further observed that a more generalised model for describing firm effects in frontier production functions accounted for the situations in which there was high probability of firms not being in the neighborhood of full technical efficiency.

Bravo-ureta and Pinheiro, (1997), analysed technical, economic, and allocative efficiency in peasant farming in the Dominican Republic. They used maximum likelihood techniques to estimate a Cobb-Douglas production frontier which was then used to derive its corresponding dual cost frontier. These two frontiers formed the basis for deriving farm-level efficiency measures. The results of their study revealed average levels of technical, allocative, and economic efficiency of 70 per cent, 44 per cent, and 31 per cent, respectively. These results suggest that substantial gains in output and/or decreases in cost could be attained given existing technology. The results also point out to the importance of examining not only *TE*, but also *AE* and *EE* when measuring productivity. In their second stage regression where they used Tobit to regress *TE*, *AE*, and *EE*, on various socio-economic attributes of the farm and farmer (contract farming, agrarian reform status, farm size, schooling, producer's age, and household size), the results showed that younger, more educated farmers exhibited higher levels of *TE, AE* and *EE* their older counterparts. Additionally, the study also showed that contract farming, medium-size farms, and being an agrarian reform beneficiary had a statistically positive association with *EE* and *AE*. On the contrary, the study also revealed that the number of people in the household had a negative association with *AE*. In conclusion, the researchers observed that for the peasant farmers in the Dominican Republic *AE* appeared to be more significant than *TE* as a source of gains in *EE* which from the policy point of view, contract production, farm size, and agrarian reform status were the variables found to be most promising for action (Kabwe, 2012).

Obwona, (2000) estimated a translog production function to determine technical efficiency differential between small and medium scale tobacco farmers in Uganda who did and did not adopt new technologies. Results showed that credit accessibility, extension service access and farm assets contributed positively to technical efficiency. The differences in efficiency between farmer groups were explained with only socio-economic and demographic factors.

Arega (2003) assessed the impact of new maize production technology and efficiency of smallholder farmers in Ethiopia using the stochastic efficiency decomposition technique to analyse technical, allocative and economic efficiency of farmers in different agro-climatic zones. Although the study revealed positive result for improved production technology and production efficiency, inefficiencies were observed under both the traditional and improved method. That is, the study revealed production inefficiency under the traditional maize production as being attributed to technical inefficiency while inefficiency under the improved system was as a result of both technical and allocative efficiencies. The implication of this was that both technical and allocative efficiencies needed to be raised under the improved technology.

Tchale (2009) studied the efficiency of smallholder agriculture in Malawi using a nationally representative sample survey of rural households undertaken by the National Statistical Office in 2004/2005. The aim of the study was to inform agricultural policy about the level and key determinants of inefficiency in the smallholder farming system that need to be addressed to raise productivity. The researcher used a parametric frontier approach because of the many variations that underlie smallholder production in developing countries. This was so because the stochastic frontier attributes part of the deviation to random errors (reflecting measurement errors and statistical noise) and farm specific inefficiency (Coelli *et al*., 1998).

The results revealed that allocative or cost inefficiency is higher than technical inefficiency, and that the low economic efficiency level could largely be explained by the low level of allocative efficiency relative to technical efficiency. High levels of cost inefficiency were probably attributable to the low profitability that resulted from inadequate agricultural market development.

2.5.4. Empirical review of studies on efficiency in rice production

Several studies evaluated production efficiency in rice production, and a summary of the literature is presented in Appendix B. Nineteen studies are listed in the table, ranging in time from 1991 to 2011. Ten studies used Stochastic Frontier Analysis, eight used Data Envelop Analysis, and one (Wadud and White, 2000) used both approaches. Most studies deal exclusively with TE measurement. Six studies measure TE, AE, and EE separately, while one study (Huang *et al*., 2002) measures EE only and another study (Abdulai and Huffman, 2000) measures profit efficiency (Profit efficiency is a macro-economic concept used in assessing whether an economy, industry or supply chain is expending an optimally balanced level of rent for the use of capital). Most rice production efficiency studies come from countries in Southeast Asia, while two studies come from African countries. All 19 studies focus on developing countries with many evaluating rice production efficiency in subsistence farming settings.

Mean TE scores across the 19 studies reporting TE scores range from 0.63 to 0.95, implying on average that technical inefficiency for these 19 studies ranges from 5 to 37%. In other words, these studies reveal that rice producers could potentially reduce their input levels on average from 5 to 37% and still achieve the same output levels. Mean AE scores across the six studies estimating AE scores range from 0.62 to 0.87, implying rice producers in these studies generally apply the wrong input mix given input prices and that on average, costs are 13 to 38% higher than the cost minimizing level. Finally, mean EE scores across the seven studies measuring such scores range from 0.39 to 0.81, implying the overall cost of rice production in these studies can be reduced on average by 19 to 61% to achieve the same level of output. Median average TE, AE, and EE scores in appendix table are 0.84, 0.78, and 0.64, respectively. These results reveal the existence of production inefficiency in rice production among developing countries.

2.6. Constraints in rice production

Yield reducing factors induce yield losses by reducing or hampering growth: including abiotic and biotic factors. Biotic factors include weeds, pests and diseases, termites and birds; abiotic factors include salinity, drought, poor soil quality and flooding.

Weeds cause economic losses to agricultural crops, and require some action to reduce their effects on crop production (Zimdahl, 2007). In sub-Saharan Africa (SSA), weeds are estimated to account for rice yield losses of at least 2.2 million tonnes (Mt) per year (Rodenburg and Johnson, 2009). Combined with costs of weed control, the financial losses surpass half the cost of current regional rice imports. If not controlled weed causes yield losses in the range of 28-74% in transplanted lowland rice, 28-89% in direct seeded lowland rice and 40-100% in upland rice (Rodenburg and Johnson, 2009). In West Africa, it has been shown that farmers can increase their yields by 15-23% by applying relatively basic measures to improve weed control, such as creating bund in the fields to retain flood water, and timely interventions such as herbicides applications and hand weeding (Becker *et al.*, 2003).

African farmers do not, however, perceive weeds as solely undesirable. Many species often considered as weeds also feature in traditional pharmacopies (Steep and Moerman, 2001) or are collected for domestic use, crop and postharvest pest control functions or as an additional source of food (Rodenburg *et al.*, 2012).

According to Oerke (2005), some 15% of global rice production is lost to animal pest (arthropods, nematodes, rodents, birds, slugs and snails). The Global Rice Science Partnership (GRiSP) identifies birds as the second most important biotic constraints in Africa rice production sector (GRiSP, 2010). About 45% of rice farmers experienced birds and rodents attacks in 2008, and affecting 29% of the area and leading to an estimated 21% yield loss (Diagne *et al*, 2013).

Becker and Johnson (2001) analysed cropping intensity effects on upland rice yield and sustainability in four agro ecological zone in Cote d'Ivoire. Increased cropping intensity and reduced fallow duration were associated with yield reduction. Intensification-induced yield loss was about 25% (a drop from an average 1.1 t/ha to 1.5 t/ha) and was mainly related to increased weed infestation and declining soil quality.

Sy and Sere (1996) identified the three major pathogens of rice in Africa: blast fungus (Magnaporthe), Rice Yellow Mottle Virus (RYMV) and bacterium which are responsible for leaf blight (Xanthomonas oryzae pv.oryzae). Since the early 1990s, a large number of studies have been conducted on the spatial variability of isolates of these disease and corresponding resistance genes in rice (Sere *et al*., 2007).

According to Bidaux (1978) rice blast was reported in Africa in 1922. It is the most widespread disease in SSA. In Burkina Faso, survey in farmers field indicated that intensifying rice cultivation (use of fertilizer and modern, but special varieties) may lead to increased yield losses due to blast, reducing an important part of the benefits created by intensifying rice cultivation (Sere *et al.,* 2011). Yield losses of 1-22% were recorded in rainfed lowland and 4-45% in irrigated systems in the south and west of the country. Yield losses of up to 44% (equivalent to 2 t/ha) were recorded in irrigated perimeter of Vallee du Kou (Sere *et al*., 2011).

In many countries, blast inflicts significant damage: heavy yield losses (up to 100%) were reported by farmers in Ghana (Nutsugah *et al.,* 2008) and in some locations in the Gambia (Jobe *et al.,* 2002). In Sierra Leone, losses in excess of 80% were reported in susceptible cultivars and accessions in experimental plots (Fomba and Taylor, 1994). In Nigeria, blast outbreaks have been reported to cause yield losses of about 35-50% and, in a serious outbreak of disease, up to 100% of yield lost (WARDA, 1999). Yield losses of 20-30% have been recorded in Benin (Vodouhe *et al.,* 1981), 36-63% in Bukina Faso (Sere, 1981), 64% in Togo (Akator *et al.,* 1981) and up to 80% in Cote d'Ivoire (Delassus, 1973).

Rice Yellow Mottle was first recorded in 1966 at Otonglo near Lake Victoria, Kenya (Bekker, 1970), Rice Yellow Mottle Virus (RYMV) is now a major biotic constraint of rice, and is present in most of the rice growing countries in Africa (Ndikumana *et al.*, 2011).

Yield losses due to RYMV ranges from 10 – 100%, depending on the timing of the infestation and the type of variety (Kouassi *et al.*, 2005). The increasing incidence and importance of RYMV in Africa is attracted to the cultivation of new highly susceptible exotic rice varieties mostly from Asia (Thresh *et al.*, 2001) and the availability of water through irrigation which allows for sequential planting and maintenance of higher crop intensity without dry season gaps, which favour increase of both insect vectors and alternative hosts (Traore *et al*., 2009). The RYMV epidemic at the beginning of the 1990s in West Africa was the result of intensification of rice cultivation (Traore *et al.*, 2009).

Bacterial Blight of rice is another major biotic constraint to rice production and productivity. The disease was first observed in Africa (Mali) (Buddenhagen *et al*, 1979). In the following year, it was reported in Senegal (Trinh, 1980), Cameroon, (Notteghem and Baudin, 1981), Niger, (Reckhaus, 1983), Madagascar and Nigeria (Buddenhagen, 1985), Tanzania (Ashura *et al.*, 1999), and later in Benin, Guinea, The Gambia, Mozambique, Rwanda and Uganda (El-Namaky, 2011).

A survey carried out in several West African countries revealed yield loses of 2.7-41% (Awoderus *et al.*, 1991) and a disease incidence of 70-85% in farmer's fields (Sere *et al.*, 2005). The introduction of high yielding but susceptible variety from

Taiwan to the bacterial blight pathogen in the mid-1990s draws scientists' attention to the importance of this disease (Ouedraogo *et al*., 2007).

In Burkina Faso, Senegal and Togo, almost 37% of rice farmers reported major soil problems, both in terms of the proportion of farmers perceiving them of major importance and the proportion of farmers having experienced in 2008. For the other countries this proportion ranged from 0.4% in Rwanda to 30% in the Gambia. The highest share of area affected was 56% (observed in Burkina Faso) and lowest proportion of area affected was 1% (Rwanda). The minimum yield loss recorded was 6% in CAR and maximum yield loss was 25% in Kenya. (Diagne *et al*, 2013).

Comparison of individual countries data indicated that the highest proportion of farmers experiencing drought were in Rwanda (45%), followed by Cameroon (30%) and Burkina Faso (28%). The largest proportion of field affected was in Senegal (51%) followed by Burkina Faso and the Gambia (46%), Benin and Code d'Ivoire (44%). Greatest yield losses were observed in the Gambia (46%), followed by Senegal (45%) and Code I'voire (41%). (Diagne *et al*, 2013)

An estimated 25% of farmers perceived flooding as a major problem across rice environments. An estimated 5% of rice farmers affecting 37% of their rice area, causing 27% of rice yield loss in 2008 (Diagne *et al*, 2013).

2.7. Conclusion

In conclusion, literature reviewed has shown huge deficit in rice supply with costly imports but this major concern can turn the rice sector into a power house of economic growth. Major findings in literature have shown that rice production can be enhanced through concerted efforts to increase production and productivity of rice per unit of land, water, labour and fertilizer application in a reasonable and sustainable manner.

Exploiting the gap between yields currently achieved on farms and those that can be achieved by using the best adapted crop varieties and best crop and land management practices is a key pathway to overcoming the considerable challenge faced by many smallholder farmers in the world (Tittonell and Giller, 2013). Overcoming labour shortage requires labour serving technologies and practices, and injecting energy into the farming system through mechanization (Menete *et al*, 2008). Policies are needed (e.g. on land tenure) to facilitate socially acceptable and environmentally sound expansion of rice production area.

Several efficiency studies have been conducted worldwide. Based on the literature reviewed this study endeavors to utilise Cobb-Douglas production functions in driving Technical and allocative efficiency. Importance of conducting efficiency analysis in determining farm level efficiency has been shown in reviewed literature. The papers reviewed are dated as far back as 1957 and as recent as 2011. In all these papers what has been apparent is that for a group of farmers it is extremely important to identify the sources of their inefficiency as well as the major determinants of such inefficiencies so as to recommend the most appropriate policy to address such problems.

The parametric approach has advantage owing to its ability to express frontier technology in simple mathematical form as well as the ability to encompass non-constant returns to scale. It also decomposes the error term into purely statistical noise (that lies outside the control of the production agent), and inefficiency (a one-sided error term). Among the advantages of stochastic frontier models are that they control random unobserved heterogeneity among firms. Based on the selected function efficiency analysis was conducted from which conclusions were made about the sample.

Results of the reviewed literature also reveal the existence of production inefficiency in rice production among rice farmers in the various study areas. Socio-economic variables (Age, Gender, Education, Member of Cooperative, Household Size, Experience, Credit and Training among others) are used in this study to measure production inefficiency of individual farmers.

Finally, major constraints that influence efficiency level were found to be abiotic (salinity, drought, poor soil and flooding), biotic (weeds, pest and diseases and birds) and socioeconomic (land tenure issues) constraints. These factors are generally known to affect rice sector, and are generally translated into low productivity.

CHAPTER THREE

3.0. METHODOLOGY

This chapter presents the study area, type and source of data, sampling procedure and sample size. It also presents the survey design, methods of data analysis, theoretical framework and empirical models. It concludes with definition, measurement and a-priori expectations of variables.

3.1. Choice and location of the study area

The study area covers one of the main rice production hubs of the Gambia. It is located in Central River Region North and Central River Region South (see Figure 3.1 below). The Hubs are the entry point and best practice concentration areas for rice production in the Gambia. A hub involves large groups of farmers (1000–5000) and all other value-chain actors (which include: millers, input dealers and marketers) who are effectively involved in the production activities.

The Central River Region North and Central River Region South is located between 13°13´22.52"N and 16°34´55.13"W, with a population of 99, 103 and 126, 910 respectively, covered a total land area of 2, 894 km², (GBoS, 2013). The study area shares the boundaries with Lower River Region and Upper River Region on the Southern bank and North Bank Region and Upper River Region on the Northern part as shown in figure 3.1 below. The study concentrates on two districts in the two regions and they are Lower Fulladu in Central River Region South and Niani in Central River

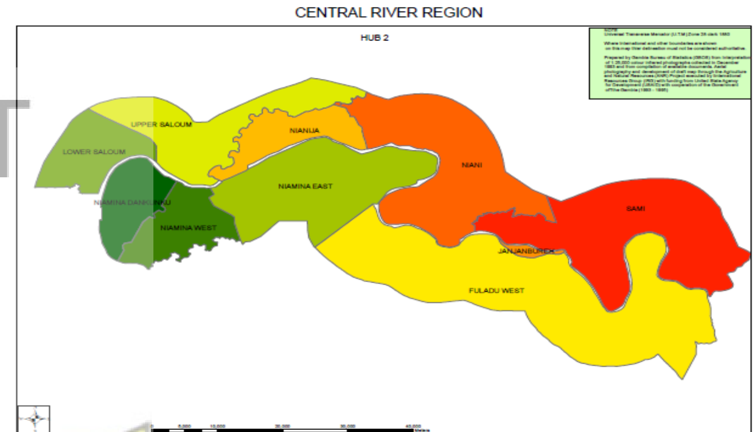
Region North. A detailed map of the Gambia showing the study area is presented in figure 3.1. Appendix C and D also presented map of the study area.

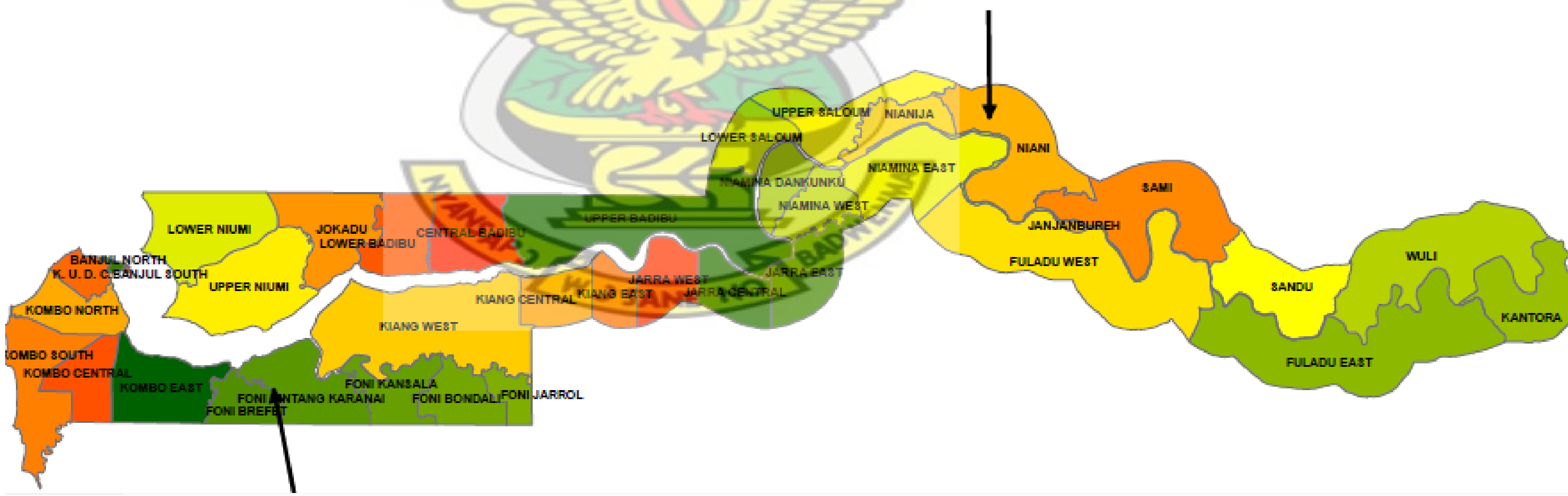
3.1.1 Climate of the study area

The climatic condition in the region is semi-arid making the area relatively dry with an average annual rainfall of approximately 750mm and an average annual temperature of 21°C-33°C. The raining season begins in June/July and ends in October, and the cropping schedule for the off season commences in February/March with land preparation and sowing.

Figure3.1. Map of Republic of the Gambia, West Africa, Showing the study areas

Source: GBoS





3.1.2 Ecologies of the study area

The study area comprises of two ecologies the lowland and what is locally called ‘BantaFaro’ and in this study referred to as upland.

3.1.2.1 Lowland ecology

Lowland rice production system have been observed to be economically sustainable and ecologically sound due to their high efficiency in nutrient replenishing mechanisms and their intrinsic resistance to soil erosion (Issaka *et al*, 1997).

The irrigated lowland system in the Gambia comprises of the tidal swamp and pump water control system. They have the potential to be doubled cropped as high yielding short duration rice varieties are transplanted to facilitate this two cropping season. The soil is high clay and organic matter and its source of water for irrigation is both river water and rainfall. Its potential for rice production is greater.

3.1.2.2 Upland ecology

The upland refers to rice grown on both flat and sloping fields that were prepared and seeded under dry conditions, and generally exclusively depend on rainfall for moisture (IRRI, 1975).

It is evidence that rice is grown in the upland area throughout the country and in this study upland has a general soil characteristic of free drainage sandy alluvial clay of poor to moderate fertility.

3.2. Data collection procedure

This section presents a discussion on how the data employed in the study was collected. It is presented in three parts. The first part presents type and source of data and the second part looks at sampling procedure and sampled size and the last section deals with survey design and field work.

3.2.1. Type and source of data

This study involved the use of both primary and secondary sources of data. The primary data was collected in a field survey by direct interview with rice farmers in the study area for the 2013 cropping season.

Secondary data which acted as supplementary data was collected from Planning Services Unit of the Ministry of Agriculture (MOA) and the Gambia Bureau of Statistics (GBoS) which collects data annually from other line ministries in the Agriculture and Natural Resources (ANR) Sector for statistics purposes. Information was also obtained from journals, books, and the internet.

3.2.2. Sampling procedure and sample size

The study was conducted in the Central River Region North and South of the Gambia representing both the up-land and low-land ecologies, and the population was all rice producers in these two regions.

A multi-stage sampling technique[6] was employed for the purpose of this research data needs. The first stage of the sampling involved purposive selection of

[6] Multi-stage sampling is a complex form of cluster sampling in which two or more levels of units are embedded one in the other.

a district from each of the two regions where the survey was conducted. They included Lower Fulladu and Niani Districts which were selected based on their rice production potentials and accessibility. The second stage involved simple random selection of 20 villages or communities (12 for Fulladu and 8 for Niani districts). Table 3.1 shows sample size and the communities that were sampled for the study. Finally, the third stage involved random selection of 10 rice producers from each community, giving a total sample size of 200 producers (120 for Fulladu and 80 for Niani). The number of communities and farmers chosen from Fulladu District were more because of its large size relative to Niani District.

Table 3.1 Sample size of the study area

Region	Districts	Communities	No of Farmers
Central River Region South	Lower Fulladu	Pacharr	10
		Sare Nfalley	10
		Sare Nyaba (Njie Kunda)	10
		Saruja	10
		Boiram	10
		Jahally	10
		Kerewan Fula Mandinka	10
		Sare Mollo	10
		Sinchu Bora	10
		Fula Bantang	10
		Madina Ceesay Kunda	10
		Faraba	10
		Sub-Total	**120**
Central River Region North	Niani	Kass Wollof	10
		Pallang Toro	10
		Pallang Mandinka	10
		Jakaba	10
		Kayai	10
		Kass Fula	10
		Sukuta	10
		Wassu	10
		Sub-Total	**80**
		TOTAL SAMPLE SIZE	**200**

3.2.3. Survey design

A reconnaissance survey was conducted. Discussions were held with different stakeholders including producers, extension agents and research staff working directly with the producers. The findings from this stage were used to guide the sampling of communities and design of the survey instruments.

3.2.4. Questionnaire Design

The questionnaire was divided into six different sections: information on personal and household characteristics, farm resources, farm production, returns, post-harvest issues and constraints in rice production etc.

The questionnaire developed sought information on socioeconomic characteristics of the sampled households such as age, sex, education level, and years in farming, land ownership, access to extension services and access to credit services. The inputs for which quantities and prices were collected on include land area under cultivation, household labour, inorganic fertilizer and rice seed. Output for which quantities and prices are collected in this case was rice produced during the 2013 cropping season. The final part of the questionnaire solicited information on rice producers' production constraints and here scale was used to rank them and responses were coded as high, medium or low. Prior to actual data collection, the questionnaire was pre-tested on a few respondents to check for the possible errors that could affect the quality and accuracy of data collected.

3.2.5. The Survey

A formal structured questionnaire was administered using 'tablet' with automated application (Mlax) developed by AfricaRice; to a sample of rice producers who were selected based on the above sampling methods.

An appointment for the interview (done in the farmer's home) was made prior to the interview so that farmers can have ample time to answer the questions and to avoid disturbing farmer's work on the farm. Eight enumerators were used in the hub for the data collection exercise. Enumerators used in the study were under the supervision of the researcher and National Agriculture Research Institute (NARI) socio-economic unit head. They were trained on how to use the survey instrument, and they were actually taken through the whole questionnaire so as to give them a clear understanding. Questionnaires were administered through the use of the three most common local languages (Mandinka, Wollof and Fulla) in the study area. The survey was done from December to May, 2013 cropping season across the study area.

3.3. Methods of data analysis

The primary data analyzed was pooled from both ecologies, transcribed on to MS Excel spread sheets from which summary statistics were obtained using MS Excel for the purpose of verifying that there were no possible outliers that have affected the results. The measures of central tendency like the mean, standard deviation, minimum and maximum were used to this effect. Data coding and definition of variables was done using SPSS.

Constraints to rice production during the 2013 cropping season were ranked using Kendall's coefficient of concordance in SPSS statistical software. The responses from the constraints were averaged to obtain the mean rank for each constraint. The constraint with the least mean is ranked the most pressing problem with higher mean being the least pressing.

Derivation of the stochastic frontier production functions as well as measurement of efficiency was done using Frontier v4.1 (Coelli, 1996); while efficiency indices scores were regressed on socioeconomic characteristics using Tobit regression model in STATA.

The stochastic frontier production function and the efficiency models were simultaneously estimated with the maximum likelihood method using FRONTIER 4.1 statistical/Econometric software in STATA.

3.3.1. Analysis of major Constraints faced by rice Producers

The relative prevalence of abiotic, biotic and socio-economic constraints were assessed in the two main rice growing environment (Upland and Lowland) in the study area in Central River Region North and South of the Gambia.

Data were collected from sampled communities in the hub, for each constraint information on awareness and its occurrence was elicited from each sampled farmer per ecology. The rice producers were asked to rank the constraints. The Kendall's Co-efficient of concordance was then used to test the agreement the rankers and significance of the ranked constraints. The ranking were collated to find the total sum and the means of the rankings.

The formula employed is given as:

$$W = \frac{12\left[\sum T^2 - \left(\sum T\right)^2 / n\right]}{nm^2\left(n^2 - 1\right)} \tag{3.16}$$

Where W is the Kendall Coefficient of Concordance and must be between 0 and 1.

T= Sum of ranks for each factor being ranked

m= Number of respondents

n= number of factors being ranked

The means were then ranked again to find the most pressing constraints to the least pressing constraint. Using the equation above the W obtained was used to calculate the chi square value X^2 to determine whether the ranking agree or not at 5% or 1% level of significance. For this test the hypotheses were:

H_0 = There is no agreement among rankings of the constraints

H_1 = There is agreement among the rankings of constraints.

The H_0 would be rejected if the calculated test statistics (TSc) > tabulated test statistics or if otherwise, it would be accepted. Alternatively, the asymptotic significance level could be used. This is based on the asymptotic distribution of a test statistic. Typically, value less than 0.05 is considered significant.

3.3.2. Stochastic frontier and efficiency analysis

The most popular approach to measure efficiency is the use of stochastic frontier production function (Rahman, 2003; Coelli *et al*, 2005). Therefore, in order to determine the production level of rice varieties in the hub and assess the efficiency of rice producers, the stochastic frontier production function is applied. The Cobb–Douglas stochastic frontier production model is assumed to be an appropriate model for this analysis because the methodology employed requires that the production function be self–dual. The model specified for a farmer in given season is defined as;

$$Y_j = g(X_{ij}; \beta) \tag{3.1}$$

Where, Y_j is the output of the jth farm, X_{ij} is the ith input used by farmer j and β is a vector of unknown parameter. From equation 3.1, it is possible to drive the *technically efficient input quantities (* X_{it} *)* for any given level of output Y, by solving simultaneously the following equation: $Y = g(X_i; \beta)$ (3.2)

And the observed input ratio $X_1 / X_i = k_i$ where k is the ratio of the observed level of input $k_i X_i (i \triangleright 1)$ at output Y.

Let, assume that the production frontier in equation 3.1 is self-dual (e.g Cobb-Douglas), therefore, the dual cost frontier can be derived and written in general form as:

$$C = h(P, Y; \alpha) \tag{3.3}$$

where *C* is the minimum cost to produce output *Y*, *P* is the vector of input prices for the *jth* farmer and α is a vector of parameters to be estimated. The *economically efficient (X*ie*)* input vector for the *jth* farmer, can be derived. The system related to the cost minimizing input demand functions through its partial derivatives with respect to input prices we obtain,

$$\partial C / \partial P_i = X_{di} = f(P, Y; \Phi) \qquad (3.4)$$

where θ is a vector of parameters. The observed technically efficient input vector (Xit), and economically efficient input vector (Xie), cost of production of the *jth* farm are used to compute allocative efficient input vector (Xia), the actual cost of operating input. The basis of calculating *TE* and *EE* are as follows;

$$TE = (Xt \cdot P)(Xa \cdot P) \qquad (3.5)$$

$$EE = (Xe \cdot P)(Xa \cdot P) \qquad (3.6)$$

Finally, in Farrell (1957) methodology, *AE* can be explained as a product of *TE* and *EE*. Therefore we can calculate *AE* from equations (3.5) and (3.6) as:

$$AE = (Xt \cdot P)(Xe \cdot P) = (EE)/(TE) \qquad (3.7)$$

However, the deterministic frontier approach by Farrell (1957) is extremely sensitive to outliers which according to Schmidt and Lovell (1979), the parameters are not estimated in any statistical sense, but are merely computed via mathematical programming techniques. In addition, efficiency measures obtained from deterministic models are affected by statistical noise as noted by Schmidt (1986).

Therefore, Stochastic Frontier Production Function is applied in this study and specified from equation (3.1) as follow;

$$\ln(Y_1^*) = \beta_0 + \sum_i \beta_i \ln X_{ij} + \varepsilon_{ij} \qquad (3.8)$$

where,

$$\varepsilon = V - U \qquad (3.9)$$

where, V is a two-sided ($-\infty \prec V \prec \infty$) normally distributed random error (V-N(0, σ^2_V) that captures the stochastic effects outside the farmer's control (e.g. weather, natural disaster, etc.), as well as the effect of measurement error in the output variable, left out explanatory variables from the model and other stochastic noise.

The term U is one-sided non-negative random variable ($u \succ 0$) associated with efficiency component that captures the *technical inefficiency of the farmer*. In order words, U measures the shortfall in output Y from its maximum value given by the stochastic frontier function $f(X_i;\beta)+V$.

This one-sided term can follow such distributions as half normal, exponential and gamma (Aigner *et al*, 1977; Green, 1980; Meeusen and Van den Broeck, 1977). In this study, it will be assume that **U** follows a half-normal distribution (U-N(0, $\sigma_u{}^2$) as typically done in the applied stochastic frontier literature. The two component V and U are also assumed to be independent of each other thus COV (V, U) =0.

The maximum likelihood estimation of equation (3.8) yields consistent estimators of β, λ and σ^2 where β is a vector of unknown parameters, $\lambda = \sigma_u / \sigma_v$ and $\sigma^2 = \sigma_u{}^2 + \sigma_v{}^2$. Jondrow *et al* (1982) noted that inferences about the technical inefficiency of individual farmers can be made by considering the conditional distribution assumed for V and U and assuming that these two components are independent of each other, the conditional mean of U given ε is defined by:

$$E = (\mu / \varepsilon) = \delta^* \frac{f^*(\varepsilon_j \lambda / \delta) - \varepsilon_j \lambda}{1 - F^*(\varepsilon j \lambda / \delta)\delta}$$

(3.10)

where, $\sigma_*^2 = \sigma_u^2 \sigma_v^2 / \sigma^2$, f^* is the standard normal density function and F^* is the distribution function, both functions being evaluated at $\varepsilon_j \lambda / \delta$. Consequently, by replacing ε, σ_* and λ by their estimates in equation (3.8) and (3.10), we derive the estimates of V and U. Subtracting V from both sides of equation (3.8) yields the stochastic frontier function:

$$\ln(Y_1^*) = \beta_0 + \sum_{i=0}^{n} \beta_1 \ln X_{ij} - U_i = \ln(Y_1^*) - V_i \qquad (3.11)$$

where ln(*Y*i*) is defined as the farm's observed output adjusted for the statistical noise contained in Vi.

From this equation, we can compute the TE input vector, X_{it}, and derive the cost frontier which is the basis for calculating minimum cost factor demand equations, they are both then used to estimate economic efficiency, X_{ie}.

Using Shepherd's Lemma, X_{ie} which is the economically efficient input vector, is derived by substituting the firm's input prices and the adjusted output quantities into a system of compensated demand equations expressed as:

$$\frac{\partial C_j}{\partial P_j} = X_j = b_i P_i^{-1} Y^* \qquad (3.12)$$

Hence, for a given level of output, TE, EE and the actual cost of production are equal to $P_j X_j^T$, $P_j X_j^c$ and $P_j X_j$, respectively. These three cost measures form the basis for calculating TE and EE for the jth firm. Therefore,

$$TE_j = \frac{P_j X_j^T}{P_j X_j} \qquad (3.13)$$

And

$$EE_j = \frac{P_j X_j^c}{P_j X_j} \qquad (3.14)$$

Since $EE = TE * AE$, it means $AE = \frac{EE}{TE}$ which is:

$$AE = \frac{P_j X_j^c}{P_j X_j^T} \qquad (3.15)$$

3.3.3. Empirical model

3.3.3.1. The Technical efficiency model

The production of each farm was assumed to be characterized by a Cobb–Douglas function. Cobb–Douglas function is one of the most popular ways of functional form to estimate the relationship between inputs and outputs. In addition, the Cobb–Douglas functional form was fit to separate stochastic frontier production for rice using maximum likelihood procedures (Bravo-Ureta and Pinheiro, 1997). The stochastic frontier production function used is of the form:

$$\ln(\mathrm{Y}_j) = \ln(\beta_0) + \beta_1 \ln FERT + \beta_2 \ln SED + \beta_3 \ln LAB + \beta_4 \ln \mathrm{FSIZ} + (\mathrm{V}_i + \mathrm{U}_i) \qquad (3.17)$$

Where; Y_j represents the total rice output in kg/ha, *FERT* denotes quantity of fertilizer (kg/ha), *SED* denotes quantity of seed (kg/ha), *LAB* denotes labour (man-day/ha), *FSIZ* denotes rice area cultivated (ha). β are unknown parameters of the production function, V_i are two sided normally distributed random error and U_i a one sided efficiency component with a half normal distribution.

3.3.3.2. Allocative efficiency model

Using equation 3.17 above, the corresponding Cobb-Douglas (CD) dual cost frontier is derived using vectors of input prices for the jth farm (P_{ij}). The Stochastic Frontier Production Function β_i of equation 3.1 and the input oriented adjusted output level Y_j^* are known. Thus the corresponding CD dual cost frontier is;

$$\ln C = \beta_0 + \beta_1 \ln P_R + \beta_2 \ln P_L + \beta_3 \ln P_F + \beta_4 \ln P_S + \beta_4 \ln Y_j^* \tag{3.18}$$

Where $\ln C$ denotes the natural logarithm of cost of rice production (GMD), P_R denotes the average rent per hectare of land (GMD), P_L denotes the cost of labour used (GMD), P_F denotes the average cost of fertilizer used (GMD), P_S denotes the cost of seed used (GMD) and Y_j^* denotes the total rice output measured in kilograms and adjusted for any statistical noise as previously specified above in equation (3.17).

3.3.3.3. Efficiency indices model

The model used is a two limit Tobit model procedure, given that the efficiency indices are bounded between 0 and 1 (Green, 1980). This model showed that technical inefficiency effects, EI, is obtained by truncation (at zero) of the normal distribution with mean, μ_i and variance, σ_u^2 such that:

$$EfficiencyIndices = \delta_0 + \delta_1 Age + \delta_2 Gender + \delta_3 Edu + \delta_4 HHSize$$
$$+\delta_5 Coop + \delta_6 Irr + \delta_7 Credit + \delta_8 Training + \delta_9 Varieties \quad (3.19)$$

Where *EFFICIENCY INDICES* is the technical, allocative and economic efficiencies of farmers calculated in the frontier function. Based on literature the variables used in this study were adopted in many other stochastic frontier studies. The variables used are defined as follows: *AGE* is defined as the age of the respondent and is also considered as the experience of the farmers in primary decision making in the farming operation or the number of years the farmers have being involved in rice farming. *GENDER* this indicates the gender of the respondents, where 1=female and 0=male. . *EDU* is dummy 1=Literate/quranic, 2=Primary, 3=Junior High, 4=Senior High and 5=Tertiary. *HHSIZE* is defined as the number of people per rice farming household. *COOP* indicates that if the rice farmer is a member of farmers association or cooperative, where 1= yes and 0=otherwise. *IRRI* is the source of water for rice production during the 2013 cropping season by the sample farmers and it was dummy 1 if irrigated system and 0 otherwise. *CREDIT* indicating whether the farming household used credit for the purchase of inputs in their production activities, where 1=yes and 0=otherwise. *TRAINING* is an indicator used to know if rice farmer have ever attended any training in relation to rice production, where 1=yes and 0=otherwise. *VARIETIES* are type of rice variety cultivated by the sample farmers and it was dummy 1 if improved variety and 0 otherwise and δ 's are a vector of unknown coefficients of the farm-specific inefficiency variables.

3.4. Definition, measurement and A-Priori expectation of variables

Tables 3.2, 3.3 and 3.4 show the definition, measurement and a-priori expectation of variables used in this economic efficiency study.

Table 3.2: Expected variables influencing output of rice production in the study area.

VARIABLE	DESCRIPTION	MEASUREMENT	A-PRIORI EXPECTATION
Y	Rice output	Kg/ha	+
X_1	Farm size	Ha	+
X_2	Family labour	Man Day	+
X_3	Quantity of Fertilizer	Kg/ha	+/-
X_4	Volume of Seed	Kg/ha	+/-

Table 3.3: Expected variables influencing cost of rice production in the hubs

VARIABLES	DESCRIPTION	MEASUREMENT	A-PRIORI EXPECTATION
C	Cost of rice production per farm	GMD	+
P_1	Rent per hectare of land	GMD	+
P_2	Cost of Labour used	GMD	+
P_3	Price of Fertilizer used	GMD	+
P_4	Cost of seed used	GMD	+
Y	Farm out adjusted for any statistical noise	Kilogram	+

Table 3.4: Expected socio-economic variables influencing rice farmers efficiency

VARIABLES	DESCRIPTION	MEASUREMENT	A-PRIORI EXPECTATION
EI	Efficiency Indices	TE, AE & EE	+/-
Z_1	Age in primary decision making on farm operation	Number of years	+/-
Z_2	Gender of the farmer	1=female 0=male	+
Z_3	Four different dummy variables were defined with tertiary used as the base	1=literate/quranic 2=primary 3=Junior High 4=Senior High 5=Tertiary	+/-
Z_4	Household size	Number of people in the rice farmers house	+/-
Z_5	Member of any cooperative society	1=yes 0=otherwise	+
Z_6	Irrigation, is the source of water rice production	1=irrigation 0=otherwise	+/-
Z_7	Credit used	1=receive credit 0=otherwise	+
Z_8	Training, if farmers ever attended rice training	1=yes 0=otherwise	+
Z_9	Varietal effect	1=Improved 0=traditional	+/-

3.4.1. Variable description and measurement

Variables used in the analysis include: production, fertilizer, seed, labour and farm size and they are also the inputs which are used in this study for rice production.

Production/output is the quantity of rice produced by each household in the 2013 cropping season measured in kilograms. Fertilizer was assumed to be the quantity of inorganic fertilizer that was purchased and applied per hectare of land by rice producers during the period under review and was measured in kilograms. Seed is the quantity in kilograms of rice seed planted by each rice farmer per hectare of land during the 2013 cropping season. Labour is measured as man-day used in rice production by the farmers in the sample and in this case it is only family labour that was used during the 2013 cropping season. Farm size is the area which was cultivated for rice production during the period under review by sample farmers and it is measured in hectares.

3.4.2. Description of predictor variables and their a-priori expectation.

1. Yield of rice was measured as the quantity of rice produced in Kg/ha during the 2013 cropping season. The output was used as the dependent variable which is influenced by several independent variables called inputs.

2. Farm size is the area of land in hectares of rice cultivated. The variable was used to investigate the influence on output. Farm size was measured in hectares.

3. Labour was measured as the man-days spent on the farm from land preparation to harvesting on a hectare of land. In this study only family labour is used.

4. Fertilizer refers to the quantity of chemical fertilizer applied on rice plot in kg per ha during the 2013 cropping year. Fertilizer is expected to have a positive effect on yield, but when overdose happens it can lead to low yield or total crop failure.

5. Seed[7] was a measure of the quantity of rice seeds in kilograms (kg) used in 2013 cropping season. Seed are the backbone of agricultural production. Despite this importance, however, rice farmers' in Africa lack assured access to sufficient, good quality seed of preferred varieties in time for sowing. With the growing awareness that promoting rice production in Africa is crucial for economic growth, food security and social stability, 'seed' is firmly back on the agenda of many government and technical and financial rice development partners. This becomes particularly evidence after the 2008 food crisis, which was manifested as a 'rice crises' in many African countries (Viatte *et al.*, 2009).

6. Efficiency Indices was the dependent variable and show the efficiency level of an individual farm/farmer in the study area. Several socio-economic independent variables are known to have influenced it; a positive sign of an estimated parameter implies that the associated variable has a positive effect on efficiency but Negative effect on inefficiency and vice versa.

7. Age in the production of a crop was related to efficiency of the farmer; more experienced farmers tend to minimise losses, and have better managerial skills which are utilized in their production process. Since, farming

[7] Note the quantity of seeds per ha determines the plant population which can have either positive or negative influence on yield. This variable was taken as an averaged over the cropped area.

experience increases with increase in number of years in farming, it is expected that the age of the farmer would have a positive effect on efficiency. This is the case even though older farmers could be more traditional and conservative and hence show less willingness to adopt new practices (Coelli, 1996).

8. Gender variable measures the effect of gender on efficiency scores. A dummy variable was used to denote this variable with; 1 if the farmer is female and 0 male. The anticipated sign of the coefficient of gender was however indeterminate because of the argument those men and women farmers are both efficient in resource use Adesina and Djato, (1996).

9. Education variable was measured from 1 to 5 if farmer ever attended formal education 1=literate/quranic, 2=primary, 3=Junior High, 4=Senior High and 5=Tertiary. It represents the managerial ability of the farmer. Education as a human capital variable is a relevant factor in technology adoption. Educated farmers easily adopt improved farming technology and therefore should have higher efficiency scores than farmers with low level of education (Seyoum *et al.*, 1998). The expected impact on efficiency indices is positive.

10. Household Size measures the number of people (adult men and women and children) who were living with the farmer during the 2013 cropping year. The expected sign for household size is mixed. A positive sign indicates that the larger the household size, the greater is the efficiency. A reason for a positive sign is allocation of financial resources to family members for their education and health (Coelli *et al,* 2002). On the other hand, larger household size will used less hired labour in the production of output and hence the less the total cost of production and vice vasa.

11. Access to Credit is a binary variable used to capture the effect of credit on the efficiency of farmers. This variable was measured as a dummy, 1 if farmer

had access to credit, 0 otherwise during the 2013 cropping season. Access to credit will result in efficiency by overcoming liquidity constraints which affect the ability to apply production inputs and implement farm management decisions on time. Lack of credit would result in the farmer becoming inefficient. The expected impact is positive.

12. Variety was defined as the type of rice variety used, where 1= Improved varieties 0=Traditional or Conventional. The expected impact on efficiency indices is indeterminate.

CHAPTER FOUR

4.0. RESULT AND DISCUSSION

This chapter presents results and discussion of the study. It is prepared into five main headings. It begins with description of the characteristics of the survey respondents (i.e. the farmers). This section also presents area of land cultivated by household per ecology, average farm size in the study area and average yield of rice per ecology. Empirical results are presented in section two which entails factors that influence production level in rice production and the maximum likelihood estimation of the Cobb-Douglas production function. Section three presents estimation of TE, AE and EE and socio-economic factors affecting farmer's efficiency. The fourth section presents determinants of efficiency among rice producers and the final section presents major constraints faced by rice producers in the Gambia.

4.1. Descriptive results

4.1.1. Farmer characteristics

Farm level efficiency has been discussed widely in literature. It has been influenced by several farm and household characteristics (Kumbhaker and Lovell, 2000). The age, gender, education level, household size, access to credit, membership of cooperative, training in rice farming, source of water for rice production and varieties cultivated are the characteristics that were analysed for the purpose of this study. Data on 192 rice producers from the study area were analysed with sample distribution of farmers according to ecology. As shown by the figure

4.1, most of the sampled households are lowland ecology rice producers accounting for 66% of the total land area and only 34% cultivated under the upland ecology.

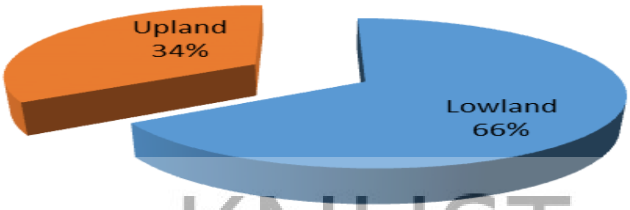


Figure 4.1: Distribution of farmers according to ecology

Source: Survey Data (2013)

Majority of rice producers interviewed were small scale producers producing below 2 ha of land. The average farm sizes as shown in Table 4.1 was found to be 1.45 ha in lowland and 2.3 ha in the upland indicating that rice fields are generally bigger under the upland ecology. For the pooled data the average land size is 1.62 ha; minimum size of land is 0.10 ha while the maximum is 7 ha across both ecologies.

Table 4.1: Distribution of farmers by land size

Variable	Lowland		Upland		Pooled	
Land Size (Ha)	**Freq.**	**Percent**	**Freq.**	**Percent**	**Freq.**	**Percent**
≤2	131	84.5	23	62.2	154	80.22
2.1-5	23	14.8	12	32.4	35	18.22
>5	1	0.6	2	5.4	3	1.56
Total	155	100	37	100	192	100
Mean	1.45		2.3		1.62	
Min	0.10		0.10		0.10	
Max	7.0		7.0		7.0	
Std.Dev	1.46		2.33		1.39	

Source: Survey Data (2013)

About 49.48 percent of the economically active labour force engaged in rice production in the study area, were between the ages of 31 and 50 years as shown in Table 4.2 below. This shows an active involvement of the economically active person in rice production. For the pooled sample, the mean age of rice producers was found to be 49 years. However, the mean age among lowland rice producer was 48 years while that of upland was 53 years. These mean ages among rice producers in the Gambia suggest that most individuals engaged in rice production in the country are still active. This can purse a great benefit in the rice sector as they easily accept and try new technologies they are introduced to.

Table 4.2: Distribution of age of respondents

Age (years)	Lowland		Upland		Pooled	
	Freq.	**Percent**	**Freq.**	**Percent**	**Freq.**	**Percent**
≤20	3	1.9	0	0	3	1.56
21-30	17	11.0	4	10.8	21	10.94
31-40	36	23.2	5	13.5	41	21.35
41-50	44	28.4	10	27.0	54	28.13
51-60	28	18.1	6	16.2	34	17.71
61-70	16	10.3	7	18.9	23	11.98
71-80	9	5.8	3	8.1	12	6.25
>80	2	1.3	2	5.4	4	2.08
Total	155	100	37	100	192	100
Mean	48		53		49	
Min	18		25		18	
Max	87		87		87	
Std.Dev	14.70		16.76		15.18	

Source: Survey Data (2013)

In table 4.3 below, about 10.42 percent have a household size less than 6 members, and household size of between 6 and 10 was revealed to be 33.85 percent. Larger household size (greater than 10) was 55.73 percent of the total respondent. The average number of people in rice producing farmer household was about 13 members; of which the minimum is 1 member and the maximum 53. Larger household sizes are important in rice production as it minimizes the cost of hiring labour.

Table 4.3: Distribution of household size

Variable	Lowland		Upland		Pooled	
Land Size (Ha)	**Freq.**	**Percent**	**Freq.**	**Percent**	**Freq.**	**Percent**
<6	19	12.3	1	2.7	20	10.42
6-10	50	32.3	15	40.5	65	33.85
>10	86	55.5	21	56.8	107	55.73
Total	155	100	37	100	192	100
Mean	13		14		13	
Min	1		4		1	
Max	53		34		53	
Std.Dev	8.64		7.35		8.38	

Source: Survey Data (2013)

The gender distributions of the respondents were 52.6% and 47.6 % for female and male headed households respectively as shown in table 4.4 below. Rice production in the Gambia particularly in the study area is predominantly women activity.

The study interviewed about 84% of rice producers who were married and 3.6% reported being single while 8.8% and 3.1% were widowed and divorced respectively (table 4.4).

Table 4.4: Household characteristics of sample farmers

	Lowland		upland		Pooled	
	Freq.	**Percent**	**Freq.**	**Percent**	**Freq.**	**Percent**
Gender						
Female	83	53.5	18	48.6	101	52.6
Male	72	46.5	19	51.4	91	47.4
Marital status of member						
Married	131	84.5	31	83.8	162	84.5
Single	6	3.9	1	2.7	7	3.6
Widow/widower	13	8.4	4	10.8	17	8.8
Divorce	5	3.2	1	2.7	6	3.1
Education level of member						
Literate/Quaranic	46	29.7	17	45.9	63	32.81
Primary	8	5.2	2	5.4	10	5.21
Junior high school	2	1.3	1	2.7	3	1.56
None	90	58.1	17	45.9	107	55.73
Senior high school	9	5.8	0	0	9	4.69
Do you have access to credit?						
Yes	61	39.4	26	70.3	87	45.31
No	94	60.6	11	29.7	105	54.69
Do you have access to training						
Yes	45	29.0	7	18.9	52	27.08
No	110	71.0	30	81.1	140	72.92
Are you a member of an association?						
Yes	144	92.9	36	97.3	180	93.75
No	11	7.1	1	2.7	12	6.25
Do you cultivate improved variety?						
Yes	102	65.8	28	75.7	130	67.71
No	53	34.2	9	24.3	62	32.29

Source: Survey Data (2013)

The education background of respondents reveals that majority of the respondents (55.73%) had no formal education. While 32.81% had Islamic education, 5.21% had primary education, 1.56% had junior high education and

4.69% senior high education. None of the respondents had tertiary education. This distribution of educational levels was largely similar in both the ecologies except that among the upland rice producers, none-had achieved senior high education. This result has revealed that literate rice producers in the study area especially among women are low.

Credit, an equally important variable that influences farm level efficiency, has been considered in this study. The percentage that received credit is 45.31% and 54.69% reported not having access.

Farmers who reported having access to training were only 52 representing 27.08 percent and the majority of the farmers of about 140, representing 72.92 percent has no access to training. About 93.75 percent of the farmers reported to have been members of an association, and very few of the sampled farmers (6.25 percent) reported to have not been members of any association.

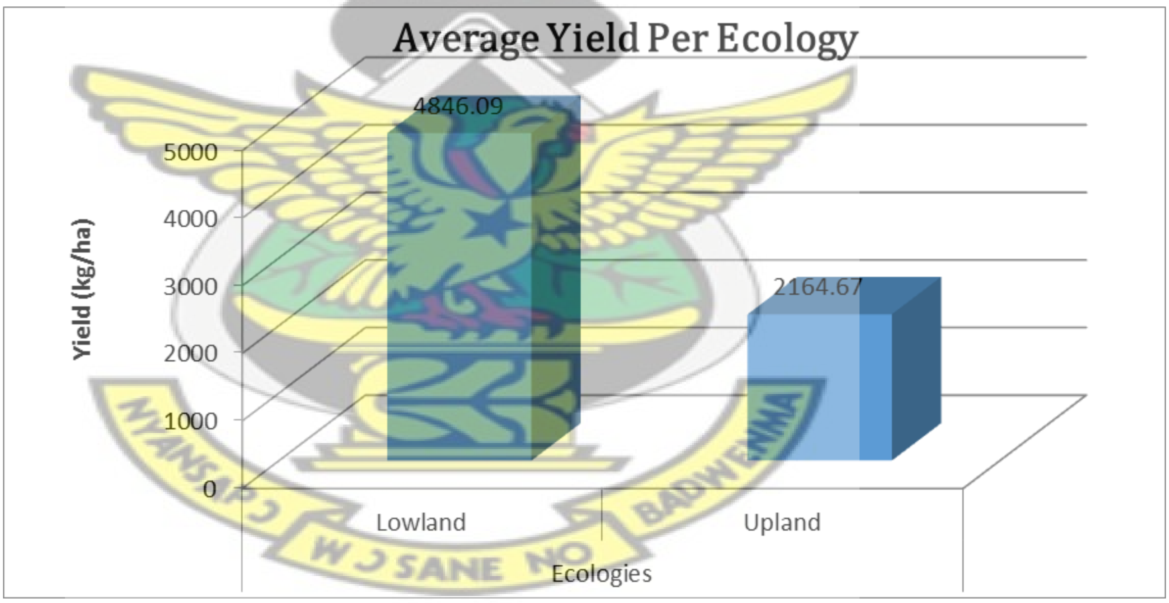
About 67.71 percent of the farmers in the study area have reported cultivating improved rice varieties and about 32.29 percent have reported growing traditional varieties.

Finally, 155 farmers (about 80.7 percent of the respondents) are in lowland rice production and about 19.3 percent (representing 37 farmers) are in upland rice production.

4.2. Yield and determinants of rice production

4.2.1. Yield of rice

Figure 4.2 below on average yield per rice ecology shows an average of 4.8 t/ha from the lowland ecology and that of the upland revealed average yield of 2.2 t/ha. This result indicated that yield from farmer's fields in both the lowland and uplands are still far below the potential achieved under research. Becker et al. (2003) have reported potential yields of irrigated lowland in West Africa ranging from 6.9 t/ha to 9.8 t/ha; while Saito and Futakuchi, (2009) have reported a potential yields under research in rainfed upland to range from 4 to 5.6 t/ha.



Source: Survey Data (2013)

Figure 4.2: Average yield of paddy rice per ecology

The yield data distribution in table 4.5 shows that majority of the farmers achieving yields between 1-2 Mt/ha in both the ecologies. About 25% of the respondent reported yield of less than 1Mt/ha, 39.6% reported yield within 1-2Mt/ha, while 16.1%, 5.2% and 14.6% reported yield within the ranges of 3-4Mt/ha, 5-6Mt/ha and above 6Mt/ha respectively.

Table 4.5 Yield data distribution

	Lowland		Upland		Pooled	
Yield(Ha)	**Freq.**	**Percent**	**Freq.**	**Percent**	**Freq.**	**Percent**
<1	38	24.5	9	24.3	47	24.5
1-2	52	33.5	24	64.9	76	39.6
3-4	29	18.7	2	5.4	31	16.1
5-6	9	5.8	1	2.7	10	5.2
6>	27	17.4	1	2.7	28	14.6
Total	155	100	37	100	192	100
Mean	4.85		2.16		3.44	
Min	407.5		6.67		6.67	
Max	35000		22000		35000	
Std.Dev	4032.76		5606.26		4390.39	

Source: Survey Data (2013)

4.2.2 Determinants of rice production

Under this objective the main purpose is to determine the level of rice yield obtained by rice producers in the Gambia and to identify the factors that influence the yield level. The production of each farm was assumed to be characterized by Cobb-Douglas function. Summary statistics of the variables used in the production unction and technical as well as allocative efficiency models are presented in Table 4.6.

Table 4.6: Summary Statistics of the variables used in the production function TE and AE model (Pooled Data)

Variables	Units	Means	Std.Dev	Min	Max
Yield	Kg/ha	3442.00	4390.40	6.67	35000
Fertilizer	Kg/ha	141.70	146.90	14.29	968
Seed	kg/ha	69.68	70.02	21.43	484
Labour	Manday/ha	55.37	70.76	2.67	430
Prices					
P_{Labour}	GMD/ha	2081.93	3597.24	28.57	28594
P_{Seed}	GMD/ha	1588.95	1228.89	88	6125
$P_{Fertilizer}$	GMD/ha	3016.79	5052.48	60	60000
P_{Rent}	GMD/ha	7731.56	13387.22	160	160000
Total cost	GMD/ha	14552.63	22911.93	687.83	271406

Source: Survey Data (2013) US$1= GMD 35

Table 4.6 above shows the mean, minimum, maximum and standard deviation quantity of rice per household in the survey unit.

Seed cost were estimated at a mean of GMD 1589 per hectare based on the above premise and mean of the cost of fertilizer, labour and rent were estimated at GMD 3017 kg/ha, GMD 2082 per man-day and GMD 7732 rent per ha respectively.

The Maximum Likelihood Estimates (MLE) of the production parameters for rice farmers in Central River Region North and Central River Region South of the Gambia are presented in Table 4.7 below.

Table 4.7.:The Maximum Likelihood Estimates of the Cobb-Douglas Stochastic Frontier Production Function (Pooled Data)

Variables (Output)	Parameter	MLE Coefficient	Std.Error	Z-Statistics
Constant	β_0	3.153***	0.924	3.41
Fertilizer	β_1	0.6169**	0.264	2.33
Seed	β_2	-0.318	0.303	-1.05
Labour	β_3	0.485***	0.061	7.94
Farm Size	β_4	0.217***	0.077	2.83
Wald chi-square		108.42 (0.000)***		
Model Variance	σ_6	0.9661		
Gamma	φ	0.6281		
Log Likelihood		-256.363		

Source: Survey Data (2013)

Note; ***, ** and * are statistically significant at 1%, 5% and 10 respectively.

Coefficients except for quantity of seed used have all positively influenced rice production and were statistically significant at 1% and 5% levels. The coefficient of quantity of fertilizer used by farmers has a positive and significant relationship (at 5% level of significance) with rice output; indicating that rice output can be increased by 0.62 percent with a percentage increase in the quantity of fertilizer. The estimated coefficient of labour was found to be positive and statistically significant at 1% level. This implies that labour is a significant factor that influences rice output in the study area. The output can therefore, be increased by 0.49 percent with a percentage increase in labour if other inputs are held constant. Farm size is another variable worth mentioning. The coefficient of farm size was also found to be positive and significant at 1% level. The 1% statistical significance level for farm size also implies that the influence of changes in farm size on production efficiency was very important. This finding agrees with the study of Ogundele and Okoruwa (2006) and Ogunniyi *et al*, (2012). Results show that a percentage increase in farm size will also increase output by 0.22 percent.

Wald Chi-square statistic = 108.42 and Probability = 0.000, since the Wald Chi-square statistic is significant at 1% level, we reject the null hypothesis that there is absence of inefficiency in favour of presence of inefficiency. We therefore conclude that there is inefficiency in production of rice, the coefficient score of Gamma is 0.6281 which indicates the proportion of variation in the model that is due to technical efficiency. This score indicates that about 62.8% of the variation in output among farms was due to the differences in technical efficiencies. Thus, 63% of the variation in composite error term was due to the inefficiency component. This also suggests that about 37% of the variation was due to random shocks outside the farmer's control. For instance, weather condition/temperature during the rice production process. If technical inefficiencies among rice producers are minimized there can be optimization of rice output.

4.3.2. Estimation of the stochastic cost frontier function

The estimates of the stochastic frontier cost function together with the estimated standard errors and their statistical significance levels are presented in table 4.8. The result revealed that all the independent variables of the stochastic cost frontier model conform to a priori expectation as all the estimated coefficients give positive coefficient. This is similar to the findings of Ogundari and Ojo, (2006), which revealed that positive coefficients or elasticities of cost with respect to all inputs confirm the assumption that cost function monotonically increases in input prices. This means that as these factors increased, total cost of production increased ceteris paribus, indicating that an increase in price of any of the inputs as well as an increase in output level will eventually increase total production cost. The significant variables according to t-ratio test are fertilizer and rent, both significant at 5% significance level. This result indicates that the named variables were significantly different from zero. That is, they are very important elements in rice production.

The economic efficiency analysis of the rice farmers revealed that there was a presence of cost inefficiency effect in rice production as confirmed by the significance of the Wald Chi-Square. The estimated gamma parameter of the model is 0.1764 implies that about 18% of the variation in the total production cost among the sampled farms was due to differences in their cost efficiencies. Thus, 18% of the variation in composite error term was due to the inefficiency component.

Table 4.8: The Maximum Likelihood Estimates of the Stochastic Cost Frontier (Pooled Data)

Variables (Cost of Production)	Parameter	MLE Coefficient	MLE Std.Error	Z-Statistics
Constant	β_0	1.991***	0.185	10.75
Fertilizer Cost	β_1	0.709**	0.102	6.93
Seed cost	β_2	0.083	0.099	0.83
Labour cost	β_3	0.158	0.012	13.30
Rent cost	β_4	0.013**	0.023	0.56
Output	β_5	0.018	0.016	1.16
Wald Chi-Square		5380.56 (0.000)***		
Model Variance	σ_δ	0.0324		
Gamma	φ	0.1764		
Log Likelihood		55.293		

Source: Survey Data (2013)

***, ** and * are statistically significant at 1%, 5% and 10% respectively.

4.4.1. Estimation of technical, allocative and economic efficiency of rice producers in lowland ecology

Table 4.9 shows the estimated scores of the frequency distribution of Technical, Allocative and Economic Efficiency of rice producers in the lowland ecology. The study reveals that TE indices of rice farmers range from 0.90 percent to 93.30 percent with a mean of 65.86 percent. This implies that the best practicing farmers operates at 93.30 percent efficiency, while the least practicing farmers operate at about 0.90 percent level. The allocative efficiency indices score for lowland rice farmers range from a low of 11 percent to the highest of 93.50 percent with a mean score of 68.84 percent. Finally, the result reveals the mean EE to be 49.70 percent, with minimum indices scores of 0.00 percent with a maximum of 86.20 percent.

To give a better indication of the distribution of TE, AE and EE a frequency distribution of their predicted efficiencies is presented in table 4.9 below. The frequencies score in the table indicate that the higher numbers of farmers have TE of 71-80 percent representing about 25% of sampled respondent. The frequencies score have also shown higher occurrence of farmers under AE to be 81-90 percent in lowland rice production representing about 28% of the respondents. Finally, for economic efficiency the frequencies score of higher number of farmers occurred between 61 and 90 percent representing 37.4% of respondents. These frequency scores of technical, allocative and economic efficiencies have shown that none of the farmers are operating on the frontier, which is 100% efficiency level. This means that rice producers have a room to improve on their productivity and production even with the same available resources.

Table 4.9: Frequency Distribution of Technical (TE), Allocative (AE) and Economic (EE) in Lowland Rice Ecology.

Efficiency score (%)	Technical Efficiency		Allocative Efficiency		Economic Efficiency	
	Freq.	%	Freq.	%	Freq.	%
< 10	6	3.9	6	3.9	15	9.7
11-20	5	3.2	3	1.9	4	2.6
21-30	4	2.6	4	2.6	15	9.7
31-40	4	2.6	5	3.2	15	9.7
41-50	13	8.4	9	5.8	19	12.3
51-60	12	7.7	13	8.4	22	14.2
61-70	29	18.7	24	15.5	29	18.7
71-80	39	25.2	34	21.9	29	18.7
81-90	37	23.9	43	27.7	7	4.5
> 90	6	3.9	14	9.0	0	0
Mean (%)	65.86		68.84		49.70	
Min (%)	0.90		11.00		0.00	
Max (%)	93.30		93.50		86.20	
Std.Dev	22.27		22.80		23.60	

Source: Survey Data (2013)

4.4.2. Estimation of technical, allocative and economic efficiency of rice producers in upland ecology.

Table 4.10 below shows the estimated scores of the frequency distribution of Technical, Allocative and Economic Efficiency of rice producers in the upland ecology. The study reveals that TE indices of rice farmers range from 31.80 percent to 90.20 percent with a mean of 61.55 percent. The allocative efficiency indices score reveals a minimum score of 17.80 percent, with a maximum of 87.90 percent and a mean score of 62.39 percent. Finally, the result reveals the mean EE in the study area to be 39.65 percent, with minimum indices scores of 7.90 and with a maximum of 76.60 percent.

To give a better indication of the distribution of efficiency indices scores, a frequency distribution of the predicted TE, AE and EE are presented in table 4.10 below. The frequencies score in the table indicate that the higher numbers of farmers have TE between 61-70 percent in upland ecology, representing about 43.2% of sampled respondent. The frequencies score of AE in the table show a range between 51-60 percent to be the occurrence of higher number of farmers in upland rice production representing about 32.4% of the respondents. The frequencies score of occurrence of the predicted EE indicated that the higher number of farmers have EE between 21-30 percent representing 24.3% of respondents. These frequency scores are revealing that upland rice farmers have room to improve on their output because none of the respondents are operating on 100% efficiency score in all the efficiency categories.

Table 4.10: Frequency Distribution of Technical (TE), Allocative (AE) and Economic (EE) in Upland Ecology.

Efficiency Score (%)	Technical Efficiency		Allocative Efficiency		Economic Efficiency	
	Freq.	%	Freq.	%	Freq.	%
< 10	0	0	1	2.7	2	5.4
11-20	0	0	1	2.7	3	8.1
21-30	0	0	1	2.7	9	24.3
31-40	3	8.1	5	13.5	7	18.9
41-50	6	16.2	6	16.2	7	18.9
51-60	5	13.5	12	32.4	2	5.4
61-70	16	43.2	5	13.5	5	13.5
71-80	3	8.1	6	16.2	2	5.4
81-90	3	8.1	0	0	0	0
> 90	1	2.7	0	0	0	0
Mean (%)	61.55		62.39		39.65	
Min (%)	31.80		17.80		7.90	
Max (%)	90.20		87.90		76.60	
Std.Dev	14.30		17.04		17.49	

Source: Survey Data (2013)

4.4.3 Distribution of technical, allocative and economic efficiency of pooled data for the rice farmers in the study area.

Table 4.11 below shows the estimated scores of the frequency and percentage distribution of Technical, Allocative and Economic Efficiency of rice producers in Central River Region. This study reveals that TE indices of rice farmers range from 0.90 percent to 93.30 percent with a mean of 65.03 percent. This implies that the best practicing farmers operates at 93.30 percent efficiency, while the least practicing farmers operate at about 0.90 percent level. The presence of technical inefficiency indicates that rice production can be raised without increasing input used in the production process.

This result means that if the household were to operate on the frontier they would have to reduce their technical inefficiency by 34.97 percent. Similarly, if the most technically inefficient farmer were to operate on the frontier they would have to reduce their inefficiency by 99.10 percent. This result also helps to reveal that average farmer in the sample could save average of 30 percent (i.e. 1-[65.03/93.30]) of cost if a farmer was to achieve the TE level of his most efficient counterpart. Similarly for the most technically inefficient farmers, they could realize cost saving of 99 percent (i.e. 1-[0.90/93.30). Farmers in Central River Region North and Central River Region South, although are relatively efficient, there are clear opportunities that exist to increase their efficiency by 34.97 percent given the prevailing current set of inputs, prices and technology at hand.

Table 4.11: Frequency Distribution of Technical, Allocative and Economic (EE) Pooled data for the rice farmers in the study Area.

Efficiency	**Technical Efficiency**		**Allocative Efficiency**		**Economic Efficiency**	
Score (%)	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
< 10	6	3.1	6	3.1	17	8.9
11-20	5	2.6	4	2.1	7	3.6
21-30	4	2.1	5	2.6	24	12.5
31-40	7	3.6	6	3.1	22	11.5
41-50	19	9.9	14	7.3	26	13.5
51-60	17	8.9	19	9.9	24	12.5
61-70	45	23.4	36	18.8	34	17.7
71-80	42	21.9	39	20.3	31	16.1
81-90	40	20.8	49	25.5	7	3.6
> 90	7	3.6	14	7.3	0	0
Mean (%)	65.03		67.47		47.76	
Min (%)	0.90		1.10		0.00	
Max (%)	93.30		93.50		86.20	
Std.Dev	21.01		22.86		22.86	

Source: Survey Data (2013)

Parameters of the corresponding dual cost function were derived by using the estimated parameters from the Cobb-Douglas SFPF. This forms the bases on which AE and EE were calculated.

The allocative efficiency indices score from table 4.11 above of rice farmers range from the lower of 1.10 percent to the highest of 93.50 percent with a mean score of 67.47 percent. This result shows that rice producers have room to improve their allocative efficiency by 32.53 percent if they are to operate on the frontier. Moreover, if the average farmers had to achieved allocative efficiency of the most efficient sample household they have to reduce their cost by 27.84 percent. The least allocative efficient sample household will on the other hand have to reduce cost by 98.82 percent.

From the combination effect of technical and allocative efficiency factors, we get the economic efficiency level among the farmers in the study area. The result reveals that EE in the study area is 47.76 percent, with indices scores ranging from 0.00 percent to 86.20 percent. From these values, we can suggest that if the average farmer in the study were to reach EE level of its most efficient counterpart, then the average farmer could realize cost savings of 45 percent (i.e., 1-[47.76/86.20]). From the figures in Table 4.11 above we can conclude that technical inefficiency indices score of farmers in the study areas is considered high, but needs serious attention in order to improve the EE of farmers. As already explained, EE is composed of AE and TE. Therefore, the average economic inefficiency score in the table above arises from a combination of the technical and allocative components.

The frequencies score in Table 4.11 indicate that the highest numbers of farmers have TE between 61-70 percent representing about 23.4% of sampled respondent. The frequencies score also show highest occurrence of farmers under AE to be between 81-90 percent representing about 25.5% of the respondents. Finally, for economic efficiency the frequencies score of highest number of farmers occurred between 61-70 percent representing 17.7% of respondents.

There are environmental, economic and institutional factors which affect TE and AE. Environmental factors may include climate related factors (flooding, drought, heat stress and cold temperatures) and soil related constraints (poor soil quality, Zn deficiency, salinity/alkalinity, N or P or K deficiency, iron toxicity, acidity, soil erosion, etc.). Institutional factors include lack of proper information and its dissemination, lack of access to credit, lack of access to extension contact, poor road infrastructure, land tenure arrangements etc. All these and other factors affect rice producers' efficiency. Finally, economic factors include high transaction cost for inputs and their prices, high processing cost and poor market outlets. Figure 4.3 shows the graphical representation of efficiency scores.

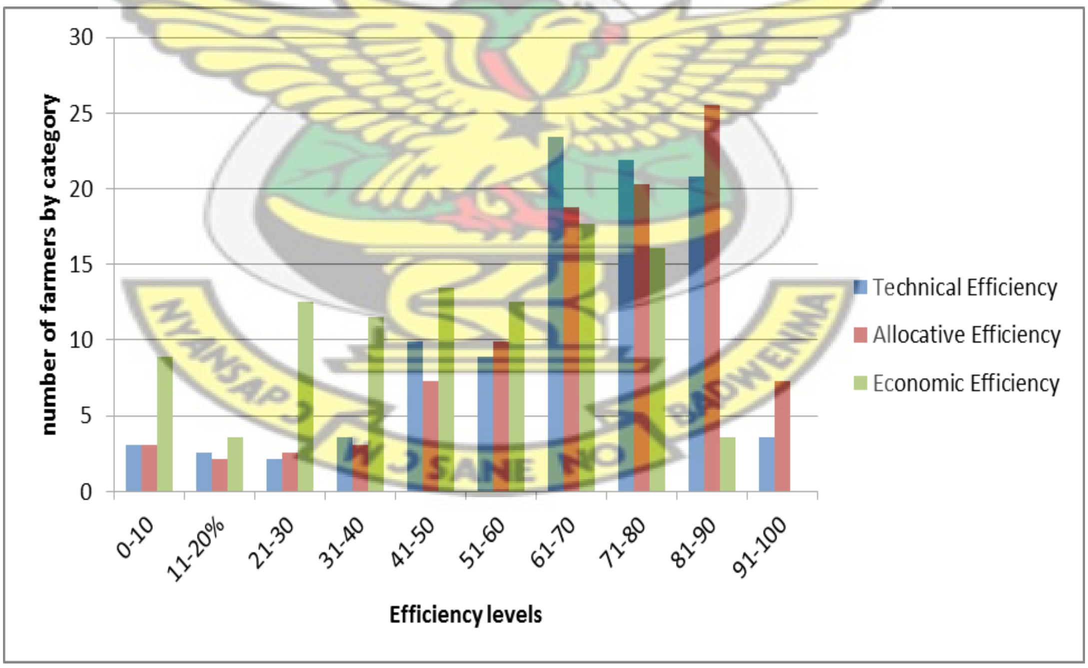


Figure 4.3. Graphical representations of TE, AE and EE scores for the Pooled Data.

Source: Survey Data (2013)

4.5. Determinants of efficiency among rice producers in the Gambia

The parameter estimates in Table 4.12 below presents the result from Tobit model the factors that affect efficiency and their relevant signs. The signs indicate the impact of explanatory variables (socio-economic variables) on the efficiency indices scores of TE, AE and EE. Explanatory variables with a larger impact should be the main focus in an effort to improve efficiency in rice production in the study area.

Results have revealed that, *AGE* has a positive effect on all efficiency categories, and was found to be statistically significant with EE at 10%. This finding could suggest that an increase in age leads to economic efficiency of rice farmers. One of the possible reasons could be due to the fact that older farmers tend to be more experienced and are more efficient through learning by doing (Shehu *et al*., 2007). Furthermore, increased farming experience may lead to better assessment of importance and complexities of good farming decision, including efficient use of resources. It is commonly believed that age can serve as a proxy for farming experience. The effect of farming experience, usually measured in number of years the farmer has been involved in rice farming, is one of the socio-economic factors that has been given greater attention in many stochastic production function literatures. It is not included in this analysis as it was highly correlated with age of rice farmers from the study area.

The result concerning *GENDER* suggests that female rice farmers have a negative association with TE but positive association with AE and EE. Based on the efficiency score we can therefore, assume that male farmers exhibit higher levels of

TE but lower levels of AE and EE. This result is in agreement with the findings of Addai (2011) that being a male farmer decreases technical inefficiency. This could be explained by the fact that men have greater access to credit, probably because of cultural prejudice, and hence men are closer to the production frontier. However, Dolisca and Jolly (2008) had contrasting result that being a male farmer increases technical inefficiency. The result also explains that female farmers are more allocative and economically efficient in rice production than their male counterpart. However, Galawat and Yabe (2011) had a contrasting result that being female farmer exhibit higher level of AE, but lower level of EE. Women are more efficient in making decision in selecting inputs compared to men. Men are more technically efficient in more labour intensive work while women have dual roles where they did not only manage the domestic affairs but also the farm. This study therefore contributes to the debate on the role of gender in farmers' level of efficiency.

The estimated coefficients in all categories for *EDUCATION* were found to have a negative relationship; the results were obtained by running each dummy variable against their counterparts. Example, those with quaranic were assigned 1 and all other respondents (primary, secondary, tertiary) were assigned 0 and the coefficient is negative, this means that those with quaranic education are less efficient compared with their counterparts who do not have quaranic education. This is the same interpretation for primary, secondary and tertiary education. So from the results, there is positive relationship between educational level and efficiency and thus this results are consistent with the findings of Addai (2011) for year of schooling is positive as expected but not significant.

Table 4.12: Tobit efficiency model estimate for TE, AE and EE (Pooled Data)

Variable	Parameters	TE		AE		EE	
		Coefficient	Std.Err	Coefficient	Std.Err	Coefficient	Std.Err
CONSTANT	Z_0	0.662***	0.106	0.5259***	0.1248	0.3996	0.111
AGE	Z_1	0.00566	0.00427	0.00497	0.00497	0.00756*	0.00443
GENDER	Z_2	-0.00500	0.0239	0.0363	0.0258	0.0192	0.0230
LITE/QURANIC	Z_3	-0.1513***	0.0352	-0.0692	0.0427	-0.1307***	0.0361
PRIMARY		-0.1276***	0.0330	-0.07844*	0.0411	-0.1208***	0.0349
JUNIOR HIGH		-0.3111***	0.0864	-0.2782	0.0844	-0.3089***	0.0772
SENIOR HIGH		-0.2686**	0.1064	-0.1064	0.1454	-0.1905***	0.0914
HH SIZE	Z_4	-0.00998***	0.00207	-0.0092	0.00199	-0.0105***	0.00178
COOP	Z_5	0.0808***	0.0221	0.0555	0.0272	0.0862***	0.0294
IRR	Z_6	0.1941***	0.0207	0.2135***	0.0241	0.2618***	0.0218
CREDIT	Z_7	-0.0527**	0.0235	-0.0492***	0.0249	-0.0748***	0.0226
TRAINING	Z_8	-0.0293	0.02741	-0.000377	0.0358	-0.0176***	0.0296
VARIETY	Z_9	0.0638***	0.0249	0.008192***	0.0279039	0.0803***	0.0241

Source: Survey Data (2013)

Note: ***, ** and * are statistically significant at 1%, 5% and 10% respectively.

Based on the estimated coefficient *HOUSEHOLD SIZE* has a negative relationship in all efficiency categories, and it was statistically significant for both TE and EE at 1% level. This indicates that households with small number of people tend to have TE and EE advantage than large household size. Large household size is very important since it determines the availability of household labour, which is essential during agricultural production season. However, in the farming communities, the sizes of the household does not necessary translate into economically active labour force. This could be true for the Gambian experience as small household size influence more than large size. This finding, concur with the work of Coelli *et al* (2002) that concluded that larger families are clearly a cause of lower level of efficiencies in the less labour intensive season, when surplus labour is a problem. This has been the case as rice producers have become less labour intensive as people resort to the use of other alternatives like using herbicides in controlling weeds.

However, the result is in contrast with Chukwuji *et al*. (2007) that concluded that a larger family enables farm activities to be completed on time in Nigeria. Therefore the larger the household size, the better it is for a household to participate in rice production in Nigeria.

The estimated coefficient for *COOP* has shown a positive relationship with TE, AE and EE for farmers who join cooperative or farmers association and is statistically significant at 1% level for both TE and EE. This indicates that participation of farmers in cooperatives tends to have positive effects on the rice producers' efficiency. Having opportunities of quick government support and donor's intervention, easy and timely access to inputs on subsidised bases, sharing information on modern rice production activities and interacting with other farmers on other production activities can easily be enhanced through cooperative membership. Therefore, inefficiencies among rice producers can be reduced if farmers formed organizations or cooperatives.

The estimated coefficient of *IRRIGATION* variable is one of the two variables that uniformly has positive sign and are statistically significant at 1% level in all three efficiency equations. This result is consistent with the findings of Galawat and Yabe (2011). Irrigation enhances efficiency significantly as it improves the soil water retention capacity and enables rice to maximize the use of fertilizer and other inputs effectively.

Though significant, the estimated coefficient for *CREDIT* indicated that there exist negative relationships in all category of efficiency. These negative relationships between access to credit and efficiency suggest that farmers who accessed credit ostensibly to purchase inputs have a higher probability of experiencing higher levels of inefficiency. It is generally believed that access to credit positively influences efficiency of farmers provided credit is judiciously utilize in farm activities. However, the results indicated opposite which can be interpreted that farmers seek credit for other purposes other than to purchase farm inputs and farm operation. It is possible farmer's accessed credit in the name of rice production but diverted it towards other crops activities or for household consumption. Credit access indicates liquidity, which is a prerequisite for flexibility in timely decision making in the purchase of inputs and farm operation. Rice production process can be facilitated with minimum credit facilities; therefore there is need for this minimum capital to purchase inputs such as seed, fertilizer and rent for land.

Training is directly related to productivity, but in this study *TRAINING* coefficient was significant with only the EE, and it has negative influence on efficiency in all three categories of efficiency. Generally, farmers who attended training in rice production related courses are supposed to be more efficient than farmers who do not, but the result of this study is stating otherwise. This result also indicated that farmers who attended training in the study area are less efficient than farmers who did not attended any training at all.

The estimated coefficient of *VARIETIES* variable is the second variable that uniformly has the positive sign and is statistically significant at 1% level in all three efficiency equations. The impact of improved rice varieties on TE, AE and EE is very high. In 2001-2002, AfricaRice conducted a major survey on the impact of improved rice varieties, from both national and international research centers in all West African rice growing environments. The study estimated that genetic enhancement and transfer had increased the value of rice production by $93/ha (Dalton and Guei, 2003).

4.6. Major constraints faced by rice producers in the Gambia

The relative prevalence of abiotic, biotic and socio-economic constraints were assessed in the two main rice growing environments (Upland and Lowland) in the study area in Central River Region North and Central River Region South of the Gambia.

A total of eight abiotic constraints were ranked based on farmer's perception; this ranking includes both soil and climate related constraints which are analyzed in table 4.13 below. Defoer et al, (2002) revealed that abiotic stresses are limiting factors in almost all rice production environments (in both upland and irrigated areas).

Soil related constraints are: poor soil quality (low fertility), salinity, soil erosion and poor water conservation measures. Climate related constraints include: drought, flooding and cold temperature.

Salinity which is caused mainly by salt intrusion in rice fields was ranked the most important constraint in lowland and ranked second in upland ecology. Similar results were reported by WARDA, (1993) in the Senegal River delta, where it was revealed that marine-derived soil salinity is an inherent problem.

Environmental related constraints like drought and cold temperature are ranked second and third under lowland while in the upland cold temperature was ranked at first and drought at fourth. This study is in agreement with Diagne *et al.*, (2013) which found out that an estimated 10% of rice farmers experienced drought affecting 37% of their rice area, causing 29% of rice yield loss. About 70% of rice area in sub-Saharan Africa is rainfed (Diagne *et al.*, 2013), the spatial and temporal variability of rainfall in this region expose rice plants to frequent drought spells.

The least important abiotic constraint under the lowland ecology was flooding, and it is ranked second least under the upland ecology which has registered poor soil quality as the least importance while it was ranked third least in lowland ecology.

Table 4.13: Ranking of abiotic, biotic and socioeconomics constraints

Constraints	Lowland		Constraints	Upland	
	Mean rank	Rank		Mean rank	Rank
			Abiotic		
Salinity	3.53	1	**Cold temperature**	3.67	1
Drought (inadequate water)	3.92	2	**Salinity**	3.70	2
Cold temperature	4.06	3	**Siltation**	4.20	3
Siltation	4.42	4	**Drought (inadequate water)**	4.48	4
Poor water conservation measures	4.53	5	**Soil erosion**	4.52	5
Poor soil quality (low fertility)	4.75	6	**Poor water conservation measures**	4.59	6
Soil erosion	4.94	7	**Flooding**	5.37	7
Flooding	5.86	8	**Poor soil quality (low fertility)**	5.48	8
			Biotic		
Diseases	2.20	1	**Termites**	2.72	1
Weeds	2.55	2	**Diseases**	2.74	2
Termites	2.98	3	**Weeds**	2.87	3
Nematodes	3.38	4	**Birds**	3.09	4
Birds	3.90	5	**Nematodes**	3.57	5

		Socioeconomic			
Small land (farm) size	2.88	1	**Small land (farm) size**	2.90	1
Poor access to the road	3.42	2	**Poor access to the road**	3.70	2
High water fees	3.65	3	**High seed cost**	3.80	3
High seed cost	3.85	4	**High labor cost**	4.02	4
High labor cost	4.40	5	**High water fees**	4.12	5
High fertilizer cost	4.88	6	**High fertilizer cost**	4.52	6
High interest rate of credit	4.92	7	**High interest rate of credit**	4.94	7

Source: Survey Data (2013)

* Mean ranks with lower means show a strong degree of agreements among respondents.

*Ranks of 1, 2, 3 … show most pressing to the least pressing respectively.

Five major biotic constraints were assessed and ranked by farmers in the communities; it should be interesting to note that diseases are ranked to be major biotic constraints that can significantly reduce rice productivity and there are many diseases that affect rice plants. This means that farmers perceived diseases to be of high relative importance.

The importance of weed as major rice production constraints has been reported in several previous studies. Weeds are ranked second and third under the lowland and upland ecology respectively. This result is in agreement with the findings of Samado *et al.* (2008) that found weeds to be the most important biophysical constraint in SSA, with annual losses estimated at around 2.2 million tonnes (Mt).

Though ranked as the least important biotic constraint under the lowland ecology, birds feed on grains before germination, during crop establishment and during grain feeling. They are perceived as major biotic constraints in sub-Saharan Africa (Diagne *et al.*, 2013) and it is recorded as the second to last under the upland ecology while nematodes are ranked the least importance.

Tables 4.13 above also gives an overview of the socioeconomic constraints considered in the study and are ranked based on farmers perception.

Small land size and its related land tenure issues are perceived by farmers as the most important socioeconomic constraint under both the lowland and upland ecology. The key inputs for rice production are ranked in importance by farmers as follows: poor road network ranked in second in both lowland and upland respectively; high seed cost ranked in fourth and third in lowland and upland ecology respectively. High labour cost are ranked in fifth and fourth positions, high fertilizer cost and high interest rate charges on credit are ranked in the sixth and seventh in both lowland and upland ecology respectively and are the least important in both the ecology as perceived by farmers in the study area.

CHAPTER FIVE

5.0. SUMMARY, CONCLUSION AND RECOMMENDATIONS

This is the final chapter which presents the summary of the study, key conclusions and recommendations drawn from the study to guide policy making for relevant stakeholders. Limitations during the study are discussed and finally suggestions are made for future research.

5.1. Summary

The main objective of this study was to evaluate technical, allocative and economic efficiency of rice producers; in Central River Region North and Central River Region South of the Gambia using the stochastic frontier approach. The technical, allocative and economic efficiency were analysed using the Cobb-Douglas production function model among 192 rice farmers in the study area during the 2013 cropping season. Results have revealed that there is a significant level of inefficiency among rice producers as illustrated by the coefficients. Technical efficiency estimates ranges from 0.90 percent to 93.30 percent with a mean efficiency of 65.03 percent, while Allocative efficiency estimates ranges from 1.10 percent to 93.50 percent with a mean of 67.47 percent. The minimum economic efficiency is 0.00 percent, with a mean of 47.76 percent and a maximum of up to 86.20 percent. The result therefore has shown that inefficiency in rice production in the study area is dominated by economic efficiency.

Rice yield per hectare from the study area shows an average of 4.8 Mt/ha from the lowland and 2.2 Mt/ha from the upland. Looking at the average technical, allocative and economic efficiency score clearly reveals that there is room for improvement in rice production and productivity among rice producers in the study area.

In the stochastic frontier production, the explanatory variables, particularly the labour and farm size, have significant effect on rice production. In an effort to improve rice yield, considerable amount of investment in these two variables could be important. Moreover, the recommended dosage of fertilizer and its appropriate use could also result in increasing farmer's rice output per hectare.

Cooperative members are more efficient than those who did not join, as the results have indicated high significant level under TE and EE. This could be owed to the fact that they received benefits like government support and donor's intervention, easy and timely access to inputs on subsidised bases, sharing information on modern rice production activities and interacting with other farmers.

Sampled farmers who use irrigation are more efficient in all three efficiency equations than those who grow rice in other ecologies. Erratic rainfall is the norm in rain-fed rice production system, associated with shortage of water and can lead to drought which makes the farmers inefficient in their production activity.

Varieties cultivated by farmers that is improved rice varieties and traditional has shown a very high positive relationship in the entire efficiency category.

Results on constraints have shown salinity and cold temperature under abiotic ranking as the most important in lowland and upland respectively based on the perception of the farmers; followed by drought and salinity under lowland and upland respectively.

Five major biotic constraints were assessed and ranked by farmers in the communities; diseases, weeds and termites are ranked as the most common biotic constraints that can significantly reduce rice productivity under the lowland ecology. They are also the three most common under the upland and are ranked accordantly as termites, diseases and weeds.

Small land size and its related land tenure issues are perceived by farmers as the most important socioeconomic constraints under both ecologies in the study area; followed by poor access to road, equally under both ecologies.

5.2. Conclusion

The mean technical, allocative and economic efficiency of 65.03%, 67.47% and 47.76% respectively of rice producers across the study area in the Gambia means that farmers are not operating on the production frontier (100% efficient), suggesting that substantial potential exist for increasing rice production with current available technology and resource to farmers. The study reveals that age, member of cooperative, irrigation used and adopters of improved varieties positively influence technical, allocative and economic efficiency.

The three categories of constraints (abotic, biotic and socio-economic) have ranked salinity, diseases and small land sizes as the most important constraints.

5.3. Recommendations

Given the empirical findings the following recommendations are made:

1. Youth involvement in rice production activities is paramount as they are more energetic in accomplishing hard task in farming. Since results have shown that increase in age is positively affecting efficiency, stakeholders in agricultural sector should design programs that will equipped rice farmers especially the youths with more information in rice production. This may result into increased technical, allocative and economic efficiency.

2. Regional Directorates of Agriculture should spearhead the formation of farmer's organization at regional levels and should sensitised farmers who are not members of cooperatives and farmer's organization to join or form their own. Cooperative organization should be used as entry point to sharing information on modern rice production activities and instituting interaction with other farmers on other production activities.

3. Adoption of improved varieties should be encouraged in rice production. Not only can this increase high yield but also creates a sustainable, safe environment, and stable yield for the long-run (Galawat and Yabe, 2011). Therefore, the role of research, extension, NGOs and Projects in introducing new technology to farmers should be encouraged. New technologies positively have an effect on increased productivity and also increase efficiency. Government and donor agencies efforts to enhance research and extension capacities towards the

generation of new technology should be incorporated and adhere to in strategic documents for agricultural development in the country.

4. The three major constraints: salinity, diseases and land size for rice production should be given proper attention in an effort to make the rice producers more productive and food secured as results have shown that they can significantly reduce rice productivity.

5.4. Limitations of the study

Some farmers have been found to have poor record keeping ability. The lack of good record system might be a limitation to validity of some production data provided by such farmers.

Problems encountered during the data collection exercise include loading problem of the Mlax, weakening of the battery which has reduced the possibility of covering more than two farmers per visit. External batteries to support the main power source during administration of the questionnaires were faulty. Failure of modules to open was reported by enumerators especially for some (Food consumptions, household labour, Organization module, fertilizer and equipment use, transaction model & socioeconomic-background) were not opening. Having access to charge the tablet was another problem encountered and finally issues of replacement as some of the farmers were unidentified and some fail to come out to respond to the questions. All of these affect the quality of data collected. The general limitation is the heavy reliance on the memory of the respondents as they don't keep records of their faming activities.

The limitation stated above resulted in the reduction of the sample size from the 200 sampled farmers to 192 rice farmers whose data were finally used for the efficiency measurement.

4.5. Suggestions for future research

For possible future research the following suggestions can be made on the basis of the present study. Cost and benefit analysis of rice production can be an interesting topic to explore. Any further efficiency study in the rice sector should adopt both the SFA and DEA so that results can be compared.

REFERENCES

1. Abdulai, A. and Eberlin, R. (2001): Technical Efficiency during Economic Reform in Nicaragua: Evidence from Farm Household Survey Data. Economic Systems, 25:113-125.

2. Abdulai, A. and W. Huffman. (2000): Structural Adjustment and Economic Efficiency of Rice Farmers in Northern Ghana. *Economic Development and Cultural Change* 43(2000):503-520.

3. Addai, K.N. (2011): Technical Efficiency of Maize Producers in three Agro-Ecological Zones of Ghana'. A Thesis Presented to the Faculty of Agriculture College of Agrculture and Natural Resources, Kwame Nkrumah University of Science and Technology in Partial Fulfillment of the Requirement of Masters of Philosophy in Agric Economics.

4. Adesina, A.A and Djato, K.K. (1996): Farm relative efficiency and agrarian policy in Cote d'Ivoire. Profit function analysis of rice farms. Agricultural Economics 14, 93-102.

5. Afriat, S.N. (1972): Efficiency estimation of production functions. *International Economic Review* 13(1):568-598.

6. Africa Rice Center (AfricaRice), (2011): Boosting Africa's Rice Sector: A research for development strategy 2011-2020. Cotonou, Benin: ii+77 pp.

7. Aigner, D.J and Chu, S.F. (1968): On estimating the industry production function. *American Economic Review* 58(1):826-839.

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

9. Akator, K.S (1981): Method de lutte contre la pyricularious du riz au Togo. In: Proceeding of symposium on Rice Resistant to Blast, Montpellier, France, 18-21 March.

10. Amos, T.T. (2007): Analysis of productivity and technical efficiency of smallholder cocoa farmers in Nigeria. Journal of social science, 15: 127-133.

11. Arega, A.D. (2003): *Improved production technology and efficiency of smallholder farmers in Ethiopia: extended parametric and non-parametric approaches to production efficiency analysis.* Unpublished doctoral thesis. Pretoria: University of Pretoria. [Online] Available from UPeTD: http://upetd.up.ac.za/thesis/available/etd-06132002-085415. [Accessed: *August*, 2013].

12. Ashura, L.K., Mabagala, R.B. and Mortensen C.N. (1999): Isolation and characterization of seed-borne pathogenic bacteria from rice (Oriza sativa L) in Tanzania. Tanzanian Journal of Agricultural Science 2(1), 71-80.

13. Awoderu, V.A., Bangura, N. and John, V.T. (1991): Incidence, distribution and severity of bacterial disease on rice in West Africa. Tropical Pest Management.

14. Bakker, W. (1970): Rice Yellow Mottle, a mechanically transmissible virus disease of rice in Kenya. Netherland Journal of Plant Pathology.

15. Barnes, A. (2008): Technical efficiency estimation of Scottish agriculture: A note, Journal of agricultural economics, 59: 370-376.

16. Battese, G.E. and 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.

17. Battese, G.E. and Coelli, T.J. (1992): Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India. *Journal of Productivity Analysis*, 3(1): 153-169.

18. Battese, G.E. and 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.

19. Becerril, J., and Abdulai, A. (2010): The Impact of Improved Maize Varieties on Poverty in Mexico: A Propensity Score-Matching Approach. *World Development*. doi:10.1016/j.worlddev.2009.11.017.

20. Becker, M. and Johnson, D.E. (1999a): Rice yield and productivity gaps in in irrigated systems of the forest zones of Cote d'Ivoire. Field Crop Research 60, 201-208.

21. Becker, M. and Johnson, D.E. (2001a): Cropping intensity effects on upland rice yield and sustainability in West Africa. *Nutrient Cycling in Agroecosystems* 59, 107-117.

22. Becker, M., Johnson D.E., Wopereis, M.C.S., and Sow, A. (2003): Rice yield gaps in irrigated systems along an agro-ecological gradient in West Africa. Journal of plant nutrient and soil science 166, 61-67.

23. Bidaux, J.M. (1978): Screening for horizontal resistance to rice blast in Africa In: Buddenhagen, I.W. and Persley, G.J. (eds) *Rice in Africa.* Proceeding of a conference held at the International Institute of Tropical Agriculture, Ibadan, Nigeria, 7-11 March, 1977. Academic press London, New York, San Francisco.

24. Bittage, A., Drammeh, E. and Jones, K. (2002): Economic Impact Assessment of the Rice Research Program in The Gambia [Online]. Available from: http://www.agecon. purdue.edu/staff/masters/ImpactCD/Etudes/ Rice-Gambia.doc (Accessed: May 2013).

25. Bravo–Ureta, B. E., and Evenson, R. E. (1994): Efficiency in Agricultural Production: The Case of Peasant Farmers in Eastern Paraguay. *Agricultural Economics*, **10**: 27–37.

26. Bravo-Ureta, B.E. and Pinheiro, A.E. (1997): Technical, economic, and allocative efficiency in peasant farming: evidence from the Dominican Republic. *The Developing Economies*, 35(1):48–67.

27. Buddenhagen, I.W., Vuong, H.H and Ba, D.D. (1979): Bacterial Blight found in Africa. *International Rice Research Newsletter 4, 11.*

28. Carter, M.R. and K.D. Wiebe. (1990): Access to capital and its impact on agrarian structure and productivity in Kenya. American journal of agricultural economics, 72: 1146-1150.

29. CEDEAO (2006): Strategy Regional de promotion des Engrais en Africa de L'ouest. Presented at the sommet Africa sur les Engrais, Abuja Nigeria 9-13 June. Economic Community of West African States, Abuja Nigeria.

30. Ceesay, M. M. (2004): 'Management of rice production systems to increase productivity in the Gambia, West Africa'. A Dissertation Presented to the Faculty of the Graduate School of Cornell University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy.

31. Cheryl, D.R., W.Mwangi, H. Verkuijl, and De Groote, (2003): Adoption of Maize and wheat Technologies in Eastern Africa. A synthesis of the findings of 22 case studies. CIMMYT Economics Working Paper 03-06. Mexico, D.F: CIMMYT.

32. Chukwuji, C. O., O. E. Inoni and P. C. Ike. (2007): Determinants of Technical Efficiency in Gari in Delta State, Nigeria. *Journal of Central European Agric*., 8(3): 327-336.

33. Coelli, T. J. (1996): A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation. CEPA Working Paper 96/07. University of New England, Armidale, Australia.

34. Coelli, T. J. (1996b): Specification and estimation of stochastic frontier production function. Unpublished PhD Dissertation, University of New England, Australia.

35. Coelli, T.J., Rao, D.S.P., O"Donnell, C.J. & Battese, G.E. (2005): *An introduction to Efficiency and Productivity Analysis*. Second Edition New York: Springer Publication.

36. Coelli, T.J., Rehman, S. and Tirtle, C. (2002): Technical, Allocative, Cost and Scale Efficiencies in Bangladesh Rice Cultivation: A Non-Parametric Approach". *Journal of Agricultural Economics*, 533607-606.

37. Coelli,T., Rao, D.S.P. and Battese, G.E. (1998): An Introduction to Efficiency and Productivity Analysis. Kluwer-Nijhoff, Boston.

38. Dalton, T.J. and Guei, R.G. (2003): Productivity gains from rice genetic enhancements in West Africa: countries and ecologies. World Development 31, 359-374.

39. Debreu, G. (1951): The coefficient of resource utilisation. *Econometrica*, 19(1):273-292.

40. Defoer, T., Woperreis, M.C.S., Jones, M.P., Lancon, F. and Erenstein, O. (2002): Challenges, innovations and change: towards rice based food security in sub-Saharan Africa. Paper presented at the 20th session of the international rice commission, Bangkok, 22-25 July.

41. Delassus, M (1973): Lutte chimique contre la pyriculariouse du riz en Casamance (Senegal). In: Seminairen ADRAO sur la protection des plantes en riziculture, Monrovia, Liberia.

42. Diagne, A., Alia, D.Y., Assagba, E.A., Wopereis, M.C.S., Saito, K. and Nakelse, T. (2013): Farmers Perceptions of the Biophysical Constraints to Rice Production in Sub-Saharan Africa, and Potential Impact of Research. Africa Rice Center (AfricaRice), Cotonou, Benin.

43. Diagne, A., Alia, D.Y., Wopereis, M.C.S. and Saito, K. (2012): Impact of rice research on income and poverty in Africa: an ex-ante analysis. Paper presented at the International Association of Agricultural Economics 28th Triennial Conference, Foz do Iguacu, Brazil, 18-24 August.

44. Diagne, A., Assagba, E.A., Futakuchi.K. and Wopereis, M.C.S. (2013): Estimation of Cultivation Area, Number of Farming Household and Yield for Major Rice Growing Environment in Africa. Africa Rice Center (AfricaRice), Cotonou, Benin.

45. Dibba, L., Fialor, S.C., Diagne, A. and Nimoh, F. (2012): The impact of NERICA adoption on productivity and poverty of the small scale rice farmers in the Gambia. Rice. Food Security: The Science, Sociology and Economic of Food Production and Access to Food 4(2), 253-265.

46. Dolisca, F. C. and M. Jolly. (2008): Technical efficiency of traditional and nontraditional crop production: A case study from Haiti. World Journal of Agric. Sciences, 4(4): 416-426.

47. Douglas, K. (2008): Analysis of the impact of the agricultural productivity enhancement program on the technical and allocative efficiency of maize farmers in Masindi District: MSc. Thesis, Makerere University Kampala Uganda.

48. El-Namaky, R. (2011): Technical Progress Report on the Green Super Rice (GSR) Project. Africa Rice Center, Cotonou, Benin.

49. FAO, (2002): Structural Adjustment Policies and the Agricultural Sector, Theoretical Concepts for Analysis of Economic Policies: The Salter-Swan-Model, http://www.fao.org/tc/tca/31chap8.htm.

50. FAO (2012): FAOSTAT http://faostat.fao.org/ (accessed April 2012).

51. Farrell, M.J. (1957): The measurement of Productive efficiency. *Journal of Royal Statistical Society*. series A, 120:253-290.

52. Fofana, B., Bandaogo, A., Sano, S., Youls, S. and Mando, A. (2010): Improving rice productivity in Africa through deep placement of Urea superphosphate. Presented at the 3rd International Rice Congress, Hanoi, Vietnam, 8-12 November.

53. Fomba, S.N. and Taylor, D.R. (1994): Rice Blast in West Africa: its nature and control. In: Zeigler, R.S., Leong, S.A. and Teng, P.S (eds) Rice Blast Disease. CAB International, Wallingford, UK and international Rice Research Institute, Los Banos, Philippines.

54. Galawat, F. and Yabe, M. (2011): Evaluation of Technical, Allocative and Economic Efficiency in Rice Production. Faculty of Agriculture, Kyushu University Japan 57(1), 317-325.

55. Gambia, (2009): The Gambia Agricultural and Natural Resources Sector Policy Document. (ANR) Policy; 2009-2015.

56. GBoS, (2013): Preliminary National Population and Housing census draft report. Gambia Bureau of Statistic, Banjul, the Gambia.

57. Greene, W.H. (1980): Maximum likelihood estimation of econometric frontier functions. J. Economet., 13: 27-56.

58. GRiSP, (2010): Global Rice Science Partnership Annual Report: International Rice Research Institute, Los Banos, Philippines; Africa Rice Center, Cotonou, Benin; and International Center for Tropical Agriculture, Cali, Colombia.

59. Haefele, S.M. and Wopereis, M.C.S. (2004): Combining Field and Simulation Studies to improve fertilizer recommendations for irrigated rice in the Senegal River Valley. Science Publishers, Enfield, New Hampshire and International Rice Research Institute, Los Banos, Philippines, pp. 265-268.

60. Haefele, S.M., Saito, K., Kabirou, M., N'Diaye, S., Mussgnug, F., Nelson, A. and Wopereis, M.C.S (2013): Increasing rice productivity through improving Nitrogen use in Africa. Africa Rice Center (AfricaRice), Cotonou, Benin.

61. Hien, T. M., Kawaguchi, T. and Suzuki, N. (2003): A Study on Technical Efficiency of Rice Production in The Mekong Delta– Vietnam by Stochastice Frontier Analysis. *Journal of Faculty of Agriculture*, Kyushu University **48**(1.2): 325–357.

62. Huang, M., C.J. Huang, and T. Fu. (2002): Cultivation Arrangements and the Cost Efficiency of Rice Farming in Taiwan." *Journal of Productivity Analysis* 18(2002):223-239.

63. International Rice Research Institute, (1975): Major research in upland rice Los Baios, Philippines. International Rice Research Institution http://irri.org/about-rice/rice-facts/rice-basic.

64. Issaka, R.N., Ishida, F., Kubota, D., Wakatsuki, T., (1997): Geographical distribution of selected soil fertility. Parameters of inland valleys in West Africa Geoderma 75, 99-116.

65. Jaiteh, S.B.W, (2003): Transformation of the Gambian Rice Sub-Sector through a Target-based Production system. Department of State for Agriculture (DOSA) Republic of the Gambia. Retrieved on 19th November, 2013, from the World Wide Web: http://www.warda.cgiar.org/workshop/RicePolicy/Suruwa%2520B.Gambi.Pres.ppt.ppt.

66. Jobe, L.M.S., Sanyang, S. and Darboe, M.L. (2002): Response of some improve exotic rice varieties to blast, *Pyricularia orizae* in the Gambia. Paper Presented at second Regional Rice Research Review (4Rs), Bouake, Cote d'Ivoire.

67. Jondrow, J., C.A.K Lovell, I.S. Materov and P. Schmidt, (1982): On the estimation of technical inefficiency in stochastic frontier production function model". *Journal of Econometrics, 19: 233-38.*

68. Kabwe. M, (2012): Assessing Technical, Allocative and Economic Efficiency of Smallholder Maize Producers Using Stochastic Frontier Approach in Chongwe District Zambia: Msc Agricultural Economics Thesis University of Pretoria South Africa.

69. Khanna, G. (2006): Technical Efficiency and Resource Use in Sugar Cane: A Stochastic Frontier Production Analysis, IHEID Working Papers 15-2006, Economic Section, The Graduate Institute Of International Studies.

70. Kibaara B.W. (2005): Technical efficiency in Kenyan's maize production: an application of the stochastic frontier approach, Colorado State University, USA.

71. Koopmans, T.C. (1951): An analysis of production as an efficient combination of activities. In T.C. Koopmans, (Ed) *activity analysis of production and allocation,*

Cowles commission for research in economics. Monograph no.13. New York: John Wiley & Sons.

72. Kouassi, N., NGuessan, P., Albar, L., Fauquet, C. and Brugidou, C. (2005): Distribution and Characteristics of Rice Yellow Mottle Virus. A threat to African Farmers. Plant Disease 89, 124-133.

73. Kumar, G.S., A. Rajarajan, N. Thavaprakash, C. Babu and R. Umashankar, (2008): Nitrogen use efficiency of rice (Oryza sativa) in systems of cultivation with varied in levels under N tracer technique Asian J. Agric. Res., 2: 37-40.

74. Kumashiro, T., Futakuchi, K., Sie,M., Ndjiondjop, M.N. and Wopereis, M.C.S (2013): A continental-Wide product oriented approach to rice breeding in Africa. Africa Rice Center (AfricaRice), Cotonou, Benin.

75. Kumbhaker, S. C. and Lovell C. A. K. (2000): *Stochastic Frontier Analysis*. Cambridge: Cambridge University Press.

76. Meeusen, W. and Van, D.B. (1977): Efficiency estimation from Cobb-Douglas production functions with composed Error. *International Economic Review*, 18(2):435-444.

77. Menete, M.Z.L., Van Es, H.M., Brito, R.M.L., DeGloria, S.D and Famba, S. (2008): Evaluation of System of Rice Intensification component practices and their synergies on salt-affected soils. Field Crop Research 109, 34-44.

78. Menete, M.Z.L., Van Es, H.M., Brito, R.M.L., DeGloria, S.D and Famba, S. (2008): Evaluation of System of Rice Intensification component practices and their synergies on salt-affected soils. Field Crop Research 109, 34-44.

79. Moreno, G., and Sunding, D. L. (2005): Joint estimation of technology adoption and land allocation with implications for the design of conservation policy. *American Journal of Agricultural Economics, 87*, 1009–1019.

80. Murillo-Zamorano, and Luis, R. (2004): Economic Efficiency and Frontier Techniques. Journal of Economic Survey, Vol.18 (No1), 33-45.

81. NARI, (2013): Cereal Programe Report on Yield Gap Survey. National Agricultural Research Institute, Banjul, the Gambia.

82. NASS, (2013): National Agricultural Sample Survey Report. Planning Services Unit of the Department of Agricultural, Ministry of Agricultural, Banjul, the Gambia.

83. Nchare, A. (2007): Analysis of Factors Affecting the Technical Efficiency of Arabica Coffee Producers in Cameroon" Final Report Presented AERC Biennial Research Workshop, Nariobi, Kenya.

84. Ndikumana, I., Gasore, R., Issaka, S., Pinel-Gaizi, A., Onasanya, A., Hassini-Mehraban, A., Fargette, D., Peters, D. and Sere, Y. (2011): *Rice Yellow Mottle Virus* in rice in Rwanda. First report and evidence of strain circulation.

85. Norton, G. W. and J. Alwang. (1993): Comparative Agriculture Systems and the Role of Women. *In* "Introduction to Economics of Agricultural Development". McGraw–Hill Inc. Ch. 9 pp.149–166.

86. Nutsugah, S.K., Twumasi, J.K., Chipili, J., Sere, Y. and Sreenivasaprasad, S. (2008): Diversity of the blast Pathogen population in Ghana and strategies for resistant management. Plant Pathology Journal.

87. Oerke, E.C. (2005): Crop losses to pests. Journal of Agricultural Science 143, 31-43.

88. Ogundari. K and S. O. Ojo, (2006): An examination of technical, economic and allocative efficiency of small farms: the case of cassava farmers in Osun State of Nigeria. Journal of Central European Agriculture, 7(3):423-432.

89. Ogundele F. O and Okoruwa, V. O. (2006): A comparative analysis of technical efficiency between traditional and improved rice variety farmers in Nigeria. Afr.J.Econ.Policy, 11:91-108.

90. Ogunniyi, L.T., Adepoju, A.A. and Ganiyu, M.O. (2012): A comparative Analysis of Economic Efficiency Between Traditional and Improved Rice Varieties Farmers on Oriade Local Government Area of Osun State. Trends in Agricultural Econ 5(3): 70-82

91. Ouedraogo, S.L., Somda, I. and Sere, Y. (2007): Etude de la resistance au fletrissement bacterien de lignees inter- et intraspecifiques de riz de bas-fonds en conditions d'infestation artificielles. Africa Crop Science Journal.

92. Owuor, G. and Shem, O. A. (2009): What Are the Key Constraints in Technical Efficiency of Smallholder Farmers in Africa? Empirical Evidence from Kenya. A Paper Presented at 111 EAAE-IAAE Seminar 'Small Farms: decline or persistence' University of Kent, 26-27th June.

93. Owusu, V. And Donkor, E. (2012): Adoption of improved cassava varieties in Ghana: Agricultural Journal 7(2): 146-151.

94. PAGE, (2011): Programme for Accelerated Growth and Employment, Ministry of Finance and economic Affairs Quadrangle, Banjul the Gambia: Page 6.

95. Penning de Vries, F.W.T. and Rabbinge. R. (1995): Model in research and education, planning and practice. P. 1-18. In: A.J. Haverkort and D.K.L. MacKerron (eds.)

Potato ecology and modelling of crops under conditions limiting growth. Current Issues in Production Ecology, Vol.3. Kluwer, Dordrecht.

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

97. Raghbendra, J., Hari, K.N. and D.P. Subbarayan. (2005): Land fragmentation and its implications for productivity: Evidence from Southern India, Australia South Asia Research Centre (ASARC) working paper 2005/01.

98. Rahman, S. (2003): Profit Efficiency among Bangladesh Rice Farmers. *Food Policy, Elsevier* **28**: 487–503.

99. Rechaus, P.H. (1983): Occurrence of Bacterial Blight of Rice in Niger, West Africa. Plant Disease 67, 1039.

100. Remington, T., Maroko, J., Omanga, P. and Charles, E. (2002): Getting off the seeds and tools tread with CRS seed vouchers and fairs. The journal of Disease Studies, Policy and Management 26(4), 316-328.

101. Richmond, J. (1974): Estimating the efficiency of production. *International Economic Review* 15(1):515-521.

102. Rickman, J., Moreira, J., Gummert, M. and Wopereis, M.C.S. (2013): Mechanizing Africa Rice Sector. Africa Rice Center (AfricaRice), Cotonou, Benin.

103. Rodenburg, J. and Johnson, D.E. (2009): Weed Management in rice-based Cropping Systems in Africa. Advances in Agronomy 102, 149-218.

104. Rodenburg, J., Both, J., Heitkonig, I.M.A., Van Koppen, C.S.A., Sinsin, B., Van Mele, P. and Kiepe, P. (2012): Land use and biodiversity in unprotected landscapes: the case of non-cultivated plant use and management by rural communities in Benin and Togo. Society and Natural Resources 25(12), 1221-1224.

105. Saito, K. and Futakuchi, K. (2009): Performance of diverse upland rice cultivars in low and high soil fertility conditions in West Africa. Field Crop Research 111, 243-250.

106. Samado, E.A., Guei, R.G. and Keya, S.O. (2008): NERICA: The New Rice for Africa- A Compendium. Africa Rice Center, Cotonou, Benin.

107. Schmidt, P. (1986): Frontier Production functions, Econometric Rev., 4: 289-328.

108. Schmidt, P., and LoveIl C.A.K. (1979): Estimating Technical and Allocative Inefficiency Relative to Stochastic Production and Cost Frontiers. ***Journal of Econometrics 9(1979): 343-66.***

109. Seck, P.A., Diagna, A., Monthy, S. and Woperies, M.C.S. (2012): Crop that feed the world 7: rice. *Food security* 4(1), 7-24.

110. Seck, P.A., Toura, A.A., Coulibaly, J.Y., Diagna, A. and Woperies, M.C.S. (2012): Africa's Rice Economy Before and After the 2008 Rice Crisis. Africa Rice Center (AfricaRice), Cotonou, Benin.

111. Sentumbwe Samuel, (2007): Intra-House Labour Allocation and Technical Efficiency among Groundnuts Producers in Eastern Uganda. MSc. Thesis, Makerere University Kampala Uganda.

112. Sere, Y., Onasanya, A., Akator, K., Afolabi, A and Abo, M.E. (2007): Serological differentiation indices and phylogenetic analysis of Rice yellow mottle virus isolates in Cote d'Ivoire. Journal of Biological Sciences 7(7), 1147-1154.

113. Sere, Y., Onasanya, A., Vverdier, V., Akator, K., Ouedraogo, L.S., Segda, Z., Coulibaly, M.M., Sido, A.Y. and Basso, A. (2005): Rice bacterial leaf blight in West Africa: preliminary studies on disease in farmers' fields and screening released varieties for resistance to the bacteria. Asian Journal of Plant Sciences.

114. Sere, Y., Sy, A.A., Sie, M., Onasanya, A., Akator, S.K., Kabore, B., Conde, C.K., Traore, M. and Kiepe, P. (2011): Importance of varietal improvement for blast disease control in Africa. In: Yanagihara, S. (ed) Next Challenge in rice Development in Africa. Workshop for New Collaboration between JIRCAS and AfricaRice. JIRCAS workshop report 70. Africa Rice Center, Cotonou, Benin and Japan International Research Center for Agricultural Science, Tsukuba, Japan.

115. Seyoum, E.T., Battese G. E. and Fleming E.M. (1998): Technical Efficiency and Productivity of Maize Producers in Eastern Ethiopia: A Study of Farmers within and Outside the Sasakawa-Global 2000 Project. Agricultural Economics, 19:341-348.

116. Sheehy, J.E., Peng, S., Dobernmann, A., Mitchell, P.L., Ferrer, A., Yang, J., Zou, Y., Zhong, X. and Huang, J. (2004): Fantastic yields in the system of Rice Intensification: fact or fallacy? Field crop research 88, 1-8.

117. Shehu, J. F., S. I. Mshelia, and A. K. Tashikalma (2007): Analysis of Technical Efficiency of Small–scale Rain–fed Upland Rice Farmers in North–west Agricultural Zone of Adamawa State, Nigeria. Journal of Agriculture and Social Sciences 3(4): 133–136.

118. Stepp, J.R. and Moerman, D.E. (2001): The importance of weeds in ethno-pharmacology. Journal of Ethno pharmacology 75, 19-23.

119. Sy, A.A and Sere, Y. (1996): Manuel de formation en pathologies du riz. Association pour le Development de la Riziculture en Afrique de l'Ouest, Bouake, Cote d'Ivoire.

120. Tchale, H. (2009): The efficiency of small Agriculture in Malawi. Africa journal of agriculture and resource economics (AFJARE). 3(2)101-121.

121. Thresh, J.M., Chancellor, T.C.B., Holt, J., Kimmins, F. and Zeigler, R.S. (2001): Comparative epidemiology of virus diseases of tropical rice. In: Sy, A.A., Hughes, J. and Diallo, A. Rice Yellow Mottle Virus (RYMV): Economic importance, diagnosis and management strategies. West African Rice Development Association, Bouake, Code d'Ivoire.

122. Tiamiyu, S.A., Akintola, J.O. and Rahji, M.A.Y. (2010): Production efficiency among growers of new rice for Africa in the Savanna Zone of Nigeria.

124. Timmer, C.P. (1971): Using a probabilistic frontier function to measure technical efficiency. *Journal of Political Economy* 79(1):776-794.

125. Tittonell, P. and Giller K.E. (2013): Field Crops Research 143 (2013) 76–90.

126. Traore, O., Pinel-Gaizi, A., Sorho, F., Sarra, S., Rakotomalala, M., Sangu, E., Kenyeka, Z., Sere, Y., Konate, G. and Fargette, D. (2009): A reassessment of the epidemiology of Rice Yellow Virus following recent advances in field and molecular studies.

127. Trinh, T.T. (1980): New Rice Disease and Insect in the Senegal River Basin in 1978/79. *International Rice Commission Newsletter 29, 37.*

128. Tsujimoto, Y., Horie, T., Randriamihary, H., Shiraiwa, T. and Homma, K. (2009): Soil Management the key factors for higher productivity in the fields utilizing the System of Rice Intensification (SRI) in the central high land of Madagascar. Agricultural System 100, 61-71.

129. UNDP, (2014): United Nation Development Programmes Human Development Report. World Map Indicating the Categories of Human Development Index by Country based on the 2013 Data. Published on July, 24, 2014.

130. USDA, (2013): Production, supply and Distribution online. Foreign Agricultural Services United States Department of Agriculture. www.fas.usda.gov/psdonline/psdquery.aspx (accessed 7 February, 2013).

131. Verma, B. and D.W. Bromley. (1987): The political economy of farm size in India: The collusive quest Economic development and cultural change, 35: 791- 808.

132. Viatte, G., De Graaf, J., Demeka, M., Takahatake, T. and Rey de Arce, M. (2009): Responding to the food crisis: Synthesis of medium term measures proposed in inter-agency assessments. Food and Agricultural Organization of the United Nation, Rome, Italy.

133. Vodouche, S.R., Ojegui, M. and Amadji, F. (1981): Impact of blast on rice cultivation in people's republic of Benin. In: Proceeding of symposium on Rice Resistant to Blast, Montpellier, France, 18-21 March.

134. Wadud, A. and White, B. (2000): Farm Household Efficiency in Bangladesh: A Comparison of Stochastic Frontier and DEA Methods. Applied Economics, 32(13): 1665–73.

135. WARDA (1999a): ROCARIZ Strategic Plan. A proposal submitted to the United State Agency for International Development. West African Rice Development Association Bouake, Cote D'Ivoire.

136. Wopereis, M.C.S., Diagne, A., Johnson, D.E. and Secka, P.A. (2013): Realizing Africa Rice Promise: Priorities for Africa. Africa Rice Center (AfricaRice), Cotonou, Benin pp424-436.

137. Wopereis-Pura, M.M., Watanabe, H., Moreira, J. and Wopereis, M.C.S. (2002): Effect of late Nitrogen application on rice yield, grain quality and profitability in the Senegal river valley. Europe Journal of Agronomy 17, 191-198.

138. Zimdahl, R.L. (2007): Fundamentals of weed science. Academic Press London.

APPENDICES

Appendix A: Questionnaire

kwame nkrumah university of science and technology

department of agricultural economics, agribusiness and extension, kumasi – ghana farm level survey questionaire: evaluation of technical, allocative and economic efficiency of rice producers in the gambia

Respondent I D #...............
Date………………………

Questionnaire for Rice Producers:

A. PERSONAL & HOUSEHOLD CHARACTERISTICS

1. Gender of respondent
1=Male [ ]
0=Female [ ]

2. Age of respondent……………………years

3. Marital status
1=Married [ ]
2=Single [ ]

4. Religion
1=None [ ]
2=Christian [ ]
3=Muslim [ ]
4=Traditionalist [ ]
5=Others (Specify)……………………………………..

5. Ethnicity
1=Mindinko [ ]
2=Fulla [ ]
3= Wolof [ ]
4=Jola [ ]
5=Sarahuleh[ ]
6=Others (Specify)……………………………………..

6. How many members are you in your household? ....

7. (i) Do you belong to any farmers organization/cooperative?
1=Yes [ ]
0=otherwise [ ]

(ii) If yes, which farmer/s organization?............................., ……………………
(iii) Do you receive any of the following assistance from the farmer organisation? Tick the appropriate box.

Assistance	Yes	No
Technical Assistance/Training		
Access to input		
Machinery services		
Equipment		
Credit in kind		
Credit in Cash		
Storage		
Marketing Services		
Transportation of inputs/products		

8. What are the name and description of the ecology where rice is grown in the village?

Local name of the ecology	Type of ecology (see code)

Code type of ecology: Type of ecology: 1=Upland, 2= Lowland, 3= Mangrove, 5= other (specify)

B. FARM RESOURCES (Land, Labour, Capital and Management)
(B)(i) LAND:

9. How many plots of lands do your cultivate in 2012 cropping season? ....

	Size(Ha)	Location	Ownership	Suitability	Cost per Ha
Plot 1					
Plot 2					
Plot 3					
Plot 4					
Plot 5					

Location: 1= Compound farm, 2= Location farm

Ownership: 1= Owner, 2= Tenant
Suitability: 1= Very suitable, 2= Suitable, 3= Not suitable

10. How far is your farm to the nearest market? ....km

(B)(ii) Labour:

11. Indicate the type and number of labour used and rate paid (Man-days) during the production period.

Activity	Type of Labour			Labour Availability	Tractor	Animal Traction	Labour Cost		Machinery Cost	Time of Operation
	Family	Hired	Cooperative				Cash	Food		
Clearing										
Plowing										
Bunding										
Leveling										
Seeding/transplanting										
Bird Scaring / Field Guarding										
Weeding										
Fertilizer application										
Herbicide application										
Water management										
Harvesting										

Labour Availability: 1=Readily Available 2= Available 3= Scares

(B)(iii). 1 Capital: Variable inputs**:**

12. Indicate the type and number of variable inputs used?

Input of Type	Unit of Measurement	Quantity used per Ha	Unit Cost	Total Coat
Seed				
Fertilizer				
Herbicide				
Pesticide				

(B)(iii). 2 Capital: Fixed Input (Machinery and Equipment)

13. Indicate the type and number of fixed inputs used?

Type of Machinery Equipment	Number on Farm	Unit Cost	Year of Purchase	Useful Life
Tractor				
Power Tiller				
Animal Traction				
Cutlasses				
Hoes				
Rakes				
Shovel				
Basket				
Sacks				

(B)(iv). Credit:
14. (i) Did you have access to credit for the 2012 cropping season?
1=Yes [ ]
0=Otherwise [ ]

(ii) If yes, provide the information below

Type	Sources	Quantity	Interest Rate	Repaymen t Period (Months)	Availabilit y	Other Coat
Cash						
Kinds						
Others						

Source of credit: 1= Formal Bank, 2= Money Lenders, 3= Friends, 4= Family/Relatives 5= Others Specify
Availability: 1=Readily Available 2= Available 3= Scares

(B)(v). Management:
15. (i)Have you ever attended formal education?
1= Yes [ ]
2= Otherwise [ ]

(ii)If yes, what is the level of formal education achieved?

1= Basic [ ]
2= Secondary [ ]
3= Tertiary [ ]
0= Otherwise (Specify)……….

16. How long have you been producing rice? ....years

17. (i) Did you have access to extension service for the 2012 cropping season ?
1=Yes [ ]
0=Otherwise [ ]

(ii) If yes, what is the source of the advice?
1= Extension [ ]
2= NGOs [ ]
3= Others Specify?.............

(iii) How often are you visited by this agents (number of extension contacts per cropping season)?
1=Once [ ]
2=Twice [ ]
3=Thrice [ ]
4=More than 3 times [ ]

(iv)What type of advice do you received from these agents?
1= Agronomic [ ]
2= Pest and Diseases [ ]
3= Other Specify…………..

18. Have you ever attended training related to rice production?
1=Yes [ ]
0=Otherwise [ ]

C. FARM PRODUCTION

19. What is the source of water for rice production in the community?

1= Rainfall [ ]
2= Irrigation [ ]
3= Otherwise [ ]

20. What type of rice variety/ies did you grow in 2012 cropping season?

1=NERICA [ ]
2=ATM [ ]
3=P104 [ ]
4=SEEDY JARJU [ ]
5=Others Specify………………

21. Methods of rice Production?

Farm Production	Method	Time of Planting	Time of Fertiliser Application	Time of Weeding	Period of Harvesting
Plot 1					
Plot 2					
Plot 3					
Plot 4					
Plot 5					

D. RETURNS:

22. Quantity of rice produced and the usage in 2012 Harvest Period.

Plot	Quantity Harvested	Sold	Consumed	Seed	Gift	Total	Price per Kg
1							
2							
3							
4							
5							

E.POST HARVEST ISSUES:

23. Indicate the post-harvest issues and answer the questions that follow?

Activity	Type of Labour			Labour Availability	Tractor	Animal Traction	Labour Cost		Machinery Cost	Time of Operation
	Family	Hired	Cooperation				Cash	Food		
Threshing										
Winnowing										
Drying										
Parboiling										
Milling										
Transport										

Labour Availability: 1=Readily Available 2= Available 3= Scares

F.CONSTRAINTS IN RICE PRODUCTION:

24. Rank all the following constraints across the ecologies under which you grow rice?

	Ranking of constraints (coded) in each ecology		
List of Constraints	**Upland**	**Lowland**	**Mangrove**
Pest and Disease incidence			
Poor Soil			
Water			
High Cost of Inputs			
Low price of output			
Lack of Market			
High rent for land for farming			
Equipment and Infrastructures			
Access to Extension Services			

Code: 1= High; 2= Medium; 3= Low; 0= Non existent (not a constraint/has never experienced); 99= don't know

Appendix B: Empirical Studies on Efficiency Measurement of Rice Production

Author(s)	Country	Efficiency Approach a	Data Set	Mean Efficiency Results b
Bäckman et al. (2011)	Bangladesh	SFA	Cross-Section in 2009, 360 farms	TE = 0.83
Zahidul Islam et al. (2011)	Bangladesh	DEA	Cross-Section in 2008-2009, 355 farms	TE(CRS) = 0.63, TE(VRS) = 0.72, AE(CRS) = 0.62, AE(VRS) = 0.66, EE(CRS) = 0.39, EE(VRS) = 0.47
Khan et al. (2010)	Bangladesh	SFA	Cross-Section in 2007, 150 farms	Aman Rice Farmers TE = 0.91 Boro Rice Farmers TE = 0.95
Rahman et al. (2009)	Thailand	SFA	Cross-Section in 1999-2000, 348 farms	TE = 0.63
Kiatpathomchai (2008)	Thailand	DEA	Cross-Section in 2004-2005, 247 farming households	TE(VRS) = 0.87 AE(VRS) = 0.78 EE(VRS) = 0.68
Nhut (2007)	Vietnam	DEA	Cross-Section in 2005, 198 farms	TE(VRS) = 0.92 AE(VRS) = 0.81 EE(VRS) = 0.75
Brázdik (2006)	Indonesia	DEA	Pannel Data (160 farms, 6 growing periods: n = 960)	TE(CRS) = 0.59, TE(VRS) = 0.65 (Pooled Frontier)
Chauhan et al. (2006)	India	DEA	Cross-Section in 2000-2001 (97 farms)	TE(CRS) = 0.77, TE(VRS) = 0.92

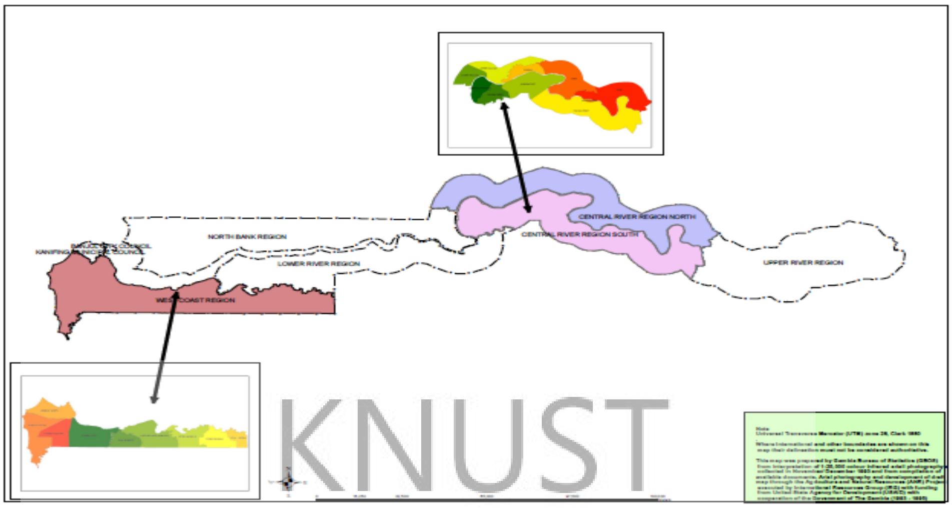
Dhungana et al. (2004)	Nepal	DEA	Cross-Section in 1999, 76 farming households	TE(CRS) = 0.76, TE(VRS) = 0.82, AE(CRS) = 0.87, EE(CRS) = 0.66
Krasachat (2004)	Thailand	DEA	Cross-Section in 1999, 74 farming households	TE(CRS) = 0.71, TE(VRS) = 0.74
Coelli et al. (2002)	Bangladesh	DEA	Cross-Section in 1997, 406 farms	Aman Rice Farms: TE(VRS) = 0.66, AE(VRS) = 0.78, EE(VRS) = 0.52 Boro Rice Farms: TE(VRS) = 0.69, AE(VRS) = 0.81, EE(VRS) = 0.56
Huang et al. (2002)	Taiwan	SFA	Cross-Section in 1998, 348 farms	EE = 0.81
Abdulai and Huffman (2000)	Ghana	SFA	Cross-Section in 1992, 256 farms	PE = 0.73
Wadud and White (2000)	Bangladesh	SFA, DEA	Cross-Section in 1997, 150 farms	TE(SFA) = 0.79 TE(CRS) = 0.79 TE(VRS) = 0.86
Xu and Jeffrey (1998)	China	SFA	Cross-Section in 1985 and 1986, 180 farming households	Hybrid Rice: TE = 0.85, AE = 0.72, EE = 0.61 Conventional Rice: TE = 0.94, AE = 0.88, EE = 0.83

Audibert (1997)	West Africa	SFA	Cross-Section in 1989 and 1990, 1671 farming households	TE = 0.68
Tadesse and Krishnamoorthy (1997)	India	SFA	Cross-Section in 1992-1993, 129 farms	TE = 0.83
Battese and Coelli (1992)	India	SFA	Panel Data of 38 farms, 1975 - 1985	Mean TE Range from 0.81 (1975-1976) to 0.94 (1984-1985)
Dawson et al. (1991)	Philippines	SFA	Subsample of 22 farms, (1970, 1974, 1979, 1982, 1984)	TE = .89

A SFA = Stochastic frontier production approach; DEA = Data envelopment analysis.

B TE = Technical efficiency; AE = Allocative efficiency; EE = Economic efficiency; CRS = Constant returns to scale; VRS = Variable returns to scale. PE (Abdulai and Huffman 2000) = Profit efficiency.

Appendix C: Map of the Gambia showing the study area



Source: GBoS

Appendix D: Map of the study area (Central River Region North & South of the Gambia)