UNIVERSITY FOR DEVELOPMENT STUDIES

IMPROVED RICE VARIETY ADOPTION AND ITS EFFECTS ON FARMERS' OUTPUT IN GHANA

ABEL KWAKU K. BRUCE

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BY

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THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS, FACULTY OF AGRIBUSINESS AND COMMUNICATION SCIENCES, UNIVERSITY FOR DEVELOPMENT STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN AGRICULTURAL ECONOMICS

2015

DECLARATION

Candidate

I hereby declare that this dissertation is the result of my own original work and that no part of it has been presented for another degree in this University or elsewhere.

Candidate's Signature: …………………………….……… Date: 04-11-2015

Name: Abel Kwaku K. Bruce

Supervisors'

We hereby declare that the preparation and presentation of the dissertation were supervised in accordance with the guidelines on supervision of dissertation laid down by the University for Development Studies.

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ABSTRACT

This study sought to investigate the factors that influence the adoption of improved rice varieties and its effects on output in Ghana. The method of analysis involved an estimation of treatment effect model comprising a probit equation and a production function. The empirical results show that the adoption of improved rice variety had a positive effect on farm output. Other inputs that had significant and positive impact on output were farm size, labour and fertilizer. The probability of adopting improved rice variety was high for the following: farmers who had formal education; farmers who had greater households; and farmers who had smaller farms. Contrary, however, farmers who had access to extension services had lower probability of adoption. The estimated Wald chi-square was 66.27 at 1% significant level. This indicates the appropriateness of the estimated model meaning that, the explanatory variables jointly determine the adoption of improved rice variety. It is however recommended that, farmers should be supported with more fertilizer subsidization. Farmers should also form farmer groups to support one another on the field especially during labour scarcity period. Also, the fundamental problems of illiteracy among farmers should be addressed by the government of Ghana.

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My special appreciation goes to the International Food Policy Research Institute (IFPRI) in collaboration with Ghana Strategy Support Programme (GSSP) for the scholarship as well as the data they gave me to carry out this work.

To my Dad and Mum, Mr. and Mrs. Ebenezer Kwaku Bruce thanks for the periodic motivation and reminders during the period of this work.

My appreciation goes to my lovely wife Priscilla and our two children Nathan and Kwesi for their daily prayers before, during and after each task regarding this thesis.

While conducting this study, I came across numerous friends, whose names regrettably cannot be mentioned here, your words of encouragement, prayers and general support are duly appreciated. Nevertheless, I have to mention William Adzawla for the collegial support and good friendship. Above all, I thank God for seeing me through this MPhil. Programme.

DEDICATION

I dedicate this work to the Lord God Almighty. It is also dedicated to my lovely wife Priscilla and our two children, Nathan and Kwesi.

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LIST OF ACRONYMS

AGDP	Agricultural Gross Domestic Product
AGRA	Alliance for Green revolution in Africa
CDF	Cumulative Density Function
CSIR	Council for Scientific and Industrial Research
GDP	Gross Domestic Product
GSS	Ghana Statistical Service
GS SP	Ghana Strategy Support Program
HYV	High Yielding Variety
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
IMR	Inverse Mills Ratio
MDGs	Millennium Development Goals
MoFA	Ministry of Food and Agriculture
NRDP	National Rice Development Project
PDF	Probability Density Function
SARI	Savanna Agricultural Research Institute
SRID	Statistical, Research and Information Directorate
SSA	Sub Saharan Africa
UN	United Nations
WAAPP	WAAPP - West Africa Agricultural Productivity Programme

CHAPTER ONE:
INTRODUCTION

1.0 Background

Agricultures has a direct influence on the attainment of at least five of the Millennium Development Goals (MDGs), especially the first goal of eradicating poverty and extreme hunger can only be achieved through agricultural productivity (METASIP, 2010). Significant improvements in the productivity of the agricultural sector are necessary to raise the average real incomes of Ghanaians as a whole.

Agriculture's contribution to the Gross Domestic Product (GDP) of the economy of Ghana has seen a decline in recent times. In 2010, the contribution was 39% compared to 26% and 31% of industry and service sectors respectively (METASIP, 2010). The share of Agricultural GDP declined to 23% in 2012 and further reduced to 22% in 2013. Even though the sector has lost its role as the leading contributor to the National GDP, it still remains the king pin to the economy of Ghana, employing 50.6% of the country's labour force (GSS, 2014).

The agricultural sector grows at 2.6%, vis-à-vis the current annual population growth rate of 2.8%. The small margins between these figures have serious implications for the attainment of food security, employment generation and improvement in rural incomes and national economy (NAPCDD, 2003)

In spite of the significant role agriculture plays in the economy of Ghana by sustaining majority of the citizens, for several decades, about 1.2 million people are still food insure (WFP, 2009, Carr Jr., 2001). These households are not only unable to produce sufficient food for themselves but also lack the income to purchase enough of it from the market.

The attainment of self-sufficiency in food and industrial raw materials through increase in production is the main interest of the Ministry of Food and Agriculture (MoFA) and the reason for the establishment of research institution such as the Savanna Agricultural Research Institute (SARI) and Crops Research Institute (CRI), both of which are institutes of the Council for Scientific and Industrial Research (CSIR). Individual researchers in these institutes and/or in collaboration with foreign institutions such as the Africa Rice Centre, West Africa Agricultural Productivity Program (WAAPP), International Institute of Tropical Agriculture (IITA) have developed and extended to farmers improved crop varieties aimed at increasing production in Ghana.

The role of rice as a strategic food crop in Africa is becoming more significant with changing habits that increase the demand for this grain. During the last three decades, rice consumption in Africa has experienced a drastic increase leading to increased productivity levels, even though to a lesser extent (Africa Rice, 2009). The consequence is an alarming dependency on rice importations for food security in African countries. Presently, rice is one of the most important staples in most developing countries, (Danso-Abbeam et al. 2014).

The consumption of rice keeps on increasing as a result of population growth, urbanization and change in consumer habits. The rice sector is an important provider of rural employment. Rice is the fastest growing staple food source in most African countries, providing the bulk of energy to the growing population. In most developing countries in Africa, rice accounts for 715kcal/caput/day and this represent 27 percent of nutritional supply of energy, 20 percent of protein and 3 percent of fat (Kassali et al. 2010). Rice occupies the 5th most prominent source of energy in diet responsible for about 9 percent of caloric intake and also serves as raw material for industries (FAOSTAT, 2012). Rice production in African grew at 3.23% per annum from 1961 to 2005 (Kassali et al., 2010). However, paddy rice production in SSA was estimated at 146 million tonnes in 2006.

In Ghana, agricultural sector is the most important sector of the economy because it provides food, raw materials for industries and generates income for households (Danso-Abbeam et al., 2014). Rice is considered to be the second most important grain food next to maize (MoFA, 2009). Rice is also the first imported cereal in the country accounting for about 58 percent of cereal imports and 5 percent of total agricultural imports over the estimated period 2005-2009 (CARD, 2010). Rice accounts for about 45 percent of the total hectares cultivated to cereals and 4 percent of the total agricultural crop harvested in hectares (Danso-Abbeam et al., 2014),In terms of value of production, rice was ranked 10th among agricultural commodities in Ghana and 8th in terms of quantity for the period 2005-2010 (MoFA, 2010). However, in terms of area of production, rice is one of the paramount cereals cultivated in Ghana that account for about 19 percent of cereal production.

From the year 2000 and 2010, rice cultivation in hectares increased from 0.09 to 0.16 million whilst productivity fluctuated between 1.7 to 2.7 tonnes per hectares (FAOSTAT, 2012). Similarly, from the year 2007 and 2010, rice productivity levels have been more than doubled, increasing from 185,000 tonnes to 491,600 in tonnes with current annual growth rate of about 15 percent over the period 2005-2010 (FAOSTAT, 2012). However, in 2007, there was a drop in production, that is, from 237,000 tonnes in 2005 to 185,000 tonnes in 2007 (SRID, 2011). Danso-Abbeam et al., (2014) reported that the improvement in production could partly be attributed to the favourable rainfall patterns and the fertilizer subsidy programme implemented in 2008 including the block farming programme organized in 2009 by the government of Ghana. Ghana depends largely on imported rice to make up the deficit in rice supply. On the average, annual rice imports is about 500,000 tons (MoFA, 2010). The self-sufficiency ratio of rice in Ghana has declined from 38% in 1999 to 24% in 2006 (MoFA, 2009).

Adoption and diffusion among small holder resource-poor farmers are essential prerequisites for increasing agricultural productivity and for that matter, economic prosperity in developing countries. Consequently, in most of these countries, considerable resources have been devoted to providing technical assistance and education to small holder farmers with the hope that these technologies would be adopted and diffused. Several researchers have studied the process of adoption and diffusion (Doss, 2005; Agboh-Noameshie et al.;Robertson et. al 1986).

1.1 Problem Statement

Extensive research activities have been conducted in Ghana by SARI and CRI. The results of these activities have been the generation of several improved rice varieties based on on-farm trials. However, judging from the yields of farmers, there is a yawning gap between results of on-farm demonstration plots (6.5 Mt/Ha) and actual yields (2.4Mt/Ha) from the farmers' fields (MoFA, 2010).

Increment to annual production are largely due to area (ha) put under cultivation, rather than yield variations (t/ha) (ibid) which results in land extensification with its attendant consequences.

Studies on the adoption of agricultural technology abound (e.g. Donkoh, 2010; Wiredu et al., 2010, Saka et al., 2009, Baidu-Forson 1999 etc.). In Ghana, many of such studies (e.g. Seidu and Yankyera, 2014; Doss et al., 2001; Besley et al., 1993 etc) focus on the determinants of adoption, with little or no emphasis on the effects of adoption on output, hence failing to account for sample selection bias.

As indicated earlier, the importance of rice to Ghana's economy cannot be overemphasized, it is therefore imperative to address some of the pertinent bottlenecks bedeviling its production. In principle technology adoption is supposed to increase output. As to whether this is true about improved rice variety production in Ghana remains an empirical issue, hence the importance of this study.

1.2 Research questions

The specific research questions to be addressed in this study are as follows:

1. What factors influence the adoption of improved rice varieties in Ghana?

2. What are the effects of adoption of improved rice varieties on the output of farmers?

The research questions give rise to the following study objectives.

1.3 Objectives of the Study

The main objective of the study is to determine the effect of adoption of improved rice varieties on the output of farmers in Ghana.

The specific objectives include;

1. To determine the factors that influence the adoption of improved rice varieties in Ghana
2. To estimate the effect of adoption on the output of farmers in Ghana.

1.4 Justification of the study

The numerous uses of rice in the Ghanaian economy warrant that empirical studies are consistently conducted to unravel the bottlenecks in production to raise productivity. Therefore, this research would be a useful guide to NGOs, Donors and Development agencies such as International Food Policy Research Institute (IFPRI) in collaborations with Ghana Strategy Support Programme (GSSP) to implement projects that would improve the country rice import deficit and subsequently food security status. Similarly, the findings would be a useful guide to the country as a whole and AGRA in particular in facilitating the re-introduction of the Green Revolution in Ghana, including Sub-Sahara Africa. The study would also provide relevant information to the farmers on the role of improve seed varieties in generating the desired output.

1.5 **Scope of study**

The study focuses on the adoption and its effects of the most popular rice varieties rice in Ghana.

1.6 **Limitation and delimitation of the study**

The study used secondary data from the Statistical, Research and Information Directorate (SRID) of the MoFA. The data collection was a pilot one for the entire country and therefore sample size covered was four hundred and seven (407) rice farmers. Not only is the sample relatively small to represent rice production in the entire country but also the availability of other relevant variables for the study. Notwithstanding, the findings in this study are relevant for policy formulation considering the objectives of the study along with the outcome of our findings.

1.7 **Organization of the study**

The research is organized into five chapters. Chapter one provides details on the background to the study which includes the problem statement, research questions and objectives. Chapter two covers the literature review and is followed by chapter three which sets out the study methodology, specifically, the study area, sampling procedure and data analysis. Chapter four presents and discusses the findings of the research while chapter five provides the summary, conclusion and recommendations emanating from the study.

Diffusion of innovations may be described as how, why and the rate at which new ideas and technologies spread through cultures over time. However, adoption is seen as an individual process that shows a series of stages that an individual must undergo from first hearing about a product to the time that he/she make use of the innovation/technology. The concepts of adoption and diffusion are often used interchangeably in the adoption literature, (Diagne and Demont, 2007).

In this study, the adoption of improved rice varieties is defined as the use of improved rice varieties by an individual farmer while diffusion is the spread or the use of the improved rice varieties across a community or the entire nation. Improved rice variety basically refers to rice varieties that have gone through the process of breeding, foundation expansion and certification.

CHAPTER TWO:

LITERATURE REVIEW

2.1 Introduction

The chapter is divided into six broad sections as follows: definition of innovation concept; Green Revolution and its development; rice and its development policies in Ghana; meaning and types of production functions, and the theoretical framework underlying the study as well as a review of some of the factors known to be influencing agricultural technology adoption.

2.2 Diffusion of innovation Concept

Rogers (2003) defines diffusion as the process by which an innovation is communicated through certain channels over a period of time among the members of a social system. An innovation is seen as an idea, practice or object that is perceived as new by individuals or other units of adoption. Rogers (2003) presented four elements that are embedded in the diffusion process. These elements are identifiable in every diffusion research study and in every diffusion campaign or program because they bring out the concept of diffusion more clearly. These elements which Rogers (2003) identified in diffusion processes are as follows; innovation, communication channels; time; and the social system. These are explained briefly below.

- **Innovation**

An idea or object that is perceived as new by individual or other units of adoption. It also refers to the application of new idea for better solutions that meet new requirements, inarticuted need, or existing market needs. The term innovation can be defined as the introduction of new idea which is seen as original into a prevailing market or society. This is accomplished through more effective products, processes, services, technology, or ideas that are readily available to markets, governments and society. Innovation is generally considered to be a process that brings together various ideas in a way that has an impact on society.

- **Communication Channels**

The second element of the diffusion of innovation process is communication channels. For Roger (2003), communication is the process by which individuals create and share new ideas with one another in order to reach a mutual understanding. Communication occurs through channels between sources. A source is an individual or an institution that brings a message.

A channel represents the passage from the source to the receiver. For adoption to occur, an innovation must be communicated through a communicated channel. Mass media and inter personal communication are two communication channels. Diffusion of innovation occurs faster between two or more individuals than it does through mass media such as TV, radio, or newspaper. Communication channels also can be categorized as local and cosmopolite channels that communicate between individual of the social system and outside sources.

- **Time**

Time is noted to have three factors namely, innovation-decision process and the relative time with which an innovation is adopted by a prospective individual or group as well as the innovations' rate of adoption. The passage of time is necessary for any innovation to be adopted because they are rarely adopted instantaneously. In Ryan and Gross (1943) study on hybrid corn adoption, adoption occurred over more than ten years due to the common reason that most farmers dedicated a fraction of their field to the new corn in the first year after adoption. Rogers (2003) argued that this makes time dimension in diffusion research one of its strength.

- **Social System**

A social system is also defined as a set of interrelated units engaged in a joint problem-solving to accomplish a common goal. A set of interrelated units that come together to solve an existing problem in order to accomplish a common goal. The social system is the combination of external influences such as mass media, organizational or governmental mandates and internal influences (strong and weak social relationships, distance from opinion leaders). There are many roles in a social system and their combination represents the total influence on a potential adopter.

The rate of diffusion is the relative speed by which an innovation is easily adopted by members of a social system. According to Rogers (2003), this usually measures the number of adopters of a new idea within a specific period of time such as a year. The rate of diffusion is a numerical indicator that shows how steep the adoption curve is for any given innovation. It has a number of attributes, which according to Rogers (2003) includes relative advantage, compatibility, trialability and observability. Rogers (2003) argued that innovations of relative advantage, compatibility, simplicity, trialability and observability will be adopted faster than other traditional ones. This means for an innovation to be adopted, farmers must see it to have a greater advantage than the one they are used to. It should be easier for farmers to use in their settings and they should be able to observe it on a demonstrated field. Additionally the following attributes facilitate the process of adoption;

- The type of innovation-decision;
- The nature of communication channels diffusing the innovation at various stages in the innovation-decision process;
- The nature of the social system in which the innovation is diffusing; and
- The extent to which change-agents promote efforts in diffusing the innovation.

In general, these attributes determine the rate of technology adoption as depicted in

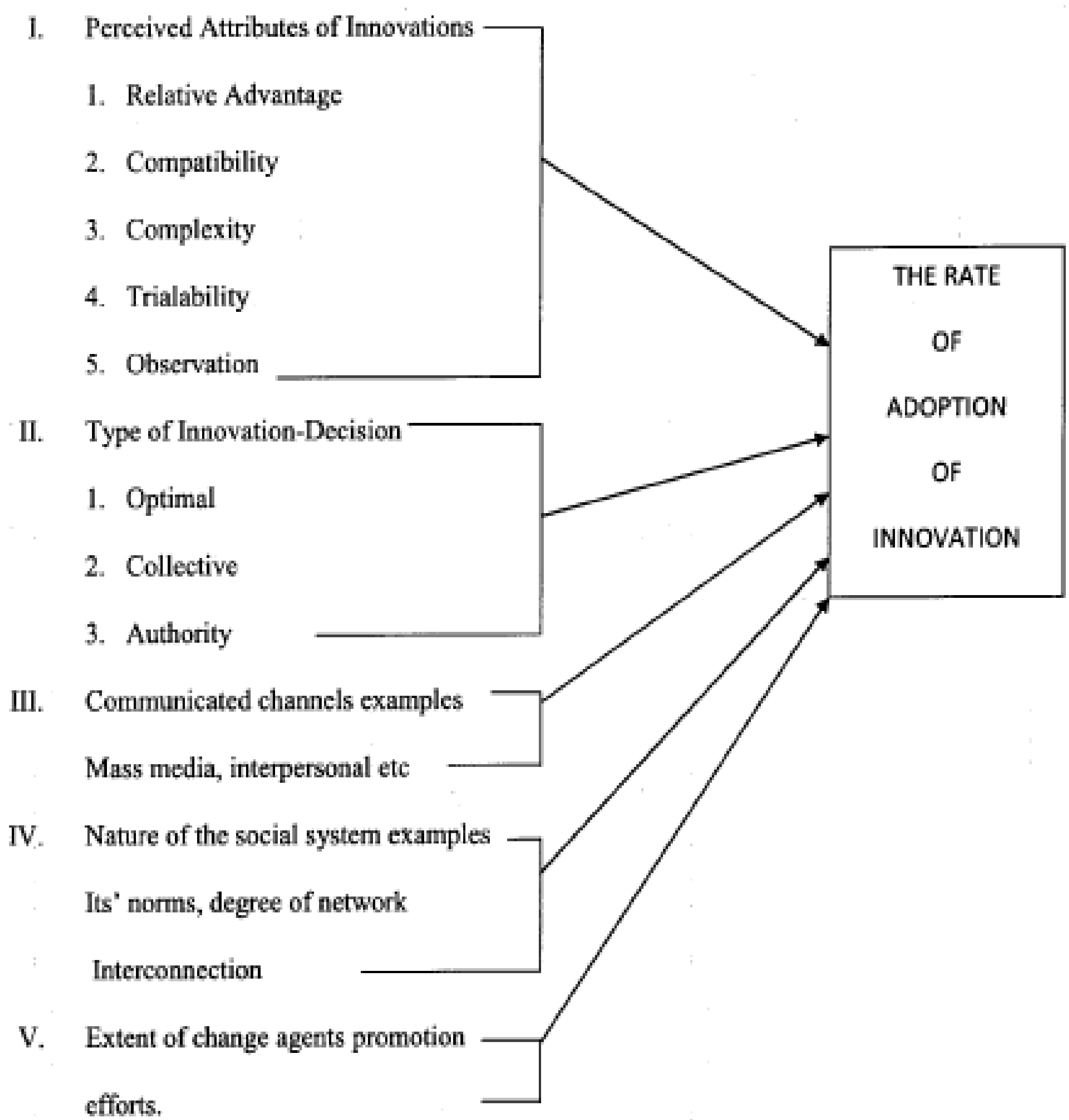


Figure 2.0 Variables Determining the Rate of Adoption of Innovation

Source: Rogers, 2003.

figure 2.0 below:

According to Rogers (2003) the innovation decision is the process of looking for information and processing an activity which ensures that an individual is motivated to reduce uncertainty about the advantages and disadvantages of an innovation. Rogers identified five decision processes or stages as follows;

- **Knowledge**

At this stage the individual is first exposed to an innovation by way of information. During this stage the individual has not yet been inspired to find out more information about the innovation and so he/she want to know the 'What', "how" and "why" of the innovation. During this phase, the individual attempts to determine "what innovation is and how and why it works.

- **Persuasion**

At this stage the individual is interested in the innovation and actively seeks related information or details.

- **Decision**

The decision stage involves the individuals taking the concept of the change and weighing the advantages/disadvantages of using the innovation and decides whether to adopt or reject the innovation. Due to the individualistic nature it is the most difficult stage and needs empirical evidence.

- **Implementation**

At the implementation stage, the individual employs the innovation to a varying degree depending on the situation. During this stage the individual also determines how useful the innovation is and may search for further information about it.

- **Confirmation**

At the confirmation stage the individual searches for support for his or her decision. Depending on the support for the adoption of the innovation and the attitude of the individual, adoption of the technology or discontinuance of adoption takes place.

- **Qualities of an innovation**

The qualities of an innovation are the attributes of the innovation that help to decrease uncertainty about it. Rogers (2003) identified five characteristics of the quality of an innovation as follows;

- **Relative advantage**

This refers to the ways by which an innovation is seen as better than the prevailing idea or technology. It is measured in economic advantage, social prestige and satisfaction, among others. The greater the perceived relative advantage of an innovation the higher the rate of adoption

- **Compatibility with its values and practices**

An innovation that is seen as compatible means it is consistent with the values, past experiences and needs of potential adopters. If an innovation is not compatible with its values, norms or practices, it presupposes that the adoption will not be rapid as much as possible.

- **Simplicity and ease of use**

The degree to which an innovation is adopted depends on how simple the new idea can easily be understood. However the adoption is impeded if the innovation requires that the adopter develops new skills and understanding.

- **Trialability**

Trialability means how easily an innovation may be experimented with. When an innovation is tried and proves to be viable, it stands the chance of being adopted as opposed to the one that cannot be tried. Thus, an innovation that is trialable represents less uncertainty to the prospective adopters.

- **Observable results**

Adoption is easier if individuals can see the result of an innovation. Uncertainty is reduced if the results of an innovation are visible. Again, it stimulates peer discussion of new ideas as friends, relatives and neighbors request information about the innovation.

The second stage (II) of the factors determining the rate of adoption is the type of innovation decision process.

The Types of Innovation Decision Process

According to Roger (2003), the types of innovation decision process include;

Optimal-Innovation Decisions: The decision here is taken by one person and it is usually an independent one.

Collective-Innovation Decisions: The decision is taken by a group of people

Authority-Innovation Decision: The decision is imposed by an authority figure

2.3 **Background on Innovation Diffusion Studies**

Diffusion research was first carried out by the French sociologist Gabriel Tarde who propounded the original S-shaped diffusion curve, (News land, 2005). The study of diffusion of innovations took off in the subfield of rural sociology in the Midwestern United States in the 1920s and 1930s. Agriculture technology was advancing rapidly, and researchers started to examine how independent farmers were adopting hybrid seeds, equipment, and techniques. Rogers (2003) argued that most innovations have an S-shape rate of adoption which makes Tarde's (1903) S-shaped curve very useful for innovation diffusion discourse. The variance lies in the slope of the 'S'. Some innovation diffusions create rapidly a steep 'S' curve whiles other innovations have a slower rate of adoption therefore creating a more gentle 'S' curve.

Later on Bryce Ryan and Neal Gross in 1940s published the study of diffusion of hybrid seed among small scale farmers rejuvenating interests in innovation diffusion studies. The now infamous hybrid-corn study resulted in a renewed wave of research. Eder, et *al.* (1985) classified adoption into an individual (farm level) adoption and aggregate adoption. Adoption at the individual farmers' level is defined as the degree of use of new technology in a long run equilibrium when the farmer has full information about the new technology and it's potential. In the context of aggregate adoption behaviour, diffusion is defined as the spread of new technology within a region. This implies that aggregate adoption is measured by the aggregate level of specific new technology with a given geographical area or within the given population. Ryan et al., (1940) classified the segments of farmers with respect to the time it took them to adopt the innovation, that is the hybrid seed. The rate of adoption of agricultural innovation followed an S-shaped normal curve when plotted on a cumulated basis over time. The five segments of farmers who adopt an innovation are categorized into:

2.3.1 Innovators

These groups of people are the first to try new ideas, processes, goods and services. It constitutes about two percent of the population. The people in this group are risk takers, have relatively high education and are attracted to change. Innovators purchase the product at the beginning of its life cycle. Additionally, they have new experiences which come as a result of the fact that they obtain multiple information sources for making a possible purchase decision. Rogers (2003) noted that innovators have the highest social status, have financial liquidity, are social and have closest contact to scientific sources and interaction with other innovators. Their risk tolerance allows them to adopt technologies that may ultimately fail. Financial resources help absorb these failures.

Rogers (2003) identified several additional characteristics of innovators as follows;

- They are adventurous, daring and risk lovers;
- They control substantial financial resources that help them to absorb possible loss from an unprofitable innovations; and
- They have the ability to understand and apply complex technical knowledge

2.3.2 Early Adopters

In the diffusion of innovation theory, early adopters are seen as those who rely on their own intuitions and visions to choose carefully. They have above-average education level. For any new product to be successful, it must attract innovators so that their acceptance moves to early majority. Other adoption characteristics for early adopters are as follows;

- They will adopt any technology based on its' economic necessity,
- They are skeptical; and
- They are cautious

2.3.5 Laggards

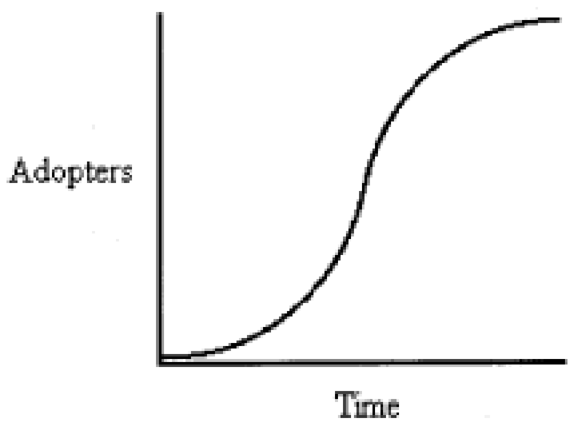
Rogers (2003) noted that laggards have a traditional view and are more skeptical about innovations than the late majority. One key characteristic is that they want to make sure that an innovation works before they adopt, mainly due to limited resources and lack of awareness of innovative knowledge. Also they don't have a leadership role. They constitute minority group of about sixteen percent (16%), and their innovation decision process is lengthy due to the fact that laggards observe the success of innovation in the past before adopting.

Rogers identified the following characteristics among the laggards:

- possess no opinion leadership;
- they isolate themselves from new innovations
- they would refer you to how they went with the traditional practices in the past
- they are suspicious of innovations;
- their innovation-decision process is lengthy; and
- they have limited resources

The S-shaped adoption curve is another important idea that Rogers (2003) stressed. As indicated earlier the curve shows that a successful innovation will go through a period of slow adoption before experiencing a sudden period of rapid adoption and then a gradual leveling off. When depicted on a graph, this slow growth, rapid expansion and leveling off form an S-shaped curve (see Figure 2.0). The period of rapid expansion, for most successful innovations, occurs when social and technical factors combine to bring about dramatic growth. The S shape innovation diffusion curve is shown below.

Figure 2.1 is an S-curve showing initial slow growth, a period of rapid adoption, and a gradual leveling off.



2.4 **Adoption and culture**

House et al. (2004) defined culture as shared motives, values, beliefs, identities, and interpretations or meanings of significant events that result from common experiences of and transmitted across generations by members of collectives. Hofstede (2001) also described culture as the collective programming of the mind that distinguishes the members in one group or category of people from another. Moral norms resulting from an individual's ecological awareness have a strong positive impact on adoption intention (Jansson et al. 2010, Jansson 2011). According to Herbig, and Dunphy (1998) existing cultural conditions determine the diffusion of an innovation. This implies that technology adoption may be reflective of cultural differences. Individuals from cultures with strong collectivistic values tend to consider their friends and family's views on a technology adoption (Dinev et al. 2009; Pavlou and Chai 2002).

Furthermore, culture influences attitudes and behavioral intention towards technology and innovation, which have been shown to affect decision to adopt technology. Rogers (2003) explains that culture influences all the five stages of innovation communication. Taylor and Todd (1995) and Van Slyke et al. (2010) confirmed the findings that if an innovation fits into both social and technical norms, including their beliefs, then this will have a positive influence on their adoption decision.

2.5 **Importance of Diffusion**

According to Rogers (2003) diffusion of innovation is important because it is relatively hard to develop or invent many kinds of useful knowledge. Again the techniques involve a lot of skills and usually the innovation requires long periods of time. Similarly an innovation may require a special environment or a historical/cultural preadaptation to make it possible. Diffusion makes the trading of ideas and techniques including diseases, organism, genus and commodities very useful to society survival.

Again most societies acquire new culture through diffusion. For example, the Europeans acquired the following basic technology during the medieval period: Arabic numeral from the Indians, paper and compass from the Chinese; and the astronomical table from the Arabs.

2.6 Green Revolution: Meaning and Development

The term Green revolution (GR) refers to a series of research, development and technological transfer initiatives, aimed at renovating agriculture worldwide with particular focus on the developing world. The term was first used in 1968 by the former director of the United States Agency for International Development (USAID), William Gaud (Gaud, 1968). According to Briney (2014), the beginning of the GR is often attributed to Norman Borlaug, an American botanist interested in agriculture. According to Borlaug (2002), GR is a public relations term that symbolizes modernization of agriculture in less industrialized countries by means of technological change rather than violent "Red Revolution" (Communism). The revolution focused on the development of High Yielding Varieties (HYV) of rice and wheat using plant improvement technologies and broad transformation of agricultural sectors in developing countries. This would ensure a reduction in food shortages and under nourishment, and the elimination of bottleneck to overall agriculture development (Griffin, 1979).

According to Evenson and Gollin (2000), GR was initiated as a result of the chronic food shortages experienced by many developing countries that had just emerged from colonization. The technology involves selecting and crossing desirable species of plants in the same genus. These farmer-selected varieties called landraces which were used as basic germplasm. To achieve high yield for rice and wheat, scientists needed to develop varieties that were more responsive to plant nutrients and had shorter, stiffer straw to support the weight of heavier heads of grains. Again, they also needed to develop varieties that could mature quicker and can be grown any time of the year, thereby permitting farmers to grow more crops each year on the same land. New varieties also needed to be resistant to major pests and diseases whilst flourishing under intensive farming conditions to retain desirable cooking and consumption traits.

2.7 The Main Elements of Green Revolution

According to leaf (1998), GR focused mainly on grain crops, called HYVs.GR started primarily with grain crops such as wheat and rice and later maize. With time, millets, legumes, roots and tubers and citrus were also developed (Gollinet *al.*, 2005; Evenson and Gollin, 2000; Johnson *et al.*, 2003. Chakravarti (1973) stressed that the qualities of GR include high responsiveness to fertilizers and shorter growing period.

It is on record that GR began in Mexico in 1943, when the Rockefeller Foundation and the Government of Mexico established a cooperative research programme to improve upon the output of wheat and maize. The director of the Mexican research programme was Dr. George Harrar, a plant pathologist from the University of Washington, who was later joined by Dr. Norman Borlaug in 1944. The idea was to alter the balance of genes for more desirable characteristics in the Mexican crop populations. In this respective, the programme built up an extensive "gene bank" from crop varieties around the world. For wheat, one of their most important achievements was the dwarf HYV released in 1961. Just four years after its' released (by 1965), its' became the most important wheat in Mexico, yielding up to 400% of those of 1950 (Randhava 1986). Another aspect of the research was to examine the growing conditions for the various genetic strains so as to make institutional and infrastructural recommendations. The HYV recommendations made included provision for irrigation, improved credit and the application of agrochemicals.

From 1945 to 1965, maize production increased four times while wheat production increased six times, making the Mexican programme a success. Cotton, another crop that the programme focused on, increased from 107,500 metric tons to 605,000 tons making it Mexico's major export commodity. The research strategy and methods of the Mexican programme were replicated on an international scale in 1960 when the Rockefeller and Ford foundations jointly established the International Rice Research Institute (IRRI) located next to the College of Agriculture of the University of the Philippines, near Manilla (Chandler 1982,).

2.8 Impacts of the Green Revolution

GR according to Hazell (1985) had a lot of impacts on food production especially, poor producers', income and employment, landless labour and poverty. According to Hazell, (1985), a few years after the introduction of GR, there were increases in output in both developed and developing countries especially on wheat and rice production. Hazell (2003) emphasized that the production of wheat and rice is a function of the area sown to the new wheat and rice varieties, and their corresponding output due to higher yield. Increasing the output of rice and wheat means more profit for these farmers than some other crop farmers. This resulted in bringing more land under cultivation (Hazell, 1985). Evenson and Gollin's (2000) and Briney (2014) reported that due to the success of GR, the United States for instance, imported about half of its' wheat in the 1940s but after using GR technologies, it became self-sufficient in the 1950s and became a net exporter by the 1960. Additionally, the growth in agricultural production, especially in India has consistently outpaced population growth (Johnson *et al.* 2003). This was attributed to irrigation, fertilizer, and seed development, at least in the case of Asian rice (Conway, 1997). Briney (2014), explained that fertilizers were largely what made the GR possible. Thus GR forever changed agricultural practices because the HYVs developed during this time could not grow successfully without the help of fertilizers. Similarly, irrigation played a major role in the GR, especially areas such as Punga in India where rice and wheat were cultivated. He stressed that by using irrigation, water was stored and sent to drier areas, putting more land into agricultural production and thus resulting in increased crop yields (Briney, 2014). Also the use of GR technologies exponentially increased the amount of food production worldwide. Places like India and China that once feared famine have not experienced it since implementing the use of the semi-dwarf rice (1R8) and other food varieties (Briney, 2014). Evenson and Gollin (2000) again argued that, despite population explosions in the 1980s and 1990s, GR helped increased food production per capita. Evenson and Gollin (2000) further argued that the prices of food crops would have been 35 to 66% higher in 2002 than they actually were in developing countries and the poor would have been hardest hit.

Haze11 (1985) also observed that GR facilitated significant expansion of irrigation and multiple cropping in many countries, thereby adding to the total acreage of these crops. This was possible because of the shorter growing periods and reduced photoperiodicity of the new varieties which resulted in increased multiple cropping (Hazell, 1985). The seeds were first released in Latin America and Asia, and according to Glaeser (1987), there were significant increases in yields after a short time of their released. Accordingly, GR was a public sector initiative with collaboration from international network of governmental and inter-governmental agricultural research and policy institutions (Brooks; 2005 and Evenson and Gollin, 2000).

The development of HYVs meant that only a few species of plants were being grown. For example, whereas there were about 30,000 rice varieties prior to GR in India, now there are only ten highly productive species.

2.8.1 Impact on Poor Producers

As was argued by Hazell (1985), individuals who used the new technology saw an increase in output on farm and thus had more produce to sell and subsequently experienced a rise in their incomes level. Consumers also benefited because of the increase in supply and this typically resulted in lower food prices. As a result of GR, governments were assured of adequate food supplies resulting in increased national and economic security. The unavailability of foreign grains through importations and the fluctuations of foreign exchange no longer threatened food security (Christina and Otsuka, 1993). According to Hazell (1985), in many regions suited for the HYVs, low-income farmers have adapted at least to the same extent as larger farmers, and the most recent studies suggest that net gains per unit of land tend to be larger on smaller farms. Thus, GR has contributed to a considerable change in regional income distribution in some countries such as India. The impact of technological change on poor farmers depends very much on institutions and policies (Hazell, 1985).

2.8.2 Impact on Landless Labour

The GR is based on a combination of varieties with high yield potential seed, fertilizers, irrigation, and in some cases pesticides and mechanization. One result of this combined package has been higher labour productivity and increased labour demand. In areas with high unemployment and a highly elastic labour supply, this has resulted in a considerable expansion in employment. In regions with little unemployment and an inelastic labour supply, whether existing prior to the introduction of, or brought about by the technology, considerable wage increases have occurred (Hazell, 1985).

2.8.3 Impact on Income and Employment

In an empirical study of agriculture and industrial performance in India, Rangarajan (1982) found that a 1% addition to the agricultural growth rate stimulated a 0.5% addition to the growth rate of industrial output, and a 0.7% addition to the growth of the national income. At the regional level, Bonabana-Gibb (1974), found that each 1% increase in agricultural income at Nueva Eeija provinces of central Luzon in the Philippian generated one to two percent (1-2%) increase in employment in most sectors of the local nonfarm economy.

2.8.4 Impact on Poverty

Johnson *et al.*, (2003) emphasized that, GR spurred economic growth as Asia, in the process, reduced world poverty significantly. In general, it has been argued that GR has had major welfare impacts on millions of poor people leading to reduction in child mortality, morbidity and malnutrition and increases in calorie consumption (Evenson and Gollin, 2000). In summary, supporters of the revolution argue that the GR is the solution to poverty and malnutrition, rural unemployment and inequalities and that without it, world poverty and hunger would have been worse than they are now (Niazi, 2004).

2.9 Criticisms of the Green Revolution

GR was bound to have some problems of its own. Critics argued that, the GR resulted in environmental degradation and income inequality, inequitable asset distribution and worsened absolute poverty. Others stressed that owners of large farms were the main adopters of the new technologies due to the fact that they had better access to irrigation water, fertilizers, and credit (IFPRI, 2002). In this case, smallholder farmers were forced out of their lands thereby becoming poorer. Critics have also argued that GR led to unnecessary mechanization which led to the destruction of farm lands and unemployment. Another shortcoming of the GR was that it spread only in irrigated and high-potential rain fed areas, and many villages or regions without access to sufficient water were left out. Evidence suggests that even in cases where villages obtained indirect benefits through increased employment and migration opportunities and cheaper food, the benefits were not sufficient to close income gaps. Similarly, IFPRI (2002) reported that the GR led to worsening of regional inequality in China. Also, excessive and inappropriate use of fertilizers and pesticides led to polluted waterways, poisoned agricultural workers, and killed beneficial insects and other wildlife bodies. Groundwater levels had diminished in areas where more water were being pumped for irrigation than can be replenished by the rains. Heavy dependence on a few major cereal varieties has led to loss of biodiversity on farms. Some of these outcomes were inevitable as millions of largely illiterate farmers began to use modem inputs for the first time, but inadequate extension and training and ineffective regulation of water quality including input pricing and subsidy policies made modem inputs too cheap and encouraged their excessive usage, which also created negative environmental impacts. These problems are slowly being addressed over the past years. This is done by the application of policy reforms and improved technologies including management practices, such as pest-resistant varieties, biological pest control, precision farming, and crop diversification. In the process huge forest and other environmental lands were preserved.

Briney (2014), noted that the major problems associated with the use of these technologies in Africa are as a result of lack of infrastructure, governmental corruption, and insecurity in nations. Taodora and Smith (2003) noted that, large-scale farmers had greater access to complementary inputs like fertilizers, insecticides and tractor equipment.

GR critics are also opposed to the one crop specie which they termed "monoculture" of modern commercial agriculture. Their grounds are that this could lead to the loss of biodiversity by the way traditional seed varieties are ignored that may have a lot to offer the farmer and humanity, now and in the future.

Further argument raised by Clive (2007) was that, the increased level of mechanization on larger farms in GR resulted in unemployment in the rural economy. The new economic difficulties of smallholder farmers and landless farm workers led to increased rural - urban migration. The increase in food production led to a cheaper food for urban dwellers, and the increase in urban population increased the potential for industrialization (Ponting, 2007). In their remarks, Evenson and Gollin (2000) noted the GR was delivered in a partial manner favouring commercial farmers over subsistence farmers and large-scale farmers over small farmers. Recent evidence clearly shows that, although exceptions exist, as a general rule, the GR has resulted in a very significant improvement in the material well-being of the poor. Hazell (1985) noted that, some studies failed to distinguish between early and subsequent adoption of new technology. Again, little or no attention was given to the multiplier effects of the GR and the resulting impact on incomes of rural poor. The impact of the GR was frequently confused with the impact of institutional arrangement, agricultural policies, and labour-saving mechanization. Such confusion led to incorrect identification of the causes of rural poverty and thus incorrect recommendations for action to reduce such poverty (Haze11, 1985).

2.10 Africa and the Green Revolution

Mengist (2011) noted the fact that GR farming has not yet reached deeply into SSA. Mengist (2011) explained that, between 1970 and 1998, while the share of cropped planted to modem GR varieties increased to 82 percent in the developing regions of Asia and up to 52 percent in Latin America, only 27 percent of area was planted to such varieties in SSA. Consequently, average cereal yields in Africa remained 1.1 tons per hectare versus 2.8 tons per hectare in Latin America and 3.7 tons per hectare in Asia. Again, growth in per capita food production in SSA was actually negative between 1980 and 2000, and one third of all Africans remain undernourished.

According to Mengist (2011), these were as a result of little adoption in Africa because, the international assistance agencies introducing the varieties had tried to "shortcut" the time-consuming process of identifying and using locally adapted plants as the starting point for breeding improvements. Varieties not suited to African conditions were brought in from Latin America and Asia, and African farmers did not like them. Harwood (2009) observed that the political and economic background conditions within which a programme operates are crucial for technological success. This was further explained by Evenson and Gollin (2000) that, in genetic modification, developing a plant prototype from the local plant to serve as a platform for local adaptation and subsequently to breed in the next generations is necessary. Mengist (2011) argued that the problem was addressed through breeding programmes that were more location specific beginning in the 1980s, but by that time, international assistance for such programs had begun to decline because the so-called world food crisis of the 1970s was deemed by rich donor governments to be over.

Mengist (2011) further observed that African farmers failed to take up the new seed varieties because they had a more complex mix of agro ecologies, and a smaller share of their land was suited to conventional irrigation. Access to farmland is generally more equitable than in either Latin America or Asia, but only 4 percent of agricultural land in Africa is irrigated. This forces farmers to rely on uncertain rainfall and weakens their incentive to invest in improved GR seeds, which only do well with adequate moisture. In addition, the dominant food crops in the region included root crops like sweet potato and cassava, or tropical white maize, rather than the leading GR cereal crops such as wheat, rice, and yellow maize. Furthermore, most farmers in Africa are women, lacking the political voice needed to demand, government investments in rural education, road infrastructure, and electrical power of the kind that were essential to the earlier uptake of the technology in Asia (Mengist, 2011).

2.11 Re-introduction of Green Revolution in Ghana

Reasons for the failure of the GR in Ghana border mainly on large agricultural production, state's inefficient way of participation in agriculture and marginalization of agriculture in favour of industrialization (Singh, 2000).To help reintroduce the GR in Ghana, AGRA’s programmes targets major obstacles faced by the country’s smallholder farmers through improving farmers' access to improved seed, fertilizer, credit, crop storage, markets, and strong farmer-based organizations (FBOs). In the Northern region, for instance, farmers grow 66 percent of the country's rice and AGRA is supporting these smallholder farmers with the necessary resources to help transform Ghana into a net exporter of rice, and free up US$500 million now spent on rice imports.

AGRA is also helping private seed companies which multiply and disseminate soybean, sorghum, maize, rice and groundnut to resource-poor farmers in Northern Ghana and other areas. Also, among its numerous contributions to the sector, is the support to the over 2,200 agro-dealers and 150 seed producers across the regions in the country to increase the availability of agro-inputs such as improved seeds and fertilizers for about 850,000 smallholder farmers. AGRA has also established and supports the West Africa Centre for Crop Improvement (WACCI) at the University of Ghana, Legon, with a PhD programme to offer training to young scientists. The centre is also supporting MSc. programme in Seed Science at the Kwame Nkrumah University of Science and Technology. AGRA has done a lot but much still needs to be done, in the area of irrigation since the improved seed, fertilizer, irrigation and agrochemicals were the main elements that fueled the success of the first GR technology.

One can clearly see that the missing element in AGRA support programme to re-introduce GR technology is irrigation which has become one of the country's major problems in modernizing Agriculture. The country is still struggling to provide adequate water for household consumption and so the provision of water for farming will come as an additional responsibility to government and other relevant institution.

2.12 Rice Production in Ghana

According to Nyanteng (1987), Ghana has experienced a rapid dietary shift to rice, particularly in the urban centers, during the early post-independence period (starting 1957) which is as a result of increased income, favourable government pricing policies, good storability of rice and ease of cooking. Rice is now the second most import staple food after maize and its consumption keeps increasing due to rapid population growth, urbanization and change in consumer habits. Rice consumption in Ghana increased from 7.4 kg per caput/annum between 1982 and 1985 (WARDA, 1986) to 13.3 kg per caput/annum (Government of Ghana, 1996) resulting in a total annual consumption of 239,400 tons of milled rice (i.e. estimated on 18 million population). The annual consumption (1991-1996) thus showed an increase of 119, 000 tone over that of 1990. The total paddy production was 329,080 tons, an estimate based on an average yield of 1.9 tons/ha over a total area of 173,200 ha. Between 1996 and 2005, production ranges 200,000 and 280,000 tons (130,000 to 182,000 tons of milled rice) with fluctuations occurring annually due to extensiveness of production lands instead of yield variation (t/ha). In 2005 total rice consumption was about 500,000 tons (JICA, 2007), equivalent to per capita consumption of 22kg per annum. Production generated a milling output of 204,030 tons (i.e. 62 percent), leaving a demand gap of 29,000 tonnes which was filled with imports. Rice is produced in all the ten regions of Ghana, covering all the major ecological-climatic zones, including the Interior Savannah zone, the High Rain Forest zone, the Semi-deciduous Rain Forest zone and the Coastal Savannah zone. Productions of rice in Ghana are grouped based on agro-ecologies and within each agro-ecological zone there are distinct rice ecosystems namely: rain fed dry lands, rain fed lowlands or hydromorphic, Inland swamps and valley bottoms and irrigated paddies. The rain fed ecology (i.e. dry lands and lowlands) accounts for 75 percent of the production area, the irrigated ecology for 16 percent and the inland swamps and valley bottoms for 15 percent (Oteng, 2000). According to MoFA (2006), there is a wide variation in rice preference in Ghana, which is basically based on the grain characteristics. Grain characteristics include long grain perfumed of good taste, appearance among others. Local brown rice is much patronized by health conscious Ghanaians and parboiled rice preferred in the North of Ghana (MoFA, 2006).

2.13 Improved Rice Varieties in Ghana

SARI has over the years developed improved rice varieties that are available for farmers' usage. The table (2.0) below shows some of the type of rice variety and their corresponding maturity period as at 2015.

2.14 Importance of rice

A vast majority of the people in the world consume rice. It is the second most important cereal in the world today and provides, together with wheat, a large proportion (95%) of the total nourishment of the world's population. It is the daily food for over 1.5 billion people (Boumas, 1985, Juliano, 1993). The reason for it being so popular is that it is easily digested.

Table 2.0 Rice varieties and their maturity period.

NO	VARIETY	MATURITY PERIOD (DAYS)
1	FARO 15	145
2	GR 18	132
3	GR 19	125
4	GR 21	125
5	DIGANG	115
6	GBEWAA (JASMINE 85)	110-115
7	NABOGU (TOX 3233)	120-130
8	KATANGA (TOX 3972)	130-140
9	SIKAMU	125

Source: Field survey

The 155 million hectares planted throughout the world produce about 596.5 million metric tons of paddy rice per year (Li, 2003). Rice is one of the most important cereal crops cultivated in SSA. It is ranked as the fourth most important crop in terms of production after sorghum, maize and millet (FAOSAT, 2006). Rice occupies 10% of the total land under cereal production and produces 15% of the total cereal production (FAOSTAT, 2006). Approximately 20 million farmers in SSA grow rice and about 100 million people depend on it for their livelihoods (Nwanze et al., 2006). Rice, which is grown under a wide diversity of climates, soils and production systems, is subjected to many biotic and abiotic stresses that vary according to site. Consumption per capita and consumer preferences for a given rice type also vary from region to region (Juliano, 1993). Rapid population growth (estimated at 2.6% per annum), increasing urbanization and the relative ease of preservation and cooking have influenced the growing trend in rice consumption. Since the 1970s, production of rice has been expanding at the rate of 5.1% per annum, with 70% of the growth due to increased area cultivated to rice, and only 30% due to higher yields, per unit area (Anon 2008).

The rice sector provides employment for a lot of rural dwellers. Due to the shift in the diet of Ghanaians to rice consumption, particularly those in the urban areas, imports of rice have been increasing steadily since the 1980s. Imported rice is estimated to account for more than 50% of all rice consumed in the country (Berisavljevic *et. al., (*2003). The increase in demand for imported rice is primarily attributed to increased income, good storability and ease of cooking (Shabbir *et. al.,* 2008). Rice consumption increased by over 20% per year in the 1990s, with the increased demand being met by imports from the Far East and the Americas (Berisavljevic *et. al.,* (2003). Imported rice, which is also perceived to be of better quality than local rice, is generally sold at higher prices and also local production of rice hardly meets the annual demand of Ghana (Takoradi, 2008).

2.15 National Rice Policies and Development Strategies

The main thrust of government policies for increased rice production under the Medium-Term Agricultural Development Programme (MTADP) include: the exploitation of the vast lands of the inland valleys and swamps to reduce emphasis on conventional irrigation schemes; and increased research and technology transfer aimed at an efficient utilization of agricultural inputs (Oteng 2000). Other policies noted by MoFA in 2006 are captured in FASDEP I, GPRS I and II, MTADP, AAGDS and MoFA policy documents.

2.16 Production Ecologies and Related Constraints

This section discusses some of the rice production ecologies and their related constraints in Ghana.

2.16.1 Rain fed dry land ecology

The rain fed dry land ecology is characteristically situated in the upper slopes of the top sequence where the crop obtains its water requirements solely from rainfall and not at all from high underground water tables. A low and erratic rainfall favours the growth of weeds more than the crop, hence effective weed control in this ecology is the primary requirement for successful rice cultivation and makes weeds the most important constraint in the ecology. The cultivation of the traditional local varieties under *Oryzaglaberrima* continues to dominate in most of the agro-ecological zones even though the yield is poor. The following is a list of desirable attributes that justify the continued cultivation of the local varieties (e.g. Abrewabesi, Akromah, AgyaAmoah, Kwame Dawo, Bakoram or Bagulam and Saka):

- tall habit and ability to compete effectively with weeds;
- tolerance of some adverse soil conditions, (example drought, poor fertility and acidity);
- tolerance of some diseases and insect pests; and
- Possession of sweet aroma when cooked.

The need to develop improved and HYVs for the ecology could hardly be overemphasized. Basologo (GR 19) and Faro 15 (Gr 21) are some of the improved varieties that have been tested and released to farmers by the SARI.

In the Transitional, Semi-deciduous and High Rain Forest zones it is imperative to fence the crop to protect it from the large rodents, *Thryonomisswindarianus* or grasscutters, otherwise the whole crop could be destroyed overnight if attacked. The other equally important constraints are the low and erratic rainfall, low inherent fertility of the soils and low level of technology used (Oteng, 2000).

2.16.2 Irrigated ecology

In terms of total size or area under rice in Ghana, the irrigated ecology is less important than the rain fed lowland/hydromorphic ecology but, in terms of production stability, control of production factors and output per unit area (i.e. 3.5 to 7 tons/ha), it is far superior to the remaining three ecologies where average yields are .2 tons/ha or less.

The irrigated ecology has been studied intensively for over four decades by the University of Ghana Agricultural Research Station, Kpong, in collaboration with the West Africa Rice Development Association (WARDA), and through the International Network for Genetic Evaluation in Rice (INGER) programme several HYVs have been released to farmers, for example GRUG 6, GRUG, ITA 222, IET 2885, IET 1996 and IET 6279. The ecology also enjoys a higher level of technology than the other ecologies.

The greatest constraint to production is, however, the ever-increasing bird and rodent population, which is seriously threatening the growth of the rice industry. The problem is exacerbated by the continuous monocropping of rice season after season in the absence of a viable alternate crop in the rice basins. Meanwhile, under the National Agricultural Research Programme (NARP), efforts are being made to develop a sustainable rice-based cropping system to break the cycle of rice monocropping.

The weed problem appears to the next most important problem after pests. The weed control problem has been worsened by the withdrawal of subsidies on agricultural inputs, and farmers are resorting increasingly to hand weeding while also reducing their farm size. Poor infrastructures in the rice industry (e.g. combine harvesters, reapers, threshers) are seriously affecting rice output in this ecology (Oteng, 2000).

2.16.3 Rain fed lowland/hydromorphic ecology

This ecology comprises the floodplains of rivers and is particularly extensive in the Interior Savannah zone where the topography is flat to gently undulating. It has a more favourable crop-water environment than the rain fed dry lands. The water level fluctuates with the flood height and, as the floods recede, the rice crop obtains its water requirements from the raised water table. The rain fed lowland/hydromorphic ecology is responsible for more than 60 percent of the rice area in Ghana and over 80 percent of the rice area in the Interior Savannah zone where rainfall is mono-modal.

The rainfall regime covers a period of about seven months (May to November), subjecting many rice fields to long periods of inundation. The uncontrolled floods tend to affect field operations (i.e. weed control, fertilizer application, bird control and harvesting), thus resulting in poor yields. Weed control, water management, the unavailability of suitable varieties and adverse soil conditions are some of the major constraints in this ecology.

2.16.4 Inland swamps and valley bottoms

The inland swamps and valley bottoms represent vast and unexploited land and water resources for rice cultivation. In 1989, MoFA initiated Valley Bottom Studies under the Agricultural Sector Review Project (ASRP), with the Crop Research Institute (CRI) as the coordinating institution in collaboration with several research institutes in Ghana. Four pilot project sites were selected in the major agro-ecological zones, viz. Besease (Rain Forest), Tolon/Yipeligu (Interior Savannah) and Aframso and Gbi-Godenu (Rain Forest, Savannah, Transitional).

The main rationale behind the scheme is that, with development of good but simple water and soil management practices, higher crop productivity could be sustained in the valley bottoms and swamps, as observed by Otoo (1994). Prominent among the major constraints encountered in the valley bottoms and swamps are a lack of suitable varieties and weed and pest problems. We will now take snap short of the literature involving our methodology.

2.17 Meaning and Types of Production Functions

According to Debertin (2012), a production function describes the technical relationship that transforms inputs (resources) into output (commodities). It shows the quantity of output that can be produced using different levels of inputs. However a function is a mathematical rule that assigns each value in one set of variable called domain to each single value in another set of variables called range. Shephard (1970) as in Mishra (2007) also defined a production function to mean a relationship between the maximal technical feasible output and the inputs needed to produce that output. It is the decision of a firm to make economic choices regarding production. That is how much of each factor input is to be used to produce how much output. Production function represents the possibilities afforded by an exogenous technology under certain market process for output and inputs. The profit-maximizing firm in perfect competition will choose to add input right up to the point where the marginal cost of additional input matches the marginal product in additional output. This implies an ideal division of the income generated from output into an income due to each input factor of production, equal to the marginal product of each input. The inputs to the production function are commonly term factors of production and may represent primary factors, which are stocks. Classically, the primary factors of production are land, labor and capital. Primary factors do not become part of the output product, nor are the primary factors, themselves, transformed in the production process. The production function is central to the marginalist focus of neoclassical economics. However its definition of allocative efficiency is based on the analysis of how market prices can govern the achievement of the efficiency in a decentralized economy. A production function is generally represented as

$$y = f(x) \qquad (2.1)$$

Where y is an output and x is an input. However equation (2.1) is an ultra-simplistic production function for agricultural commodities. Such a function assumes that the production process can be accurately described by a function in which only one input or factor of production is used to produce an output. Few, if any, agricultural commodities are produced in this manner. Most agricultural commodities require several, if not a dozen or more inputs. As an alternative, suppose a production function where there are several inputs and all but one are assumed to be held fixed at some constant level, this would take the form

$$y = f(x_1, x_2, x_3, x_4, x_5, x_6, x_7) \qquad (2.2)$$

From the above example, y might be the yield of corn in kilograms per acre, and x_1 might represent the amount of nitrogen fertilizer applied per acre. Variables x_2 ... x_7 might represent each of the other inputs used in the production of corn, such as land, labor, and machinery. Thus, in example (2.2) the input x_1 is treated as the "variable" input, while the remaining inputs $(x_2...x_7)$ are assumed to be held constant at some fixed level. Debertin (2012) explained that variable input is an input that the farm manager can control or for which he or she can alter the level of use. This implies that the farmer has sufficient time to adjust the amount of input being used. Nitrogen in corn production has often been cited as an example of a variable input, in that the farmer can control the amount to be applied to the field. However he said fixed input is usually describes as an input which for some reason the farmer has no control over the amount available. An example being the amount of land a farmer has.

2.18 Features of Agricultural Production as Compared to Industrial Production

Subba et al., (2004) stated the conditions under which agricultural production is carried out as compared with the industrial and the nature of agricultural commodities. These are being discussed in the context of Ghana below;

- *Farming is a way of life and not business:*

Farming is usually considered as way of life rather than a productive venture which can earn farmers a fortune as other sectors. The small land holdings as well as the scattered family providing labour are proofs to farmers' attitude towards farming. They are contended if their family requirements are met from farming. This is very different from what take place at the industrial sector where entrepreneurs have a business approach to maximizing profit.

- *Dependency on weather:*

Agriculture has been a biological activity because of its dependence on nature. The variation of the weather parameters such as erratic rainfall, temperature, sunshine among others, does not permit farmers to realize their full benefits. Similarly, the vagaries of nature prevent farmers from having little control over their production decisions such as when to plant, what to plant and so on. On the other hand weather has little influence on the industrial production. Again the entrepreneur can plan and control the entire production process and therefore he/she could increase or decrease output to meet market situations.

- *Seasonality of production:*

The climate of Ghana is tropical and there are two main seasons namely wet and dry season. Northern Ghana experiences its rainy season from March to September while the Southern Ghana experiences its rainy seasons from April tomid-November. The harmattan, a dry desert wind, blows from the north-east from December to March, lowering the humidity and creating hot days and cool nights in the north. In the south, the effects of the harmattan are felt in January. Farmers in the north usually have to wait for the rainy season except those few fortunate ones who have access to irrigation facilities for dry season fanning. Thus the productions of agricultural commodities are not uniform throughout the year. Such a limitation does not exist in the production of industrial commodities.

- *Perishable nature of agricultural products:*

The storage period of farm commodities ranges from a few days in respect to fruits and vegetables and few years for cereals and oilseeds. These characteristics of the farm products cause price fluctuation in the dry season. On the other hand, the industrial products are durable and thus prices do not vary drastically like the agricultural products. In Ghana, bad road networks especially at farming communities mean that commodities stay longer than usual at the farm gates and this result in post-harvest losses.

- *Joint products:*

Many agricultural commodities are joint product like paddy and straw, cotton lint and cotton seed, etc. Due to these joint products the cost of production of many products and by-product cannot be separated. In the industrial settings, products are easily separated from each other to determine the cost of in the same plant.

- *Bulkiness of agricultural products:*

Most agricultural products are bulky in nature exerting pressure during storage and transportation. This results in high unit cost of storage and transportation. This high cost of transportation limits the movement from surplus to deficit areas. This characteristic of bulkiness is reduce due to better packaging in the industrial sector.

- *Problems of standardization:*

The availability of a large number of crop varieties introduces a variation in the size, shape, appearance, colour and length among others. This brings to bear the problem of grading and standardization. This including quality makes a lot of differences in prices of agricultural commodities. In the industrial sector, products are uniform in all respect. Special machines are used to produce uniform commodities and qualities in the industrial sector. Because of differences in agro-soil-climatic conditions it is not possible to recommend the production of uniform production practices.

- *Time lag in production of agricultural products:*

There is a time lapse between the decision to produce and actual realization of output in agriculture. This time is four months for paddy, one year for sugarcane, etc. This time-lapse usually can upset the plans of the farmers. A farmer's hope of obtaining a given net income may not materialize considering the fact that prices may fall after harvest. Prices fluctuations of agricultural commodities cause a lot of variations in farm incomes. This problem is minimized in industrial production.

- *Large proportion of land:*

Agriculture requires larger proportion of arable land divided into smaller and scattered holding but this is not the case in the industrial sector. There are economies of scale in industrial production but such production is not a common feature in agriculture production. These refer to the cost advantages that enterprises obtain due to size, output, or scale of operation, with cost per unit of output generally decreasing with increasing scale as fixed costs are spread out over more units of output.

- *Law of diminishing returns:*

The law states that if one input in the production of a commodity is increased while all others inputs are held fixed, a point will eventually be reached at which additional input yield progressively smaller, or diminishing output. The law is both applicable to agriculture and industry but the difference is that, it set earlier in the agricultural sector than the industry. The reasons are the dependence of agriculture on weather conditions, depletion of soil fertility with time, limited scope of division of labour, exhaustion of soil health in the course of time etc.

- *Nature of demand:*

The demand of farm products is relatively inelastic because agricultural commodities are necessities of life while that of industrial goods is relatively elastic.

- *Efficiency of capital:*

The farm business takes relatively large time to return the investment through income as compared to industrial production. This makes the rate of capital turnover to be slower for agriculture.

- *Producer's share in consumer's expenditure:*

Agricultural marketing is characterized by the existence of too many middlemen and therefore the share of producer in consumer's cedi is low, whereas for industrial goods there are well-defined distributing channels. Thus the share of producer in consumer's expenditure is high.

2.19 Three Stages of Production Function

The classical production function can be divided into three stages or zones or regions. The reason is to identify and operate in the stage that production is rational (Subba Reddy S. et. al., 2004).Before we take a look at the stages briefly, the following terminology should be understood;

2.19.1 Total Physical Product (TPP)

It is the total amount of output obtained by using different units of inputs, which is measured in physical units like kilograms (kg), quintals among others

2.19.2 Average Physical Product (APP)

APP is the average amount of output produced by each corresponding unit of input. It is obtained by dividing the total output at a given level by the number of units of input applied at the corresponding level. APP shows the technical efficiency of the variable input.

2.19.3 Marginal Physical Product (MPP)

MPP is the additional quantity of output added by an additional unit of input. It is also said to be the change in output as a result of the change in the variable input. The figure 2.2 below shows Production Function in the Short Run and the Corresponding Marginal and Average Production Functions.

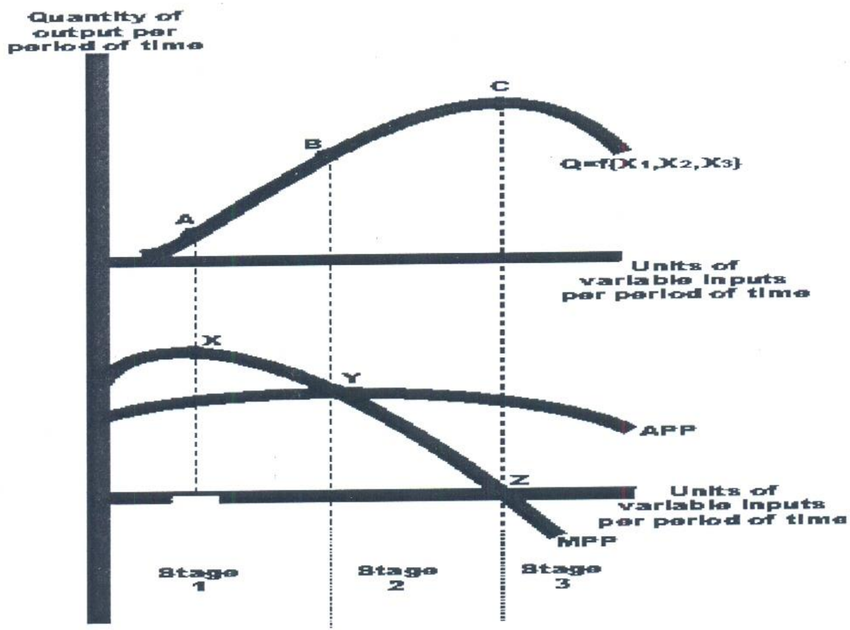


Figure 2.2 Production Function in the Short Run and the Corresponding Marginal and Average Production Functions.

Any production can be plotted on a graph. A typical quadratic production function is shown in the figure 2.2 above which is drawn under the assumption of a single variable input (or fixed ratios of inputs so that they can be treated as a single variable). All points above the production function cannot be obtained under the current technology. However all points below the production function are technically feasible and also all points on the function shows the maximum quantity of output that can be obtained at specific levels of inputs used. From the origin through to point A, unto the point C, the production function is rising positively but at a decreasing rate of marginal returns to the variable input. As additional units of inputs are employed output increases but at a decreasing rate. Beyond point B there are diminishing average returns which is shown by the declining slope of the APP curve beyond point Y. It can be seen that point B is tangent to the steepest ray from the origin, thus the APP is at a maximum. Now let us look at the three stages to simplify the interpretation of the production function.

Stage I

It start from the origin and ends at point B, where MPP = APP. At this point, the variable input is used at increasing output per unit before it reaches its maximum at point B. The MPP attains the maximum at the point of reflection, thereafter it begins to decline, (Subba et al., 2004). In this stage fixed resources are abundant relative to the variable resources. Because the output per unit of the variable input is improving throughout stage 1, a price-taking firm will always operate beyond this stage.

Stage II

This is the point at which MPP and APP are equal and ends where MPP is zero and also TPP is at its' maximum. In this stage output increases at a decreasing rate and the average and marginal physical product are declining. However, the average product of fixed inputs is still rising (which is not shown), because output is rising while fixed input usage is constant. In this stage, the employment of additional variable inputs increases the output per unit of fixed input but decreases the output per unit of the variable input. The optimum input/output combination for the price-taking firm will be in stage II, although a firm facing a downward-sloped demand curve might find it most profitable to operate in Stage 1.

Stage III

The starting point of stage III is the end of stage II**,** at which MPP is zero. In this stage MPP becomes negative. APP continuously declines and TPP which is at its maximum at the end of stage II begins to decline. Here too much variable input is being used relative to the available fixed inputs. Variable inputs are over-utilized in the sense that their presence on the margin obstructs the production process rather than enhancing it. Output per unit of the fixed and the variable input declines throughout this stage. At the boundary between stage II and stage III, the highest possible output is being obtained from the fixed input.

2.20 Types of Production Functions

There are different types of production functions that can be classified according to the degree of substitution of one input by the other. These are briefly discussed below;

2.20.1 Cobb-Douglas Production Function

The credit for presenting the first Cobb-Douglas function indirectly must go to Von Thunen in the 1840s (Humphrey, 1997). Von Thfinen constituted the first algebraic production function as $P = h(L + C)nL^{n-1}$. Where p is output per worker $(^{Q}/_{L})$, and h is the parameter that represents fertility of soil and efficiency of labour. The exponent n is another parameter that lies between zero and one. Multiplying both sides of von Thiinen's function by L (labour), we get;

$$Lp = hq^{n}L = hCn^{n}L^{1-n} = P = output$$

Where q is the capital per worker $(^{C}/_{L})$ and the rest is as defined earlier.

Thus, we have the Cobb-Douglas production function hidden in Von Thiinen's production function (Lloyd, 1969). Cobb- Douglas gave two general statements about production function in their literature before 1961. One of them being $P = Ae^{(\alpha K/L)}[K^{\beta}L^{1-\beta}]$ and the transcendental production function given as $e^{\alpha k + bL}[K^{\alpha}L^{\beta}]$, $o < \alpha, \beta < 1$ (Mishra, 2007). The first of these functions is a neoclassical production function and the region in which the marginal products are nonnegative and diminishing marginal rate of substitution holds.

Cobb-Douglas production function refers to the production function in which one input can be substituted by the other but to a limited extent. The Cobb-Douglas production function is based on the empirical study of the American manufacturing industry made by Paul H. Douglas and C. W. Cobb. It is a linear homogeneous production function of degree one which take into account two inputs, labour and capital, for the entire output of the manufacturing industry. The Cobb-Douglas production function is given by;

$$Q = AL^{\alpha}C^{\beta} \qquad (2.3)$$

Where Q is output and L and C are inputs of labour and capital respectively. A, α *and* β are positive parameters where $\alpha > 0$, $\beta > 0$.

The equation explains how output depends directly on L and C. Similarly, the part of the output which cannot be explained by L and C is explained by A, which is called technical change. The coefficient of labour (α), in the Cobb-Douglas function measures the percentage increase in Q that would result from a one percent increase in L, while holding C constant. Similarly, β is the percentage increase in Q that would result from a one percent increase in C, while holding L constant.

Criticisms of Cobb-Douglas Production Function

The Cobb-Douglas production function has been criticized by Arrow et. al. (1961), which we will discuss briefly below.

- The Cobb-Douglas production function considers only two inputs, labour and capital, and neglects some important inputs, like raw materials, which are used in production. It is therefore, not possible to generalize this function to more than two inputs.
- There is the problem of measurement of capital which arises because it takes only the quantity of capital available for production. But the full use of the available capital can be made only in periods of full employment. This is unrealistic for no economy is always fully employed.
- The Cobb-Douglas production function is based on the assumption of substitutability of factors and neglects the complementarity of factors.
- This function is based on the assumption of perfect competition in the factor market which is unrealistic. If this assumption is dropped the coefficients α *and* β do not represent factor shares.
- One of the weaknesses of Cobb-Douglas function is the aggregation problem. This problem arises when this function is applied to every firm in an industry and to the entire industry. In this situation, there will be many productions of low or high aggregation. Thus the Cobb-Douglas function does not measure what it aims at measuring.
- The Cobb-Douglas production function is criticized because it shows constant returns to scale. But constant returns to scale are not an actuality, for either increasing or decreasing returns to scale are applicable to production. It is not possible to change all inputs to bring a proportionate change in the output of all the industries. Inputs like

machines, entrepreneurship, among others are indivisible. As output increases to their maximum capacity per unit cost falls due to indivisible factors. When the units of different inputs are increased in the production, economies of scale and specialization lead to increasing returns to scale. In practice, however, no entrepreneur will like to increase the various units of inputs in order to have a proportionate increase in output. His endeavor is to have more than proportionate increase in output, though diminishing returns to scale are also not ruled out.

Importance of Cobb-Douglas Production Function

Despite these criticisms, Jhingan (2009) enumerated the importance of Cobb-Douglas production function which is widely used in empirical studies as follows;

- It is used to determine the relative shares of labour capital in total output.
- It is used to prove Euler's Theorem.
- Its parameters α *and* β represent elasticity coefficients that are used for inter-sectoral comparisons.
- The Cobb-Douglas production function could exhibit linear homogeneous of degree one $(\alpha + \beta = 1)$ which shows constant returns to scale. However, if, $\alpha + \beta > 1$, there are increasing returns to scale and if $\alpha + \beta < 1$, there are diminishing returns to scale.
- Economists have extended this production function to more than two variables

2.20.2 The Constant Elasticity of Substitution (CES) Production Function

Arrow et. al., (1961) developed the CSE production function and the function consists of three variables, namely, output (Q), capital (C) and labour (L), and three parameters A, α *and* θ. It may be expressed in the form

$$Q = A[\alpha C^{-0} + (1-\alpha)L^{-\theta}]^{-1/\theta} \qquad (2.4)$$

$A > 0$; $0 < \alpha < 1$; $\theta > -1$

Where A is the efficiency parameter indicating the state of technology and organizational aspect of production. The efficiency parameter leads to a shift in the production function. α is the distribution parameter or capital intensity factor coefficient concerned with the relative factor shares in the total output, and θ is the substitution parameter which determines the elasticity of substitution.

Limitations of CES Production Function

Jhingan (2009) outlined the following limitations of CES functions

- The CES production function considers only two inputs. It can be extended to more than two inputs. But it becomes very difficult and complicated mathematically to use it for more than two inputs.
- The distribution parameter or capital intensity factor coefficient α, is not dimensionless.
- If data are fitted to the CES function, the value of the efficiency parameter A cannot be made independent of θ or of the units of Q, C *and* L.

- If the CES function is used to describe the production function of a firm it cannot be used to describe the aggregate production function of all the firms in the industry. Thus it involves the problem of aggregation of production functions of different firms in the industry.

Despite these limitations, the CES production function is useful in its application to prove Euler's theorem, to exhibit constant returns to scale, to show that average and marginal products of *C and L* are homogeneous of degree zero, and to determine the elasticity of substitution.

2.20.3 Leontief Production Function

Leontief production function was formulated by Jevons, Menger and Leon Walras. It represents a constant elasticity of substitution in a limited case. The Leontief production function or fixed proportions production function is a production function that implies the factors of production will be used in fixed (technologically pre-determined) proportions, as there is no substitutability between factors. It was named after Wassily Leontief and represents a limiting case of the constant elasticity of substitution production function.

The function is of the form;

$$q = Min\left(\frac{z_1}{\alpha}, \frac{z_2}{b}\right) \qquad (2.5)$$

Where q is the quantity of output produced, z_1 and z_2 are the utilized quantities of input 1 and input 2 respectively, and a and b are technologically determined constants.

Debertin (2012) discussed other Agricultural production functions which are briefly explained as follows.

2.20.4 Spillman Production Function

The Spillman function investigated the law of diminishing returns in the United State of America agriculture in the early 1920s. This is an exponential function linked to the work of Von Thuenen on exponential functions. For one input, the Spillman function is given as;

$$y = M - AR^{x} \quad (2.6)$$

Where;

M = the maximum total production obtainable by the use of x or the total physical product of x (APP_X)

A =increase in output due to x which is termed marginal physical product (MPP_X)

R =the ratio of successive increments in the output relative to total input a $(\sum APP_X)$

For n inputs, we have:

$$y = A(1 - R_1^{x1})(1 - R_2^{x2}) \ldots\ldots (1 - R_n^{xn}) \quad (2.7)$$

Since this type of function is non-linear and cannot be converted to linear, OLS techniques cannot be used to estimate them. Estimating Spillman production function requires complex iterative procedure or the use of least squares regressions.

Since the advent of Cobb-Douglas, the Spillman has seldom been used by agricultural economists. It is primarily of historical interest because the Spillman research represented one of the first efforts to estimate parameters of a production function for some basic agricultural processes.

2.20.5 The Transcendental Production Function

This is a hybrid of the Cobb-Douglas function and the difference is that in translog production function the number of parameters, practically explodes as the number of function increases. According to Pavelescu (2010), the shortcoming in the estimation of production function is the occurrence of collinearity. Theoretically, the collinearity impact is Minimum if a single production factor is taken into account. The two-input transcendental function is given as:

$$y = Ax1\alpha e^{y1x1} x_2^{\beta} e^{Y2x2} \qquad (2.8)$$

Where:

Y = Output (gross domestic output)

K = Fixed capital

L =Employed population

e = Natural log

A, α, β, y are parameters to be estimated.

2.21 Review of Empirical studies on Production functions

Aidoo et al., (2014) carried out a research on the factors influencing Soya bean production and willingness to pay for inoculum use in Northern Ghana. A total of 240 grain legume producers were sampled from the three Northern Regions in Ghana, out of which 188 were soybean producers. Farmers who were selected through a combination of stratified and simple random sampling techniques were interviewed with the use of standardized structured questionnaires to elicit primary information for analysis.

The OLS estimation procedure was used to estimate a Cobb-Douglas soya bean production function. In addition, a binary logistic regression model was used to examine factors that determine farmers' willingness to pay for inoculum use in soya bean production. Evidence from the study showed that area cultivated and farming experience significantly influenced soya bean output positively at the 5% level. However, quantity of labour employed in production and educational level had significant negative relationship with soya bean output, all things being equal. Farmers' willingness to pay for inoculum was found to be positively influenced by experience in soya bean production, access to credit, percentage of produce sold and awareness about inoculum at the 5% significance level. Male farmers were found to be more willing to pay for inoculum than female farmers, and distance from home to farm was found to be negatively related to farmers' willingness to pay for inoculum, *ceteris paribus*. In an attempt to step up soya bean production and increase the uptake of inoculum among farmers without subsidy, awareness creation about inoculum, credit access and commercial orientation of farmers should be targeted as the key variables in any strategy or policy formulation.

Wongnaa (2013) studied the factors affecting the production of Cashew in Wenchi Municipality of Brong-Ahafo Region of Ghana. Wongnaa (2013), estimated the determinants of Cashew production using Cobb-Douglas production function and descriptive statistics along with OLS criterion to estimate the parameters of the production function. Results showed that majority of the farmers were ageing and about 55.7% had a maximum of five years' experience in Cashew cultivating an average of 3.33 acres. Wongnaa (2013) also reported that about 61.4% of total respondents had no formal education. His results further showed that farm size, fertilizer, pesticides, pruning, education and contact with extension officers are positively related to cashew output while labour and years of experience are inversely related. The R^2 value was 0.840912 and this means that 84.1% of the variation in output was explained in factor inputs. Wongnaa (2013) recommended the use of fertilizer and pesticides to increase productivity. Furthermore, Government should address the problem of illiteracy through the introduction of adult literacy education, evening classes and the establishment of demonstration farms.

Enu et al. (2013) carried out a research on the factors influence agricultural production in Ghana. The Cobb-Douglas production was employed and the OLS estimation technique was used. They found that 1% increase in labour force caused agricultural production to decrease by 0.655946%. Also a 1% increase in inflation caused agricultural production to increase by 0.00459045%. In addition, a 1% increase in real exchange rate caused agricultural production to increase by 0.083949%. Finally, a 1% increase in real GDP per capita caused agricultural production to decrease by 1.05825%. Apart from inflation, labour force, real exchange rate and real GDP per capita were statistically significant.

Therefore, the key macro-economic factors that influence agricultural production in Ghana are labour force, real exchange rate and real GDP per capita. The agricultural sector should be made more attractive and conductive to ensure continuous production of food in Ghana. From their findings, the following policy recommendations were suggested:

- The skilled and the unskilled labour force should be encouraged, motivated to go into agricultural production by creating a conductive atmosphere for them to exist since agricultural is the engine of growth in Ghana.
- There should be massive campaign on birth control methods to reduce the population size.
- Food prices should be increased moderately to increase food production in Ghana.
- The stabilization of the monetary and fiscal policies should be continued both in the short run and long run.
- The inefficiencies in the agricultural sector should be corrected in order to keep existing producers of farm produce and then attract other potential producers.

Morris et. al., (1999) conducted a survey on the adoption and impacts of improved Maize production technology as a case study on the Ghana Grains Development Project (GGDP). The objectives of the case study were to evaluate the success of GGDP in developing improved maize production technologies and in transferring those technologies to farmers as well as assess the impacts of adoption at the farm level. The study revealed that adoption of maize technologies had been extensive. During 1997, more than half of the sample farmers (54%) planted Modern Varieties (MVs) on at least one of their maize fields, and a similar proportion (53%) implemented the plant configuration recommendations. The rate of fertilizer use on maize, however, was lower, as less than one-quarter of the sample farmers (21%) reported applied fertilizer to their maize fields.

Adoption rates were varied by agro-ecological zone, with adoption of all three technologies lowest in the forest zone. Adoption rates were however higher among male farmers than among female farmers, except in the case of fertilizer, in which no significant difference was found. It was clear that adoption of the GGDP-generated technologies has been associated with significant farm-level productivity gains and noticeable increases in the income earned from sales of maize. Impacts on the nutritional status of rural households, however, appear to have been less pronounced. Even though the latest MVs have been extensively promoted for their improved nutritional status, relatively few of the survey respondents were aware of this. Those who were aware said they rarely seek out nutritionally enhanced MVs to prepare weaning foods for infants and young children. In addition to documenting the uptake and diffusion of the three GGDP-generated maize technologies, this case study provided valuable insights about the many factors that can affect the adoption of agricultural innovations in general.

The results showed that adoption of improved production technology is directly influenced by three sets of factors: characteristics of the technology (e.g., complexity, profitability, riskiness, divisibility, compatibility with other technologies); characteristics of the farming environment (e.g., agro-climatic conditions, prevailing cropping systems, degree of commercialization of agriculture, factor availabilities, farmer knowledge, availability of physical inputs); and characteristics of the fanner which included ethnicity and culture, wealth, education, gender. The results also showed that technology adoption may be affected indirectly by factors beyond the control of researchers, including the agricultural extension service, the inputs distribution system, and the economic policy environment.

2.22 Theoretical Framework

We expect to estimate the effects of adoption of improved rice varieties on farmers output. It is important to note that in this instance the dependent variable is discrete or binary, that is it takes the value one (1) for adopters and zero (0) for non-adopters. According to Maddala (2003) discrete regression model or discrete choice models are models in which the dependent variable y assumes discrete values. This means that the dependent variable y assumes only two values which are usually denoted by 0 or 1. For example y can be defined as 1if an individual participates in an agricultural program or 0 for otherwise. The dependent variable y can assume more than two values, that is (a) categorical and (b) non categorical variables. Under categorical variables individuals are divided into different categories. For example y = 1 if the individual earns less than GH¢ 10,000.00, y = 2 if the individual earns between GH¢ 10,000.00 and GH¢ 30,000.00, y = 3 if the individual earns between GH¢ 30,000.00. However it is worth mentioning that categorical variable are further classified into (a) unordered, (b) sequential, and (c) ordered variables (Maddala, 1983, Cox, 1970). In the case of non-categorical variable, the dependent variable denotes the number of patients issued to a company within a given year and although y is discrete variables, its' assumes values of 0, 1, 2, 4...The methods of analysis are different for models for either categorical or non-categorical variables. For the purpose of this study, we will consider the simplest case that is where the dependent variable is binary (1 for adopters and 0 for non-adopters).

Consider a liner model of the form;

$$y_i = \beta^1 x_i + u_i \tag{2.9}$$

Where E (u_i) = 0

The mathematical expectation of 2.9 is given as

$E\ (y_i \mathrm{l} x_i) = \beta'_{xi}$.

This has to be interpreted in this case as the probability that the event will occur given that X_i has occurred. The calculated value of y from the regression equation, $\hat{y}_i = \beta_i x_i$, will then give the estimated probability that the event will occur given the value of X. However in practical terms, the estimated probabilities can lie outside the admissible range (0, 1). The residuals in equation (2.1) can take only two values: 1- $\beta' x_i$ and - $_1\beta x_i$, because y_i takes the value of 1or 0, Maddala (1983).

Again given our interpretation of equation (2.9) and the fact that $E(u_i)$ = 0, the resultant probabilities of these events will yield $\beta' X_i$ and 1- $\beta' x_i$. Thus the error term in its function form becomes;

u_i	$f\ (u_i)$
$1- \beta' x_t$	$\beta' x_i$
$-\beta' X_i$	$1- \beta' x_i$

$Var\ (u_i) = \beta'\ xi\ (1- \beta'\ \mathrm{x})\ 2 + (1 - \beta' x_i)(\ \beta' x_i) 2 = \beta'_{xi}\ E(y_i) = E(y_i)[1- Ey_i)]$

Goldberger (1964) as in Maddala (2003) provided the solution to this problem of heteroscedasticity by developing the linear probability model (MPL).

However Maddala (2003) outlined a number of problems with this procedure which are as follows;

1. The least squares method is not efficient, this is because they found out that the nonlinear procedures are more efficient than the least-squares procedure.
2. The formulation was noted to lie outside the limits (0, 1) contrary to the interpretation given to its earlier that the conditional expectations $E(y_i I x_i)$ is the probability that the event will occur.
3. Practically, $\hat{y}_i(1-\hat{y}_i)$ may be negative in small sample and therefore the computation of the weighted average may result in negatives outcomes.

This then lead to the introduction of the logit and probit model as a better to solution to these estimation problems.

2.23 The Linear Probability Model (MPL)

The idea of linear probability is to look up for a linear combination of explanatory variables. It assumes there is a linear relationship between the default rate and the factors. The probit model which assumes the probability of default follows the standard cumulative normal distribution function. The probability of default is logistically distributed in the logit model and discriminate analysis divides borrowers into high and low default-risk classes (Mester, 1997). However, Pyndick and Rubinfeld (1998), Greene (1997), and Judge et al. (1985) indicate that the linear probability model could predict the default rate, but the predictive value might not necessary lie between zero and one.

Moreover, because the variance of the models is generally heteroscedasticity, it leads to inconsistent estimation problem and invalid conventional measure of fit such as the R^2.

Maddala (2003) explained the term linear probability model to mean a regression model in which the dependent variable *y* is a binary variable which takes the value I to mean the occurrences of an event and 0 for otherwise. A typical example includes; the purchases of durable goods in a given year, the decision to marry and the decision to have children.

The process involves the estimation of equation (2.9) by OLS (Goldberger, 1964; Maddala, 2003). In the next step, we compute $\hat{y}_i$ (1 - $\hat{y}_i$) and use the weighted least squares and regress $^{y}/_{wi}$ on $x_i/_{wt}$, $wi - [\hat{y}_i (1 - \hat{y}_i)]^{1/2}$

2.24 The Logit and Probit Model

The approach which provides a better solution according to Goldberger (1964) as in Maddala (2003) is called the probit analysis model. The model assumes that there is an underlying response variable y* defined by the regression relationship

$$Y^*_I = \beta' X_i + \mu i \qquad (2.10)$$

This y_i* is not observed in practice, however the dummy variable y is observed and it is defined by y = 1 *if* y_i* > 0

$$y = 0 \text{ otherwise} \qquad (2.11)$$

Therefore the expected value becomes

$$E(y_i \mid x_i) = \beta' xi$$

From equation (2.10) and (2.11) we get

Prob($y_i = 1$)= Prob($u_i > -\beta' x_i$)

$$= 1 - F(-\beta' x_i) \quad (2.12)$$

Where F is the cumulative distribution function for u. The observe

This result in heteroscedasticity and the resultant estimates of β by the Ordinary least Square (OLS) from equation (2.9) will not be efficient (Maddala, 2003). Hence the corresponding variance of the error term becomes;

values of y are the realizations of the probabilities which is given by the equation (2.12), (Maddala ,2003). Hence the likelihood function is

$$L = \prod_{yi=0} F(-\beta' x_i) \prod_{yi=1} [1 - F(-\beta' x_i)] \quad (2.13)$$

According to Maddala (2003), the cumulative distribution of u_i will result in a logistic model of the form;

$$F(-\beta' x_i) = \frac{\exp(-\beta' x_i)}{1+\exp(\beta' x_i)} = \frac{1}{1+\exp(\beta' x_i)}$$

Hence,

$$1 - F(-\beta' x_i) = \frac{\exp(\beta' x_i)}{1+\exp(\beta' x_i)} \quad (2.14)$$

In a probit model we assume that u_i are normally distributed with constant variance (IN $0,\sigma^2$). In this case the equation (2.14) becomes;

$$\int_{-\infty}^{-\beta' x_i/\sigma} \frac{1}{(2\pi)^{1/2}} \exp\left(-\frac{t^2}{2}\right) dt \quad (2.15)$$

We can therefore estimate β/σ from the likelihood function (2.13) and the probit model (2.15). The probit or logit model will give the same outcome because the cumulative normal distribution and the logistic distribution are very close to each other, except at the tails where there are differences but which can only be observe in large samples, Maddala (2003).

2.25 Sample Selectivity Bias

Sample selection bias refers to the selection of individuals, groups or data for analysis such that proper randomization is not achieved, thereby ensuring that the sample obtained is not representative of the population intended to be analyzed. Selection bias often refers to the distortion of a statistical analysis resulting from the method of collecting samples. Essentially, sample selection bias can arise whenever potential observations cannot be observed. In the 1970s James Heckman developed techniques that corrected the bias introduced by sample selection bias. Since then, most econometric computer programs include a command that automatically use Heckman's method. However, blind use of these commands can lead to errors that would be avoided by a better understanding of his correction technique. To get a better understanding, let assume,

$$Y = X\beta + al + u \qquad (2.16)$$

Where Y is the outcome, X is the vector of exogenous personal characteristics, and / is a dummy variable (1= **1** if the individual participates in the program; 1 = 0 otherwise).The coefficienta measures the effects of the program. However, the dummy variable I cannot be treated as exogenous if the decision of an individual to participate or not in the program is based on individual self-selection. If the variable I is exogenous then equation (2.16) must be estimated by instrumental-variable techniques. The foregoing model is very restrictive in that the program may create interactive effects with observed or unobserved personal characteristics. Again a more generalized model can be seen below;

$y_{1i} = X_i\beta_1 + u_{1i}$ (for participants)

$y_{2i} = X_i\beta_2 + u_{2i}$ (for nonparticipants)

$I^*{}_i = Z_i\gamma = \epsilon_i$ (Participant decision function)

$I_i = 1 \text{iff } I^*{}_i > 0$

$I_i = 0 \text{ iff } I^*{}_i \leqslant 0$

The observed y_i is defined as

$y_i = y_{i1} \text{iff } \mathrm{I}_i = 1$

$y_i = y_{2i} \text{ iff } \mathrm{I}_i = 0$

The covariance of $u_{1i}, u_{2i} and\ \epsilon_i$ is as follows:

$$Cov(u_{1i}, u_{2i}, \epsilon_i) = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{1\epsilon} \\ \sigma_{12} & \sigma_{22} & \sigma_{2\epsilon} \\ \sigma_{1\epsilon} & \sigma_{2\varepsilon} & 1 \end{bmatrix}$$

In order to evaluate the benefit of the program, we need to consider the total gross benefit for the entire participants. To do this, we compare each of the characteristics $X_i$and $Z_{i,}$with the outcome in the programy_{1i}, and the expected potential outcome without the program, that is,

$E(y_{21} \,|\mathrm{I}_i = 1)$. The gross benefits for the participants I is

$$y_{1i} - E\left(y_{21} \,\middle|\mathrm{I}_i = 1\right) = y_{1i} - X_i\beta_2 + \sigma_{2\epsilon}\frac{\emptyset(Z_i\gamma)}{\Phi(Z_i\gamma)} \qquad (2.17)$$

The total benefit becomes the summation of equation (2.17) over all the participants. Thus to evaluate the success of a program from the cost-benefit point of view, the conditional expectation of u_{2i} for the participants needs to be evaluated. Under self-selection, those individuals who have a comparative advantage with the program will be joining the program and thus will benefit more from it than would a randomly selected individual with the same characteristics (Maddala, 2003). The expected gross benefit for the participant i is

$$E\left(y_{1i}\ \middle|\mathrm{I}_i = 1\right) - E\left(y_{21}\ \middle|\mathrm{I}_i = 1\right) = X_i(\beta_1 - \beta_2) + (\sigma_{2\epsilon} - \sigma_{1\epsilon})\frac{\phi(Z_i\gamma)}{\Phi(Z_i\gamma)} \qquad (2.18)$$

Since $\sigma_{2\epsilon} - \sigma_{1\epsilon} > 0$, the program will produce greater benefit under self-selection than under a random assignment. However the difference is measured by the summation of the last term in equation (2.18) over participants.

Another problem of great concern is that of truncated samples and they come about by non-availability of data on all the individuals, participants and nonparticipants. However if the data involves only participants in a social program amid self-selection and again we have data on the variables determining the participant decision making process, then we can still correct for selectivity bias by using Maximum Likelihood method. The model is

$$y_{1i} = X_i\beta_1 + u_{1i} \qquad (2.19)$$

$$I_i^* = Z_i\gamma - \epsilon_i \qquad (2.20)$$

As before,

$I_i = 1 \mathrm{iff} I_i^* > 0$

$I_i = 0$ otherwise

We note that we are given only those observations for which $I_i = 1$ and we can therefore observe y_{1i}, X_i and Z_i. The probit estimates of γ cannot be obtained because we do not have the corresponding observations to $I_i = 0$. This implies that we cannot use the two-stage methods but we can use the ML method to correct for the selectivity bias. The likelihood function for the model is

$$L = \prod_i \frac{\int_{-\infty}^{Z_i\gamma} f(u_{1i},\epsilon_1)d\epsilon_i}{Prob(I_i=1)} \tag{2.21}$$

Where $f(u_1, \varepsilon)$ is the joint density function of u_i. If we assume that u_1 and ϵ are jointly normally distributed, with mean vector zero and covariance matrix

$$\sum = \begin{bmatrix} \sigma_1^2 & \rho\sigma_1 \\ \rho\sigma_1 & 1 \end{bmatrix}$$

Then by writing $f(u_1, \epsilon)$ as $f_1 . f_2\left(\epsilon \middle| u_i\right)$, we can simplify the likelihood function as $L =$

$$\prod_i [\Phi(Z_i\gamma]^{-1} \frac{1}{\sigma_1} exp\left[-\frac{1}{2\sigma_1^2}(y_{1i} - X_i\beta_1)^2\right] X\Phi\left(\frac{[Z_i\gamma - \rho(y_{1i} - X_i\beta_1)]/\sigma_1}{(1-\rho^2)^{1/2}}\right) \tag{2.22}$$

In summary, if the sample data for subgroups are truncated, we can try to correct for selectivity bias in the OLS estimates by using the ML method provided we know what variables affect the selectivity criterion.

2.26 Heckman two stage model

Heckman (1979) stated that selection bias is resulted from using non-randomly selected samples to estimate behavioral relationships as an ordinary specification bias that arises because of a missing data problem. In the analysis of sample selection bias, it is possible to estimate the variables which when omitted from a regression analysis give rise to the specification error. He also mentioned that sample selection bias usually arise in practice for two reasons. First, there may be self-selection by the individuals or data units being investigated. Second, sample selection decisions by analysts or data processors operate in much the same fashion as self-selection.

The Heckman's approach involves estimation of a probit model for selection, followed by the insertion of a correction factor - the Inverse Mills Ratio (IMR), calculated from the probit model - into the second OLS model of interest.

Heckman's two-step estimation is based on the recognition that the sample selection problem is really an example of omitted variable bias (Heckman1979). To illustrate this, the precise form of the Heckman two-step method is presented below, where equation 2.23 is the selection equation and 2.24 is the substantive equation of interest.

$$Y_2 = \alpha + \delta \qquad (2.23)$$

$$Y_1 = \beta_0 + \beta_1 X + \sigma p_{\varepsilon\delta}\, \lambda(T - \alpha Z) + \sigma^1 \varepsilon^1 \qquad (2.24)$$

In the selection equation, which is estimated with a probit, Y2 is the dichotomous dependent variable, Z is the independent variable, α is the coefficient of Z, and S is the normally distributed error term. In the regression equation the value of Y_1 is observed when Y_2 is greater than some threshold T, and it is censored (that is missing) if $Y_2 \leq T$. Estimation of 2.24 by simply regressing Y on X will be biased because of the sigma term, which represents the omitted variable. This problem can be solved in two steps according to Heckman.

First the selection equation 2.24 is estimated using probit and the predicted values are retained as estimates of $T - \alpha Z$. The IMR is then estimated for each case by dividing the normal density function evaluated at - *(T-αZ)* by one minus the normal cumulative distribution function estimated at - *(T-αZ)* which gives us equation (2.24).

$$\lambda(T\text{-}\alpha Z) = \frac{\theta(T\text{-}\alpha Z)}{1 - \phi(T\text{-}\alpha Z)} \qquad (2.24)$$

The second step is an OLS regression with *X* and the IMR included as an additional regressor.

The estimator is consistent when the assumptions are met.

2.27 Switching Regression Model

Switching models are widely used in contexts with two or more regression equations to describe the behavior of distinct agents or settings (Maddala 2003). According to Perminger et al., (2007), switching regression models are those models in which the parameters are determined by a latent discrete state variable. A model is then constructed with several latent state variables, where the model parameters are partitioned into disjoint groups, each one of which is independently determined by a corresponding state variable. Such a model is called an extended switching regression (ESR) model. An EM algorithm is also developed to estimate the model parameters, and discuss the consistency and asymptotic normality of the maximum likelihood estimates. Finally, the ESR model is combined with the volatility forecasts of foreign exchange rates. The resulting forecast combination using the ESR model tends to dominate those generated by traditional procedures.

Switching Regression Models are very useful in the union-nonunion-wage model (Lee, 1978), the housing-demand model (Trost, 1977), disequilibrium Market model (Fair and

Jaffee, 1972), the Labor- supply model (Heckman, 1974; Gronau, 1974), needs vs. reluctance model (Polakoff and Sibler, 1967). Maddala (2003) enumerated a number of methods we could estimate a switching regression model such as the OLS method, Maximum Likelihood estimation, Tobit, Two-stage method for Tobit models, censored and the self-selection model.

2.28 Treatment effect model

The Treatment effect model is similar to the Heckman's two stage sample selection model. The main difference between the two however, is that in the case of the former, the treatment (adoption in this case) enters the substantive equation to measure the direct effect on output (Maddala, 2003). As shown earlier, in the case of the Switching regression model, the data is divided into adopters and non-adopters before the regression is carried out. However, in the case of Treatment effect model, the data is pooled together. The main advantage of the Treatment effect model is the additional regressor that is added to the output equation which comes from the adoption equation.

Consider an equation of the form

$$Y = X_i' + \delta A_i + \varepsilon_i \qquad (2.25)$$

Where Y is the output variable, *X;* is a set of factors that influence adoption of improved rice variety, A_i is a dummy variable which represents the adopters of improved rice variety and non-adopters. According to Maddala (2003), estimating equation 2.25 with OLS will not measure the pure effects of the variable on output. In other words, although could be specified correctly, S may not measure the true value of A_i. Also Maddala (2003) explained that we will overestimate the parameter, *S* if we estimate the equation

12.25 by OLS. Greene (2003) suggested we estimate the predicted values of A_i and use it as an additional regressor in the second stage. Mathematically, we have

$$A_i^* = w_i' + u_1 \tag{2.26}$$

$A_i = 1$if $A_i^* > 0$, or 0 otherwise

Since, the ε_i andu_i are correlated, if we estimate the adoption equation (equation 2.26) without first estimating the treatment equation (2.25) the estimates of the betas ($\beta's$) would be bias, since the adoption variable is endogenous, meaning it is also determined by other socio-economic factors. Therefore the expected values of equation 2.25 become;

$$E[y_i/A_i = 1, x_i, Z_i] = X_i'\beta + \delta + E[\varepsilon_i/A_I = 1, x_i, Z_i]$$

Then the outcome equation can be estimated as:

$$\gamma = X_i'\beta + \delta + \ \rho\sigma_\varepsilon\lambda(-w_i'\gamma) \tag{2.27}$$

$$\lambda = \frac{-\emptyset(w_i'\gamma)}{1 - \phi(w_i'\gamma)}$$

The lambda (λ) is what is known as the Inverse Mills Ratio (IMS)

The two step estimator provides a follow-up result of δ which accounts for self-selection or treatment problem. This is the case for participants or adopters.

In the case of non-participants or non-adopters, we have our expected values as

$E[y_i/A_i = 0, x_i, Z_i]$

$$= X_i'\beta + \rho\sigma_\varepsilon\left[\frac{-\emptyset(w_i'\gamma)}{1-\phi(w_i'\gamma)}\right] \tag{2.28}$$

The difference in the expected income between participant and non-participant becomes

$$E[y_i/A_i = 1, x_i, Z_i] - E[y_i/A_i = 0, x_i, Z_i]$$

$$= \delta + \rho\sigma_\varepsilon \left[\frac{\phi_i}{\Phi_i(1-\Phi_i)}\right] \quad (2.29)$$

The omitted λ is what OLS would have estimated to measure the value on the treatment A_i.

2.29 Factors influencing adoption of a new technology

Before discussing the categories of factors influencing the adoption of a new technology, it is very important Foltz's (2003) and Aberas' (2008) broad views on the determination of adoption is review.

2.29.1 Hypothesis 1: Resources Scarcity

According to Foltz (2003) when natural resource endowments dwindle, it forces farmers to switch to a resource-conserving technology. The resource scarcity hypothesis argues that new innovations/technologies will diffuse quickly or slowly depending on the relative prices of resources in the area. Those with the most severe resource constraint will be the early adopters of the technology while those with abundant supply of the resource may not adopt the technology at all. In order to solve this difference in the society, appropriate policies, such as reducing market imperfections in pricing natural resources, output prices and markets should be reformed to ensure that farmers pay the actual cost of input resources needed.

2.29.2 Hypothesis 2: Capital Constraint

Capital scarcity comes as a result of credit constraints or lack of collateral to give farmers the opportunity to access credit for present consumption, including long term investments. The capital constraint hypothesis suggests that new technologies will spread faster among farmers who have access to capital to pay for the new technology.

2.29.3 Hypothesis 3: Learning Cost

Technology adoption is directly proportional to the knowledge levels of farmers. This implies that if the diffusion of knowledge of the technology is slow it suggests that farmers do not know the benefits of the new technology and they will not risk the adoption to an unknown technology. The learning cost hypothesis suggests that technologies will diffuse fastest in areas where there exist adequate information about the availability of the technology, and also the ease with which it can be evaluated by prospective adopters. Similarly, farmers who have the opportunity to observe technology experimentation on demonstration plots stand a better chance of adopting the new technology.

It is easy to realize that farmers with high exposure to extension servicers, better levels of education, demonstration fields and greater numbers of neighboring adopters would tend to be adopters.

2.29.4 Hypothesis 4: Risk Aversion

Risk aversion implies that farmers will not invest in an unknown new technology because of the uncertainty surrounding output. However, farmers would readily welcome a technology that reduces their risks especially those farmers who are exposed to greater risks.

Abera (2008) identified two common approaches in the adoption literature that explain the mode and sequence of agricultural technology adoption. The first approach emphasizes the adoption of the whole package while the second one stresses step-wise or sequential adoption of components of a package. He noted that scientists often recommend the former approach while field practitioners, specifically farming system and participatory research groups, advance the latter. Abera (2008) noted that there is often a great tendency in agricultural extension programmes of developing countries to promote technologies as a package and farmers are expected to adopt the whole package. Several other studies on adoption reviewed by Nagy and Sanders (1990) and Leather and Smale (1991) concluded that farmers choose to adopt inputs sequentially by first adopting only one component of the package and sequentially adding components over time, one at a time. Some of the major reasons given for the sequential adoption of a package of technologies are profitability, riskiness, uncertainty, lumpiness of investment and institutional constraints.

On the other hand, some studies (Mann, 1978; Byrlee and Hesse de Polanco, 1986) argued against the whole package-approach, stressing that farmers do not adopt technologies as a package, but rather as a single component or a few suitable technologies.

Several factors have been found to influence farmers' decisions to adopt a given agricultural technology. Traditionally, economic analysis of agricultural technology adoption has focused on imperfect information, risk, uncertainty, institutional constraints, human capital, input availability and infrastructure as factors that explain the adoption decisions of farmers (Federet *al.*, 1985; Foster and Rosenzweig 1995). Some studies classify the factors influencing adoption into broad categories, such as fanner characteristics, farm structure, institutional characteristics and managerial structures

(McNamara, Wetzstein and Douce, 1991) while others classify them under social, economic and physical categories (Kebede, Gunjal and Coffin 1990). However, for the purpose of this study, the potential determinants of technology adoption are categorized under economic, social and institutional factors.

2.30 Economic factors

There are several economic factors that may influence the adoption of new agricultural technology. Some of the important economic factors that have been found to significantly influence agricultural technology adoption are farm size, cost of technology and expected benefits from adopting the technology and off-farm hours (Wabbi, 2002).

Farm size has been found to positively influence adoption (McNamara, Wetzstein, and Douce, 1991; Abara and Singh, 1993; Feder, Just and Zilberman, 1985; Fernandez-Cornejo, 1996, Kasenge, 1998). However, others (Harper et al, 1990; Yaron, Dinar and Voet, 1992) found a negative effect of farm size on adoption. Also Mugisa-Mutetikkaet *al.*, (2000) found adoption and farm size to be independent of each other.

The decision to adopt a technology is often considered as an investment decision, which Caswell *et al.*, (2001) found it's to reduce the possibility of the farm business experiencing years of poor performance. This is because technology adoption presents an increase in cost incurred by a given farmer and therefore technologies that are capital intensive are only affordable by wealthier farmers (Khanna, 2001; El Oster and Morehart, 1999). Moreover, the profitability of a given technology can serve as a motivation for the adoption of such technology. Farmers are rational beings, who will only adopt a technology if they find it beneficial. Abara and Singh (1993) noted that if farmers do not perceive a significant difference between two options, then it is less likely that they will change their behaviour about adopting a new technology. In other words as McNamara, Wetzstein, and Douce, (1991) and Fernandez-Cornejo (1996) concluded, there should be a high positive correlation between the adoption of a new technology and output.

Furthermore, the availability of time to adopt a new technology can be an important determinant of adoption. For this reason, practices that heavily draw on farmers' leisure may inhibit adoption (Mugisa-Mutetikkaet *al.*, 2000).

2.31 Social factors

Social factors such as education, age and gender have been found to explain farmers' adoption decision in several studies. Studies that establish an effect of education on the adoption decision of farmers in most cases relate it to years of schooling (Ferder and Slade 1984; Tjornhorm, 1995). Rogers (2003) noted that the complexity of a technology often poses a negative effect on adoption and that education is thought to reduce the amount of complexity perceived in a technology, thereby increasing its adoption. Furthermore, farmers' age is found to positively influence adoption of sorghum in Burkina Faso (Adesina and Baidu-Forson, 1995). However, studies on adoption of land conservation practices in Niger (Baidu-Forson, 1999), rice in Guinea (Adesina and Baidu-Forson, 1995), Hybrid Cocoa in Ghana (Boahene, Snijders and Folmer, 1999) found age to be negatively correlated with adoption. Also gender has been found in some studies to significantly explain the adoption decision of farmers (Doss and Morris, 2001; Overfield and Fleming, 2001). Assets and vulnerability makes up the social factors which are discuss briefly below;

2.31.1 Assets

These factors deal with whether farmers have the assets necessary for technology adoption. Meinzien-Dick et al., 2004 argued strongly that, lack of assets limit technology adoption and therefore they recommended that researchers, policy makers and development workers should promote technology with low asset requirement if they are to increase the rate of adoption.

2.31.2 Vulnerability

Vulnerability includes whether the technology expected will increase or decrease people's vulnerability to loss of income, bad health and natural disasters. Investing in a new technology such as buying inputs can make farmers more vulnerable, because their precious cash resources as well as food security will be at risk if their crops fail due to an unexpected drought or flood.

2.31.3 Institutions

Institutions include agriculture extension services, government policies, non-governmental organization, the private sector, gender roles, and markets for inputs and outputs. These institutions will encourage or discourage adoption (Foltz, 2003). For instance, in Foltz's study farmers' adoption decision was influenced by information or knowledge and their ability to access farm credit, among others. Farmers who faced information and credit constraints were not efficient in allocating resources to their drip irrigation technology. It is worth mentioning that every adoption happens in a certain culture settings and therefore we will take a brief look at adoption as it relates to culture.

2.32 Review of Empirical Studies on the determinants and effects of technology adoption

This section reviews some similar studies on the determinants and effects of technology adoption.

Donkoh (2010) studied the technology adoption and efficiency in Ghanaian agriculture aimed to access at the micro level, the socio-economic factors influencing the adoption of Green Revolution technologies and the effect of adoption on the efficiency levels of agricultural households in Ghana. The method of analysis involved probit estimation of an adoption model, a stochastic frontier estimation of the inefficiency model and a maximum likelihood estimation of a consumption equation. His findings showed that adoption is greater for male-headed households, richer households, literate-headed households and urban dwellers. However, the educational background of household heads and capital availability variables (non-agricultural income and credit) did not play an important role in increasing the efficiency of households. Donkoh identified illiteracy, inequality and lack of effective markets as the main problems that must be addressed if adoption, and for that matter the welfare of agricultural households are to be enhanced. This may be done through stepping up both formal and non-formal education and ensuring equitable distribution of the national resources, among others.

Wiredu et al., 2010 examined the impact of improved varieties on the yield of rice producing households in Ghana. Wiredu et al., 2010 employed average treatment effects to estimate the effects of new improved rice variety adoption on yields. The result shows that adoption had a positive impact on farmers rice yield. Additionally experience, gender (male headed households) and expectations about the yield and performance of improved technologies had positive effect on yield. The results suggest significant differences between the yields of adopters and non-adopters. They recommended, among others, embarking on promotion activities as well as training in good agricultural practices in order to encourage wide adoption of improved rice varieties.

Faltermeriier et al., 2009 carried out a study to determine the impact of water conservation and intensification technologies among small scale lowland rice farmers in the northern region of Ghana. Their studies employed propensity score matching model to examine the effects of the adoption of water conservation and intensification technologies on farm output and income difference. The cumulated results showed a positive and significant effect on output when dibbling method was combined intensely with weeding. They argued that dibbling seed and dibbling fertilizer as well as weeding are important technologies that should be supported because of their potential of increasing crop productivity and farm income.

Saka et al., 2009 examined the adoption of improved rice varieties and its' effect on rice productivity among smallholder farmers in southwestern Nigeria. The estimation involved the use of adoption index, logit model and stochastic frontier model to assess the adoption and the effects on farmers' productivity. The results showed that the decision of whether or not to cultivate improved rice varieties was significantly influenced by the size of the rice farm, yield rating of improved rice varieties and the frequency of extension contact. Additionally yield performance of the varieties and the frequency of extension contacts were found to significantly increase farmers' yield and income.

Meinzen-dick et al (2004) conducted an interdisciplinary assessment of the impact of agricultural new technologies on incomes and yields. They argued that measuring the direct impacts of a new technology on incomes and yields do not tell the whole story. The results of the study showed that both economic and non-economic factors such as sources of vulnerability, gender roles and the sources of the discriminated technology play an important role in determining a technology adoption decision. In general, social, cultural and economic factors all play a critical role in determining whether a new technology will be adopted or not.

CHAPTER THREE:

METHODOLOGY

3.0 Introduction

Research Methodology is an essential component of any study and provides the framework upon which the whole research process is conducted. Hence, it is important that the methodology is good to produce efficient and accurate results in order to achieve the research objectives. This section presents the methodology of the study. It covers aspects such as the study area, and sources of data among others.

3.1 Study area- The Republic of Ghana

The Republic of Ghana and formally Gold Coast lies within latitude 4° 44'N and 11°11'N and 3° 11'W and 1°11'E. The country is located along the Gulf of Guinea and Atlantic Ocean in the sub-region of West Africa (see figure 3.0a). The country has a land mass of 238,535km^2 and is bordered by Ivory Coast in the west, Burkina Faso to the north, Togo to the east and the Gulf of Guinea and Atlantic Ocean to the south as shown in figure 3.0 below. The Population and Housing Census, 2010 recorded 24.2 million as the population of Ghana with a variety of ethnic and religious group. The population density is approximately 259 persons per square meters. The population distribution is varied across the 10 administrative regions and eco-zones of the country with 68 % and 32 % living in the rural and urban areas respectively. About 52 percent of the labour forces are engaged in agriculture, 29 percent in services and 19 percent in industry. About 136,000 km^2 of land (57 %) of the country's total land area of 238,539 km^2 is classified as agricultural land out of which 58,000 km^2 (24.4 %) is under cultivation and 11,000 hectares under irrigation. About 60 % of all farms in the country are less than 1.2 hectares. 25 percent are between 1.2 to 2.0 hectares with a mere 15 percent above 2.0 hectares, and the mean farm size is less than 1.6 hectares (SRID, 2001). Ghana's farming systems vary with agro-ecological zones. Staple crops are mixed-cropped while cash are mono-cropped (MoFA, 1998).

Oppong-Anane (2001) reported that the soils of Ghana are developed on thoroughly weathered parent materials, with alluvial soils and eroded shallow soils common to all the ecological zones.

Ghana's climate is influenced by the hot, dry and dusty-laden air mass that moves from the north east across the Sahara and by the tropical maritime air mass that moves from the south-west across the southern Atlantic ocean. The climate ranges from the bimodal rainfall equatorial type in the south to the tropical unimodal monsoon type in the north. The mean monthly temperature over most of the country never falls below 25° C, a consequence of the low latitude position of Ghana and the absence of high altitude areas. Mean annual temperature averages 27° C. Absolute maxima approach 40° C, especially in the north; with absolute minima descending to about 115° C. (Dickson and Benneh, 1988; Benneh *et al.* 1990).

Ghana is divided into six major agro-ecological zones: these are Rain Forest, Deciduous Forest, Forest-Savannah Transition, Coastal Savannah and Northern (Interior) Savannah which comprises Guinea and Sudan Savannahs. The bimodal rainfall pattern in the Forest, Deciduous Forest, Transitional and Coastal Savannah zones give rise to major and minor growing seasons. In the Northern Savannah the unimodal distribution results in a single growing season. The rainfall determines largely the type of agricultural enterprise carried out in each zone. The vegetation of Ghana lies between the Sahara and the Gulf of Guinea. The main vegetation formations as described by Benneh *et. al*., (1990) are the Coastal Strand and Mangrove, the Coastal Savannah, the Closed Forest, the Derived Savannah and the Interior Savannah.

Figure 3.0a: The map of Africa showing the location of Ghana.

Figure 3.0b: The Map of Ghana

3.2 Empirical Model

From the literature review the model to estimate the determinants as well as the effects of improved rice variety on farmers' output may be represented as follows;

$A = \gamma' Z + u_1$ (Adoption model) (3.1)

Where;

$A = 1$ if the ith farmer has adopted the improved rice variety; 0 otherwise

Z = the co-efficient of the explanatory variable (factors believed to influence the adoption of improved rice adoption)

u_1 = two sided error term with a normal mean and constant variance

$$Y = \beta^1 x + \delta A + u_2 \qquad (3.2)$$

Where;

Y = output of rice farmers

f3 = the co-efficient of the explanatory variable

x = the independent variable which explains the factors which determines the output model such as the farm size, labour, seeds, fertilizer among others

δ = the coefficient of the Adoption variable *"A"*

u_2 =also two sided error term with a normal mean and constant variance

To correct for possible selection bias, Maddala (2003) suggested equation (3.1) is estimated to obtained the predicted values of *A* which is used to form an IMR as an additional regressor and where all the observation are used (output and input values for both adoption model and non-adopters), the following is obtain;

$$In\, Y_i = \beta^{'} (Q_i In\, X_i) + \delta^{'} (\phi A_i) + \sigma ø_i + u_3 \qquad (3.3)$$

(Maddala, 2003)

Where $ø_i$ *and* dare the probability density function (PDF) and the cumulative density function (CDF) of the standard normal distribution and $\phi_i = \phi(w_i y)$. u_3 is two sided error term with $N(0, \sigma_v^2)$. The rest are us defined earlier.

The theoretical models above then give the following empirical models;

$Adoption = Y_o + Y_i Age + Y_2 Agesqd + \lambda_3 Education + Y_4 Extension + Y_5 Farmsize + Y_6\ Householdsize + u_1$
(Adoption Model)

$$In\ output = \beta_o + \beta_1 1n\ x_1 + \beta_2 In\ x_2 + \beta_3 In\ x_3 + \beta_4 In\ x_4 + \delta_1 \mathrm{A}$$

(Output model)

Where δ_i is the variable that measures the adoption of improved rice variety.

3.3 Goodness-of-fit test

Chi-Square test is normally used to determine the goodness-of-fit test. The test is applied to two categorical variables (such as adopters and non-adopters) from a single population. It is used to determine whether there is a significant association between the two variables. The test is appropriate when the following conditions are met:

- The sampling method is simple random sampling.
- The variables under study are each categorical.
- If sample data are displayed in a contingency table, the expected frequency count for each cell of the table is a least five.

Mathematically, Chi-square (x^2) is given as;

$$X^2 = \sum \frac{(\text{Observed - expected})^2}{\text{expected}}$$

The critical value is determined based on a table of Chi-square values, which determines the critical value based on the degrees of freedom at the selected level of confidence. If the computed Chi-square value is greater than the critical value, the result is significant.

The null hypothesis states that the rice variety adoption and output are independent against the alternative hypothesis which states that the rice variety adoption and output are not independent.

3.4 Survey Methodology

Survey methodology involves the sampling method that was used in collecting the data.

3.4.1Sampling

The Ghana Agricultural Production Survey (GAPS) employed a three stage multi-sampling design in response to the Government of Ghana's requirement for reliable agricultural statistics at the national, regional and district levels. A multi-stage sampling procedure was used in the sampling process and the stages are briefly explained below:

3.4.2 First Stage Sampling

This involves the random selection of two (2) districts from each of the ten (10) regions in Ghana with probability proportional to size, using districts population in year 2000 as a measure of size. This gives a total sample size of twenty (20). However, eleven metropolitan and municipal assemblies namely Kumasi, Sunyani, cape Coast, New Juaben, Accra, Tema, Tamale, Bolgatanga, Wa, Ho and ShamaAhanta East were excluded from the study, given their urban predominance.

3.4.3 Second Stage Sampling

The second stage involves the random selection of forty (40) enumeration areas from each of the twenty (20) districts which gives a total of eight hundred (800) enumeration areas with a probability proportional to size in each district. GAPS used the lists of enumeration areas compiled from the 2010 census as a sample frame and the projected total population as a measure of size. In the Kassena-Nankana East district, fifty three (53) of the prevalent one hundred and eighty seven (187) enumeration areas compiled by 2010 census were excluded from the study because of the land dispute prevalent in the area earlier in 2011.

3.4.4 Third Stage Sampling

At the third stage, five holders were randomly chosen in each enumeration areas, using as a sample frame, the full list of all holders, compiled from the household listing questionnaire. This provided a total sample of four thousand (4000) holders, consisting of two hundred (200) holders per district.

3.5 Instruments

A set of questionnaires were used to gather the necessary data at both the household and farming activities levels. It is important to note the estimated data was sorted, cleaned to arrive at the sample size of four hundred and seven (407) rice farmers before the final estimation was done.

3.6 Data and Data Sources

The data for this study was obtained from the Statistical, Research and Information Directorate (SRID) of the Ministry of Food and Agriculture (MoFA) collected in conjunction with the Ghana Strategy Support Program (GSSP) of the International Food Policy Research Institute (IFPRI). It must be mentioned that the data was collected as a pilot study and as such the sample size for rice producers was only 414 from eleven rice producing communities in selected districts in Ghana. The final data was sorted to select 407 because 8 of the farmers did not have all the information that was needed. 2010 population figures were not available at the time when the first phase started. The data used is for the 2011/2012 cropping season.

3.7 Definition of variables used in the study

Table 3.0 shows the definition of variables and their expected signs used in the estimation of the adoption model. From the literature, the effect of the farmer's age is ambiguous; it can be positive or negative depending on the study. The argument is that older farmers may have more experience, resources, or authority that may give them more possibilities for trying a new technology. On the other hand, younger farmers have been found to be more knowledgeable about new practices and may be more willing to bear risk and adopt new technology because of their longer planning horizons.

Education is also expected to have a positive effect on adoption because it increases knowledge thereby enhancing the ability to derive, decode and evaluate useful information for technology adoption. Household size has been identified to have either positive or negative influence on adoption. Larger family size is generally associated with a greater amount of labour for the timely operation of farm activities. The negative relationship of the variable with adoption has been linked to increased consumption pressure associated with large families, which does not permit them to have the means to invest in new technologies for their farms. Normally farming households with bigger landholdings are supposed to have an enhanced ability to afford improved technologies and a greater capacity to cope with losses if the technologies fail.

Furthermore, access to extension gives famers the opportunity to gain knowledge and also obtain some encouragement with respect to the adoption of technologies. Hence it is expected to have positive effect on technology adoption. Lastly, from neoclassical production economics output is a positive function of land (farm size), labour and capital (seeds and fertilizer) (Koutsoyannis, 1979).

Table 3.0 below shows a summary of the *a priori* expectation of the variables to influence adoption and output

Table 3.0: Definition of variables used in the study

Variable	Definition	Expected sign
Age	Age of the farmer in years	+/-
Education	Number of years of formal education	+
Household size	Number of people in a farmer's house eating from the same bowl	+/-
Farm size	Size of a farmer's rice plot in acres	+
Extension	Dummy; 1 if farmer had access to extension service during farm season in question ; 0 if otherwise	+
Adoption (A)	Dummy; 1 if farmer adopted improved rice seed; 0 if otherwise	+
Rice output y_1	Natural Logarithm of rice output in kilograms	+
Farm size (x_1)	Natural Logarithm of farm size in acres	+
Labour cost (x_2)	Natural Logarithm of labour cost in Kilograms	+
Seeds (x_3)	Natural Logarithm of seeds in kilograms	+
Fertilizer cost (x_4)	Natural Logarithm of fertilizer cost in Kilograms	+

CHAPTER FOUR:
RESULTS AND DISCUSSION

4.0 Introduction

This chapter presents the estimation results and the analyses of the study. However before this the socio-economic indicators of the respondents are discussed.

4.1 Socio-Economic Characteristics of Rice Farmers

The table 4.0 below shows the descriptive statistics of the various socio-economic and farm specific variables included in the study. From the table, on the average, a farmer is almost 49 years with 2 years of formal education and 8 household members. Additionally, a farmer on the average cultivates 5 acres of rice farm and spends an average of GHS110.11 on labour, GHS 24.41 on seed and GHS 60.65 on the cost of fertilizer.

Table 4.0: Descriptive Statistics of the Variables Used In the Study

Variable	Mean	Standard Dev.	Minimum	Maximum
Age	48.63	16.44	4.00	90.00
Education	2.15	4.16	0	15.00
Household size	7.47	5.88	1.00	40.00
Farm size	4.92	5.32	0.50	42.00
Labour cost	110.11	251.24	2.00	2876.00
Seed	24.41	40.62	2.00	250.00
Fertilizer cost	60.56	93.92	0.00	850.00

Source: Field survey

Note that the amounts quoted here are in old Ghana Cedis. The equivalence is as follows: 2,000 Old Ghana Cedis = 2 New Ghana Cedis= l US Dollar.

4.1.1 **Sex Distribution of Respondents**

From the figure below, majority of the farmers were male constituting 75.4% of the sampled populations while the females constituted only 24.6%. Generally, men are noted as the bread winners of the family and in rural communities where farming is the major occupation, most males are engaged in farming. This finding confirms the notion that farming in Ghana is dominated by males. In rural or farming communities of the country, household resources such as land are owned and managed by the males exposing the potential female farmers to less access to these resources to enable them own and manage their individual farms.

4.1.2 **Ages of Farmers**

In table 4.0, the minimum and maximum age of the sampled farmers was 4 and 90 years respectively. Also, the average farmer in the study was 48.3 years old. Table 4.1 below shows the distribution of the farmers' age. It would be observed that the modal age group was recorded between 40 and 49 years old and it forms about 26 % of the respondents. This however falls outside the youth age group of 15 to 24 years according to the United Nations. In recent times, farming has become unattractive to the youth who prefer to migrate into the cities to search for non-existent white collar jobs. In order to sustain rice production in the country, more production incentives should be provided to the rice sector to attract the youths who are very exuberant to adopting improved and modern technologies. The finding is consistent with the ageing farming population in Ghana.

This shows that the rice production and farming in general has become unattractive to the youth in Ghana. Also about 26% of the rice farmers were aged between 60 to 89 years which means they are working in their retirement age.

Table 4.1: Age distribution of the farmers

Ages (years)	Number	Percentages (%)
20-29	42	10
30-39	73	18
40-49	106	26
50-59	81	20
60-69	48	12
70-79	40	10
80-89	17	4
Total	407	100

Source: Field survey

4.1.3 **Household Size of Rice Farmers**

The distribution of household size ranged from 1-40 members with a mean of 7.5.The highest percentage (48.9%) of the farmers had a household size of 1 to 5. In table 4.2 below, the higher percentage (48.9%) of the farmers had household member of up to five (5) which is consistent with the national average household size of 4.4. This is followed by the household size of 6 to 10 members with a percentage of 32.4.Small holder farming is largely dependent on family labour and larger household is a major asset to the farming households. Rice production, right from land preparation, planting of seeds, managing pests and harvesting is highly labour intensive. This means that the use of hired labour in production would require more capital which most of the small holder farmers' lack.

Table 4.2: Household size distribution of the farmers

Household size	Frequency	Percentage
1-5	199	48.9
6-10	132	32.4
11-15	40	9.8
16-20	16	3.9
21-25	12	2.9
26-30	8	2.0
Total	407	100.0

Source: Field survey

4.1.4 Education Level of Respondents

Figure 4.0 below shows the levels of education of the rice farmers. The study found that about 24% of the farm holders had formal education whilst 76 % of the farmers had no formal education. The average years spent in school was 2.15. In Ghana six years is spent in primary school while an additional three years is spent in the Junior Secondary School to complete basic education. The average years spent in school by the sample farmers attests to the fact that farmers have low level of education. Perhaps embarking onnon-formal education programme may be in the right direction to build the capacity of the farmers.

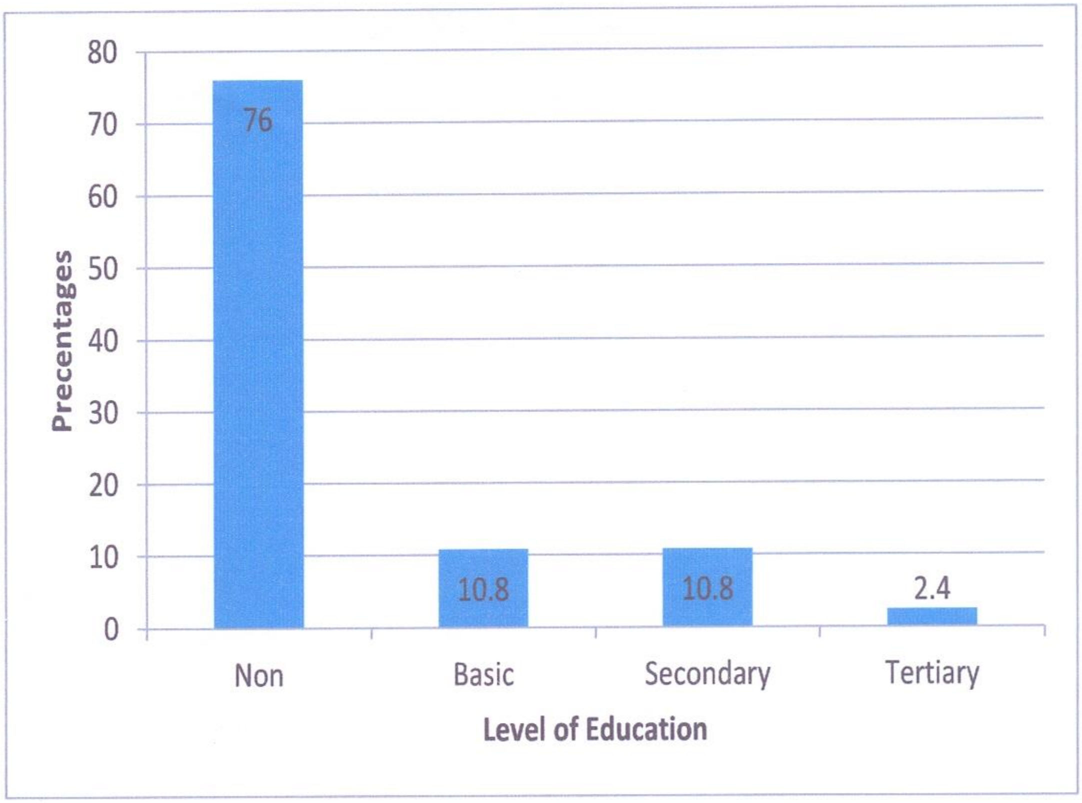


Figure 4.0: The level of education of rice respondents

4.1.5 Access to extension services

Extension services are very vital in encouraging the adoption of a new technology or variety. Extension officers educate farmers on the cultural or production practices required of a particular technology to achieve the maximum desired output. In this study, the majority of the farmers (54.5%) had access to extension services during the production year. This is in the right direction since the farmers can share their challenges with these extension experts for technical advice. However, considering the significant role of extension services, the percentage of farmers who did not receive the service is alarming. In Ghana the ratio of farmers to extension staff is as high as 1500:1 (GSS, 2010).

4.2 Farm Size of Respondents

In Ghana, small-scale farmers constitute about 92% of the farming population (MoFA, 2010). The study revealed that the farm sizes ranged from as low as 0.50 acres to 42 acres with a mean of 4.92 acres. This is almost the same as the national average farm size of 5 acres. The farmers with the highest percentage were recorded among farmers with farm sizes ranging between 2 to 3.9 acres whilst the lowest percentage of 1 was recorded among the farmers with farm sizes ranging from 12 to 15.9 and 16 to 17.9 acres.

Table 4.3: Farm size distribution of rice farmers

Farm size (Acres)	Number	Percentages (%)
< 2	88	22
2.0-3.9	140	34
4.0-5.9	68	17
6.0-7.9	54	13
8.0-9.9	15	4
10.0-11.9	18	4
12.0 - 15.9	4	1
16.0 - 17.9	6	1
≥ 18	14	14
Total	407	100

Source: Field survey

4.3Unit Cost of Labour, Fertilizer and Seed

Labour is one of the most important and inevitable resources needed in farming especially crop farming. From the study, the number of persons per day who work permanently on a farmer's field varies from one (1) to three (3) depending on the size of the farm. One important factor that determines the number of labour used on the farm by the rice farmers is the unit cost of labour. From the sample, farmers spent an average amount of GH¢11.01 per labour to cultivate 4.92 acres of rice. However, Uaiene et al., (2009) reported that the more the labour one uses, the higher the output. This is because labour assists in the removal of weeds which compete with rice for available nutrients. Similarly, the average cost of fertilizer on the average farm size (4.92) was GH06.50. The introduction of fertilizer subsidy was effective during the cropping season to achieve this unit cost of fertilizer. However, the subsidy has been erratic. On the average, 24.4 1 kg of seeds are needed to effectively cultivate 4.92 acres of rice farm.

4.4The Determinants of Improved Rice Adoption

The main determinants of adoption of improved rice varieties are shown in table 4.3 below. From the results, all the variables, except age and age squared were significant. However, whereas household size and education had a positive effect on the probability of adoption, farm size and extension service had a negative effect on adoption.

Formal education is very essential in developing the capacity of people. Specifically, farmers' ability to understand modern technologies is enhanced with education. Improved rice varieties come with some production practices that require some level of education. The positive significance of education in the model suggests that farmers who had some level of formal education had a higher probability of adopting improved rice varieties than those who had no formal education. This meets the *a priori* expectation of the research and also consistent with that of Foltz in (2001). Foltz (2001) noted that formal education helps farmers to understand the information about a technology which in turn facilitates the adoption of a technology. Several other studies (Uaiene, et al, 2009; Nzomoi et al, 2007; Salasya et al, 1996) argued that, education gives farmers the ability to perceive, interpret and respond to new information much faster.

The positive significance of the household size in the model means that, the larger the farmers' households, the higher their probability to adopt improve rice seed. In other words, farmers with larger household size have a greater probability of adopting an improved rice seed than those with smaller size. In other words, larger household farmers adopts improved rice varieties than the lesser household farmers. Household labour is an important asset for crop production. It is a cheap source of labour especially in smallholder farms. The labour requirement for improved rice production is quite high and this could be the reason for the higher adoption probability for the larger household farmers.

However, contrary to the *a priori* expectations is the negative marginal effect of extension on adoption on the adoption of improved rice varieties. Extension services involve providing education, training as well as monitoring farmers on how to produce crops. This means that with the introduction of improved rice variety, more extension service is needed not only to enhance adoption but to reap the maximum output from the adoption of the improved seed variety. However, in this study, farmers who had no access to extension service had a higher probability of adopting improved rice seed variety. This is confirms the study of John Ulimwengo and Prabuddha Sanyal (2011) on a research topic "the joint estimation of farmers' willingness to pay for agricultural services". Ulimwengo, J. and Sanyal, P. (2011) explained that the negative effect of extension services on farmers' willingness to pay for agricultural services could mean their appreciation of the services being offered. From the findings, farm size also had a negative effect on the probability of adopting improved rice variety. One would have expected that farmers who did the cultivation of rice on a larger scale should adopt the improved varieties since they had greater control of resources and are able to allocate some portions of their field to cultivating the improved seed as a trial, pending their full acceptance of the new technology.

Table 4.4: Maximum likelihood Estimation results of the Determinants of Improved Rice Adoption in Ghana.

Variable	Coefficient	Standard Error	Z-Value	P > IZI
Age	0.026	.029	0.90	0.367
Agee	-0.000	0.003	-0.74	0.460
Education	0.518	.225	2.30	0.021**
Extension	-0.330	0.189	-1.74	0.082*
Farm Size	-0.031	0.175	-1.79	0.074*
HH Size	0.666	0.017	3.96	0.000***
Constant	-0.966	0.693	-1.39	0.163
Lambda	-0.585	0.338	-1.73	0.084*

Source: Field Survey *** Significant at 1%, significant at 5%

Note: Dependent variable: Adoption of improved seeds. Number of observation=203.

Wald chit (5) =66.27 and pro > chi^2=0.000

4.5 Effects of Adoption on Output

The main objective of this study was to investigate the effect of improved seed adoption on rice output. In other words, the study sought to find out whether the adoption of improved rice seeds leads to increased output as opposed to the traditional varieties, other things being constant. From table 4.5, not only was the adoption significant but it maintained its expected positive sign confirming our *a priori* expectation that the adoption of improved rice seeds leads to increased output. This is consistent with the findings of Wiredu et al (2010); Uaiene, et al, (2009); Sserunkuuma (2005).

It can also be observed from the table that apart from seeds, all the other variables were significant and maintained their positive sign. The sum of the coefficient of the conventional inputs is 0.76, implying that there was decreasing returns to scale. A 100% increase in land led to a 26 % increase in output while a 100% increase in labour led to a 21% increase in output. Also, a 100% increase in fertilizer led to a 24 % increase in output.

The significance of lambda (λ) in Table 4.5 implies that selectivity bias was present in our model and that if this was not corrected, the estimated coefficients including the adoption variable would have been bias. Thus, we could not have measured the pure effects of the explanatory variables on output. However, the correction of the selectivity problem ensured that the estimated coefficients were freed from the effects of unobserved factors that correlated with the adoption variable. The estimated Wald chi-square is 66.27 at 1%

significant level. This indicates the appropriateness of the estimated model and that, the explanatory variables jointly determine the adoption of improved rice variety.

Table 4.5: Maximum Likelihood Estimates of treatment effect model-two step estimates

Variable	Coefficient	Standard Error	Z	P >|Z|
Farm Size	0.255	0.122	2.09	0.036*
Labor	0.212	0.628	3.38	0.001***
Seeds	0.550	0.801	0.69	0.492
Fertilizer	0.240	0.055	4.38	0.000***
Adoption	1.419	0.535	2.65	0.008***
Constant	3.237	0.431	7.50	0.000***

Source: Field survey ***, significant at 1%, ** significant at 5%, * significant at 10%

Note: Number of observation= 205, Wald chi^2 (5) = 66.27, Prob > chi^2 = 0.000

CHAPTER FIVE:

CONCLUSIONS AND RECOMMENDATIONS

5.0 Summary

Although the annual production of most crops in Ghana has been increasing, this is largely due to the expansion of the land area (ha) put under cultivation, rather than yield variations (t/ha). Improved seed adoption is one way of changing this trend. Several existing literature focus mainly on the development of conceptual frameworks of adoption and the determinants of adoption of new technologies but fails to explicitly establish a causal relationship between agricultural technology adoption and output. The objective of this study was to identify the effect of the adoption of improved rice seed variety on rice farmers' output.

This study used secondary data from the Statistical, Research and Information Directorate (SRID) of the Ministry of Food and Agriculture (MoFA) in conjunction with the Ghana Strategy Support Program (GSSP) of the International Food Policy Research Institute (IFPRI). Information on a total of 407 rice farmers from Ghana' was sorted and used. The analysis of the data involved the estimation of a treatment effect model; this is a two-step model that allows the estimation of the adoption and the output functions simultaneously.

From the results, all the variables, except age and age squared were significant. However, whereas household size and education had a positive effect on the probability of adoption, farm size and extension service had a negative effect on adoption. This means that larger household farmers, highly educated farmers, farmers with smaller farm sizes and farmers without extension contacts had a higher probability of adopting improved seed variety. In the second stage of the treatment effect model where the output function was specified, adoption was found to have a positive effect on output. Other significant and positive factors were farm size, labour and fertilizer.

5.1 Conclusion

While rice is driven by improved seed adoption, farm size, labour and fertilizer application, improved seed adoption is driven by formal education and household size. Smallholder farmers may not have much problem with the adoption of improved seeds, rather their access to the complementary factors are a big issue as they often find it difficult competing with their counterparts with large farms.

As indicated earlier, the findings of this study are consistent with that of many studies that evaluated the effects of the Asian Green revolution that took place in the early 1960s (Johnson *et al* 2003; Janvry and Sadoulet, 2003; Evenson and Gollin, 2000; Hazell and Ramsamy, 1991). These studies found that with complementary inputs like fertilizer, irrigation and insecticides, the improved varieties of rice and maize did far better than the traditional seeds. The net effects of the Green revolution was that many countries that were hitherto net rice importers became net exporters leading to overall increased world output. Proponents of GR argued further that with expanded market as a results of export, farmers had the opportunity to increase their output, leading to increase income and for that matter poverty reduction. On the other hand, critics argued that the GR led to income inequalities in favour of large-scale farmers who had access to the complementary inputs. They stressed that since the high yielding varieties of rice and maize could not do well without the complementary inputs, little or no access on the part of poor small-scale farmers meant that they were often out-competed and marginalized by their well-to-do counterparts, leading to a further widening of the gap between them (Cleaver, 1972; Gadgil and Guha, 1995; Todaro and Smith, 2003). The implication then is that for the former to also benefit from the adoption of improved seeds, there should be conscious and affirmative efforts to support them in accessing the complementary inputs. As indicated earlier, SSA and for that matter, Ghana, missed out of the initial Green revolution. However, with support from AGRA through the instrumentality of Kofi Annan, a former UN Secretary-General, the revolution has been re-introduced into the country. For the revolution to succeed this time, there is the need to correct the mistakes associated with the first one. Currently in Ghana, the fertilizer subsidy programme that was removed some years back has been restored. However, not only is the price of the input the same for all farmers, the mode of sale is such that large-scale farmers can have greater access to the disadvantage of small scale farmers. In the long run, if this is not checked the consequence would be that some small scale-farmers may buy the input at a higher price.

Fortunately, in this study the probability of adoption was greater for small-scale farmers. Since they constitute over 90% of the farming population (MoFA, 2010), they need to be supported. However, the fact that output increased with farm size means that we cannot relegate large-scale farmers to the background. Generally both groups of farmers must be supported but there should be a conscious effort to ensure that large-scale farmers do not enjoy at the detriment of small scale farmers.

5.2 Recommendations

It is recommended that farmers should be supported with more fertilizer subsidization. Fertilizer subsidy should not be erratic as we are experiencing now, so that we can measure the full benefits of its implementation.

Also farmers should be encouraged to form groups to help themselves on the field especially during labour scarcity period.

Government should collaborate with Chiefs to design a modality for easy access to land for the purpose of farming.

Additionally the fundamental problem of illiteracy could be addressed through the introduction of night school in farming communities.

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