ECONOMICS OF TECHNOLOGICAL CHANGE IN RICE PRODUCTION IN THE EJURA-SEKYEDUMASE AND ATEBUBU-AMANTIN DISTRICTS, GHANA

By
Edward Tsinigo,
BSc Agriculture Technology (Hons.)

A Thesis submitted to the Department of Agricultural Economics, Agribusiness, and Extension, Kwame Nkrumah University of Science and Technology in partial fulfilment of the requirements for the degree of

MASTER OF PHILOSOPHY IN AGRICULTURAL ECONOMICS

Faculty of Agriculture
College of Agriculture and Renewable Natural Resources

JANUARY 2014

DECLARATION

I, Edward Tsinigo, hereby declare that this submission is my own work towards the MPhil Agricultural Economics and that, to the best of my knowledge, it contains no material previously published by another person nor 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.

Edward Tsinigo (PG5302411) ……………………... ……………………...
Student's Name & ID Signature Date

Certified by:

Dr. K. Ohene-Yankyera ……………………... ……………………...
(Major supervisor) Signature Date

Dr. S. C. Fialor ……………………... ……………………...
(Minor supervisor) Signature Date

Dr. Dadson Awunyo-Vitor ……………………... ……………………...
(Head of Department) Signature Date

ABSTRACT

Globally, technological change in rice production has ushered in an era of agricultural transformation and has increased economic incentives for farmers. However, such gains appear to be unevenly distributed among farmers. This study, therefore, examined the economics of technological change in rice production in the Ejura-Sekyedumase and Atebubu-Amantin Districts of Ghana. Specifically, the study established whether the improved variety increases the cost of production and returns than did the traditional variety. It also evaluated the nature and magnitude of rice productivity due to the shift from the traditional to the improved rice varieties. Further, the study isolated the sources of productivity differences between the two varieties. The study was largely descriptive using the survey method. The study sampled 208 rice farmers from the two districts using a three-stage stratified random sampling method. Data were collected using a semi-structured questionnaire and an interview guide. The independent samples t-tests, Cobb-Douglas production, and a modified output decomposition analyses techniques were used to analyse the data. The study found that the per hectare cost of production, gross returns, and gross margin of the improved variety were statistically higher, compared to the traditional variety. Second, the magnitude of the impact of the improved variety on rice productivity was 47%. The nature of such productivity increase was largely of the non-neutral type. Third, the estimated productivity difference between the two varieties was 39%, of which a greater share (46%) was contributed by the differences in technology. However, the differences in input use level contributed negatively (-6%) to the productivity difference between the two varieties. Among technical change, non-neutral technical change contributed the greatest share of 45% while neutral technical change contributed about 1%. Finally, the study found that rice farmers who used fertiliser and herbicide as well as accessed extension services and credit facilities were more likely to have higher yield gains than those who did not. The study, therefore, concludes that the technological change in rice production was largely non-neutral and had highly favoured adopters with higher economic incentives such as productivity and returns because they were resource-endowed. The study recommends that technology promotion activities must be integrated with effective input supply and credit systems. Further, mechanised technologies should be developed to reduce the overreliance on manual labour.

ACKNOWLEDGEMENT

One of the most rewarding achievements in my life is the completion of my MPhil programme. I would like to take this opportunity to express my immense gratitude to all those persons who have given their invaluable support and assistance towards this pursuit.

I am profoundly indebted to my major supervisor, Dr. K. Ohene-Yankyera, who was very generous with his time, vast knowledge, and assisted me with the necessary technical guidance in each step to complete this thesis. I am also grateful for the assistance of my minor supervisor, Dr. S. C. Fialor, for his invaluable advice, guidance, and concern during the period of this study.

I would also like to extend thanks to the faculty members of the Department of Agricultural Economics, Agribusiness, and Extension for their generosity. In particular, I am very grateful to Prof. Saa Dittoh, Dr. Robert Aidoo, and Dr. G. K. Nurah, for their advice and assistance. In addition, I appreciate the thoughtful comments provided by the late Prof. K. Asenso-Okyere, formally of the International Food Policy Research Institute (IFPRI), Ghana, and a former Vice Chancellor of the University of Ghana. I am also grateful for the prayers, advice, and encouragement of Dr. R. W. N. Yeboah of the University for Development Studies, Tamale, during the period of my study.

The Ghana Strategy Support Programme of the IFPRI-Ghana provided the financial support for the research for this thesis. In addition, the Finatrade Foundation provided a scholarship for my master's programme. These supports have immensely motivated me throughout the period of my study. I am, therefore, most grateful for their support.

Words cannot express my appreciation for the help of the rice farmers in the two districts in providing data for this study. I equally acknowledge the immense role of the extension officers, especially, Lawrence, Aboagyei, and Adjei who supported me in collecting the data.

Special thanks are reserved for my mother, Rose Tsinigo for her care and best wishes during my study. To my siblings, especially Peace and Christy; uncles – Rev. William Tsinigo and Mr. Anthony Tsinigo; and course mates; I am very grateful for everything. I also thank Pastor Maggie for her prayers and counselling during the period of my study.

DEDICATION

To My Beloved Mother, Mrs Rose Tsinigo.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURE

Figure **Page**

LIST OF ABBREVIATIONS/ACRONYMS

BHU	Banaras Hindu University.
Bt	*Bacilus thuringiensis*
CDP	Cobb-Douglas Production function.
CRI	Crop Research Institute.
df	Degree of Freedom.
FAO	Food and Agriculture Organisations.
GM	Gross Margin.
M	Mean.
MoFA	Ministry of Food and Agriculture.
NERICA	New Rice for Africa.
NPK	Nitrogen, Potassium, and Calcium.
NRDP	NERICA Rice Dissemination Project.
OECD	Organisation for Economic Cooperation and Development.
PFP	Partial Factor Productivity.
SA	Sulphate of Ammonia.
SD	Standard Deviation.
SPSS	Statistical Package for the Social Sciences.
SRI	System of Rice Intensification.
TFP	Total Factor Productivity.
TR	Total Revenue.
TVC	Total Variable Cost.
WARDA	West African Rice Development Association.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Globally, food insecurity has remained a major threat to human survival. This has necessitated agricultural and food security policies aimed at ensuring agricultural productivity increases. More clearly, governments across the world have devoted considerable resources to the development of new and improved rice varieties. Technological breakthrough in rice production has ushered in an era of agricultural transformation across the world. The possible potentials from such technological breakthrough present increased economic incentives for smallholder rice farmers and therefore improves the prospects for sustained productivity increases in the rice sector. The challenge facing researchers and policymakers is to convert these potentials into a sustained basis for the socio-economic development of smallholder rice farmers.

Technological change refers to increase in total factor productivity (Angelsen et al., 2001) due to the shift from traditional to improved technologies. Technological change is vital for driving the productivity and sustainability in the agricultural sector (Dixon et al., 2001). Concerns for the spread of appropriate technologies have dominated the focus of researchers and policy makers across the world. In particular, as new technologies substantially increase yield and income, less-developed countries derive their livelihood from agricultural production technologies (Feder et al., 1985). Therefore, the integration of agricultural technologies into major food production systems provides feasible policy alternatives for addressing the socioeconomic challenges facing less developed countries.

The literature on the economics of technological change has grown considerably in recent times. Past studies have mostly focused on two key concepts that influence farmers' response to technological change - constraints and economic incentives. That is, farmers' resource allocation in the midst of constraints (Algelsen et al., 2001; Jaffe et al., 2003) and economic incentives such as profitability and productivity (Abdullahi, 2012; Dixon et al., 2001; Shideed, 2005). Such empirical evidences have given credence to the potential of improved technologies in ensuring new production functions, thereby, boosting productivity, and profitability in the agricultural sector (Dixon et al., 2001; Shideed, 2005). This implies that, productivity increase among farmers requires a policy focus on investment in productivity enhancing technologies.

The New Rice for Africa (NERICA), developed by the African Rice Centre, is one of the major high yielding technological breakthroughs in the agricultural sector. The improved rice variety is produced through conventional crossbreeding between an ancient, hardy African rice variety (*O. glaberrima* Steud), and a high-yielding Asian variety (O. sativa L.) (Somado et al., 2008). There are more than 3000 lines in the family of NERICA (Institute of Science in Society [ISIS], 2004). The major advantages of the improved rice variety are its higher yield advantage, as well as resistance to drought, diseases, and pests. The potential yield of NERICA depends on the particular NERICA lines; higher yields up to 6000 kg ha^{-1} are obtained when appropriate levels of fertiliser are used (Ministry of Food & Agriculture [MoFA/CRI], 2009; Somado et al., 2008). Moreover, NERICA is early maturing (within 80 – 100 days, i.e., 50 – 70 days earlier than farmers' varieties) and is resistant to local stresses such as blast, stem borers, and termites (Somado et al., 2008).

Following its introduction in 1996, the improved rice variety has spread rapidly in sub-Saharan African countries, including Nigeria, Cote D'Ivoire, and Ghana. Past studies have focused on the impact of the improved variety on variables such as costs and returns as well as productivity. Research shows that in rain-fed dependent upland production system, the improved variety leads to high yields between 3000 and 6000 kg ha^{-1} (Zenna et al., 2008). Similar studies reveal significant positive impacts with an additional yield gain of nearly 1000 kg ha^{-1} in Benin (Adégbola et al., 2006) and 140 kg ha^{-1} in The Gambia (Dibba, 2010). These yield gains are against the very low yields of between 700 and 1500 kg ha^{-1} (African Development Fund, 2001) of normal rice varieties grown under the same production system. Further, prior studies suggest that the improved rice varieties have increased the costs and returns and thus the profitability of farmers who have embraced them (Abdullahi, 2012; Adhinkari, 2011). Therefore, the technological breakthrough in rice production has obviously generated increased productivity and profitability for the rice farmers. However, this raises the fundamental question of whether these gains are evenly distributed among rice farmers.

Existing research on the improved rice variety (e.g., Asuming-Brempong et al., 2011; Dibba, 2010; Zenna et al., 2008) neglect to consider the nature (i.e., whether technological change is neutral or non-neutral) and magnitude of the change in technology of rice production from the traditional to improved rice varieties. Further, prior research suggests that technical change and input use differentials might be key factors in driving the productivity differences between traditional and improved crop varieties (Basavaraja et al., 2008; Tan, 1992). However, no systematic analysis of how these factors explain the productivity differences between the improved and traditional varieties has been carried out. Moreover, existing research in Ghana has failed to address the effects of technical change and input use differentials to explaining the productivity differences between the two rice varieties. This study has the potential to provide a better theoretical and practical understanding of the nature and magnitude of the technological change associated with the improved rice variety. This study further decomposes the sources of productivity differences between the adopters and non-adopters of the improved rice variety.

1.2 Problem Statement

Rice is the most important staple food crop and second-highest grown cereal in the world (Food and Agricultural Organisations [FAO], 2006). Rice production provides several socioeconomic gains, including income generation, poverty alleviation, and ensuring food security. However, low productivity of rice in Ghana is a major concern for not only rice farmers, but also for policy makers (e.g., MoFA) and crop breeders/researchers who are interested in increasing and sustaining agricultural productivity. Across the various regions in Ghana, average yield estimates continue to differ and persist. For instance, during the 2010 season, the average yields of rice were 1340, 1220, 3120, 5490, and 3080 kg ha^{-1} for Western, Central, Eastern, Accra, and Volta Regions, respectively. The rest were 2740, 1640, 2950, 1600, and 2860 kg ha^{-1} for Ashanti, Brong-Ahafo, Northern, Upper-West, and Upper-East Regions, respectively. Out of these, six regions have productivity rates above the national average of 2600 kg ha^{-1} (MoFA, 2011). The remaining four regions have yields below the national average. In fact, there are considerable gains in the productivity of rice in the country (MoFA, 2011). Nevertheless, there are still certain districts and/or regions where rice productivity is low. Rice productivity in such areas fluctuates significantly due to various factors such as low soil fertility, weed infestation, drought, diseases, and pest infestations (Somado et al., 2008). These yields gaps present sufficient scope to increase the productivity of rice through productivity enhancing technologies.

Efforts to increase productivity gains among the rice farmers have led to the development and promotion of the improved rice variety, NERICA rice. Apart from its higher yield potential, NERICA is resistant to pests, tolerates drought, and infertile soils better than other varieties (West African Rice Development Association [WARDA], 2001). For instance, WARDA (2001) establishes that NERICA's yield increases from 1000 to 2500 kg ha^{-1} without fertiliser. Conversely, its yield increases to 5000 kg ha^{-1} with fertiliser (WARDA, 2001). These yield gains are higher than the very low outputs of between 700 and 1500 kg ha^{-1} of local varieties (African Development Fund, 2001). The shift from the production of the traditional varieties to improved varieties represents technological change. Smallholder farmers respond to economic opportunities such as presented by the technological change in rice production. They do so by allocating their scarce resources (such as labour and capital) to meet their objectives. However, available technologies and resource constraints hinder the choices that farmers make. Technological change, in turn, may modify these constraints and provide incentives that encourage them to allocate their resources differently.

Smallholder farmers benefit from technological change through opportunities to lower production costs; either by increasing output from the same inputs or by holding the same output from reduced inputs (Adewuyi, 2006; Oni et al., 2009). Further, the profitability of adopting improved varieties depends on changes in the input demands, the magnitude of the productivity increase (Lin, 1994) and the output price. Consequently, while the technological breakthrough in rice production has generated increased productivity and farm incomes, there appears to be uneven distribution of such gains. Resource endowed farmers who adopt improved varieties seem to be benefiting from such technologies more than those who rely on the traditional varieties. The questions that arise are what are the nature and magnitude of change in technology of rice production from traditional to improved rice varieties? Moreover, how has this shift affected the productivity differences between farmers who adopted and those who did not adopt the improved rice variety? This study, therefore, sought to investigate the technological change in rice production in the Ejura-Sekyedumase and Atebubu-Amantin Districts of Ghana.

1.3 Research Questions

The research questions of the study were:

a. Do rice farmers who adopt the improved rice variety report higher cost and returns than those who did not adopt?
b. Do rice farmers who adopt the improved rice variety report higher productivity than those who did not adopt?
c. How do technical change and input use explain any productivity differences between the traditional and improved rice varieties?
d. How do other factors explain any productivity differences among the rice farmers in the study areas?

1.4 Research Objectives

The primary research objective was to investigate the economics of technological change in rice production in the Ejura-Sekyedumase and Atebubu-Amantin Districts of Ghana. Specifically, the study sought to:

a. Establish whether the improved rice variety increases the cost and returns for the adopters compared with the non-adopters.
b. Evaluate the nature and magnitude of rice productivity due to the shift from the traditional to improved rice varieties.
c. Decompose the sources of any productivity differences between the traditional and improved rice varieties.
d. Investigate the role of other factors in explaining any productivity differences among the rice farmers.

1.5 Research Hypotheses and Justification

It was hypothesised that the technological change in rice production will lead to higher magnitude in inputs and outputs in rice production. Researchers have hypothesised that improved crop technologies may alter the optimal levels of inputs used in their production. Consistent with this hypothesis, several researchers have found that the adoption of improved crop varieties has increased the demand for variable inputs of production (Diiro et al., 2011; Shideed, 2005). However, research also found that improved rice varieties might reduce inputs such as seeds due to their quality (International Rice Research Institute, 2013). This presupposes that improved crop varieties may either increase or decrease the requirements for variable inputs. Economically, increased demands for inputs imply incremental capital or cash requirements. Accordingly, this study hypothesised that:

Hypothesis one: Rice farmers who adopt the improved rice variety will have higher cost and returns than those who did not adopt.

Most researchers have hypothesised that the adoption of improved technologies may lead to increase in productivity (Basavaraja et al., 2008; Diiro et al., 2011; Pouchepparadjoyu et al., 2005). Researchers have also identified new crop varieties as important sources of productivity increase in several production systems. Further, prior empirical studies (Adewuyi, 2006; Oni et al., 2009) suggest that farmers benefit from inputs or maintain the same outputs from reduced inputs. Similarly, several studies report that output differences between adopters and non-adopters of improved crop varieties are due to changes in the inputs used and shifts in technology (Basavaraja et al., 2008; Pouchepparadjoyu et al., 2005). Accordingly, this study hypothesised that:

Hypothesis two; Rice farmers who adopt the improved rice variety will have higher productivity than those who did not adopt.

Hypothesis three: Productivity differences between the adopters and non-adopters are partly due to neutral technical change, i.e., efficiency in input use.

Hypothesis four: Productivity differences between the adopters and non-adopters are partly due to non-neutral technical change, i.e. reallocation of inputs in production.

1.6 Significance of the Study

A major threat to human survival is food insecurity. Attempts to reach self-sufficiency in rice through boosting domestic production has the potential of eliminating hunger, ensuring sustainable food security, and thereby guaranteeing human survival. The role of technology evolution, implementation, and adoption of a given production system are pivotal in the realisation of this objective. In Ghana, rice production has experienced a relative improvement in the recent past (MoFA, 2011). However, domestic production still falls short of the requirement. Successive governments since independence have expended enormous resources in the importation of rice for consumption. Therefore, attempts to understand technological factors necessary for increasing rice productivity may deepen not only academic knowledge, but also enhance policy decision-makings.

1.6.1 Theoretical relevance

This study contributes to the literature on the economics of technological change in rice production in various aspects. First, the study examined the nature (i.e., whether the technological change in rice production was neutral or non-neutral) and magnitude of change in technology of rice production from the traditional to improved rice variety. Second, the productivity differences between the traditional and improved rice varieties form potential additional insights from this study. The study highlighted the importance of technology and input use differentials in explaining the productivity differences between the traditional and improved rice varieties. Finally, the study may also provide the empirical basis for future studies on the economics of technological change in rice production, especially in Ghana.

1.6.2 Practical relevance

A study on the economics of technological change in rice production may benefit three major stakeholders, namely, researchers/plant breeders, policy makers (e.g., MoFA), and rice farmers. First, the results of the study may help plant breeders understand farmers' selection criteria for the improved variety and how the improved rice variety fits into farmers' farming system. Similarly, by identifying breeding problems such as difficulty in threshing associated with the improved rice variety, plant breeders will be able to address such agronomic constraints to facilitate its adoption. In the same vein, the study will highlight the institutional problems such as lack of access to inputs and information on the improved variety that impede the adoption of the improved variety. This may help facilitate a participatory plant breeding approach by plant breeders, social scientists, and policy makers in promoting improved rice varieties. Further, MoFA, through its extension services, may use the findings to revise its agricultural extension services and programmes to address significant constraints to the adoption of improved rice varieties. Second, a fundamental decision confronting the various stakeholders in the rice sector concerns strategies to encourage to closing the productivity differences among rice farmers. Knowledge of the sources of productivity differences between the traditional and improved rice variety can serve as input to that decision. Overall, the recommendations from this study may form the basis for formulating specific policies for promoting future agricultural technologies in Ghana.

1.7 Scope of the Study

Technological change and the adoption of improved varieties play a vital role in agricultural production and productivity increases. This study focused on the economics of technological change in rice production. Specifically, the study examined the nature and magnitude of change in technology of rice production from traditional to improved rice varieties and the effect of such change on the productivity differences among farmers. Geographically, the study concentrated on the Ejura-Sekyedumase District of the Ashanti Region and the Atebubu-Amantin Municipality in the Brong-Ahafo Region of Ghana. These two districts were selected because of their inclusion in the pilot phase of the NERICA Rice Dissemination Project (NRDP) and the high concentration of rice farmers. Accordingly, the producers of the improved and traditional rice varieties were the main participants. Moreover, this study used a structured survey research strategy. In order to assure manageability of the collected data, the research instrument used multiple-choice items with few open-ended response items.

1.8 Limitations of the Study

This study has two major limitations. First, the lack of, and/or poor record keeping behaviour of the rice farmers imply that the results might not accurately reflect the actual input-output figures observed. Second, rice production in the two districts represents a part of the entire rice geographical locations in Ghana. Thus, the results of the study may suffer from extensive generalisation. Nonetheless, it is applicable within the given context.

1.9 Organisation of the Remainder of the Study

The remainder of the thesis is organised as follows. Chapter two provides a theoretical and empirical framework for the study by reviewing current literature on the importance of rice production and the economics of technological change. Chapter three explains the methods that have been used for conducting the research and for the analysis of the data used in this study. Chapter four presents the results of the data obtained from the rice farmers and provide discussion of the issues raised. Chapter five summarises the research findings, draws conclusions from those findings, and suggests policy recommendations. Limitations of the study and suggestions for further research in this field are also considered.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents the review of theoretical and empirical literature on the economics of technological change. The chapter begins with the economic importance of rice. Thereafter, it discusses the economics of technological change and the measurement of technological change using the production function approach. The final parts of the chapter reviews empirical evidence on the economics of technological change.

2.2 The Economic Importance of Rice

The World Bank (2010) recognises the agricultural sector as predominantly in most Sub-Saharan Africa economies, contributing more than one-third of the regional gross national product and employing more than two-thirds of the labour force. Further, agriculture is one of the major sources of foreign exchange earnings. However, the sector remains largely underdeveloped, in respect of production both for the domestic market and for export (FAO, 2000). In particular, the sector's performance in Sub-Sahara Africa has continued to lag behind other developing nations due to its low cereal yield and high reliance on grain imports (Wikipedia, 2013). Consequently, policy directives of governments have been to increase domestic production of major food staples, especially rice, and reduce the unsustainable overreliance on imports.

Rice plays a decisive role in the socioeconomic development goals of countries. FAO (2006) and MoFA (2011) report that rice is the most important staple food for a large share of the world's human population (particularly in East and South Asia) making it the grain with the second-highest worldwide and locally (i.e., in

Ghana) after maize. Thus, rice is a key commercial food product and requires a more holistic approach to its production, management, and marketing in a manner that lead to poverty reduction. An earlier report of the FAO (2004) identifies rice as vital in hunger eradication, poverty alleviation, ensuring food security, and promoting economic growth through the improvement in productivity. In Ghana, rice has become the second most important food staple after maize and its consumption keeps increasing as a result of population growth, urbanisation, and change in consumer habits (MoFA, 2009).

Globally, rice production has risen steadily from approximately 200 million tonnes of paddy rice in 1960 to over 678 million tonnes in 2009 with Asia (particularly, China and India) still accounting for 92% of the world's total rice production (Wikipedia, 2013). That is, rice production during the stated period has increased by 239%. This significant growth in the total world production is attributable to the increasing production in Western and Eastern Asia. It is also due to the increase demand across the globe and especially in the developing regions. Unfortunately, Africa contributes only four percent (FAO, 2011) to this total world production. This calls for pragmatic policy initiatives to increase its production to an acceptable level that will bring down the continent's increasingly overreliance on import.

In terms of consumption, world rice consumption increased by 40% in the last 30 years, from 61.5 kg capita^{-1} to about 85.9 kg capita^{-1} (milled rice) (United Nations Conference on Trade and Development Secretariat, 2011). Annual per capita rice consumption in Africa as a whole increased by about 91% from 11 kg in the 1970s to 21 kg in 2009 (FAO, 2011). The situation is even more pronounced in West Africa given the rise in annual per capital consumption from 14 kg in the 1970s to 22 kg in the 1980s and more than 39 kg in 2009 (Diagne et al., 2006). This indicates that annual per capita percentage increase in rice, in West Africa alone, was nearly twice (178%) that of Africa as a whole (90%) during the period under consideration. Balasubramanian et al. (2007) observe that such increases are due to population growth, rising incomes, and shift in consumer preferences in favour of rice, particularly in urban areas.

In Ghana, total rice consumption is about 500,000 tonnes, of which more than 350,000 tonnes (70%) costing over US$600 million are imported (Government of Ghana, 2009). Conversely, domestic production accounts for less than 30% of the total supply and is increasing at a very slow pace. Thus, roughly only 150,000 tonnes of rice consumed in this country constitute total domestic production. The vast amount of hard-earned foreign currency spent on rice import in Ghana is a potentially very risky and unsustainable situation. Notwithstanding, the country's ability to increase domestic production is constrained by several factors such as high cost of inputs and production constraints, difficulties in accessing credit, use of poor yielding seed varieties, inappropriate agronomic practices, limited mechanisation, poor processing methods, and poor marketing strategies (Obirih-Opareh, 2008). Therefore, policy directives aimed at increasing domestic production and marketing are required. In addition, the increase demands for rice globally, Africa, and Ghana, in particular, justifies intense efforts to increase its productivity under various production systems through the development of improved rice varieties.

One such effort is the promotion of an improved rice variety, NERICA rice, through the NRDP by the Government of Ghana in 2003. The main goal of the NRDP was to contribute to poverty reduction and food security, through enhanced access to high yielding NERICA upland rice varieties. The objectives were to contribute to increasing locally produced rice for food security and to conserve foreign exchange earnings through import substitution. The NRDP was financed through a concessional loan of US$ 3,840,000 from the African Development Bank and a counterpart funding of US$ 730,000 from the Government of Ghana (MoFA, 2013). The NRDP has four components – technology transfer, production support, capacity building, and project coordination. The NRDP promoted the upland NERICA rice as a package with complementary inputs such as fertiliser, herbicide, as well as tractor ploughing and harrowing of farmers' rice field.

2.3 Definitions of Technological Change

Technological change is seen as a social process (Huesemann & Huesemann, 2011; Rogers, 2005). This view is premised upon social context and communication, through which cultural setting, political institutions, and marketing strategies greatly affect stakeholders such as producers, adopters, and governments (Wikipedia, 2013). As a social process, technological change occurs through a three-phase process - invention, innovation, and diffusion of technologies (Jaffe et al., 2002; Ibrahim, 2012). Invention is the creation of something new (i.e., based on original ideas and knowledge) or a "breakthrough" technology (Ibrahim, 2012; Wikipedia, 2013). Rogers (2003) defines innovation as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (p. 12). Diffusion refers to the spread of a technology through a society or industry. The evolution of diffusion decisions derived their foundations from the works of Rogers (2003).

Technological change is an important driver of productivity growth and the emergence of new products from which consumers derive welfare (Verspagen, 2010). It is the outcome of the overall process of invention, innovation, and diffusion of technologies that transforms ideas and knowledge into tangible products that have a high utility value to human needs (Jaffe et al., 2002; Ibrahim, 2012). According to Ibrahim (2012), the term refers to an incremental change in the quality and quantity of knowledge and ideas that are applied in the stream of activities to enhance the social and economic wellbeing of the society. Technological change is also the invention of a technology, the continuous process of improving a technology and its diffusion throughout society, i.e., it is based on both better and more technology (Wikipedia, 2013).

Economically, Angelsen et al. (2001) define technological change as "… an increase in total factor productivity" (p. 20). That is, farmers can produce more with the same inputs, or the same output with fewer inputs. This definition has been adopted for this study. Researchers have used technological change and technical change interchangeably, especially within the context of technology. Hence, these terms are used in a similar manner in this study. Solow defines technical change as a "catch-all" expression for any kind of shift in production function assuming returns to scale, homogeneous inputs and competitive equilibrium (as cited in Ibrahim, 2012).

A technical change can be either neutral or non-neutral. Solow defines neutral technical change as any shifts in the production that leave marginal rates of substitution untouched, but simply increase or decrease the output attainable from given inputs. Angelsen et al. (2001) refers to neutral technologies as those technologies (e.g., pure yield-increasing technologies), which raise yields without altering the labour and capital requirements per-hectare. Non-neutral technical change, on the other hand, depicts any shifts in the production function that leads to changes in the marginal rates of substitution and outputs produced from given inputs. According to Tan (1992), non-neutral technical change is a reallocation of inputs at the new level of efficiency in production. This implies that both neutral and non-neutral technical change lead to changes in the production function; however, only non-neutral technical change alters the requirements of inputs.

The above definitions points to two fundamental outcomes of technological change – output increase and profit increase. First, technological change leads to the development of a new production function such that a greater output is achieved from a given input level (Angelsen et al., 2001; Shideed, 2005). This implies that producers increase outputs through technological change. Zandstra et al. (1981) demonstrated that farmers are more likely to adopt new technologies, which have at least 30% higher return than traditional technologies. Consistent with this, Heady argues that producers would never adopt an innovation if the output were not increased from given resources, or if input decreased for a given output (as cited in Shideed, 2005). Second, technological change economically increases/decreases the discounted profits/losses of producers (Angelsen et al., 2001; Shideed, 2005). Huesemann and Huesemann (2011) lend more credence to this when they affirm that the main driver of technological change in free market economies is the ability to increase profits. They further explain that technological change as a social process is strongly biased by the financial interests of capital (Huesemann & Huesemann, 2011).

Researchers have classified technological change based on the change in physical yields and factor intensities (Angelsen et al., 2001; Feder et al., 1985). Technology classifications based on factor intensities are essential in determining the effects of technologies on productivity when farmers are resource constrained. Accordingly, technologies can be resource saving or resource intensive. Resources are distinguished in terms of labour and capital. Angelsen et al. (2001) explain that labour-intensive technologies increase labour input per-hectare, whereas labour-saving technologies decreases labour. Similarly, a capital-intensive technology increases capital inputs per-hectare and a capital-saving technology reduces them. Resource saving technologies may increase or decrease yield, but farmers will only adopt them if it is consistent with their profit maximising goal. New technologies can be both labour- and capital-intensive. A key example is an improved rice variety that increases both the use of inputs such as fertiliser and labour for other farm operations (Angelsen et al., 2001).

2.4 Definition of Agricultural Productivity

Generally, a number of varying definitions of agricultural productivity exist. However, these definitions are sufficiently exact to avoid misunderstanding and provide a common basis for measuring performance objectives in the agricultural sector. Olayide and Heady (1982) define agricultural productivity as the ratio of the value of total farm outputs to the value of total inputs used in farm production. This definition is consistent with that of Fulginiti and Perrin (1998). According to Fulginiti and Perrin (1998), agricultural productivity is the output produced by a given level of input in the agricultural sector of a given economy. In their view, Ha et al. (2001) explain that productivity is a physical concept that measures the physical quantity of outputs produced from given amounts of input. That is, the measure of the capacity to transform inputs into outputs (Ha et al., 2001). These definitions provide two main indicators for measuring productivity: inputs and outputs. In simple term, agricultural productivity refers to the ratio of agricultural outputs to agricultural inputs used in a given production system.

Agricultural productivity reflects improvements in the efficiency of input combination for production and serves as a key mechanism for maintaining profit and competitiveness of the sector (Gray et al., 2012). Two strands of agricultural productivity literature abound on how to increase productivity. These are the alterations of input levels and the alterations of output levels in varying proportions (Adewuyi, 2006; Oni et al., 2009). Changes in these productivity indicators take several forms: an increase in output and input with output, increasing proportionately more than inputs; an increase in output while inputs remain the same; a decrease in both output and input with input decreasing more; or decreasing input while output remains the same (Adewuyi, 2006; Oni et al., 2009). Agricultural productivity can therefore be said to be the result of the efficiency of input use and/or reallocation of inputs.

Agricultural productivity changes are driven by several factors. Generally, these factors are classified into four: technical change, socioeconomic, climatic, and economic policies (Ahearn et al., 1998; Hussain & Perera, 2004; Kaur & Sekhon, 2005). Technical/agronomic factors result from the use of technologies such as mechanisation, high yielding varieties, fertilisers, irrigation, herbicides, and pesticides (Ahearn et al., 1998; Hussain & Perera, 2004). Socioeconomic factors that drive productivity include education, experience, farm size, tenancy terms, prices, and availability of credit (Hussain & Perera, 2004). Climatic factors such as rainfall, temperature, and sunshine play a vital role in influencing agricultural productivity (Hussain & Perera, 2004). Ultimately, the efficacy of these factors depend largely on the prevailing economic policies on agricultural productivity growth. Accordingly, Ahearn et al. (1998) and Kaur and Sekhon (2005) identify economic policies as a vital precondition for productivity increases. While each of these factors may affect productivity separately, the combined effects of these factors on productivity are visible.

Increasing agricultural productivity, therefore, requires a focus on technical change, input availability, seasonal finance, and marketing systems to increase production and ensure a guaranteed price (Poulton et al., 2006). In particular, the adoption of new technologies and management practices resulting from technological changes has been the main driver of long-run productivity (Hughes et al., 2011). This study focused on the technological change associated with the introduction of an improved rice variety, NERICA rice. For this variety, productivity and productivity differences could be due to the complementary role of the substantive technology and its recommended inputs. The role of effective economic policies in promoting these complementary inputs is thus crucial if productivity increases are to be achieved through technological change.

The importance of agricultural productivity is immense. The World Bank (2008) identifies the agricultural sector as a necessary tool for sustainable development, poverty reduction, and reliable source of self-food sufficiency for the Sub-Sahara Africa. Therefore, with increasing world population growth, agricultural productivity provides impetus for sustaining human survival through enhanced food security. For example, increase in yields of major cereals such as maize and rice provides impetus for increased availability of food for the human population (Fuglie et al., 2007). These gains in productivity are even more pronounced in developing countries where the agricultural sector is the largest employer.

Apart from providing more food, productivity increases provide the prospects for growth and competitiveness on the agricultural market, income distribution, and savings, and labour migration as well as help to alleviate poverty in poor and developing countries (Mundlak, 1992; Organisation for Economic Cooperation and Development [OECD], 2006). The OECD (2006) explains the mechanisms though which productivity increases lead to growth. As farmers become more productive, the wages earned by agriculture workers increases. Consequently, food prices decrease and food suppliers become more stable so that labourers have more money to spend on food and other products. Ultimately, this leads to agricultural growth. Moreover, an increase productivity leads to more efficient distribution of scarce resources. By adopting improved techniques, the more productive farmers increase their welfare (Mundlak, 1992).

2.5 Economics of Technological Change

Two major concepts explain the process of technological change. These are constraints and incentives (Algelsen et al., 2001; Jaffe et al., 2003). As farmers respond to economic opportunities, technological change may modify constraints (e.g., available technology, credit, labour, and land tenure) that farmers face in resource allocation and provide incentives that enhance such decisions. Accordingly, the economics of technological change focus on comparing old and new technologies and identifying changes in the whole farm system caused by changing part of the system (Norman et al., 1995). The economic impacts of technological change have been measured variously, especially at the farm level. Such measures include the budgeting process (Norman et al., 1995; Shideed, 2005) and the production function methods (Angelsen et al., 2001; Lipsey & Carlaw, 2004; Shideed, 2005).

The budgeting process involves average returns analysis (gross margin analysis), budget analysis, and risk analysis (Norman et al., 1995; Shideed, 2005). These economic analyses are commonly used to compare different technologies. The average returns approach involves estimating the relative cost and revenue differences between the technologies being compared (Norman et al., 1995; Shideed, 2005). It forms the basis for most of the other analyses. The average returns approach requires information on both variable and fixed inputs. However, a limited form of this analysis (i.e., gross margin analysis) involves comparing different technologies that use the same fixed inputs. The gross margin analysis is used to compare the average returns above variable costs for different technologies and the returns to other production factors such as capital and labour (Norman et al., 1995). Budget analysis comprises of three types; enterprise budget for a particular enterprise; whole farm budgets that builds on the enterprise budget; and the partial budget which compare elements within enterprise budgets that change between technologies. Finally, risk analysis involves comparing the risk of present technologies with new technologies (Norman et al., 1995).

The production function method of measuring technological change has focused on measuring agricultural production changes emanating from technologies. Several economic models are used in this regard. Broadly, these measures are index numbers methods, growth accounting techniques, econometric estimation of production relationships, and nonparametric approaches (Coelli et al., 1998; Lipsey & Carlaw, 2004; Zepeda, 2001). The parametric approach involves estimating the coefficients of the production function statistically using econometric approach. It is also commonly used in the estimation of production functions. The non-parametric approach on the other hand uses mathematical programming in estimating the coefficients of the production function. The non-parametric approach is also used in efficiency analysis (Coelli et al., 1998).

2.6 Measuring Technological Change Using Production Function Method

The production function method perhaps has remained the dominant model for measuring changes in technology. Measuring technological change in this case involves two commonly used methods: partial productivity of a sole production factor and multifactor (total factor) productivity (de Avillez, 2011; Mullen, 2002). These methods are discussed as follow.

2.6.1 Partial factor productivity

Partial factor productivity (PFP) measures the amount of output per unit of a particular input, i.e., it considers the productivity of each input used in production. The PFP measures focus mostly on yield (i.e., output per unit of land) and labour productivity (i.e., output per agricultural person-hour). The yield is commonly used to assess the success of new agricultural production technologies. A major limitation of the PFP measures is that its results can be misleading, as it provides no clear indication of the factors causing productivity to change (Block, 1995; Zepeda, 2001). Accordingly, Mullen (2002) asserts that PFP measures are limited measures of productivity since the contribution of other inputs is not held constant. In order to correct this defect, a more elaborate measure of productivity, known as total factor productivity, is considered more appropriate.

Past research, measuring technological changes using the PFP approach has employed the decomposition analysis. Decomposition analysis is a mathematical technique for partitioning an aggregate into its components elements (Tan, 1992). Earlier studies such as Solow (1957) have used the decomposition analysis to investigate the effects of technological change on output growth. Solow's (1957) study, which used the geometric productivity index, has formed the basis of subsequent studies that employed the decomposition analysis. Using the production function approach, Bisaliah (1977) decomposed total change in yield due to new production technology into technical change and changes in the input levels. Recent studies (Balakrishna, 2012; Kumar & Singh, 2013) using the decomposition analysis have modified Bisaliah's production function approach in measuring technological change at the farm-level. This study adopted the modified production function model of the decomposition analysis based on the Cobb-Douglas production (CDP) function.

The CDP function is commonly used in the theoretical and empirical analysis of productivity growth (Felipe & Adams, 2005). Accordingly, this study adopted the CDP function. Bhanumurthy (2002) argues that the CDP function is viewed as a simple tool, which can be handled easily. It also facilitates computation and properties of parsimony and flexibility (Bhanumurthy, 2002). Moreover, partial output elasticities of the CDP function add up to unity based on the standard restrictions imposed which are indeed consistent with competition in goods markets and factor markets (Welfens, 2005). In spite of these merits of the CDP function, Bhanumurthy (2002) exposes its inability to handle large number of input and problem of serial correlation and hetroscedasticity. Further, it has an imposition of some assumptions about technology, such as unitary elasticity of substitution (Zepeda, 2001). Notwithstanding, production function analysis in agriculture have relied on the CDP function (Balakrishna, 2012; Kumar & Singh, 2013). Therefore, this study considers it appropriate in addressing the research questions. The CDP function in its stochastic form may be expressed as (Gujarati, 2004; Syverson, 2011):

$$Y = AL^{\beta} K^{\alpha} \ell^{u_i} \quad (1)$$

Where; Y = total production;

L = Labour input;

K = Capital input;

A = Total factor productivity;

α and β are the output elasticities of capital and labour, respectively;

u = stochastic disturbance term; and

e = base of natural logarithm.

According to Gujarati (2004), the CDP function has two properties. First, the partial elasticity of outputs with respect to any of the inputs measures the responsiveness of output to a change in levels of either labour or capital used in production, ceteris paribus. Second, the sum of the output elasticities of the inputs gives information about the returns to scale, i.e., the response of output to a proportionate change in the inputs. If this sum is one, then there are constant returns to scale, i.e., doubling the inputs will double the output. If the sum is less than one, there are decreasing returns to scale, i.e., doubling the inputs will less than double the output. Finally, if the sum is greater than one, there are increasing returns to scale, i.e., doubling the inputs will more than double the output (Gujarati, 2004).

2.6.2 Total factor productivity

Total factor productivity (TFP) measures the ratio of the index of agricultural output to index of agricultural inputs. The output index presents the value-weighted sum of all agricultural production components. The input index is the value-weighted sum of conventional agricultural inputs such as land, labour, physical capital, livestock as well as chemical fertilisers and pesticides (Ahearn et al., 1998; Zepeda, 2001). Unlike the PFP measures, TFP measures are more useful as they relate all farm inputs to all farm outputs. Gray et al. (2012) assert that total factor productivity growth in agriculture reflects improvements in the efficiency with which farmers combine market inputs to produce outputs. The major limitation of TFP is, however, its inability to account for un-priced environmental inputs and outputs (Mullen, 2002).

Measurement of TFP involves two commonly used measures, namely, growth accounting or residual method and index number method (Lipsey & Carlaw, 2004;

Shideed, 2005). The growth accounting methods of TFP measurement emanates from the pioneering works of Solow (1957). By relating measured inputs to measured output, any output growth not associated statistically with the growth in measured inputs is assumed to result from technological change (Lipsey & Carlaw, 2004). Zepeda (2001) contends that changes in TFP are usually attributed to technological improvements. Prior empirical studies (Lin, 1994; Shideed & Salem, 2005) using this approach have sought to measure the impact of a new technology on the total factor productivity by introducing a dummy variable to the production function. The index number method extends and compliments the growth accounting method. The index number method does not require an aggregate production function, though an appropriate index can be selected via the economic approach for some specified production function (Lipsey & Carlaw, 2004).

2.7 Empirical Studies on Technological Change and Research Hypotheses

According to Angelsen et al. (2001), technological change and TFP is defined at the farm level to include technological change for a particular crop and/or production system; the introduction of a new crop and/or production system (technology) with higher TFP; and a shift in farm inputs towards crops/systems with higher TFP. In all three cases, TFP at the farm level increases, and are, therefore, qualified as technological change. Accordingly, past studies have focused on the impact of technological change on cost/returns; productivity; and productivity differences. These are considered as follow.

2.7.1 Technological change and costs/returns of production

Empirical studies on the impact of technological change on cost and returns of production have mostly used the gross margin analysis. Basavaraja et al. (2008)

estimated the costs and returns of production between the system of rice intensification (SRI) method and the traditional method. They found that there was glaring differences in the cost of production of the two methods of rice production. Total variable cost was higher in the SRI method compared with the traditional method. They found that the largest contributor to the cost of production of the two methods was labour cost. They further found that in spite of the higher cost of production in the SRI method, it recorded higher net returns and gross margins than the traditional method. These results are consistent with the findings of Adhinkari (2011) and Omotesho et al. (2010) that made similar observations.

Abdullahi (2012) compared the economic analysis of rice production between the adopters and non-adopters of improved rice varieties in Paikoro Local Government Area of Niger State. The cost and returns analysis showed that the adopters had the highest cost of production and gross margin, compared with the non-adopters. The high cost of production among the adopters was because of the cost of labour. A more recent study using the same method of analysis provided consistent result. Kumar and Singh (2013) found that the cost of production in Banaras Hindu University (BHU) fish production system was higher than the Maharajganj District (MD) system. As expected, they found that the main source of the cost of production between the two systems was the cost of human labour. Further, the BHU production system has the highest gross income compared with the MD production system (Kumar & Singh, 2013). A major limitation of these studies lies in their inability to statistically test for the significant differences in the cost of production, returns, and gross margins between the technologies being compared. Nonetheless, these studies have shown that the cost of production, gross return, and gross margin of improved technologies is higher than that of the traditional technologies. Hence, this study hypothesises that:

Hypothesis one*:* Rice farmers who adopt the improved rice variety will have higher costs of production, gross returns, and gross margin compared with the non-adopters.

2.7.2 Technological change and productivity

Shideed and Salem (2005) assert that among the factors that contribute to agricultural productivity, technology is the most important one in the long term. Research shows that improved technologies increase the productivity of crops (Dibba, 2010; Shideed & Salem, 2005). Omotesho et al. (2010) examined the economics of small-scale rice production in the Kwara State of Nigeria using the CDP function. They found that farm size, labour, fertiliser, and quantity of seeds were the significant factors affecting rice production. Further, Balakrishna (2012) studied the economics of *Bacilus thuringiensis* (Bt) cotton in India using the same production function. He found that seeds and fertiliser were the most important input to which output is highly responsive in both Bt and non-Bt cotton. Similarly, Abdullahi (2012) found that farm size, fertiliser, and improved seed were the significant predictors of productivity of improved rice variety. He further found that the productivity of traditional rice varieties was due to farm size and agro-chemicals.

Evidence of the major determinants of productivity is also provided by recent studies. Kumar and Singh (2013) found that fertiliser was a significant determinant of output in BHU ponds aquaculture production system. However, seed, feed, fertiliser, and human labour were significant predictors of output in the Maharajganj fishponds production system. Similarly, Resmi et al. (2013) studied the determinants of productivity in black pepper production in Idukki district of Kerala. They established a positive influence of the age of the plants in years, human labour, and plant protection measures on the modern varieties of black pepper. They identified plant age and cost of plant protection as the major determinants of output in the traditional variety. These findings suggest that productivity increases are due to the (a) shift in production systems and (b) the complimentary use of appropriate technologies such as improved varieties, fertiliser, and chemicals like herbicide. This supports the need to ensure the simultaneous promotion of improved varieties and their recommended technologies. The major limitations associated with some of these past studies (e.g., Abdullahi, 2012; Balakrishna, 2012) lies in their inability to test for the structural change and sources in the production functions. This study overcomes this limitation by testing for the structural differences in the production functions based on the dummy variable technique. Accordingly, the study hypothesises that:

***Hypothesis two**:* Rice farmers who adopt the improved rice variety will have higher productivity than those who did not adopt.

2.7.3 Technological change and productivity differences

Prior studies have used the CDP function and the output decomposition analysis in estimating the sources of productivity differences between two technologies. Research has shown that new or improved technologies cause a shift in the production function (Shideed, 2005; Tiamiyu et al., 2009). In one such study, Badal and Singh (2001) found that total differences in the productivities per-hectare between traditional varieties and high yielding varieties of maize were 69% in *kharif* and 80% in *rabi*. Differences in input were the major source of output differences. Consistent with Badal and Singh (2001), Patil et al. (2003) analysed the constituent sources of yield gaps in groundnut production in Dharwad district of Karnataka.

They found about 27% of yield gap between the potential farms and the sample farms. The contribution of techniques of production to the yield gap was comparatively less, compared to that of the input use.

Moreover, Pouchepparadjoyu et al. (2005) studied the effect of integrated pest management on the productivity of paddy using the output decomposition analysis. They found that technical significantly contributes 53% to output. Basavaraja et al. (2008) studied technological change in paddy production in Andhra Pradesh and found that the SRI method contributes significantly to yield than the traditional method. They further found that technological change in paddy production contributes about 32% to the productivity differences between the two methods. Further, using intercept and slope dummy technique, they found that an increase in productivity exclusively from technological improvement was due to a shift in the scale and/or slope parameters of the production function.

Balakrishna (2012) reported similar findings. Balakrishna (2012) studied the economics of Bt cotton in India. His decomposition analysis revealed that the net impact of Bt technology alone have increased the output by about 11%. However, two limitations arose from Balakrishna's (2012) study. First, he did not establish whether there was a structural break/change in the production function between Bt cotton and non-Bt cotton. Structural change is a test that is used to verify the equality of coefficients in separate subsamples. Balakrishna (2012) only relied on the decomposition analysis as the basis for establishing a structural change in the production functions. However, the decomposition analysis employed in the study does not have internal mechanisms for testing for structural change. Second, no attempt was made to establish whether the structural break was due to the shift in the scale parameter, slope parameter or both.

Recent studies have also used the decomposition analysis to measure productivity differences. Resmi et al. (2013) found that output differences between modern black pepper variety and the traditional variety was purely due to differences in technology and neutral technical change, in particular. They established that there was a structural change in the production function of the two production systems. However, their study did not statistically test for the sources of output differences. In a related study, Kumar and Singh (2013) found that differences in technology were the major source of output differences between BHU fishponds and Maharajganj fishpond production systems. Using the dummy variable technique, they established that output differences were solely due to the shift in the slope coefficient, and human labour, in particular. From the aforementioned, this study hypothesises that:

Hypothesis three: Productivity differences between the adopters and non-adopters are partly due to neutral technical change.

Hypothesis four: Productivity difference between the adopters and non-adopters are partly due to non-neutral technical change.

2.8 Conclusions

The concept of technological change has generated intense interest among researchers. Such interest emanates from the realisable potential of technological change in increasing productivity and profitability among farmers. Attempts to measure technological change has led to the development of parametric and non-parametric approaches. Perhaps, the most commonly used method is the parametric and the production function approach, in particular. The production function approach to measuring technological change has focused solely on measuring TFP and PFP. Further, economic analytical methods such as gross margin analysis have emerged as the basis for budgeting approaches used to compare traditional and new technologies. This study used both the gross margin analysis and the production function approaches in measuring technological change in rice production.

Evidence from past studies (Basavaraja et al., 2008; Pouchepparadjoyu et al., 2005; Tan, 1992) suggests that productivity differences between different production methods or technologies emanate from changes in inputs use and a shift in technology. Some existing studies (e.g., Balakrishna, 2012; Resmi et al., 2013), however, have inherent limitations in that they did not statistically test for structural change and its sources. This study adopts the CDP function and the output decomposition model to estimate the productivity differences between the adopters and non-adopters of the improved rice variety. This study also used the dummy variable technique to test for structural change and sources of productivity differences between the improved rice variety and the traditional rice variety. Following Tan (1992), this study decomposed the impact of technological change into two main components: technical change and input use differentials. Technical change was further divided into neutral technical change and non-neutral technical change. Neutral technical change (i.e., efficiency component) implies that more output could be produced under the improved rice variety with the same level of inputs. Non-neutral technical change (i.e., adjustment component) implies the efforts of rice farmers to reallocate the use of inputs at the new level of efficiency. Input use differentials are the changes in the volume of inputs used. The next chapter presents the methodology of the study.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

Chapter two identified relevant theoretical and empirical literatures that shape the focus of this study. This chapter presents the methodology of the study. The chapter starts by describing the study areas. Thereafter, the research design and the population of the study are presented. Next, the sample and sampling procedure are presented. This is followed by the description of the instruments for the data collection. The procedure for the administration of the research instruments is then presented. The final part of this chapter presents the data analysis methods and procedures.

3.2 The Study Areas

The study was conducted in the Ejura-Sekyedumase District of the Ashanti Region and the Atebubu-Amantin Municipality in the Brong-Ahafo Region of Ghana. The Ejura-Sekyedumase District was carved out of the former Sekyere and Offinso Districts. It is located within longitudes 1˚5W and 1˚39'W and latitudes 7˚9'N and 7˚36'N. It has a large land size of about 1,782.2sq. km. (690.781sq. miles) and is the fifth largest district in the Ashanti Region. It constitutes about 7.3% of the Region's total land area with about one third of its land area lying in the Afram Plains. Atebubu-Amantin Municipal, on the other hand, is bordered to the north by the East Gonja District in the Northern Region, Pru district and to the south by Ejura-Sekyeredumasi District in the Ashanti Region. To the east, it shares boundaries with the Sene District and to the west with Kintampo and Nkoranza Districts, all in the Brong-Ahafo Region. The Municipality has predominantly subsistence farmers, who mainly engage in the production of food crops such as rice, yam, cassava, millet, and beans. Some 63% of the active labour force engages in farming, while 19% are involved in commerce. Farming in the Municipality is mostly small-scale in nature (www.ghanadistricts.com).

3.3 Research Design

The study adopted the descriptive research design. The descriptive research design was chosen because of the need to describe the characteristics of certain groups (i.e., adopters and non-adopters of the improved rice variety); determine the proportion of people who behave in a certain way; determine relationships between variables; and make predictions (Brown & Suter, 2012; Saunders et al., 2007). The descriptive research design focused on obtaining both qualitative and quantitative data for the study. The qualitative data employed checklists to explore the production of rice in the two districts using focus group discussions. The quantitative approach used structured interview to examine the economics of technological change in rice production. A cross-sectional survey method was employed in this study. The researcher adopted the survey research method for this study as it is comparatively less costly, less time consuming, easier to employ, and most appropriate for data collection from the rice farmers. The cross-sectional survey was used to collect data on current attitudes, opinion, or practices regarding the technological change in rice production are measured.

3.4 Population of the Study

The target population of this study comprised of all rice farmers in the Ejura-Sekyedumase District of the Ashanti Region and the Atebubu-Amantin Municipality of the Brong-Ahafo Region of Ghana. These rice farmers comprised of those who have adopted the improved rice variety (i.e., NERICA) and those who did not adopt the improved rice variety.

3.5 Sample and Sampling Procedure

Given the large population of rice farmers in the two districts, the farmers were sampled for the study. Sampling was done because it is less costly, have low labour intensity, and less time-consuming (Saunders et al., 2007). The sample size for this study comprised of 216 rice farmers in the two districts. The study selected this sample size because of its feasibility for statistical purposes and logistical considerations. The researcher used multistage stratified random sampling method to select the required sample size. This method was used because of its ability to ensure high degree of representativeness by providing the elements with equal chances of being selected (Babbie, 2007). More clearly, the researcher used a three-stage stratified random sampling design for the operational areas, communities, and rice farmers. In the first stage, three operational areas were selected from each of the two districts using purposive sampling method. The selection was based on the dominance of the adopters and non-adopters of the improved rice variety. For the Ejura-Sekyedumase District, Aframso, Samari Nkwanta, and Dromankuma were selected. Similarly, the selected operational areas in the Atebubu-Amantin Municipal were Atebubu Central, Amantin, and Fakwasi. In the second stage, two rice growing communities were selected from each of the selected operational areas (totalling six communities) using simple random sampling. The final stage involved the selection of 18 rice farmers from each of the selected community using stratified random sampling method. The rice farmers were divided into two strata, namely, adopters and non-adopters. Nine farmers from each stratum were then selected using simple random sampling. Thus, 216 rice farmers from the two districts were sampled for the study.

3.6 Instruments for Data Collection

The study employed two research instruments in gathering data and information relevant to the main research question of this study. These are a semi-structured questionnaire (see *Appendix A*) and a checklist (see *Appendix B*). These instruments were used because of the need for considerable amount of information for this study, reliability of information gathered, and triangulating the results of different methods against each other (McCormick & Schmitz, 2001). However, the questionnaire was the main data collection instrument for the study. The questionnaire was used because of its relatively low cost, structured information that makes analysis relatively straightforward, quick results, as well as its stable, consistent, and uniform method of collecting data (Denzin & Lincoln, 2000). A semi-structured questionnaire was designed for this study based on the research question and in line with literature.

The questionnaire comprised of two main sections: the rice farmers' profile and the survey proper. The profile of the rice farmers focused on such information as age, gender, educational background, household size, farming experience, farm size, and land ownership status. The survey-proper dealt with the input-output data and the use of recommended technologies in rice production. Specifically, the survey proper had two parts. The first part comprised of input utilisation and outputs in rice production. This section focused on land ownership, rice variety, fertiliser, herbicide, and labour. The output from rice production was also covered. The second part of the survey proper dealt with other information relating to rice production. Such information focused on extension services, membership of association, and credit use among the rice farmers. Apart from the questionnaire, a checklist was used to gather information generally on rice production through a focus group discussion. The checklist focused generally on the rice production system and was used to obtained qualitative information on rice production systems in the two districts.

3.7 Data Collection Procedure

Both primary and secondary data formed the basis for this study. Secondary data were obtained from books, journals, and the internet. Further, publications from institutions such as the MoFA, FAO, and African Rice Centre were used. Conversely, primary data formed the basis for the empirical data for this study. Primary data were obtained from the rice farmers in the Ejura-Sekyedumase District and Atebubu-Amantin Municipality, using the research instruments. The collection of the primary data involved three stages. In the first stage, a focus group discussion was conducted in November 2012. Six rice farmers from each of the operational areas and five agricultural extension agents (AEAs) participated in the discussion.

The second stage of the data collection process involved piloting the questionnaire. The AEAs were trained in the administration of the questionnaire. The questionnaire was pretested through a pilot study. Pilot test was conducted for ten rice farmers, comprising of five adopters and five non-adopters. This was done to eliminate and/or rephrase unnecessary and ambiguous questions that may pose a challenge to the rice farmers. Piloting of the questionnaire was done during the first week in April 2013. The researcher with the support from the AEAs administered the questionnaire. The final stage involved the actual data collection. The actual data were collected during the month of May 2013. The researcher with support from the AEAs collected the data. The researcher was actively involved in the monitoring of the entire data collection process. The data were collected based on the 2011/2012 major production season. Out of the 216 rice farmers who participated in the study, eight of them were dropped due to the incomplete information on their input use and output.

3.8 Data Analysis Methods and Procedures

The data from the rice farmers were evaluated using the IBM SPSS Statistics (version 22) and the GNU Regression, Econometric, and Time-series Library (Gretl version 1.9.13) software. A combination of analytical tools, namely, gross margin analysis, descriptive statistics, and inferential statistics were used in analysing the data. Descriptive statistics were employed to analyse and present the farmer/farm characteristics, and to rank the responses of the farmers with regard to certain questions. The descriptive statistics used were frequencies, percentages, mean, and standard deviation. In addition, exploratory data analysis tool such as tables and figures were employed to make the necessary graphical illustration of the data.

The Kendall's coefficient of concordance ω was conducted to measure the degree of agreement among the rice farmers (i.e., adopters and non-adopters) regarding the ranking of the factors that influenced their adoption or non-adoption of the improved rice variety. The null hypothesis was that there was no agreement between the rankings of the factors that influence the adoption or otherwise of the improved rice variety.

Changes in input use patterns due to the adoption of the improved rice variety were computed by estimating the changes in the physical quantity of inputs. Mathematically, changes in the physical quantities of input (per-hectare) were computed using the formula:

$$\%Input\,requirement_{X_i} = \left(\frac{X_{IV_i} - X_{UV_i}}{X_{UV_i}} \right) \times 100 \qquad (2)$$

Where; X_{IV_i} is the quantity of the i^{th} variable input of the improved rice variety and the X_{UV_i} is the quantity of the i^{th} variable input of the traditional rice variety. The decision criteria are that if $X_{IV_i} > X_{UV_i}$; there is an increase in the requirement of the i^{th} input, while $X_{IV_i} < X_{UV_i}$ depicts a reduction in the requirement of the i^{th} input with the introduction of the improved rice variety.

Further, a 2 × 2 contingency table with Pearson Chi-square was used to test whether a statistically significant relationship exists between some categorical variables and the type of rice variety adopted. The categorical variables were method of land acquisition, tenurial security, type of tenurial security, fertiliser use, and herbicide use. The null hypothesis was that there was no association between these variables and adoption/non-adoption of the improved rice variety. This was done to establish whether there exist some relationship between the adoption or non-adoption of the improved rice variety and the use of inputs in production. Moreover, an independent samples t-test was used to examine whether there was a significant difference between physical quantities of inputs used per-hectare and the adoption/non-adoption of the improved variety. Specifically, the independent variables were seeding rate, fertiliser application dates, intensity of fertiliser application, herbicide application dates, intensity of herbicide application, and total labour requirements. The null hypothesis was that there was a statistically significant difference in the physical quantities of inputs used per-hectare between adopters and non-adopters.

Gross margin analysis was employed to determine the cost and returns associated with the production of the improved and traditional rice varieties. The gross margin is the money value of the crop after the direct costs (costs that can be attributed directly to that crop) have been deducted (Murphy & Sprey, 1983). Gross margin (GM) per-hectare is the difference between the gross return (TR) and the total variable cost (TVC), given by:

$$GM = TR - TVC \tag{3}$$

The major assumptions underlying the gross margin analysis in this study are that the two varieties have fixed costs and labour was valued at the price of its best alternative use (i.e., opportunity cost). The gross margin per person-day was computed by dividing the gross margin by total person-days per-hectare. Following Murphey and Sprey (1983), the working capacity of one adult man was expressed as one labour unit, the working capacity of one adult woman as 0.8 of a labour unit, and that of a child as 0.5 of a labour unit. The person-days were computed based on 8 hours of a day's work. Further, the independent samples t-test was used to examine whether there was a significant difference in the costs, gross returns, and gross margins between the adopters and non-adopters of the improved variety. Two main efficiency analyses were computed from the gross margin as measures of net returns to the most limiting resources (i.e., labour and capital). Accordingly, the gross margin per person-days and the gross margin per unit cost were computed. The gross margin per person-days was computed by dividing the gross margin per-hectare by the labour person-days. Similarly, the gross margin per unit cost was computed by dividing the gross margin per-hectare by the total variable cost (Murphey & Sprey, 1983). As gross margins do not account for changes in prices and yields, a sensitivity analysis was conducted to measure the impact on the gross margin for both varieties due to changes in total variable costs, yield, and output price.

The impact of the improved rice variety on per-hectare productivity was estimated using the CDP function. The following logarithmic production functions forms were used:

$$InY_{NA} = In\alpha_1 + a_1 InS_1 + a_2 InF_2 + a_3 InH_3 + a_4 InL_4 + u \quad (4.1)$$

$$InY_{A} = In\alpha_1 + b_1 InS_1 + b_2 InF_2 + b_3 InH_3 + b_4 InL_4 + u \quad (4.2)$$

$$InY_{P_I} = In\alpha_1 + c_1 InS_1 + c_2 InF_2 + c_3 InH_3 + c_4 InL_4 + u \quad (4.3)$$

$$InY_{P_{II}} = In\alpha_1 + dInS_1 + d_2 InF_2 + d_3 InH_3 + d_4 InL_4 + d_5 DV_1 + u \quad (4.4)$$

Where: Y_{NA} = output of non-adopters; Y_A = output of adopters; Y_{P_I} = output for both non-adopters and adopters without varietal dummy; $Y_{P_{II}}$ = output for both non-adopters with varietal dummy; u_1 = error term; DV_1 = Varietal dummy variable (1 for adopters, and zero for non-adopters). The explanatory variables are described in Table 3.1.

Table 3.1: Description of Variables in the Per-Hectare Production Function

Variables	Description	Type of Measure	Sign
S (Seed)	Rice seeds	Kg ha^{-1}	+
L (Labour)	Number of labour used	Person-days ha^{-1}	+/-
F (Fertiliser)	Quantity of fertiliser used	Kg ha^{-1}	+
H (Herbicide)	Quantity of herbicides apply	*L* ha^{-1}	+

An attempt was made to establish whether there was a structural difference in the production functions of the adopters and non-adopters. This helped to establish the need or otherwise of a single production function for both the adopters and non-adopters or estimate separate production functions for each group. A structural break test was conducted using F-test, based on the Chow test (Gujarati, 2004). The null and alternate hypotheses sets under the test were:

$$H_O : \alpha_{NA1} = \alpha_{A1}; a_1 = b_1; a_2 = b_2; a_3 = b_3; a_4 = b_4$$

$$H_A : \alpha_{NA1} \neq \alpha_{A1}; a_1 \neq b_1; a_2 \neq b_2; a_3 \neq b_3; a_4 \neq b_4$$

Based on the structural break, two separate production functions were estimated, one each for the non-adopters [NA] (*equation 5.1*) and the adopters [A] (*equation 5.2*). However, to capture the impact of the improved rice variety on productivity, a varietal dummy variable was introduced into the pooled production function [P_{II}] (*equation 5.4*). Shideed and Saleem (2005) and Lin (1994) have justified the use of the dummy variable approach to measuring the impact of a qualitative variable on a quantitative outcome.

The output decomposition model developed by Bisaliah (1977) was used to estimate the output productivity differences between the traditional and the improved rice varieties. It was further used to identify the contribution of technology and resource use differentials to the productivity differences. The decomposition analysis employed in this study is a revised model of Bisaliah's (1977) approach, using the Cobb-Douglas production model. Several studies have used this approach extensively (Balakrishna, 2012; Basavaraja et al., 2008; Kumar & Singh, 2013; Resmi et al., 2013). Therefore, it was considered appropriate for this study. Accordingly, the production function for the improved rice variety or adopters (A) is expressed as:

$$Y_A = \alpha_A S_A^{B_1} L_A^{B_2} F_A^{B_3} H_A^{B_4} u_A \tag{5.1}$$

Similarly, the production function for the traditional rice variety or non-adopters (NA) is given as:

$$Y_{NA} = \alpha_{NA} S_{NA}^{Z_1} L_{NA}^{Z_2} F_{NA}^{Z_3} H_{NA}^{Z_4} u_{NA} \tag{5.2}$$

These two production functions (*equations 5.1* and *5.2*) were transformed into the logarithmic form. The specifications are as follows:

$$InY_A = In\alpha_A + B_1 InS_A + B_2 InL_A + B_3 InF_A + B_4 InH_A + u_A \tag{5.3}$$

$$InY_{NA} = In\alpha_{NA} + Z_1 InS_{NA} + Z_2 InL_{NA} + Z_3 InF_{NA} + Z_4 InH_{NA} + u_{NA} \tag{5.4}$$

Where: Y = yield of paddy (kg ha^{-1}); α = scale parameter; S = quantity of rice seeds (kg ha^{-1}); L = number of labour used (person-days ha^{-1}); F = quantity of fertiliser (kg ha^{-1}); H = quantity of herbicide (l ha^{-1}); B_i = output elasticities of inputs for the adopters; Z_i = output elasticities of inputs for the non-adopters, and U_i = disturbance terms.

Taking differences between equations (5.3) and (5.4) gives:

$$\begin{aligned} InY_A - InY_{NA} &= (In\alpha_A - In\alpha_{NA}) + (B_1 InS_A - Z_1 InS_{NA}) + (B_2 InL_A - Z_2 InL_{NA}) \\ &+ (B_3 InF_A - Z_3 InF_{NA}) + (B_4 InH_A - Z_4 InH_{NA}) + (u_A - u_{NA}) \end{aligned} \quad (5.5)$$

Adding and subtracting $\sum_{i=1}^{4}\left[\beta_i InX_{NAi}\right]$ in equation (5.5) and rearranging gives:

$$\begin{aligned} [InY_A - InY_{NA}] &= [In\alpha_A - In\alpha_{NA}] + [(B_1 - Z_1)InS_{NA} + (B_2 - Z_2)InL_{NA} \\ &+ (B_3 - Z_3)InF_{NA} + (B_4 - Z_4)InH_{NA}] + [B_1(InS_A - InS_{NA}) \\ &+ B_2(InL_A - InL_{NA}) + B_3(InF_A - InF_{NA}) + B_4(InH_A - InH_{NA}) \\ &+ [u_A - u_{NA}] \end{aligned} \quad (5.6)$$

By applying logarithm rule, equation (5.6) becomes;

$$\begin{aligned} In(Y_A / Y_{NA}) &= [In(\alpha_A / \alpha_{NA})] + [(B_1 - Z_1)InS_{NA} + (B_2 - Z_2)InL_{NA} \\ &+ (B_3 - Z_3)InF_{NA} + (B_4 - Z_4)InH_{NA}] + [B_1 In(S_A / S_{NA}) \\ &+ B_2 In(L_A / L_{NA}) + B_3 In(F_A / F_{NA}) + B_4 In(H_A / H_{NA}) \\ &+ [u_A - u_{NA}] \end{aligned} \quad (5.7)$$

In notation form, equation (5.7) becomes;

$$In(Y_A / Y_{NA}) = In(\alpha_A / \alpha_{NA}) + \sum_{i=1}^{4}[B_i - Z_i]InX_{NA_i} + \sum_{i=1}^{4} B_i\left[In(X_{A_i} / X_{NA_i}\right] \quad (5.8)$$

Where;

$In(Y_A / Y_{NA})$ = Per-hectare output differences between adopters and non-adopters. It gives approximately a measure of percentage change in output with the introduction of the improved rice variety.

$In(\alpha_A / \alpha_{NA})$ = Output differences due to neutral technical change.

$$\sum_{i=1}^{4}[B_i - Z_i]InX_{NA_i}$$ = Output differences due to non-neutral technical change

$$In(\alpha_A / \alpha_{NA}) + \sum_{i=1}^{4}[B_i - Z_i]InX_{NA_i}$$ = Output differences due to technical change.

$$\sum_{i=1}^{4} B_i \left[In(X_{A_i} / X_{NA_i} \right]$$ = Output differences due to input use differentials, and

$[u_A - u_{NA}]$ = Differences in the error term.

Using equation (5.7), the per-hectare productivity difference between the adopters and non-adopters was decomposed into three components. These are neutral technical change (i.e., a shift in the intercept of the production function); non-neutral technical change (i.e., a shift in the slope parameters of the production); and change in the volume of inputs used (i.e., rice seed, labour, fertiliser, and herbicides).

The structural differences in the production functions derived from the adopters and non-adopters were tested using the dummy variable approach (Gujarati, 2004). This technique helped to establish whether the difference in the two regressions was because of differences in the intercept terms or the slope coefficients, or both. It also helped to establish the nature of the technical change associated with the improved variety i.e., whether the technical change associated with the improved rice variety was of the neutral or non-neutral type. Accordingly, the intercept and slope dummies were introduced into the log linear production function as:

$$\begin{aligned} InY &= Ina + b_1 InS_1 + b_2 InL_2 + b_3 InF_3 + b_4 InH_4 + cD \\ &+ d_1[D_1 InS_1] + d_2[D_2 InL_2] + d_3[D_3 InF_3] + d_4[D_4 InH_4] + u \end{aligned} \quad (5.9)$$

Where: D = Varietal intercept dummy; 1 for adopters and 0 for non-adopters.

$\sum_{i=1}^{4} d_i[D_i InX_i]$ = Slope dummies of seed, labour, fertiliser, and herbicide; taking the values of 1 for the adopters and 0 for non-adopters.

The independent samples t-test was used to examine whether such independent variables as the use or otherwise of fertiliser, herbicide, and tractor as well as access to extension services and credit facilities could explain the differences in productivity among the rice farmers. The null hypothesis was that there was a statistically significant difference in the observed variables and the yield of rice.

3.9 Diagnostic Testing of Data

The data were tested for multicollinearity and disturbance terms assumptions. Multicollinearity is present in the data when the explanatory variables are not independent but are corrected among themselves. The variance inflation factor (VIF) was used to test for multicollinearity. As a rule of thumb, if the VIF of a variable exceeds 10, the variable is said to be highly collinear (Cottrell & Lucchetti, 2012; Gujarati, 2004). The problems of non-autocorrelation and heteroscedasticity were corrected using the Hetroscedasticity-correct function (Cottrell & Lucchetti, 2012) in Gretl.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

The study sought to analyse the economics of technological change in rice production in the Ejura-Sekyedumase District and Atebubu-Amantin Municipality. This chapter presents the results and discussions of the study. It starts with the presentation of the farmer/farm characteristics; followed by the technological change and inputs utilisation in rice production. Thereafter, the costs and returns associated with the technological change and the impact of the improved variety on per-hectare productivity are presented. An output decomposition analysis is then conducted to decompose productivity differences between the two varieties.

4.2 Farmer and Farm Characteristics of the Rice Farmers

4.2.1 Farmer characteristics

In this study, the sample was stratified into non-adopters and adopters. The non-adopters were those who did not grow the improved rice varieties. Table 4.1 presents the characteristics of the sampled rice farmers. The result showed that 58% of the rice farmers were males. For non-adopters, 65% were males and for adopters, 51% were males. The proportions of the female rice farmers were 35% and 49% for the non-adopters and adopters, respectively. Further, the mean ages of the rice farmers were 47 and 50 years for the non-adopters and adopters, respectively. The result indicates that the non-adopters are relatively younger than the adopters are. In general, a greater proportion of both the non-adopters and adopters were 50 years and above. This is consistent with the mean age of 50 years in Ghana as reported by MoFA (2011). The finding indicates that rice farming is a preserve for middle-aged people, as the younger generation perceives farming as a low economically rewarding venture. This illustrates the need to step up efforts to increase the interest of the younger generation in farming. Promoting farming among the younger generation is vital because they are energetic and hence can actively involve in productive activities (Lupilya, 2007).

Table 4.1: Farmer Characteristics of the Non-Adopters and Adopters

Variables	Non-Adopters (n = 103)		Adopters (n = 105)	
	Count	Percentage	Count	Percentage
Gender				
Male	67	65.00	54	51.40
Female	36	35.00	51	48.60
Age				
Less than 30 years	11	10.70	7	6.70
30 – 39 years	22	21.40	18	17.10
40 – 49 years	30	29.10	24	22.90
50 years and over	40	38.80	56	53.30
Mean ± SD	46.54 (13.37)		49.51 (13.06)	
Educational status				
No schooling	69	67.00	55	52.40
Schooling	34	33.00	50	47.60
Mean ± SD	2.60 (4.12)		49.51 (13.06)	
Household size				
Less than 5	21	20.40	14	13.30
5 – 10	66	64.10	76	72.40
10 and more	16	15.50	15	14.30
Mean ± SD	7.15 (3.06)		7.68 (3.99)	

Source: Field Survey, 2013. Note: SD = standard deviation.

The survey further revealed that most of the rice farmers (60%) had no formal education. This illustrates the need to provide an informal form of education to the farmers to increase their skills and knowledge. A greater proportion of the adopters had formal education (48%) compared to the non-adopters (33%). The adopters were more educated than the non-adopters were. This implies that with their educational level, they are in a better position to process information relating to improved technologies. This is in line with Caswell et al. (2001) who observed that education creates more awareness and favourable attitude toward the acceptance of improved technologies. Moreover, average household size among the non-adopters and adopters were seven (7) and eight (8) people, respectively. This indicates that both non-adopters and adopters have enough exploited labour for farm activities and are more likely to adopt labour intensive technologies.

4.2.2 Farm characteristics

Table 4.2 presents the farm characteristics or information relating to rice farming among the farmers. The result shows that both the non-adopters and adopters had extensive experience in farming (23 years) and in particular, rice farming (13 years). Thus, the rice farmers have accumulated substantial farming knowledge and skill that could contribute to the adoption of improved rice technologies. It is further evident that most of the adopters (79%) were members of a farmer-based association (that is, NERICA Growers Association), compared with the non-adopters (33%). The study further revealed that the mean cultivated rice farm sizes were 0.95 and 0.74 ha for the non-adopters and adopters, respectively. Ninety-five percent of the rice farmers had rice farm size less than 2 ha, even though 5% had farms larger than 2 ha. The finding indicates that the rice farmers are predominantly smallholders. The 2 ha rice farm size in this study is consistent with MoFA's (2011) reported average farm holdings in Ghana. The small-cultivated farm size could be due to the increased demands for cash and labour in rice production. The finding demonstrates that perhaps efforts to promote improved technologies with credit supports to smallholder farmers need to be stepped up.

Table 4.2: Farm Characteristics of the Non-Adopters and Adopters

Variables	Non-Adopters		Adopters	
Experience (years)	***Mean***	***SD***	***Mean***	***SD***
Farming experience	23.01	12.81	22.50	12.26
Rice experience	13.17	11.84	13.03	11.04
	Frequency	***Percentage***	***Frequency***	***Percentage***
Farm size				
Less than 2 ha	95	92.20	102	97.10
2 – 3 ha	5	4.90	1	1.00
More than 3 ha	3	2.90	2	1.90
Mean ± SD	0.95 (0.64)		0.74 (0.56)	
Membership of organisation				
Yes	34	33.00	83	79.00
No	69	67.00	22	21.00
Access to extension services				
Yes	42	40.80	102	97.10
No	61	59.20	3	2.90
Access to credit				
Yes	17	16.50	71	67.60
No	86	83.50	34	32.40

Source: Field Survey, 2013.

Access to extension services was more visible among the adopters compared to the non-adopters. An overwhelming proportion of the adopters (97%) had contact with the extension agents. This is partly because extension service delivery was an integral part of the NRDP. Apart from creating the awareness and building the capacity of the adopters, the extension agents also provided technical guidance to the rice farmers. However, 59% of the non-adopters had no access to extension services. This is due to the poor extension service delivery in the districts. Beneficiary rice farmers under government-sponsored projects such as the NRDP appear to benefit from extension services compared to non-beneficiaries. The survey further indicated that only 17% of the non-adopters had access to credit facilities. This finding shows how the non-adopters are constrained in accessing credit. This finding therefore illustrates that perhaps efforts to provide specialised credit facilities for non-adopters need to be stepped up. In contrast, the high proportion of the adopters (68%) who accessed credit facilities benefited from the specialised credit scheme under the NRDP.

4.3 Technological Change and Inputs Use Patterns in Rice Production

4.3.1 Improve variety/seed

Evidence from the focus group discussions revealed that the NERICA rice was introduced to the farmers as a package. The package for the beneficiaries in the two districts comprised of the provision of ploughing services (1st and 2nd ploughing); the provision of NERICA seeds, fertiliser and herbicides. The NERICA rice varieties grown in the districts were NERICA4 and NERICA9. MoFA through the NRDP originally supplied the inputs or provided the ploughing services. However, challenges associated with the input distribution systems compelled some of the beneficiaries to procure their own services/inputs. Given that these inputs were provided as credit facilities, the NERICA growers selected bundles of the package for their production depending on their ability to repay. However, the selection of NERICA seed and fertiliser was mandatory. The main traditional rice varieties cultivated by the farmers in the two districts were red rice and Mr Moorl.

4.3.1.1 Reasons for not adopting the improved rice variety

The non-adopters were asked to rank seven reasons considered for not adopting the improved rice variety. The most important reason was ranked one, while the least, seven. Table 4.3 presents the results of the ranking of the reasons for the non-adoption of the improved rice variety and the tests for Kendall's coefficient of concordance. The results showed that Kendall's chi-square had a value of 0.246 with 6 degrees of freedom and a p-value of 0.000. The result was statistically significant at the 5% significant level. Hence, the null hypothesis was rejected in favour of the alternate hypothesis. It can also be observed that the value of the Kendall's coefficient of concordance (0.246) suggests that 24.6% of the non-adopters agreed to the ranking of the reasons for not adopting the improved rice variety. The finding thus suggests that 49% of the rice farmers did not cultivate the improved rice variety because of (1) the non-availability of the improved seed, (2) lack, and/or inadequate information on the improved rice variety, and (3) delays in input supply as well as high price of the improved seeds. The result revealed that the non-availability of the improved seed coupled with lack or inadequate information on the improved variety were solely responsible for the non-adoption of the improved variety. The non-availability of the improved seed and the lack/inadequate information on the improved variety suggests poor extension service delivery.

Table 4.3: Reasons for Not Adopting the Improved Rice Variety

Reasons	Mean Rank	Overall Rank
Non-availability of the improved seed	2.34	1st
Lack/inadequate information on the improved rice variety	3.59	2nd
Delays in input supply	3.66	3rd
High price of NERICA seeds	3.66	3rd
High demands for inputs by the improved rice variety	4.24	4th
Loss of quality of the improved rice when delayed on field	4.73	5th
Difficulty in threshing	5.77	6th
Total N	58	
Kendall's W	0.246	
Test Statistic	85.581	
Degree of Freedom	6	
Asymptotic sig. (2 sided test)	0.000	

Source: Field Survey, 2013.

Further, evidence from the focus group discussion re-enforced the lack of or inadequate information factor. It emerged from the focus group discussion with the rice farmers that some of the adopters were included in the project because of their relationship with the extension agents, experience in rice farming, and their scale/consistency in production. Such purposive nature of selecting the adopters may have disadvantaged some of the non-adopters. Thus, apart from the non-availability of the improved rice variety, technical and other constraints might have prevented some of the rice farmers from adopting the improved rice variety. The finding therefore illustrates that efforts to promote improved technologies must remove impediments that prevent its adoption.

4.3.1.2 Reasons for adopting the improved rice variety

The rice farmers were asked to rank a number of factors for the adoption or non-adoption of the improved rice variety. In particular, the adopters were asked to rank six reasons for adopting the improved rice variety. The most important reason was ranked one while the least important six. Table 4.4 presents the ranking of the reasons for adopting the improved rice variety and the tests for Kendall's coefficient of concordance. Kendall's chi-square had a value of 0.738 with 5 degrees of freedom and a p-value of 0.000. The result was statistically significant at the 5% significance level. The researcher rejects the null hypothesis in favour of the alternate hypothesis. The value of the Kendall's coefficient of concordance (0.738) implies that 73.8% of the adopters agreed to the ranking of the reasons for adopting the improved variety. Hence, there is a reasonable degree of agreement among the adopters regarding their reasons for adopting the improved variety.

The result suggests that the main reasons why rice farmers adopted the improved rice variety were because of its: (1) higher yield advantage; (2) early maturity; (3) good taste and aroma; (4) and resistance to pest and diseases. The findings indicate that farmers want more yields so that they could consume some and sell the rest to meet their household financial needs. Early maturity of the improved rice variety gave farmers the added advantage to harvest quickly on time and sell the produce at the time that paddy is relatively unavailable. In fact, the improved rice variety takes within 80 – 100 days to mature, compared with the traditional rice varieties, which takes longer days (about 120 days). Nonetheless, the results from the focus group discussions revealed that the rice farmers experienced some challenges in adopting the improved variety. These challenges were non-availability/delays in the input (i.e., seed and fertiliser) supply and the difficulties in threshing. The issues of non-availability and delays in input supply were consistent with the reasons reported by the non-adopters for not adopting the improved rice variety. The finding thus illustrates that efforts to promote improved technologies need to be integrated with an efficient input supply system to facilitate their adoption processes.

Table 4.4: Reasons for Adopting the Improved Rice Variety

Reasons	Mean Rank	Overall Rank
Higher yield advantage	1.77	1st
Early maturing	2.20	2nd
Good taste and aroma	2.41	3rd
Resistance to drought	4.07	4th
Resistance to pest and diseases	4.84	5th
Acid tolerant	5.71	6th
Total N	105	
Kendall's W	0.738	
Test Statistic	387.420	
Degree of Freedom	5	
Asymptotic Sig. (2 sided test)	0.000	

Source: Field Survey, 2013.

4.3.1.3 Sources of seeds

The sources of seeds used in the production of rice in the two districts are presented in Table 4.5. The survey showed that about 53% of the non-adopters obtained their seeds from the market while 39% used seeds from their previous years' harvest. The result revealed an over-reliance on previous year's seed and purchase of seeds from the market among the non-adopters. The focus group discussion revealed that seeds sold in the market emanated from the farmers' field. Such seeds were not certified. The major challenge to these sources is their potential contamination and low quality. The cultivation of quality seeds, therefore, requires adequate education and training of farmers in the selection and/or purchase of quality seeds. Efforts to create awareness of the yield advantage of certified seeds should also be stepped up to minimise the use of poor quality seeds. For the adopters, 73% had their seeds from MoFA. It emerged from the focus group discussion that MoFA as part of the NRDP was responsible for the distribution of the improved rice seed to the adopters; however, some of the adopters obtained theirs from sources.

Table 4.5: Sources of Seeds for Rice Production by Non-Adopters and Adopters

Sources of Seeds	Non-Adopters		Adopters	
	Count	%	Count	%
Previous years' harvest	40	38.80	5	4.80
Market	55	53.40	6	5.70
Purchase from colleague farmer	7	6.80	14	13.30
MoFA	-	-	77	73.30
A gift from another farmer	1	1.00	3	2.90
Total	**103**	**100.00**	**105**	**100.00**

Source: Field Survey, 2013.

4.3.1.4 Seeding rate

Table 4.6 presents the mean differences in the seeding rate between the adopters and non-adopters. The study revealed that the seeding rate for the adopters was 58.00 kg ha^{-1}; lower than the non-adopters (71.69 kg ha^{-1}). The finding indicated that the adoption of the improved rice variety had reduced the requirements of seeds by 19%. The recommended seeding rate for the improved rice variety is 50 kg ha^{-1}

(MoFA/CRI, 2009); suggesting that the adopters applied slightly higher seeding rate. The independent samples t-test was conducted to examine whether there was a significant difference in the seeding rate between the non-adopters and adopters. The test revealed a statistically significant difference in the seeding rate between the non-adopters and adopters ($t = -5.487$, $df = 147.70$, $p < 0.001$). The result indicated that the non-adopters ($M = 71.69$, $SD = 22.79$) applied significantly higher seed rates than the adopters ($M = 58.00$, $SD = 11.17$). Therefore, rice farmers who cultivate traditional rice varieties are more likely to use more seeding rates, compared to those who cultivate improved varieties. The high seeding rate requirement for the traditional rice variety is because of the low quality of some of the seeds bought from the market.

Table 4.6: Mean Differences in Seeding Rate for Non-Adopters and Adopters

Variable	Non-Adopters	Adopters	t-value	df
Seeding rate (kg ha^{-1})	71.69 (22.79)	58.00 (11.17)	-5.484***	147.70

Source: Field Survey, 2013. Standard deviations appear in parentheses. ***ρ< 0.01.

4.3.2 Land tenure

4.3.2.1 Method of land acquisition

Land tenure is a critical factor affecting the adoption of new and/or improved technologies. In particular, access to land and its security have great implications for adoption of technologies and for long-term use of such technologies. The results showed in Table 4.7 that the majority (73%) of the non-adopters rented their rice farmlands. The high proportion of the rice farmers who rented their farmland could be due to the large proportion of migrant farmers in the study area. The average rent for an acre of land was GH¢20.00. The lease period for renting is one year (i.e., production season) and renewable based on satisfactory compliance with the terms;

i.e., observing taboos on the land as well as honouring financial and/or kind obligations. Rice farmers who practiced sharecropping gave one bag (100 kg) of paddy in return after harvesting. A significantly larger proportion of the adopters (52%) obtained their land through direct ownership while 20% of the non-adopters did. The Pearson Chi-square test revealed a statistically significant relationship between the variety cultivated and method of land acquisition (χ^2 = 22.962, df = 2, p < 0.001). Clearly, the null hypothesis that there was no association between the variety cultivated and the method of land acquisition was rejected. The finding indicates that most of the rice farmers adopted the improved rice variety because they own their farmland.

Table 4.7: Crosstabulation of Adoption-Category and Land Acquisition

Adoption Category	Land Acquisition			χ^2	df
	Owned	Rented	Sharecropping		
Non-adopters	21 (20.40)	75 (72.80)	7 (6.80)	22.962***	2
Adopters	55 (52.40)	46 (43.80)	4 (3.80)		

Source: Field Survey, 2013. Note: Percentages appear in parentheses after frequencies. χ^2 = Pearson Chi-Square. df = degree of freedom. ***ρ < 0.01.

4.3.2.2 Tenurial security

The second aspect of land tenure that affects technology adoption is tenurial security. The security of tenure was measured in this study using land rights. Farmers were asked whether they have access to their land for an unspecified length of time or enjoy its property rights. Table 4.8 suggests that 91% of the adopters reported having a secured tenure of land as against 73% of the non-adopters. The Chi-square test revealed that there was a significant relationship between adoption/rejection and tenurial security (χ^2 = 12.318, df = 1, p < 0.001). This implies that rice farmers are more likely to adopt improved varieties when they feel secure with their farmland. Accordingly, they could undertake long-term investments on the land.

Table 4.8: Crosstabulation of Adoption Category and Tenurial Security

Adoption Category	**Tenurial Security**		χ^2	**df**
	Yes	**No**		
Non-adopters	75 (72.80)	28 (27.20)	12.318***	1
Adopters	96 (91.40)	9 (8.60)		

Source: Field Survey, 2013. Note: Percentages appear in parentheses after frequencies. χ^2 = Pearson Chi-Square. df = degree of freedom. ***ρ < 0.01.

To explore the relationship between adoption and types of tenurial security, a cross-tabulation was used (Table 4.9). Three types of property rights (i.e., tenurial security) were examined: use security; control security; and transfer security. Use security in this study refers to the farmers' right to use the land for growing any rice variety only. Control security refers to the right to decide on what crops to grow and the benefits to derive from its sales. Transfer right is an extended tenurial security arrangement. Here, the farmer has the right to sell or reallocate its use and have control security as well. The result suggested that about 70% of the adopters have control security, while 56% of the non-adopters have it. The Chi-square test revealed that there was a significant relationship between adoption/rejection and tenurial security of rice farmers (χ^2 = 7.730, df = 2, p < 0.05). This implies that rice farmers who have the right to grow any crop and determine the use of its returns are more likely to adopt improved varieties. The second dominant form of tenurial security was use security for the non-adopters and transfer security for the adopters. This suggests that rice farmers who feel secure with their land are more likely to adopt improved technologies. The rice farmers were equally more likely to undertake greater investment on the land.

Table 4.9: Crosstabulation of Adoption Category and Tenurial Security Types

Adoption Category	Tenurial Security			χ^2	df
	User	Control	Transfer		
Non-adopters	20 (26.70)	42 (56.00)	13 (17.30)	7.730**	2
Adopters	10 (10.40)	67 (69.80)	19 (19.80)		

Source: Field Survey, 2013. Note: Percentages appear in parentheses after frequencies. χ^2 = Pearson Chi-Square. df = degree of freedom. **$\rho < 0.05$.

4.3.3 Fertiliser

4.3.3.1 Adoption

Table 4.10 presents the use of fertiliser in rice production among the rice farmers. The result indicated that a greater proportion (80%) of the rice farmers applied fertiliser. This suggests that fertiliser use is high among rice farmers in the two districts. However, only 20% did not use fertiliser during their previous production season. The lack of fertiliser use among these categories of rice farmers is surprising considering the many opportunities (e.g., through fertiliser subsidy) offered to the farmers to increase their productivity. Nonetheless, the lack of fertiliser use as evident from the focus group discussion is due to lack of capital to purchase the fertiliser. Hence, there is the need for providing credit facilities to the rice farmers. Rice farmers apply fertiliser using either manual broadcasting or side placement. About 68% of the rice farmers who applied fertiliser used broadcasting while 13% used side placement. Rice farmers who apply fertiliser by side placement may require additional labour compares with those who use broadcasting.

A chi-square test was further conducted to test the relationship between adoption/rejection and fertiliser application. The result revealed that there was a statistically significant relationship between the two variables (χ^2 = 19.59, df = 1, p < 0.001). A significantly larger proportion of the adopters (92%) applied fertiliser, compared with 68% of the non-adopters. More adopters used fertiliser than the non-adopters. This is because the improved rice variety is fertiliser demanding (Somado et al., 2008). Therefore, rice farmers who adopt improved rice varieties are more likely to use fertiliser since the two inputs are complementary.

Table 4.10: Crosstabulation of Adoption Category and Fertiliser Use

Adoption Category	**Fertiliser Use**		χ^2	**df**
	Yes	**No**		
Non-adoption	70 (68.00)	33 (32.00)	19.59***	1
Adoption	97 (92.40)	8 (7.60)		

Source: Field Survey, 2013. Note: Percentages appear in parentheses after frequencies. χ^2 = Pearson Chi-Square. df = degree of freedom. ***ρ < 0.01.

4.3.3.2 Timing of fertiliser application

Rice farmers apply fertiliser at two time phases: basal application and top dressing. Fertiliser application, either at the basal state or as top dressing occurs after seedling emergence. The timing of fertiliser application is presented in Table 4.11. The survey showed that the average weeks of basal application were about 2 weeks for the non-adopters and about 2½ weeks for the adopters. Similarly, the non-adopters and adopters applied fertiliser as top dressing during the 4th and 5th weeks, respectively. The recommended number of weeks of basal fertiliser application for the improved rice variety is 2 - 3 weeks while that for top dressing is between 5 and 6 weeks (MoFA/CRI, 2009). Thus, the majority of the adopters applied fertiliser (i.e., basal and topdressing) within the recommended period. The result of the independent sample t-test indicated that there was a statistically significant difference between the mean weeks of basal application for the non-adopters and adopters ($t = 2.624$, $df = 182.64$, $p < 0.05$). In other words, the non-adopters applied NPK earlier after seedling emergence than the adopters. Differences in the timing of fertiliser application could be due to the differences in the maturity cycle of the varieties and lack of capital to purchase and apply the fertiliser at the right time. Similarly, there was a statistically significant difference between the mean weeks for top dressing by the non-adopters and adopters ($t = 2.478$, $df = 173.92$, $p < 0.05$). This implies that, the non-adopters apply sulphate of ammonia (SA) earlier than the adopters do.

Table 4.11: Mean Differences in Fertiliser Application Dates between Non-Adopters and Adopters

	Non-Adopters	Adopters	t-value	df
Basal application (weeks)	1.80 (1.71)	2.33 (1.20)	2.624**	182.68
Top dressing (weeks)	4.17 (3.18)	5.10 (2.05)	2.478**	173.92

Source: Field Survey, 2013. Standard deviations appear in parentheses. **$\rho < 0.05$.

4.3.3.3 Intensity of fertiliser application

The intensity of fertiliser application is presented in Table 4.12. The result revealed that, on the average, the majority of the non-adopters used 98.30 kg ha^{-1} each of NPK and SA, totalling 196.60 kg ha^{-1} of fertiliser. Conversely, the adopters applied, on the average, 189.88 kg ha^{-1}, 129.76 kg ha^{-1}, and 319.64 kg ha^{-1} of NPK, SA, and total fertiliser, respectively. Thus, fertiliser use was more intense for the adopters than the non-adopters. The high intensity of fertiliser use among the adopters could be due to the responsiveness of the improved rice variety to fertiliser. MoFA/CRI (2009) recommends five bags/ha (i.e., 250 kg ha^{-1}) and 2.5 bags ha^{-1} (i.e., 125 kg ha^{-1}) of NPK and SA, respectively. In totality, MoFA recommends 375 kg ha^{-1} of fertiliser. Therefore, with the current intensity of fertiliser application, the majority of the adopters, on the average, applied NPK and total fertiliser below the recommended levels. However, the intensity of SA application, on the average, was slightly more than its recommended level of 125 kg ha^{-1}.

Table 4.12: Mean Differences in the Intensity of Fertiliser between Non-Adopters and Adopters

Quantity (kg ha^{-1})	Non-Adopters	Adopters	t-value	df
NPK	98.30 (95.31)	189.88 (86.20)	7.271***	206
SA	98.30 (86.46)	129.76 (59.23)	3.056**	180.09
Total fertiliser	196.60 (166.38)	319.64 (119.88)	6.109***	185.21

Source: Field Survey, 2013. Note: Values in parentheses are standard deviations. **$\rho < 0.05$. ***$\rho < 0.01$.

It is further evident that the adoption of the improved rice variety had increased the requirement for fertiliser by 63% over the traditional rice variety. The results of the independent sample t-tests indicated that there was a statistically significant difference between the intensity of fertiliser use among the non-adopters and adopters for NPK ($t = 7.271$, $df = 206$, $p < 0.001$); SA ($t = 3.056$, $df = 180.09$, $p < 0.05$); and total fertiliser ($t = 6.109$, $df = 185.21$, $p < 0.001$). Thus, rice farmers who adopt improved rice varieties apply more quantities of fertiliser per-hectare compared to non-adopters. This still re-enforce the responsiveness of the improved rice variety to fertiliser. As stated earlier, the high demands for inputs by the improved variety is one of the reasons for not adopting the improved variety. Further, the focus group discussion revealed that the major constraints limiting the use and adequacy of fertiliser among the rice farmers were lack of capital and the late supply of fertiliser. The major challenge then is to make fertiliser supply readily available to the rice farmers. Similarly, a possible decentralisation of fertiliser supply to rice farming communities will be helpful. Moreover, the provision of credit facilities will facilitate the timely access to the input.

4.3.4 Herbicide

4.3.4.1 Adoption

The result indicated that an overwhelming proportion (92%) of the rice farmers applied herbicide in controlling weeds. An almost equal proportion of the non-adopters and adopters applied herbicide on their rice field. Crosstabulation of herbicide application and adoption category is presented in Table 4.13. There was no statistically significant relationship between the adoption of the improved rice variety and herbicide use. Thus, the adoption of the improved rice variety is not contingent on the use of herbicides since it competes favourably well with weeds than the traditional variety.

Table 4.13: Crosstabulation of Adoption Category and Herbicide use

Adoption Category	Herbicide use		χ^2	df
	Yes	No		
Non-adopters	95 (92.2)	8 (7.8)	0.002	1
Adoption	97 (92.4)	8 (7.6)		

Source: Field Survey, 2013. Note: Figures in parentheses are percentages. χ^2 = Pearson Chi-Square. df = degree of freedom.

4.3.4.2 Timing of herbicide application

Rice farmers apply herbicide at either during land preparation or after seedling emergence, or both. They apply herbicides as pre-emergence and/or post-emergence herbicides. Rice farmers apply pre-emergence herbicides prior to the emergence of the rice seedling while they apply post-emergence herbicide after the emergence of the rice seedling. The result revealed that non-adopters and adopters of the improved rice variety applied pre-emergence herbicide, on the average, about 5 and 2 days, respectively, prior to the emergence of rice seedling (Table 4.14). The result further showed that there was a statistically significant difference between the mean days of pre-emergence herbicide application for the non-adopters and adopters ($t = -4.879$, $df = 206$, $p < 0.001$). This means that, the non-adopters had a significantly higher mean day of pre-emergence herbicide application (M = 5.06, SD = 6.74) than the adopters (M = 1.67, SD = 2.10).

Table 4.14: Mean Differences in Herbicides Application Dates between Non-Adopters and Adopters

Timing (Days)	Non-Adopters	Adopters	t	df
Pre-emergence application	5.06 (6.74)	1.67 (2.10)	-4.879***	206
Post-emergence application	23.56 (19.33)	19.32 (17.69)	-1.650*	206

Source: Field Survey, 2013. Note: Standard deviations appear in parentheses. *$\rho < 0.10$. ***$\rho < 0.01$.

This trend is further evident in the application of the post-emergence herbicide. The non-adopters reported a higher number of days (M = 23.56, SD = 19.33) than the adopters (M = 19.32, SD = 17.69). The result of the t-test suggested that there was a statistically significant difference between the mean days of post-emergence herbicide application for non-adopters and adopters ($t = -1.650$, $df = 206$, $p = 0.10$). That is, the non-adopters have significantly higher mean days of post-emergence herbicide application than the adopters do. Rice farmers who adopt the improved varieties apply post-emergence herbicide earlier, partly, because the improved rice variety has shorter production cycle.

4.3.4.3 Intensity of herbicide application

Table 4.15 depicts the intensity of herbicide application by the adopters and non-adopters. The mean volume of pre-emergence herbicide applied by the non-adopters was 2.52 *l* ha^{-1} as against 1.83 *l* ha^{-1} by the adopters. Similarly, the mean volumes of post-emergence herbicide applied were 2.18 *l* ha^{-1} and 2.45 *l* ha^{-1} for the non-adopters and adopters, respectively. Total volumes of herbicide applied were 4.71 *l* ha^{-1} and 4.29 *l* ha^{-1} for the non-adopters and adopters, respectively. Thus, the adoption of the improved rice variety had reduced the intensity of herbicide by about 9%. The result of the independent sample t-tests showed that there was a statistically significant difference between the intensity of pre-emergence herbicide for the non-adopters and adopters ($t = -2.784$, $df = 206$, $p < 0.05$). Thus, the non-adopters use more herbicide per-hectare than the adopters do. The high intensity of herbicide among the non-adopters could be due to the inability of the traditional rice variety to compete well with weeds.

Table 4.15: Mean Differences in the Intensity of Herbicides between Non-Adopters and Adopters

Timing (*l* ha^{-1})	Non-Adopters	Adopters	t	df
Pre-emergence herbicide	2.52 (1.90)	1.83 (1.67)	-2.784**	206
Post-emergence herbicide	2.18 (2.00)	2.45 (2.25)	0.908	206
Total herbicide	4.71 (2.60)	4.29 (2.61)	-1.170	206

Source: Field Survey, 2013. Standard deviations appear in parentheses. **$\rho < 0.05$.

Rice farmers use such herbicides as glyphosate, propanol, and 2-4D. Since different dosage for different types of herbicide exist, no attempt was made to disaggregate the various herbicides used in this study. This is partly because; most of the rice farmers were unable to identify the particular herbicide they used since they are illiterate. In addition, the intensity of herbicide application depends on the stage of the weeds on a particular farmer's field. Interaction with the rice farmers during the focus group discussion revealed that the major constraint to the use and the intensity of herbicide is capital; suggesting that credit facilities should be made available to the rice farmers to purchase the input.

4.3.5 Labour

Labour availability and labour use pattern in rice production forms the basis for analysing labour requirements in this study. Table 4.16 presents the labour differences between the non-adopters and adopters. The mean labour demand for the improved rice variety was 136 person-days ha^{-1}; about 16% higher than the traditional rice variety (117 person-days ha^{-1}). The independent samples t-test revealed a statistically significant difference between the non- adopters and adopters in terms of their labour requirement ($t = 2.049$, $df = 186.57$, $p < 0.05$). The finding indicated that adopters ($M = 135.66$, $SD = 55.02$) reported significantly higher requirements for labour than did the non-adopters ($M = 116.89$, $SD = 75.34$).

Table 4.16: Mean Differences in Labour between Non-Adopters and Adopters

	Non-Adopters	**Adopters**	**t**	**df**
Labour (person-days ha^{-1})	116.89 (75.34)	135.66 (55.02)	2.049**	186.57

Source: Field Survey, 2013. Standard deviations appear in parentheses. **$\rho < 0.05$.

The covariance for labour use is 41% for adopters and 64% for non-adopters, perhaps providing evidence that there is greater flexibility in labour use for the traditional variety than the improved variety. Thus, rice farmers who adopt the improved varieties use more labour as the technology is labour intensive. This additional labour requirement is required for harvesting and threshing (see Table 4.17). Increased labour requirement for these two activities in turn could be due to the higher yield and difficulty in threshing of the improved rice variety. The result thus indicates that the improved rice variety requires more labour compared with the traditional rice variety. This raises the additional requirement for labour and thus the cost of rice production. The high labour requirements partly explain why some of the rice farmers did not adopt the improved rice variety. The high labour requirement further limits further expansion of the cultivated land area and the potential of increasing production on farmers' currently cultivated field.

4.3.5.1 Activity-based labour use pattern

Table 4.17 and Figure 4.1 present the labour requirement for specific activities in rice production. The result showed that the major labour consuming activities for the production of the improved rice variety are harvesting (44%) and threshing (27%). Similarly, labour required for the improved rice variety was high for harvesting (46%) and threshing (17%). Thus, harvesting and threshing are the most labour intensive activities in rice production for both non-adopters and adopters. The result is thus consistent with similar findings by Kimani et al. (2011). Another observation is that these activities have time constraints and represent peak season activities. Therefore, unavailability of labour during these periods could affect the whole production process leading to yield losses. The challenge then is for technology development to take into account the limited availability of labour during such periods. The development of labour saving technologies to reduce manual labour requirement during the peak period is highly crucial.

Labour requirements for land preparation included clearing, spraying, and weeding using either hoe or tractor. The result suggested that labour requirement for land preparation for the production of the improved rice variety was 10 person-days ha^{-1}; a reduction of 29% of the labour requirement for the traditional rice variety (14 person-days ha^{-1}). The mean 10 person-days ha^{-1} for the improved rice variety suggest that a hectare of land requires two working people to work for 5 days in land preparation. The reduction in labour requirement for land preparation could be due to the use of mechanisation, i.e., tractor ploughing and harrowing. The mechanisation service was implemented alongside the promotion of the improved varietal technology to arouse the interest of the rice farmers in the improved technology. Therefore, the integration of the technology promoting activities with the mechanisation activity has helped to alleviate labour bottlenecks among the adopters. Future agricultural policies must therefore adopt this integrative approach in the promotion of improved rice varieties.

Table 4.17: Activity-Based Labour Demands for Non-Adopters and Adopters

Operation	Non-Adopters		Adopters	
	Person-days ha^{-1}	%	Person-days ha^{-1}	%
Land preparation	14	11.9	10	7.3
Sowing	12	10.3	16	11.8
Weeding	13	11.1	9	6.6
Fertiliser application	4	3.4	5	3.8
Harvesting	54	46.2	60	44.0
Threshing	20	17.1	36	26.5
Total	**117**	**100.0**	**136**	**100.0**

Source: Field Survey, 2013. Note: Person-days are based on 8 hours of work per day.

The study further revealed that sowing required 12 person-days for the traditional rice variety and 16 person-days for the improved rice variety. This implies that the introduction of the improved rice variety has increased labour requirement for sowing by 25%. This increase could partly be due to the method of sowing employed by the adopters, that is, the use of line placement and broadcasting. The high labour requirement for sowing could restrict the adoption of the improved rice variety by labour and capital constrained rice farmers. Further, it could restrict further expansion of land holdings above the currently cultivated size by the rice farmers. A technological improvement to reduce such increased labour requirement is not only needed to increase the area under cultivation but also promote the adoption of improved varieties.

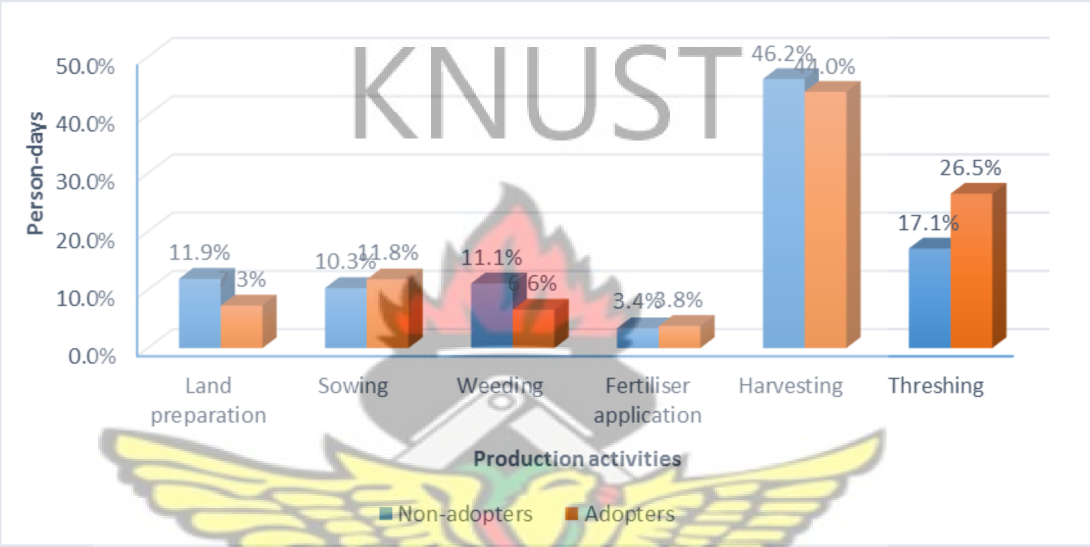

Figure 4.1: Activity-based labour demands for non-adopters and adopters

Labour for weeding practices amounted to 9 person-days ha^{-1} for the adopters and 13 person-days ha^{-1} for the non-adopters. Labour for weeding includes the application of herbicides/weedicides. Thus, labour requirement has reduced by 31% with the adoption of the improved rice variety and its complementary inputs. This reduction could be due to the use of improved land preparation methods such as tractor ploughing and harrowing. Improved land preparation methods are effective in controlling weeds, thus reducing the labour requirements for weeding. In fact, 95% of the adopters used tractor in ploughing their field, compared to 84% of the non-adopters (see Table 4.30). More importantly, 55% of the adopters ploughed and harrowed their field using a tractor, compared to the 18% of the non-adopters. Statistically, the relationship between these two variables was significant at 1%. This implies that the intensity of land preparation for rice production is associated with reduced labour requirements for weeding. Further, the reduction in labour for weeding could be due to the weed competitive nature of the improved rice variety (Kijima, 2008). Fertiliser application requires 5 and 4 person-days ha^{-1} for the improved and traditional varieties, respectively. As stated earlier, fertiliser use and its intensity were more concentrated among the adopters (92%) than the non-adopters (68%) were. Further, the adopters applied fertiliser by either side placement or broadcasting while the non-adopters used only broadcast. This explains the extra labour requirements for fertiliser application for the improved rice variety.

Harvesting is the most labour consuming activity on the rice field for both the non-adopters and adopters. This activity required 60 and 54 person-days ha^{-1} for the improved and traditional rice varieties, respectively. Labour for harvesting has increased by 11% with the adoption of the improved rice variety. Currently, rice farmers in the study areas harvest using handheld sickle and knife. However, this activity has to be timely to obtain high quality grain and minimise field losses. Thus, the development of mechanised harvesters is necessary in reducing the high demand for manual labour and minimising loses at this stage.

The second most labour demanding activity for both the adopters and non-adopters is threshing. Threshing requires 36 and 20 person-days ha^{-1} for the improved and traditional rice varieties, respectively. Thus, the improved rice variety and its complementary inputs had increased labour requirement for threshing by 80%. This increase can be attributed to the difficulty in threshing the improved rice variety. The grains of the improved variety becomes hard when matured; thereby making it difficult during manual threshing. The manual threshing is done by beating the harvested crop on the tarpaulin. To avoid unnecessary delays of the harvested rice on the field, the farmers increase the labour requirement for threshing. Thus, the development of mechanised threshers will reduce labour requirements for threshing and facilitate the adoption of the improved rice variety. In general, the adoption of the improved rice variety has increased the demand for labour for harvesting, threshing, and sowing. These labour peaks are very critical since they must be performed within limited periods. The implication is that post-harvest losses could be high. Increase in the seasonal requirements for labour in the production of the improved rice variety may thus be a limiting factor for labour and capital constrained rice farmers.

4.4 Technological Change and Production Costs and Returns

4.4.1 Costs of rice production

Cost of production was analysed based on the use of variable inputs seed, labour, herbicide, fertiliser, and miscellaneous costs such as transportation. Table 4.18 presents the cost of rice production in the two districts. The result indicated that input-specific costs differed between the non-adopters and adopters. The share of land preparation through ploughing was GH¢144.67 ha^{-1} for the adopters and GH¢95.80 ha^{-1} for the non-adopters. The cost of ploughing had thus increased by 51% due to the adoption of the improved rice variety. The increased cost of ploughing was because unlike the non-adopters, the adopters plough the land twice. The first ploughing is the usual tractor ploughing while the second is meant for harrowing. In fact, about 69% of the non-adopters only ploughed their land without harrowing while 55% of the adopters both ploughed and harrowed their land. The focus group discussion revealed that most of the non-adopters plough the land once because of inadequate capital. The share of seed cost was GH¢59.89 ha^{-1} for the adopters and GH¢71.38 ha^{-1} for the non-adopters. The reduction in the cost of seed

(16%) for the improved rice variety could be due to the subsidised nature of the certified seed and the considerable reduction in seed rate. It could also be due to the quality of seeds used as quality seeds have high germination and thus less quantity for planting. Polices to promote and create awareness on the economic gains from quality seed is therefore highly needed.

Table 4.18: Costs of Production for the Non-Adopters and Adopters

Variable Inputs	Non-Adopters		Adopters	
	Amount (GH¢ ha^{-1})	%	Amount (GH¢ ha^{-1})	%
Land preparation*	95.80	8.46	144.67	9.78
Seed	71.38	6.31	59.89	4.05
Fertiliser	146.46	12.94	240.37	16.26
Herbicide	37.95	3.35	34.01	2.30
Labour	736.03	65.02	935.38	63.27
Miscellaneous	44.37	3.92	64.19	4.34
Total Variable Cost	**1131.99**	**100.00**	**1478.51**	**100.00**

Source: Field Survey, 2013. *= Land preparing by tractor ploughing and/or harrowing.

Further, expenditure on fertiliser (64%) was higher for the adopters (GH¢240.37 ha^{-1}) compared with the non-adopters (GH¢146.46 ha^{-1}). The high expenditure on fertiliser by the adopters could be due to the high demand for fertiliser by the improved rice variety. The result further revealed that the cost of herbicide was higher for the non-adopters (GH¢37.95 ha^{-1}) compared to the adopters (GH¢34.01 ha^{-1}); a reduction by 10%. This suggests that the non-adopters incur higher expenditure on herbicide since it is non-weed competitive. Moreover, the expenditure on labour was higher for the adopters (GH¢935.38 ha^{-1}) than the non-adopters (GH¢736.03 ha^{-1}). This implies that the cost of labour has increased by 27% because of the adoption of the improved rice variety. The high expenditure on labour is due to the increased demand for labour for harvesting and threshing. Miscellaneous cost (including cost of transportation) for the adopters was higher (GH¢64.19 ha^{-1}) than the non-adopters (GH¢44.37 ha^{-1}).

Overall, the average cost of producing the improved rice variety was GH¢1478.51 ha^{-1}, which is higher compared to GH¢1131.99 ha^{-1} for the traditional rice variety. This implies that the improved rice variety and its complementary inputs had increased the cost of producing rice by about 31%. Therefore, the improved rice variety is capital intensive. In cash-constrained, subsistence setting, this limitation is severe. The adoption of the improved rice variety is therefore be dependent on whether farmers have access to credit for the additional expenses they incur. In contrast, the cultivation of the traditional rice variety requires minimal amount of cash. The major constituent of the expenditure for the improved rice variety is labour. Cost incurred on fertiliser ranked the second highest in the total variable cost for the improved rice producers. For the non-adopters, the dominant cost components were labour and fertiliser. In general, expenditure on labour and fertiliser occupies a very high proportion of the total capital expended in the production of the improved and traditional rice varieties. The results are therefore consistent with Abdullahi (2012) who found the expenditure on these inputs to constitute more than half of the cost of producing the improved rice variety.

The study hypothesised that the cost of producing the improved rice variety is significantly higher than that of the traditional rice variety. Accordingly, an independent-samples t-test was run to determine whether there was a significant difference in the cost of production between the non-adopters and adopters (Table

4.19). The test revealed a statistically significant difference between the adopters and non-adopters ($t = 5.246$, $df = 206$, $p < 0.001$). The adopters ($M = 1478.51$, $SD = 456.45$) reported significantly higher total variable cost per-hectare than did the non-adopters ($M = 1131.99$, $SD = 495.81$). Thus, production cost differs substantially by the type of variety grown. The higher covariance for the non-adopters (44%) suggests that there is greater flexibility in the cash requirements for the production of the traditional variety compared to the improved variety, which has a covariance of 31%. The glaring difference in the cost of rice production is due to the high labour expenditure for the improved rice variety. The high cost of rice production might have contributed to the non-adoption of the improved rice variety. This is particularly a challenge to the rice farmers, as the majority of non-adopters (84%) had no access to credit facilities. Clearly, the cost of production of the improved rice variety has to be reduced substantially if it is to be competitive.

Table 4.19: Mean Production Cost Between Non-Adopters and Adopters

	Non-Adopters	Adopters	Difference	t-value	df
Cost of production (GH¢ ha^{-1})	1131.99 (495.81)	1478.51 (456.45)	346.52	5.246***	206

Source: Field Survey, 2013. Standard deviations appear in parentheses ***$\rho < 0.01$.

4.4.2 Production, yields and gross returns of paddy

Table 4.20 presents the mean production, yield, and gross returns for the non-adopters and adopters. The study showed that the average rice production was 4345.57 kg and 5348.39 kg for the non-adopters and adopters, respectively. The productivity of the improved rice varies from 1100 kg ha^{-1} to 5500 kg ha^{-1}. For the traditional rice variety, the productivity was as low as 500 kg ha^{-1} and high as 4400 kg ha^{-1} with a range of 3900 kg ha^{-1}. Further, the average productivity of the improved rice variety was 3027.26 kg ha^{-1}, about 56% higher than that of the traditional rice variety (1936.89 kg ha^{-1}). The average yield of the improved rice is higher than the national average of 2600 kg ha^{-1} (MoFA, 2011). It can be deduced that the adopters gained additional yields of 1090.37 kg ha^{-1} by cultivating the improved rice variety and its complementary inputs. This additional yield could be partly due to the use of quality seeds and the responsiveness of the improved rice variety to soil nutrients. The current yield of the improved rice variety is comparable with reported yield from other studies. Reported yields in West Africa were about 2500 kg ha^{-1} with low use of inputs and yield of 5000 kg ha^{-1} or more with prudent fertiliser use (Kijima et al., 2006; WARDA, 2001). Similarly, Kijima et al. (2006) reported of average yield of 2200 kg ha^{-1} in Uganda while in Guinea, Japan International Cooperation Centre (2006) reported of 3500 kg ha^{-1}. Differences in the yields of the improved varieties could be due to the differences in geographical/climatic conditions and efficiency in input use among the rice farmers.

Table 4.20: Mean Production and Productivity for Non-Adopters and Adopters

Variables	**Non-Adopters**	**Adopters**	**t-test**	**df**
Production (kg)	4345.57 (3113.04)	5348.39 (3717.62)	2.074**	206
Yield (kg ha^{-1})	1936.89 (888.56)	3027.26 (1075.09)	7.979***	200.26
Number of bags (maxi ha^{-1})	16.52	27.05		
Price (GH¢ bag^{-1})	87.77	87.33		
Gross return (GH¢)	**1449.64**	**2362.44**	**7.928*** **	**182**

Source: Field Survey, 2013. Note: Figures in parentheses are standard deviation. **$\rho < 0.05$. ***$\rho < 0.01$.

The result further indicated that the improved rice variety increases net farm income. It generates net returns with GH¢2362.44 ha^{-1}, which is about two times more than its cost of production and the gross return from the traditional rice variety (GH¢1449.64 ha^{-1}). The gross return of the improved rice variety has actually increased by about 63% over that of the traditional rice variety. There was no observed difference in the paddy price for the non-adopters and adopters. The result demonstrates a higher gross return of the improved rice variety. The higher gross return in this study is more than likely linked to the high productivity of the improved rice variety and its complementary inputs. Thus, rice farmers who adopt the improved variety reports higher gross returns.

The result of the independent sample t-test revealed that there was a statistically significant difference in production between the non-adopters and adopters ($t = 2.074$, $df = 206$, $p < 0.05$). Similar findings were reported for yield ($t = 7.979$, $df = 200.26$, $p < 0.001$). The adopters ($M = 4345.57$, $SD = 3113.04$) reported significantly higher yield compared to the non-adopters. High mean differences in the production and productivity between the non-adopters and adopters could be due to the quality of seeds and the responsiveness of the improved seeds to soil nutrients and/or fertiliser supplementation. The results further indicated a statistically significant difference in the gross return between the non-adopters and adopters ($t = 7.928$, $df = 182$, $p < 0.001$). The adopters ($M = 2362.44$, $SD = 978.82$) reported significantly higher gross returns from paddy than the non-adopters ($M = 1449.64$, $SD = 652.45$). The significant difference in the gross return could be due to the higher productivity of the improved rice variety and its complementary inputs. According to Zandstra et al. (1981), new technologies, which have at least 30% higher return than that of traditional technology, are more likely to be adopted by farmers. Thus, it can be inferred that rice farmers adopt the improve variety because of economic motivation. The covariance for the non-adopters was 43% while for the adopters was 41%. Hence, even though there were greater variations in cost of production for non-adopters, implying greater flexibility in input requirements, the covariance for gross returns are almost the same. The implication is that yields of traditional variety are more stable and less sensitive to variable input use than the improved variety.

4.4.2.1 Causes of low productivity in rice production

The rice farmers were asked to indicate whether their output meets their expectation, based on their experience. The result showed that 47% and 25% of the non-adopters and adopters, respectively, reported on the negative, suggesting that a greater proportion of the rice farmers recorded normal output levels. Those who considered their yields as 'abnormal' were then asked to identify a number of factors they think are responsible for their low yields. The farmer-identified factors were then grouped into three major factors, namely, soil-nutrient factors, water supply factors, and crop management factors. The result is presented in Table 4.21.

The study showed that the factors responsible for the low productivity among the non-adopters were soil-nutrient factors (77%), water supply factors (38%), and crop management factors (38%). More clearly, lack, delay, and inadequacy of fertiliser were the single most important factor (69%) affecting the productivity of rice among the non-adopters. Factors associated with water supply were mainly inadequate rainfall (17%) and flooding (15%). The next most important factor responsible for the low productivity among the non-adopters was late land preparation practices (19%) and inadequate rainfall (17%).

Table 4.21: Causes of Low Rice Productivity among the Farmers

Factors	Non-Adopters (n = 48)		Adopters (n = 26)	
	Frequency	Percentage	Frequency	Percentage
Soil-Nutrient Factors	*37*	*77.08*	*7*	*26.92*
Low soil fertility	4	8.33	-	-
Fertiliser				
Lack of fertiliser	18	37.50	3	11.54
Delayed fertiliser	4	8.33	4	15.38
Inadequate fertiliser	11	22.92	-	-
Water Supply Factors	*18*	*37.50*	*14*	*53.85*
Drought	3	6.25	3	11.54
Inadequate rainfall	8	16.67	9	34.62
Flooding	7	14.58	2	7.69
Crop Management Factors	*18*	*37.50*	*14*	*53.85*
Disease and pest	2	4.17	4	15.38
Late planting	4	8.33	5	19.23
Late land preparation	9	18.75	3	11.54
Herbicide				
Lack of herbicide	2	4.17	2	7.69
Delayed application	1	2.08	-	-

Source: Field Survey, 2013. Note: Multiple responses; percentages do not add up.

For the adopters, low productivity was caused by water supply factors such as inadequate rainfall (35%), drought (12%), and flooding (8%) as well as crop management factors such as late planting (19%), disease and pest (15%), and late land preparation practices (12%). The low productivity among the rice farmers is due to low soil fertility and nutrient supplementation, water supply problems, and poor crop management practices. In general, the lack and timeliness in the management and use of resources on the farm are the major causes of low rice productivity among the rice farmers. The intensities of input use are equally contributing factors. The results are consistent with the finding of Somado et al. (2008) that low soil fertility, weed infestation, drought, diseases, and pest infestations are key factors causing the fluctuating yields among rice farmers. The result is further consistent with the findings of Kijima et al. (2006) and WARDA (2001) that yields of rice farmers are 50% less due to inadequate use of recommended inputs like fertiliser. Hence, productivity agenda must address these impediments to productivity increases.

4.4.3 Gross margin analysis

The gross margin analysis of rice cultivation is presented in Table 4.22. The result showed that adopters had a higher gross return (GH¢2362.44 ha^{-1}) and gross margin (GH¢883.93 ha^{-1}) than the non-adopters (gross return = GH¢1449.64 ha^{-1}; gross margin = GH¢317.65 ha^{-1}). This implies that the improved rice variety is more economically viable and therefore has a larger positive return to capital, management, and return than the traditional rice variety. The gross margin for the improved rice variety was about 178% more than the traditional rice variety, that is, the gross margin was more than doubled for the adopters. Hence, smallholder rice farmers may be motivated by economic incentives in adopting the improved variety. Overall, the adopters has realised increased productivity (in the midst of the high cost of production) and returns than the non-adopters. This conforms to the findings of Abdullahi (2012), which reported higher gross margin for the improved rice variety. As indicated in Table 4.20, there was no difference in the mean paddy price received by the non-adopters and adopters. Thus, given the output price, productivity and cost of production are the main determinants of profitability in rice production in the two districts. Thus, an increase in the cultivation of the improved rice variety will lead to increased productivity and thus more returns to the adopters. Encouraging and supporting farmers to adopt the improved rice variety and its complementary inputs will greatly increase their income, thereby, reducing rural poverty.

Table 4.22: Gross Margin Analysis for the Non-Adopters and Adopters

	Non-Adopters	**Adopters**
Labour (person-days ha^{-1})	116.89	135.66
Total variable cost (GH¢ ha^{-1})	1131.99	1478.51
Gross return (GH¢ ha^{-1})	1449.64	2362.44
Gross Margin [GM] (GH¢ ha^{-1})	**317.65**	**883.93**
Gross Margin Per Person-Days[1]	**2.72**	**6.52**
Gross Margin Per Unit of Cost[2]	**0.28**	**0.60**

Source: Field Survey, 2013. Note: [1] was calculated by dividing the GM by number of labour used; [2] was calculated by dividing the GM by total variable cost.

The result further revealed two efficiency estimates from the gross margin analysis, that is, gross margin per person-days and gross margin per unit of cost. The gross margin per person-days was higher for the adopters (GH¢ 6.52 person-days^{-1}) than the non-adopters (GH¢ 2.72 person-days^{-1}). Thus, in spite of the high labour demand for the improved rice variety, it is still more economically worthwhile and profitable than the traditional rice variety. This could partly be due to the high productivity of the improved variety with its complementary inputs. Moreover, the gross margin per unit of cost (i.e., total variable cost) revealed that the improved rice variety gave a higher return per unit of money spent on inputs (0.60) compared to the traditional rice variety (0.28). Therefore, even though the improved variety has high capital expenditure, its benefit/cost ratio was higher than the traditional rice variety. Notwithstanding, the high benefit/cost ratio may be due to the high expenditure on labour and partly, on fertiliser. The results illustrate that the improved variety gives higher returns on labour and total variable cost, compared to the traditional variety; making it more competitive.

To determine whether there was a statistical difference in the gross margin between the adopters and non-adopters, independent samples t-test was employed (Table 4.23). The result revealed a statistically significant difference between non-adopters and adopters ($t = 4.405$, $df = 193.68$, $p < 0.001$). Adopters ($M = 883.93$, $SD = 1046.38$) reported significantly higher gross returns from rice production than the non-adopters ($M = 317.65$, $SD = 792.62$). Therefore, rice farmers who adopt the improved variety will have higher gross margins compared to those who did not adopt. The significant difference in the gross margin could be due to the higher productivity of the improved rice variety.

Table 4.23: Mean Gross Margin Between Non-Adopters and Adopters

	Non-Adopters	Adopters	Difference	t-value	df
Gross Margin (GH¢ ha^{-1})	317.65 (792.62)	883.93 (1046.38)	566.29	4.405***	193.68

Source: Field Survey, 2013. Standard deviations appear in parentheses. ***$\rho < 0.01$.

4.4.3.1 Sensitivity of gross margin to changes in prices and yield

As gross margin analysis fails to account for risks, sensitivity analyses were conducted to illustrate the impact of gross margin due to changes in yield, output prices, and total variable costs. Two cases of the sensitivity analysis are presented. The first case of the sensitivity analysis relates to the changes in the gross margin of both varieties from a 10% change above and below the yield and output price of rice (Table 4.24). Two scenarios were presented. In the first scenario, a 10% increase or decrease in the yield of the traditional rice variety (assuming the output price remains constant) results in 45.55% increase or decrease in the gross margin for the non-adopters. For the adopters, a 10% change in the yield will result in 26.56% increase or decrease in the gross margin. Hence, the traditional rice variety is highly sensitive to 10% change in the yield of rice at constant output price than the improved rice variety. In the second scenario, a 10% change in the output price (assuming the yield remains constant) results in 45.62% increase or decrease in the gross margin of the traditional variety and 26.52% change in the gross margin of the improved variety. This implies that the profitability of the traditional variety is more sensitive to changes in the output price and yield than the improved variety.

Table 4.24: Sensitivity of Gross Margin to Changes in the Yield and Price

Yield		Price (GH¢ bag^{-1})			
Kg ha^{-1}	***70.21***	***78.99***	***87.77***	***96.55***	***105.33***
		Non-adopters			
1743.20	-87.97	42.59	173.15	303.71	434.27
1936.89	27.88	172.92	317.97	463.02	608.06
2130.58	143.73	303.26	462.79	622.32	781.86
		Adopters			
2724.53	230.40	444.11	657.81	871.52	1085.22
3027.26	420.67	658.17	895.67	1133.17	1370.67
3329.99	610.94	872.23	1133.53	1394.82	1656.11

Source: Field Survey, 2013. Note: Sensitivity analysis was done based on a 10% change in yield and output price. Reference gross margins are GH¢ 317.97 and GH¢ 895.67 ha^{-1} for the non-adopters and adopters, respectively.

The second sensitivity analysis emphasised the resulting effect on the gross margin from a 10% change in the cost of production (Table 4.25). Keeping the gross returns constant, a 10% decrease or increase in the cost of production of the traditional rice variety leads to a 35.64% increase or decrease in the gross margin for the non-adopters. In contrast, a 10% decrease or increase in the cost of production of the improved rice variety leads to a 16.71% increase or decrease in the gross margin for the adopters. The results illustrates that the gross margin of the non-adopters is more sensitive to a 10% decrease in the cost of production compared with the adopters. This could be due to the low productivity of the traditional variety. Overall, the sensitivity analyses demonstrate that the traditional rice variety showed very high sensitivity to changes in the prices of input and output compared with the improved rice variety.

Table 4.25: Sensitivity of Gross Margin to Changes in the Cost of Production

Gross Returns (GH¢ ha^{-1})	10% Change in Cost of Production (GH¢ ha^{-1})	Gross Margin	
		GH¢ ha^{-1}	% Change
Non-adopters			
1449.64	1018.79	430.85	35.64
1449.64	1131.99	317.65	Reference
1449.64	1245.19	204.45	-35.64
Adopters			
2362.44	1330.66	1032.78	16.71
2362.44	1478.51	884.93	Reference
2362.44	1626.36	737.08	-16.71

Source: Field Survey, 2013. Note: Sensitivity analysis was based on a 10% change cost of production. Reference gross margins are GH¢ 317.97 and GH¢ 895.67 ha^{-1} for the non-adopters and adopters, respectively.

4.5 Technological Change and Rice Productivity

4.5.1 Means and standards deviations of the variables

Table 4.26 presents the descriptive statistics of the variables. There is ample evidence of differences in the per-hectare use of inputs among the rice farmers. Non-adopters reported higher use of seed (71.68 kg ha^{-1}) and herbicide (4.71 *l* ha^{-1}) compared with the adopters. In contrast, the use of labour (135.66 person-days ha^{-1}) and fertiliser (319.64 kg ha^{-1}) were higher for the adopters than the non-adopters. The higher demands for labour and fertiliser among the adopters could be due to the responsiveness of the improved rice variety to such inputs. Further, the improved rice variety requires less seed and herbicide because of its high quality seed and weed-competitive nature. Therefore, the adoption of the improved rice variety could result in substantial yield gain and reduction in the cost of seeds and herbicides.

Table 4.26: Means and Standard Deviations of Variables Used in the Analysis

Variables	Non-Adopters	Adopters	Pooled
Yield (kg ha^{-1})	1936.89 (888.56)	3027.26 (1075.09)	2487.32 (1126.23)
Seed (kg ha^{-1})	71.69 (22.79)	58.00 (11.17)	64.78 (19.12)
Labour (person-days ha^{-1})	116.89 (75.34)	135.66 (55.02)	126.36 (66.38)
Fertiliser (kg ha^{-1})	196.60 (166.38)	319.64 (119.88)	258.71 (157.05)
Herbicide (l ha^{-1})	4.71 (2.60)	4.29 (2.61)	4.50 (2.61)

Source: Field Survey, 2013. Note: Figures in parentheses are standard deviations.

4.5.2 Hypotheses tests

A series of tests were conducted to establish whether the disturbance term assumptions have been violated and whether there is multicollinearity in the data. Test for normality of the residuals for all the estimated per-hectare production functions revealed that the residuals were normally distributed (see Table 4.27). The production functions were estimated using the Heteroskedasticity-corrected approach to correct heteroscedasticity problem in the data. Multicollinearity was tested using variance inflation factor. None of the explanatory variables exceeded the threshold value of 10. Thus, multicollinearity was not a problem in the data. A stability test was conducted to test the hypothesis that the coefficients of the production functions are different for the adopters and non-adopters. The analysis of variance gives an F-ratio of 15.457 with 5 and 198 degrees of freedom, which is statistically significant at 1% level. Therefore, the null hypothesis was rejected in favour of the alternate hypothesis. The result indicates that structural change exists in the per-hectare production functions for the adopters and non-adopters. Hence, this study estimated separate production functions for both the adopters and non-adopters. Notwithstanding, a varietal dummy variable was used to capture the impact of the improved rice variety on the per-hectare productivity.

4.5.3 Estimated per-hectare production functions

Table 4.27 presents the per-hectare production functions for the adopters and non-adopters. The explanatory powers of the per-hectare production functions for the non-adopters, adopters, and the pooled II model were low (i.e., 0.360, 0.198, and 0.369, respectively). The three models generally fit the data moderately but the estimated production functions were all highly significant at the 1% level. This implies that the variations in the (log of) yield were explained by 36%, 20%, and

37% of the (logs) of all the explanatory variables for the non-adopters, adopters, and the pooled II model, respectively. Further, the output elasticities satisfied a priori expectations. Gujarati (2004) justifies the possibility of low R^2 in cross-sectional data due to the diversity of its units. Gujarati (2004) further recommends that the relevancy of a model should be judged in the light of correct specification, correct expected signs of the regressors, and statistical significance of the regression coefficient. Accordingly, these conditions have been satisfied in this study.

Table 4.27: Per-Hectare CDP Estimates for the Non-Adopters and Adopters

Variables	**Non-Adopters**	**Adopters**	**Pooled 1**	**Pooled II**
Intercept	5.893*** (0.532)	5.950*** (0.910)	6.727*** (0.483)	6.232*** (0.505)
Seed	0.238** (0.103)	0.502*** (0.189)	0.040 (0.091)	0.260*** (0.100)
Labour	-0.036 (0.054)	-0.092 (0.079)	0.008 (0.048)	-0.068 (0.047)
Fertiliser	0.080*** (0.016)	0.072*** (0.016)	0.116*** (0.014)	0.070*** (0.015)
Herbicide	0.241*** (0.241)	0.012 (0.589)	0.123*** (0.046)	0.091** (0.042)
DV1				0.472*** (0.063)
No. observations	103	105	208	208
R^2	0.360	0.198	0.265	0.369
F-value	13.780***	6.153***	18.285***	23.597***
JB test	1.061	1.263	7.580	2.720

Source: Field Survey, 2013. Note: JB = Jarque-Bera test of normality. Pooled I and II = Polled production function without (I) and with dummy variable (II), respectively. Figures in parentheses are standard errors. **$\rho < 0.05$. ***$\rho < 0.01$.

For the non-adopters, the result indicated that the seed, fertiliser, and herbicide were statistically significant at the 5%, 1%, and 1% levels, respectively. Further, the output elasticities of these variables are consistent with the expected signs and economic logic. The output elasticities of seed, fertiliser, and herbicide were 0.238, 0.080, and 0.241, respectively. In other words, holding other factors constant, a 1% increase in seeding rate is associated with an average of about 0.2% increase in the yield of the traditional rice variety. Similarly, on the average, a 1% increase in the quantity of herbicide leads to about 0.2% increase in the yield of the traditional variety, holding all other factors constant. Further, holding all other factors constant, a 1% increase in the use of fertiliser leads, on the average, to about 0.1% increase in production. Overall, the use of seed, herbicide, and fertiliser were the major determinants of the yield of the traditional rice variety in the two districts. The low impact of fertiliser on the yield of the traditional rice variety could be due to the lack/delay/inadequacy of fertiliser application among the non-adopters.

Further, the output elasticities for the adopters indicated that the statistically significant variables were seed and fertiliser. Further, all the significant variables had their expected signs. Seed and fertiliser had output elasticities of 0.502 and 0.072, respectively. The result indicated that a 1% increase in the seeding rate, holding all other factors constant, leads on the average to 0.5% increase in the yield of the improved rice variety. The output elasticity of fertiliser suggests that, holding all other factors constant, a 1% increase in the quantity of fertiliser application leads on the average to about 0.1% increase in the yield of the improved rice variety. The high elasticity of seed underscores the importance of the improved seed in the production of rice. Therefore, seed is the most important factor in the production of the improved rice variety. The low effect of fertilisation on the yield of the improved variety is due to the use of fertiliser below the recommended level. This study refutes Abdullahi's (2012) reported negative effect of seed on the productivity of the improved rice variety.

The estimated pooled model with the intercept dummy (Pooled II) showed that seed, fertiliser, herbicide, and the varietal dummy variable (DV_1) were statistically significant (see Table 4.27). All variables had their expected signs. The result suggested that a percentage increase in seeding rate, fertiliser, and herbicide would, on the average, lead to a corresponding percentage increase in the output, *ceteris paribus*. The study hypothesised that the improved rice variety has a significantly higher impact on the yield of rice, compared to the traditional rice variety. The output elasticity of the varietal dummy variable measures the shift in the intercept of the per-hectare production function due to the improved rice variety. The output elasticity for this variable was 0.472 and was statistically significant at the 1% level. This suggests that the improved rice variety increases yield by as much as 47%, compared to the traditional rice variety. This is the magnitude of the impact of the shift from the traditional to the improved rice variety.

Generally, the output elasticity of seed is higher for the adopters compared to the non-adopters. In contrast, non-adopters reported higher output elasticities for fertiliser and herbicide. The low effect of fertiliser on the production of the improved seed could be due to the diversion of the fertiliser supposedly meant for the improved rice variety into the production of other crops. This view is further re-enforced by the farmers' assertion that the improved rice variety has higher yield advantages even with minimum fertiliser application. It is further evident that, the intercept term for the adopters (i.e., 5.950) was slightly higher, compared with the non-adopters

(5.893). This virtually signifies an upward shift in the production function due to technological change associated with the improved rice variety.

The sum of the output elasticities for the variable inputs gives 0.523 and 0.492 for the non-adopters and adopters, respectively. These suggest that the rice farmers during the 2011/2012 production season experienced diminishing returns to scale. A linear equality restriction was tested for the production functions by imposing the restriction that there are constant returns to scale. The null hypothesis was that the sum of the output elasticities of the per-hectare production functions equal to one. The F-test for the non-adopters reported F(1, 98) = 11.1074, with p-value = 0.001 while that of the adopters reported F(1, 100) = 5.35129, with p-value = 0.023. The *F* values were both significant at the 5% level. Therefore, the researcher rejected the hypothesis of constant returns to scale in the production functions for both varieties. The findings suggest that the production of the two rice varieties were characterised by diminishing returns to scale during the 2011/2012 production seasons in the two districts. That is, a one percent increase in all inputs leads to less than same percentage increase in output, all other factors held constant. This could be due to changes in the production technology or input requirements rather than though changes in size. Improving productivity among the rice farmers would depend more on their ability to access improved technologies.

In the light of the diminishing returns to scale reported, there is evidence that rice productivity could be increased through greater use of cultivated seeds, fertiliser, and herbicides. The implication is that agricultural policy must seek to remove the impediments that prevent greater use of modern inputs in rice production. Specifically, input supply must be decentralised to village markets within the farming communities. Similarly, inputs must be timely and readily available in the right amount while guaranteeing their quality. Further, the provision of appropriate credit facilities will be beneficial to the credit constrained farmers. Moreover, farmers need to be trained on the best use of improved technologies.

4.6 Productivity Differences Between Non-Adopters and Adopters

4.6.1 Tests for structural differences between the non-adopters and adopters

Sources of structural differences in the coefficients of the per-hectare production function for the non-adopters and adopters were tested using the dummy variable technique. The test further sought to establish whether the shift from the traditional to the improved rice variety was of the neutral or non-neutral type. The result of the structural difference test is presented in Table 4.28. The result showed that the differential intercept coefficient (i.e., the coefficient for the intercept dummy variable) was statistically insignificant. Hence, the hypothesis that the regressors for the adopters and non-adopters have the same intercept is not rejected. Further, the differential slope coefficient (i.e., the coefficient for the slope dummies for seed, labour, and fertiliser) were all statistically insignificant, except for herbicide. Hence, the hypothesis that the two regressions have different slopes is rejected. This implies that structural differences in the regressions for the adopters and non-adopters are due to the differences in the slope dummy of herbicide.

Overall, the analysis of covariance gives an F-ratio of 15.457 with 5 and 198 degrees of freedom, which is significant at the 1% level. The study thus rejects the null hypothesis of no structural difference in the two regressions. The result illustrates that the main source of structural difference in the two regressions is the shift in the slope dummy for herbicide. Thus, the nature of the impact of the improved rice variety on the per-hectare productivity of rice was due to the slope parameter of the herbicide (i.e., non-neutral technical change) rather than neutral technical change. That is, the shift from the traditional to the improved rice variety was neither capital saving nor labour saving.

Table 4.28: Test for Structural Difference using Intercept and Slope Dummies

Variables	Coefficients	Standard Error	p-value
Intercept	5.816	0.578	1.72e-019***
Seed	0.240	0.113	0.034**
Labour	-0.017	0.057	0.7635
Fertiliser	0.079	0.018	1.46e-05***
Herbicide	0.232	0.070	0.001***
Intercept dummy	0.576	1.025	0.575
Slope dummy for seeds	0.181	0.217	0.401
Slope dummy for labour	-0.098	0.073	0.181
Slope dummy for fertiliser	-0.001	0.024	0.970
Slope dummy for herbicide	-0.225	0.091	0.014**
No. observations	208		
R^2	0.434		
F-value	16.872***		

Source: Field Survey, 2013. Note: Figures in parentheses are standard errors. **$\rho < 0.05$. ***$\rho < 0.01$.

4.6.2 Sources of productivity differences between the two rice varieties

The results of the structural change test presented in Table 4.28 provide the justification for decomposing the sources of the productivity differences between the traditional and the improved rice varieties. Accordingly, the estimated parameters of the per-hectare production functions (Table 4.27) and the mean input levels (Table

4.26) were used for the *model 5.7*. Total changes in the productivity between the traditional and improved rice varieties were then decomposed into two main sources: technical change and input use differentials. The sources of the productivity differences between the two varieties are shown in Table 4.29. The results showed a moderate discrepancy between the observed productivity difference (44.66%) and the estimated productivity difference (39.46%) of the adopters and non-adopters. This discrepancy could be due to the random term - the non-inclusion of certain factors (i.e., flood and drought) due to quantification problem. The total estimated difference in the productivity between the two rice varieties was 39.46%.

Table 4.29: Sources of Productivity Differences Between the Two Rice Varieties

Sources of Productivity Differences	**Percent Contribution**
Observed differences in productivity	44.66
Sources of contribution	
A Due to differences in technology	
Neutral technical change	0.96
Non-neutral technical change	45.32
Total due to technology	46.28
B Due to difference in input use	
Seed	-10.64
Fertiliser	3.50
Herbicide	-0.11
Labour	0.43
Total due to all inputs	-6.82
Estimated difference in output (A + B)	**39.46**

Source: Field Survey, 2013.

Of the 39.46% productivity differences, technical change contributed 46.28% to the productivity differences between the two varieties. This implies that, with no further input application; rice productivity could be increased by 46.28% just by adopting the improved rice variety. Technical change affects output by shifting either the intercept or the slope coefficients, or both. Disaggregating technical change into neutral technical and non-neutral technical changes revealed a 0.96% contribution in the scale parameter (i.e., neutral technical change) and a 45.32% contribution from the slope parameters (i.e., non-neutral technical change). The 0.96% contribution of the neutral technical change signifies that with the present level of input used for the improved rice variety, the rice farmers could have increased the productivity level by 0.96% in rice production provided that the efficiency level of inputs use remain constant. The greatest contribution of 45.32% suggests that productivity differences between the two varieties were mostly from the non-neutral technical change. In other words, the differences in output are due to the differences in the reallocation of resources to the various inputs used. This implies that the rice farmers were able to adjust to the requirements of the improved technology of rice production. Therefore, the differences in productivity were due to the shift in the slope parameter (and herbicide, in particular) of the production function.

The result further suggested that the total contribution of changes in the levels of input use to the productivity differences between the two varieties was -6.82%. This implies that the productivity of the improved rice variety could decline by about 7% if the input use leads to increase in the same level as that of the traditional variety. The highest input contributor to the productivity differences was fertiliser, which amounted to 3.50%, followed by labour's share of 0.43. Further, seed and herbicide registered a negative contribution of -10.64% and -0.11%, respectively.

This means that the large quantity of seeding rate applied by the non-adopters has helped to increase output by 10.64% for the traditional variety. Similarly, higher levels of herbicide application have increased the output of the traditional rice variety by 0.11%. Conversely, high intensities of fertiliser and labour used by the adopters had led to yield increases by 3.50% and 0.43%, respectively. This implies that the adopters gained a higher yield by spending more on fertiliser and labour than the non-adopters spend. This is consistent with the assertion of WARDA (2001) that the yield of the improved rice variety is very responsive to inputs, such as fertiliser.

Generally, the total gain in productivity due to the shift from the traditional variety to the improved rice variety was found to be about 46%. This was mainly due to non-neutral technical change, i.e., the shift in the slope coefficient of herbicide. This implies that the productivity differences between the two rice varieties were due to the re-allocation of inputs at the new level of efficiency. However, as stated earlier, the slope dummy for herbicide was the only statistically significant variable in the structural difference test (see Table 4.28). Hence, the major source of structural difference between the two varieties was the non-neutral technical change, which in turn is due solely to herbicide use. This study concludes that structural differences between two farming systems can only be determined through statistical tests and the dummy variable technique, in particular. Therefore, the dummy variable approach is a necessary and a sufficient condition for testing for the structural change and its sources between two technologies.

4.7 Other Factors Explaining Productivity Differences among the Farmers

Table 4.30 presents the input use and yield differences among the farmers. The result indicated a very pronounced effect of fertiliser application on the yield of rice for all farmers. About 68% of the non-adopters who used fertiliser reported an average yield of 2146.96 kg ha^{-1} compared to non-users (1491.29 kg ha^{-1}). Similarly, 92% of the adopters who used fertiliser had a mean yield of 3104.51 kg ha^{-1} compared to the non-users (2090.63 kg ha^{-1}). These mean differences are both statistically significant at the 1% level. Thus, fertiliser use had increased the yield of rice by 44% and 48% for the non-adopters and adopters, respectively. This clearly underscores the importance of fertiliser in realising substantial yield gains in rice production.

The result further revealed that the use of herbicide has increased the yield of the non-adopters and adopters by 34% and 15%, respectively. The contribution of tractor ploughing to yield was marginal; 6% and 1% for the non-adopters and adopters, respectively. Moreover, the non-adopters who had access to extension service reported higher mean yield of 2179.46 kg ha^{-1} compared to 1769.88 kg ha^{-1} for those who did not. Percentage differences were about 23%. Even though greater proportions of the adopters had access to extension service, it did not have much effect on their productivity. Access to credit contributed negatively to the yield of the improved rice variety, partly, because most of the non-adopters (84%) did not have access to credit. Overall, yield variability in rice production was due to the lack of fertiliser and herbicide use as well as lack of access to extension services and credit.

The results suggest that rice farmers who use fertiliser and herbicide were more likely to have higher yields compared with those who did not use these inputs. Similarly, the yield of rice tends to increase more with the intensity of use of fertiliser. Further, rice farmers who have access to extension service will be more exposed to better information on production leading to higher yields. However, rice farmers who do not have access to credit facilities will have lower yields as they will not have enough capital to purchase the required inputs on time for their production.

The implications are that there is the need to ensure that these inputs are made readily available to the farmers.

Table 4.30: Input Use and Yield Differences among Non-Adopters and Adopters

Variables	Non-Adopters		Adopters	
	Count [a]	Mean [b]	Count [a]	Mean [b]
Fertiliser				
Use	70 (67.96)	2146.96 (872.23)	97 (92.38)	3104.51 (1070.75)
No use	33 (32.04)	1491.29 (758.25)	8 (7.62)	2090.63 (602.77)
t-test	3.706***, df = 101		4.238***, df = 11	
Herbicide				
Use	95 (92.23)	1975.39 (904.59)	97 (92.38)	3058.51 (1064.38)
No use	8 (7.77)	1479.69 (507.40)	8 (7.62)	2648.44 (1207.39)
t-test	2.454**, df = 11		1.037, df = 103	
Tractor				
Use	87 (84.47)	1953.74 (899.58)	100 (95.24)	3028.63 (1061.47)
No use	16 (15.53)	1845.31 (847.77)	5 (4.76)	3000.00 (1471.08)
t-test	0.447, df = 101		0.058, df = 103	
Extension service				
Access	42 (40.78)	2179.46 (889.29)	102 (97.14)	3038.11 (1088.80)
No access	61 (59.22)	1769.88 (855.73)	3 (2.86)	2658.33 (158.77)
t-test	2.349**, df = 101		2.684**, df = 11	
Credit				
Yes	17 (16.50)	1632.35 (523.87)	71 (67.62)	3096.65 (1127.99)
No	86 (83.50)	1997.09 (934.66)	34 (32.38)	2882.35 (954.80)
t-test	-2.249**, df = 40		0.955, df = 103	

Source: Field Survey, 2013. Note: [a] = counts with percentages in parentheses, [b] = mean with standard deviations in parentheses. **$\rho < 0.05$. ***$\rho < 0.01$.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary of the Findings

The study investigated the economics of technological change in rice production in the Ejura-Sekyedumase and Atebubu-Amantin Districts of Ghana. Specifically, the study established whether the improved rice variety increases the cost and returns for the adopters compared with the non-adopters; evaluated the nature and magnitude of rice productivity; decomposed the sources of productivity difference between the two varieties; and investigated the role of other factors in explaining productivity differences among the rice farmers.

The study used the descriptive research design with the survey research method. The target population of the study comprised of all the rice farmers in the two districts. The rice farmers were sampled using a three-stage stratified random sampling design involving operational areas, communities, and rice farmers. The study sampled 216 rice farmers. The main research instrument used for this study was a semi-structured questionnaire. Nonetheless, focus group discussions involving six rice farmers from each separate area was conducted using checklist. Data were analysed using gross margin analysis and descriptive statistics. Moreover, a chi-square, independent samples t-tests, Cobb-Douglas production function and output decomposition analysis were used to analyse the specific research questions.

The study sought to find out whether rice farmers who adopt the improved rice variety report higher costs and returns than those who did not adopt. Rice farmers who adopted the improved rice variety reported higher costs of production, gross returns, and gross margins compared with those who did not adopt. The gross margin for the traditional variety was highly sensitivity to changes in the input price, output price, and cost of production than the improved variety. The results of the independent samples-t test confirmed the hypothesis that the adopters reported significantly higher cost of production, gross return, and gross margin than the non-adopters did. Moreover, the adopters reported higher production and productivity compared to the non-adopters. The adoption of the improved rice variety had increased per-hectare productivity by as much as 47%. The main factors that determined the productivity of the traditional varieties were seed, herbicide, and fertiliser. For the adopters, seed and fertiliser were the significant predicators of productivity. The study confirmed that hypothesis that rice farmers who adopted the improved rice variety had higher per-hectare productivity than the non-adopters.

The estimated productivity differences between the traditional and improved rice varieties was 39.46% and was mainly contributed by the technical change (46.28%) associated with the shift from the traditional to the improved variety. A greater share of the technical change was due to the non-neutral technical change, which accounted for 45.32% of the productivity differences between the two varieties. However, input use differentials contributed negatively (-6.82%) to the productivity differences between the two varieties. The hypothesis that the productivity differences between the non-adopters and adopters were partly due to neutral technical change was rejected. However, the hypothesis that the productivity differences between the two varieties were partly due to non-neutral technical change was accepted. Finally, the study found that rice farmers (i.e., both adopters and non-adopters) who used fertiliser reported higher yields than those who did not use fertiliser. Similar reports were made for those who had access to extension services. Non-adopters who used herbicides had higher yields than those who did not use herbicides.

5.2 Conclusions

This study has provided empirical evidence on the economics of technological change in rice production in the two districts. The study has shown that the shift from the traditional to the improved rice variety can help to significantly improve rice productivity and increase farmers' income. In view of the aforementioned findings, the study draws on the following conclusions.

a. The improved rice variety has changed the input use patterns in rice production by reducing the requirements for seeds and herbicides as well as increasing the demands for fertiliser and labour. Therefore, the improved rice variety has been cost saving of seeds and herbicides. In contrast, it was mainly cost intensive for fertiliser and labour. The cost intensive nature of the improved rice variety is due mostly to the high demands for labour for harvesting and threshing activities as well as the high demand for fertiliser.

b. Even though it is economical to produce both rice varieties, the improved rice variety has increased the cost of rice production due to the higher demands for its complementary inputs such as fertiliser and high expenditure on labour. It has, however, led to high returns due to its productivity and the complementary role of seeds and fertiliser.

c. The magnitude of the impact of the shift from traditional to the improved rice variety on the per-hectare productivity of rice was 47%. Productivity differences between the two rice varieties was largely accounted for by the rice farmers' ability to adjust to the requirements of the improved variety and its complementary inputs. Moreover, productivity differences among the rice farmers were because of the use and non-use of such inputs as fertiliser, herbicides, and access to extension services and credit facilities.

d. In spite of the gains from the improved rice variety, some of the farmers did not adopt it. The non-adoption of the improved variety was due to the following. The improved rice variety was both cost-intensive and labour-intensive, compared with the traditional rice variety. It has mostly increased the incidence and intensity/cost of fertiliser and labour. These inputs occupy the greatest share of the cost of producing the improved rice variety. As most of the non-adopters had no access to credit, these increased costs possess limitation to them; leading to its non-adoption. Moreover, poor extension service delivery and input distribution systems have denied some of the traditional growers from benefiting from the improved rice variety.

e. Overall, the technological change in rice production in the two districts has highly favoured adopters with higher economic incentives of productivity and returns since they were resource endowed.

5.3 Policy Recommendations

a. There is the urgent need to provide credit facilities to rice farmers to facilitate technology promotion activities undertaken by the Government and other development organisations. Such credit facilities should not only be collateral-free, but also be readily available to farmers so that they can acquire the needed inputs at the right time and in the right quantity. Emphasis on in-kind credit systems when promoted will equally facilitate the decision-making behaviour of the rice farmers.

b. Labour intensive and timely nature of major farming activities imply that the overreliance on manual labour in rice production is not sustainable in increasing rice productivity. Rice breeders and researchers should seriously consider the need for developing labour-saving technologies rather than labour intensive technologies. Similarly, the development of mechanised technologies such as harvesters and threshers could potentially reduce the considerable amount of manual labour required in rice production. The on-going agricultural mechanisation programme should be made available to rice farming communities at very moderate cost to allow them access the full services of the programme. Future improved varieties must seek to decrease cost and increase profitability.

c. For improved technologies to be effective in achieving their productivity goals, appropriate and effective input supply system should be developed alongside with the promotion of such technologies. In particular, timely and adequate supply of inputs should be promoted without compromising the quality of the inputs. A possible decentralisation of input supply to farming communities should be seriously considered to facilitate the delivery of such inputs by removing impediments to their acquisition. Input subsidy regime should be integrated with appropriate credit facilities for resource constrained farmers. Further, the Government and other policy makers should ensure greater integration of technology promotion activities with input pricing or subsidy regime to facilitate technology adoption by resource-constrained farmers. The provision of credit and input supply therefore needs strong government interventions.

d. Policies aimed at promoting rice productivity among farmers must focus on redesigning more intensive and integrated extension programmes. Technology promotion activities should implement and explore mechanisms for increasing the awareness on technologies. This could be done through field trips, exhibitions, group discussions, use of community radio, and extension talks. Further, demonstrations on farmers' field should be promoted with a follow up approach. Further, information on improved technologies should be widely circulated among the rice farmers and should not be restricted to certain farmer groups.

e. Evidence from the study suggests the need to enhance the capacity of the rice farmers. Farmers should be adequately educated and trained on the recommended requirements for inputs to promote efficient use of resources. Regular on-the-field demonstrations should be conducted to train the farmers on better farm management practices. Farmers also need to be educated on the economic gains of using certified seed for production.

5.4 Limitations of the Study

The major limitation of the study is that not only do the farmers not have formal education, but also they do not keep records of their farming activities. As a result, the farmers could not provide candid responses to the questions asked.

5.5 Suggestions for Further Studies

The study suggests that further studies may be concentrated on the following: (1) means of reducing cost of rice production and associated problems; and (2) gender differences in adoption and productivity; and (3) the impact of the improved rice variety on factor demands using the restricted profit approach.

REFERENCES

Abdullahi, A. (2012). Comparative economic analysis of rice production by adopters and non-adopters of improved varieties among farmer in Paikoro Local Government Area of Niger State. *Nigerian Journal of Basic and Applied Science*, *20*(2), 146-151.

Adégbola, P. Y., Arouna, A., Diagne, A., & Souléïmane, A. A. (2006). *Evaluation de l'impact économique des nouvelles variétés de riz NERICA au Bénin: Évidence avecles modèles basés sur l'approche contre factuel*. Paper presented at the First Africa Rice Congress, Dares Salaam.

Adewuyi, S. A. (2006). Resource use productivity of rural farmers in Kwara State, Nigeria. *International Journal of Agricultural Sciences, Sciences, Environment and Technology, 1*(1), 20-31.

Adhinkari, R. K. (2011). Economics of organic rice production. *The Journal of Agriculture and Environment, 12*, 97-103.

African Development Fund. (2001). *Republic of Ghana: Inland valleys rice development project appraisal report.* Accra, Ghana: African Development Fund.

Ahearn, J., Yee, J., Ball, V. E., & Nehring, O. (1998). *Agricultural productivity in the United States* (Agriculture Information Bulletin No. 740). Washington, DC: US Department of Agricultural.

Angelsen, A. A., van Soest, D., Kaimowitz, D., Bulte, E. (2001). Technological change and deforestation: A theoretical review. In A. Angelsen & D. Kaimowitz (Eds.), *Agricultural technologies and tropical deforestation* (pp. 19-34). New York, NY: CABI Publishing.

Asuming-Brempong, S., Gyasi, K. O., Marfo, K. A., Diagne, A., Wiredu, A. N., Asuming-Boakye, A., Haleegoah, J., & Frimpong, B. N. (2011). The exposure and adoption of NERICA among Ghanaian rice farmers: What is the evidence? *African Journal of Agricultural Research, 6*(27), 5911-5917.

Babbie, E. R. (2007). *The practice of social research* (13th ed.). Belmont, CA: Thomson Wadsworth.

Badal, P. S., & Singh, R. P. (2001). Technological change in maize production: A case study of Bihar. *Indian Journal of Agricultural Economics*, *56*(2), 211-219.

Balakrishna, A. (2012). Economics of Bt cotton in India. *Journal of Development and Agricultural Economics, 4*(5), 119-124.

Balasubramanian, V., Sie, M., Hijmans, R. J., & Otsuka, K. (2007). Increasing rice production in Sub-Saharan Africa: Challenges and opportunities. *Advances in Agronomy*, *94*, 55-133.

Basavaraja, H., Mahajanashetti, S. B., & Sivanagaraju, P. (2008). Technological change in paddy production: A comparative analysis of traditional and SRI methods of cultivation. *Indian Journal of Agricultural Eco*nomics, *63*(4), 629-640.

Bhanumurthy, K. V. (2002). *Arguing a case for the Cobb-Douglas production function*. Delhi, India: University of Delhi.

Bisaliah, S. (1977). Decomposition analysis of output change under new production technology in wheat farming. *Indian Journal of Agricultural Economics*, *23*(3), 193-201.

Block, S. (1994). A new view of agricultural productivity in Sub-Saharan Africa. *American Journal of Agricultural Economics, 76*, 619-624.

Brown, T., & Suter, T. (2012). *Marketing research (8th ed.).* Mason, OH: South-Western Publishing.

Caswell, M., Fuglie, K., Ingram, C., Jans, S., & Kascak, C. (2001). *Adoption of agricultural production practices: Lessons learned from the US Department of Agriculture (USDA) area studies project*. Washington, DC: USDA.

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

Cottrell, A., & Lucchetti, R. J. (2012). *Gretl user's guide: Gnu regression, econometrics and time-series library*. Boston, MA: Free Software Foundation.

de Avillez, R. (2011). *A detailed analysis of the productivity performance of the Canadian primary agriculture sector* (CSLS Research Report 2011-06). Ottawa, Canada: Centre for the Study of Living Standards.

Denzin, N., & Lincoln, Y. (Eds.) (2000). *Handbook of qualitative research*. London, England: Sage Publication Inc.

Diagne, A. K., Camoe, D. H., & Guei, R. G. (2006). *Les contraintes à la diffusion et à l'adoption des variétés améliorées de riz en Côte d'Ivoire*. Mimeo, Cotonou, Bénin: Centre du riz pour l'Afrique (ADRAO).

Dibba, L. (2010). *Estimation of NERICA adoption rates and impact on productivity and poverty of the small-scale rice farmers in The Gambia* (Unpublished master's thesis). KNUST, Kumasi, Ghana.

Diiro, G. M., Sam, A. G., & Kraybill, D. (2011). *Impact of adoption of improved groundnut varieties on factor demand and productivity in Uganda*. Poster session presented at the AAEA and NAREA joint annual meeting, Pittsburgh, Pennsylvania.

Dixon, J., Gulliver, A., & Gibbon, D. (2001). *Farming systems and poverty: Improving farmers' livelihoods in a changing world*. Rome, Italy: FAO.

Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change*, *33*, 255-299.

Felipe, J., & Adams, F. G. (2005). The estimation of Cobb-Douglas function. *Eastern Economic Journal*, *31*(3), 427-445.

Food and Agriculture Organisations. (2000). *Agriculture, trade and food security: Issues and options in the WTO negotiations from the perspective of developing countries*. Rome, Italy: FAO.

Food and Agriculture Organisations. (2004). *Food outlook No. 4.* Rome, Italy: FAO.

Food and Agriculture Organisations. (2005). *The state of food insecurity in the world*. Rome, Italy: FAO.

Food and Agriculture Organisations. (2006). *World agriculture towards 2030/2050: Interim report.* Rome, Italy: FAO.

Food and Agriculture Organisations. (2011). *FAOSTAT*. Retrieved from http://*faostat.fao.org*. [assessed 12 August 2011].

Fuglie, K., Macdonald, O., James, M., & Ball, E. (2007). *Productivity growth in US agriculture*. Washington, DC: US Department of Agriculture.

Fulginiti, L. & Perrin, R. (1998). Agricultural productivity in developing countries. *Elsevier Science B.V. Agricultural Economics*, *19*, 45-51.

Government of Ghana. (2009). *Budget statement and economic policy for 2010*. Retrieved from http://www.ghana.gov.gh/.../budget-statement/514-budget-statemen. [Assessed 4 March 2012].

Gray, E. M., Sheng, Y., Oss-Emer, M., & Dividson, A. (2012). Agricultural productivity: Trends and policies for growth. *Agricultural Commodities, 2*(1), 166-179.

Gujarati, D. N. (2004). *Basic econometrics* (4th ed.). New York, NY: The McGraw-Hill Companies.

Ha, A., Strappazzon, L., & Fisher, W. (2001). *What is the difference between productivity and profit?* (Economics Branch Working Paper). Melbourne: Australia: Department of Natural Resources, and Environment.

Huesemann, M. H., & Huesemann, J. A. (2011). *Technofix: Why technology won't save us or the environment.* Gabriola Island, Canada: New Society Publishers.

Hughes, N., Lawson, K., Davidson, A., Jackson, T., & Sheng, Y. (2011). *Productivity pathways: Climate adjusted production frontiers for the Australian broadacre cropping industry.* Paper presented at the 55th Annual Conference of the AARES, Melbourne, Australia.

Hussain, I., & Perera, I. R. (2004). *Improving agricultural productivity through integrated service provision with public-private-sector partnerships* (Working Paper 66). Columbia. Sri Lanka: International Water Management Institute.

Ibrahim, M. J. (2012). Technological change and economic transformation. In A. A. C. Teixeira (Ed.), *Technological change* (pp. 3-24). Rijeka, Croatia: InTech.

Institute of Science in Society. (2004). *New rice for Africa*. London, England: ISIS.

International Rice Research Institute. (2013). *Rice production and processing*. Los Baños, Philippines: International Rice Research Institute. Retrieved from http://irri.org/index.php?option=com_k2&view=item&layout=item&id=9151 &lang=en. [Accessed on 5 June 2013].

Jaffe, A. B., Newell, R., & Stavins, R. N. (2002). Technological change and the environment. *Environmental and Resources Economics, 22*(1/2), 41-69.

Japan International Cooperation Agency. (2006). *Proceedings of JAICAF/WARDA/JICA joint seminar on NERICA dissemination in Africa*. Accra, Ghana: JICA.

Kaur, M., & Sekhon, M. K. (2005). Input growth, total factor productivity and the components in Punjab agriculture: District-wise Analysis. *Indian Journal of Agricultural Economics, 60*(30), 473-482.

Kijima, Y. (2008). *New technology and emergence of markets: Evidence from NERICA rice in Uganda* (Discussion Paper No. 165). Nagoya, Japan: Graduate School of International Development, Nagoya University.

Kijima, Y., Sserunkuuma, D., & Otsuka, K. (2006). How revolutionary is the NERICA revolution? Evidence from Uganda. *Developing Economies, 44*(2), 252-267.

Kimani, J. M., Tongoona, P., Derera, J., & Nyende, A. B. (2011). Upland rice varieties development through participatory plant breeding. *ARPN Journal of Agricultural and Biological Science, 6*(9), 39-49.

Kumar, H., & Singh, R. (2013). Economic analysis of freshwater aquaculture production: A comparative analysis of different production systems. *Russian Journal of Agricultural and Socio-Economic Sciences*, *1*(13), 49-55.

Lin, J. Y. (1994). Impact of hybrid rice on input demand and productivity. *Agricultural Systems, 10*, 153-164.

Lipsey, R. G., & Carlaw, K. I. (2004). Total factor productivity and the measurement of technological change. *Canadian Journal of Economics*, *37*(4), 1118-1150.

Lupilya, G. S. (2007). *Assessment of social support projects for vulnerable groups towards poverty reduction: A case study of TASAF in Bukoba district* (Unpublished MA Dissertation), Morogoro, Tanzania: Sokoine University of Agriculture.

McCormick, D. & Schmitz, H. (2001). *Manual for value chain research on homeworkers in the garment industry*. Sussex, England: University of Sussex.

Ministry of Food and Agriculture. (2009). *The Republic of Ghana national rice development strategy (Draft)*. Accra, Ghana: MoFA.

Ministry of Food and Agriculture/Crop Research Institute. (2009). *Production manual for upland NERICA rice*. Accra, Ghana: MoFA/CRI.

Ministry of Food and Agriculture. (2011). *Agriculture in Ghana: Facts and figures 2010*. Accra, Ghana: MoFA.

Ministry of Food and Agriculture. (2013). *NERICA rice dissemination project*. Retrieved from http://mofa.gov.gh/site/?page_id=4626 [accessed 12 January 2013].

Mullen, J. D. (2002). *Farm management in the 21st Century*. Paper presented at the 46th Annual Conference of the Australian Agricultural and resource Economics Society, Canberra.

Mundlak, Y. (1992). *Agricultural productivity and economic policies: Concepts and measurements* (OECD Working Paper No. 75). Paris, France: OECD.

Murphy, J., & Sprey, L. H. (1983). *Introduction to farm surveys.* Wageningen, The Netherlands: International Institute for Land Reclamation and Improvement.

Norman, D. W., Worman, F. D., Siebert, J. D., & Modiakgotla, E. (1995). *The farming systems approach to development and appropriate technology generation.* Rome, Italy: Food and Agricultural Organisations.

Obirih-Opareh, N. (2008). Socio-economic analysis of rice production in Ghana: Agenda for policy study. *Ghana Journal of Agricultural Science*, 41(2), 45-59.

Organisation for Economic Cooperation and Development. (2006). *Promoting pro-poor growth: Agriculture, DAC Guidelines and Reference Series*. Paris, France: OECD.

Olayide, S. O., & Heady, E. O. (1982). *Introduction to agricultural production economics*. Ibadan, Nigeria: Ibadan University Press.

Omotesho, O. A., Muhammad-Lawal, A., & Yusuf, Y. K. (2010). Economics of small scale rice production in Patigi and Edu local government areas of Kwara state, Nigeria. *African Journal of Agricultural Research*, *5*(4), 45-58.

Oni, O., Pender, J., Phillips, D., & Kato, E. (2009). *Trends and drivers of agricultural productivity in Nigeria* (Nigeria Strategy Support Programme, Report 001). Abuja, Nigeria: IFPRI.

Patil, C. V., Yaledahalli, N. A., & Prakash, S.S. (2003). *Integrated nutrient management for sustainable productivity of groundnut in India.* Paper presented at the National workshop on groundnut seed technology, Raichur.

Pouchepparadjoyu, A., Kumaravelu, P., & Achoth, L. (2005). An econometric analysis of green technology adoption in irrigated rice in Pondicherry Union Territory. *Indian Journal of Agricultural Economics*, *60*(4), 660-675.

Poulton, C., Kydd, J., & Dorward, A. (2006). Overcoming market constraints on pro-poor agricultural growth in Sub-Saharan Africa. *Development Policy Review, 24*(3), 243-277.

Resmi, P., Kunnal, L. B., Basavaraja, H., Bhat, A. R. S., Handigol, J. A., & Sonnad, J .S. (2013). Technological change in black pepper production in Idukki district of Kerala: A decomposition analysis. *Karnataka Journal of Agricultural Science, 26*(1), 76-79.

Rogers, E. M. (2003; 2005). *Diffusion of innovations* (5th & 6th eds.). New York, NY: Free Press.

Saunders, M., Lewis, P., & Thornhill, A. (2007). *Research methods for business students* (4th ed.). Harlow, England: Financial Times/Prentice Hall.

Shideed, K. H. (2005). Theoretical framework for assessing adoption and impact of improved technologies. In K. H. Shideed & M. E. Mourid (Eds.), *Adoption and impact assessment of improved technologies in crop and livestock production systems in the WANA Region* (pp. 1-30). Aleppo, Syria: International Centre for Agricultural Research in the Dry Areas.

Shideed, K. H., & Salem, K. K. (2005). The impact of barley varietal technology in Iraq. In K. H. Shideed & M. E. Mourid (Eds.), *Adoption and impact assessment of improved technologies in crop and livestock production systems in the WANA Region* (pp. 55-72). Aleppo, Syria: International Centre for Agricultural Research in the Dry Areas.

Somado, E. A., Guei, R. G., & Keya, S. O. (Eds.) (2008). *NERICA (The New Rice for Africa): A compendium.* Cotonou, Benin: Africa Rice Centre.

Syverson, C. (2011). What determines productivity? *Journal of Economic Literature, 49(2),* 326-365.

Tan, Y. L. (1992). *The impact of farm mechanisation on small-scale rice production* (Unpublished master's thesis). University of the Philippines, Los Banos, Philippines.

Tiamiyu, S. A., Akintola, J. O., & Rahji, M. A. Y. (2009). Technology adoption and productivity difference among growers of new rice for Africa in savannah zone of Nigeria. *TROPICULTURA*, *27*(4), 193-197.

United Nations Conference on Trade and Development. (2011). *Market*. Retrieved from http://*www.unctad.info/en/Infocomm/Agricultural.../Riz/Market*. [assessed 15 December 2012].

Verspagen, B. (2010). The spatial hierarchy of technological change and economic development in Europe. *Annals in Regional Science*, *45*, 109-132.

WARDA. (2001). *New rice for Africa offers hope to women farmers and millions more*. Abidjan, Ivory Coast: WARDA. Retrieved at http://www.warda.org/main/Achivements/nerica.htm.

Welfens, P. J. J. (2005). *A quasi Cobb-Douglas production function with sectoral progress: Theory and application to the new economy*. Freudenberg, Rainer-Gruenter-Straße 21: Bergische Universität Wuppertal.

Wikipedia. (2013). *Rice*. Retrieved from http://*en.wikipedia.org/wiki/Rice*. [assessed on 6 May 2013].

Wikipedia. (2013). *Technological change*. Retrieved from: *http://en.wikipedia.org/wiki/Technological_change* [assessed on 6 May 2013].

World Bank. (2008). *World development report 2008: Agriculture for development.* Washington, DC: The World Bank.

World Bank. (2010). *World development indicators*. Retrieved from http://data.worldbank.org/data-catalog/world-development-indicators [accessed 15 November 2011].

Zandstra, H., Price, E., Litsinger, J., & Morris, R. (1981). *A methodology for on-farm cropping systems research.* Los Banos, Philippines: International Rice Research Institute.

Zenna, N. S., Gebre-Tsadik, Z., & Berhe T. (2008). *Moving up in Ethiopia*. Retrieved from http://irri.org/knowledge/publications/rice-today/features/features-africa/moving-up-in-ethiopia [assessed on 6 May 2013].

Zepeda, L. (ed.). (2001). *Agricultural investment and productivity in developing countries* (Economic and Social Development Paper No. 148). Rome, Italy: FAO.

APPENDICES

Appendix A

School of Graduate Studies, KNUST

Sample Questionnaire on Technological Change in Rice Production

Introduction

I (Edward Tsinigo) am a second year graduate student of the KNUST conducting a study into "**Economics of Technological Change in Rice Production in the Ejura-Sekyedumase and Atebubu-Amantin Districts, Ghana.**" The information being sought for is meant for academic purposes only and it is part of the requirements for the award of an MPhil in Agricultural Economics. Therefore, be assured that the strictest sense of anonymity and confidentiality will be maintained in the study. I deeply appreciate your time and cooperation.

Section A: Farmer's Information

1. Gender a. Male [ ] b. Female [ ]
2. How old are you? ………………. years
3. What is your marital status?
   a. Single [ ] b. Married [ ] c. Divorced [ ]
   d. Widowed [ ] e. Separated [ ]
4. What is your educational background?
   a. Illiterate [ ] b. Literate [ ] ………….. years of formal education.
5. What is the composition of your household?

Age group	**Gender**	
	Male	***Female***
Less than 18 years		
18 – 60 years		
60 years and over		

6. For how long have you been a farmer? …………………… years

a. For how long have you been growing rice? ………. years

Section B: Input Utilisation in Rice Production

a. Land utilisation

7. How did you acquire your farmland for the production of rice?

   a. Owned [ ]   b. Rented [ ]   c. Sharecropping [ ]

8. If you rented the land, what was the lease period? ………………….. years
9. What was the cost of renting the land? GH¢ …………………………………
10. If you acquired the land through sharecropping, what proportion of your produce did you give in return (in kg)? ………………………………………
11. Do you have the right to enjoy the property rights for an unspecified length of time? a. Yes [ ]   b. No [ ]
12. If you answered '***yes***' to ***question 11***, what kind of representation of property right is it?
    a. Use rights i.e. the right to use the land for growing subsistence crops e.g. rice [ ]
    b. Control rights i.e. the right to decide on what crops to grow and benefits from its sale [ ]
    c. Transfer rights i.e. the right to sell the land or reallocate use and control rights [ ]
13. How many total acreage of cultivated land do you have? ……..……….. acres
14. What proportion of this farmland did you allocate to rice? ……………...acres

b. Variety of rice planted

15. What was the ***principal rice variety*** you planted during the last production season? a. NERICA rice [ ]   b. Local variety [ ]

16. If you planted NERICA, which particular variety did you grow during the last season? a. N1 [ ] b. N2 [ ] c. N4 [ ] d. N9 [ ] d. N14 [ ]

17. If you planted a local variety, which particular variety did you grow during the last season? a. Red rice [ ] b. Mr. Harry [ ] c. Mr. Moorl [ ]

18. If you cultivated the NERICA rice, please rank, in order of importance, each of the following reasons for doing so. Allocate a rank of ***1*** to the ***most important*** reason, a rank of ***2*** to the ***second most important*** reason, etc. Allocate a rank of ***6*** to the ***least important*** reason for adopting the NERICA rice. ***Use each of the numbers 1 to 6 only once.***

Reasons for Cultivating NERICA	Rank
Higher yield advantage	
Early maturing	
Ability to withstand drought and other stressful field conditions	
Disease and pest resistant	
Acid tolerant	
Good taste and aroma	

19. Which other reason(s) is/are responsible for your adoption of the NERICA variety? ……………………..……………………………………………………….

20. If you did ***not*** cultivate the NERICA rice, please rank, in order of importance, each of the following reasons for ***NOT*** adopting the NERICA rice. Allocate a rank of ***1*** to the ***most important*** reason, a rank of ***2*** to the ***second most important*** reason, etc. Allocate a rank of ***7*** to the ***least important*** reason. ***Use each of the numbers 1 to 7 only once.***

Reasons for NOT Cultivating NERICA	Rank
Non-availability of NERICA seeds	
High demand for inputs such as fertiliser and herbicide	
Delays in the supply of inputs	

High certified seed price compared to the local variety	
Difficulty in threshing	
Loss of quality (i.e. poor taste, broken kennel) if delayed o the field after harvesting	
Lack/inadequate information on NERICA	

21. Which other reason(s) is/are responsible for your non-adoption of the NERICA variety?.....…………………………………………………………..

22. Where did you obtain the rice seed that you planted during the last production season?

    a. From last year's harvest [ ] b. Purchased from the seed depot [ ]

    c. Purchased from the market [ ] d. Purchased from another farmer [ ]

    e. Purchased from MoFA [ ] f. Gift from another farmer [ ]

23. What quantity of rice seeds did you use during the last season? ………….kg.

24. What was the price of the rice seeds used in your production? GH¢/kg/ ……

25. What proportion of your total rice field did you allocate to the cultivation of the particular rice variety (***in question 16 or 17 above***)? ………………acres.

c. Fertiliser application

26. Did you use fertiliser on your rice field during the last production season?

    a. Yes [ ] b. No [ ] (***if you answered 'no' please skip to question 31***)

27. How was the fertiliser applied?

    a. Side placement [ ] b. Broadcasting [ ] c. Dibbling [ ]

28. When was the fertiliser applied?

    a. Basal application: Number of weeks after seedling emergence …………..

    b. Top dressing: Number of weeks after seedling emergence ………………

29. Please complete the table below:

Type of fertiliser applied	Number of bags used/ acres	Kg/ acres	Price (GH¢/kg)
NKP			
Sulphate of ammonia			

d. Herbicide application

30. Did you use herbicides in controlling weeds on your rice field during the last production season? a. Yes [ ] b. No [ ] (***if you answered 'no' please skip to question 34***)

31. If you use herbicide to control weeds, can you tell us about your practice?

	Pre Emergence (After Sowing)	Post Emergence (After Seeding)
Date of application (days)		
Name of herbicide		
Volume applied per ha		
Price of herbicide (GH¢/kg)		

e. Tractor ploughing

32. Did you use tractor in ploughing your rice field during the last production season? a. Yes [ ] b. No [ ] (*if you answered 'no', answer only **question 33***)

33. If you answered '***no***' to ***question 34***, which method did you use? ……………

34. If "yes", how many times did you plough during the last season? ……………

35. What was the cost per each ploughing during the last season? GH¢/acre ....

f. Labour utilisation

36. What was your main source of labour for rice production during the last season? a. Family labour [ ] b. Hired labour [ ] c. Both [ ]

37. What was the cost of labour per day? GH¢ …………………………………..

38. Please indicate your labour demands for the following activities during the last season per acre.

Operation	Adult Male			Adult Female			Children < 18		
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Land preparation (i.e. clearing, spraying, use of tractor, or manual)									
Transplanting/sowing									
Weeding (spraying, manual weeding)									
Fertiliser application									
Harvesting									
Threshing (drying, packaging and storage)									

Hint: 1 = No. of workers; 2 = Hours worked per day; and 3 = Number of days worked

g. Miscellaneous Costs

39. How much have you incurred in transporting the product from to the market? GH¢ …………………..

h. Output from rice production

40. Please provide the following information on the output from rice during the last season.

Quantity harvested (kg/acre)	Quantity sold (kg)	Price (GH¢) /kg	Quantity consumed	Quantity given out as gift

41. Did the quantity you harvested meet your expectation? a. Yes [ ] b. No [ ]

42. If you answered '***no***' to ***question 41***, what do you think is/are the reason(s) for the low output? ……………………………………………………….. ………………………………………………………………………………

Section C: General Information on Rice Production

a. Extension services

43. Did you get advisory services on rice production from extension agents during the last season? a. Yes [ ] b. No [ ] (***if you answered 'no' please skip to question 46***)

44. How many extension visits/contacts did you have during the last season? ….

45. When you accessed the information from the extension agents, did they provide the answers you were looking for? a. Yes [ ] b. No [ ]

    a. If you answered 'no' please briefly explain the reasons for your answer ………………………………………………………………………………… …………………………………………………………………………………

46. What are your other sources of information on rice production during the last season? a. Researchers [ ] b. Fellow farmers [ ]

    c. Farmer based association [ ] d. Input dealers [ ] e. Media (TV, radio) []

b. Membership of an association

47. Did you belong to a farmer organisation during the last season?

    a. Yes [ ] b. No [ ]

48. How many times did you attend meetings during the last season? …………

c. Credit utilisation

49. What was/were your main source(s) of finance for the production of rice during the last production season? ***Tick as many as applicable***.

    a. Income from farming activity [ ] b. Assistance from spouse [ ]

    c. Friends and relatives [ ] d. Micro finance institutions [ ]

    e. Rural banks [ ] f. Commercial banks [ ] g. NRDP-MoFA [ ]

    i. Customers [ ]

50. Did you borrow credit for the production of rice? a. Yes [ ] b. No [ ]

You have finished the questions! Thank you for your time and cooperation.

Appendix B
Focus Group Discussion Checklist

1. Rice varieties, sources of seeds and method of planting.
2. Access to land, tenurial arrangements, and conditions as well as challenges with land tenure systems.
3. Forms of land preparation (slashing, application of herbicides, tractor harrowing, animal traction).
4. Source of information on rice production, access to extension service and extension programmes.
5. Types of farmer organisations.
6. Access to credit facilities, sources, forms, and conditions.
7. Sources of labour for production, form of labour used for production.
8. Planting season in the area.
9. Use of inputs in production.
10. Measurements of units of inputs for production.
11. Challenges encountered in the adoption of the improved rice variety.