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Economic Efficiency and Productivity of Maize Farmers in Ghana

By

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DECLARATION

I, **Camillus Abawiera Wongnaa**, the author of this thesis (**Economic Efficiency and Productivity of Maize Farmers in Ghana)** do hereby declare that with the exception of references of other authors' work, which were duly acknowledged, the research work in this thesis is original and to the best of my knowledge contains no work previously published by another person nor work which has been accepted for the award of any other degree.

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DEDICATION

I joyfully dedicate this work first of all to my parents, Mr. Nicholas Wongnaa and Ms. Agatha Poxiemah, and then to my siblings and Mrs. Elizabeth Dwomo-Fokuo, former Director of Institute of Entrepreneurship and Enterprise Development of Kumasi Polytechnic, Ghana. Your love, encouragement, sacrifices and prayers saw me through.

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ABSTRACT

In spite of the economic importance of maize, its productivity is still low in Ghana. This study examined the economic efficiency and productivity of maize farmers to shed light on the causes of low productivity of maize in Ghana. Multi-stage sampling technique was employed to collect crosssectional data from 576 maize farmers in eight districts in four agro ecological zones of Ghana. Multinomial logit model and the stochastic frontier production function were the methods of analyses adopted in addition to descriptive statistics. The study revealed that an increase in educational level, credit, extension contact, experience, price of maize, group membership and ready market would increase use of maize productivity enhancing technologies. Also, fertilizer, pesticides, manure, herbicide, seed and land inputs were found to be positively related to maize output. With technical efficiency scores of 61.2%, 70.2%, 49.9% and 66% for maize farmers in the northern savannah, transitional, forest and coastal savannah zones respectively, it is most economical to produce maize in the transitional belt of Ghana. Generally, educational level, experience, income, extension contact, male gender, group membership, credit, household size, ready market as well as use of fertilizer, pesticides and improved seeds would increase the technical efficiency of maize farmers in Ghana. Whereas fertilizer, herbicides, pesticides, manure and land were underutilized by farmers, capital was over utilized. The scale efficiency analysis revealed that the overall mean scale efficiencies were 85.7%, 90.9%, 88.6% and 85.5% for maize farmers in the northern savannah, transitional, forest and coastal savannah zones respectively. Generally, it can be concluded that an increase in educational level, experience, access to good roads, extension contact, household size as well as use of fertilizer and improved seeds would increase the scale efficiency of maize farmers in Ghana. Policies aimed at addressing the efficiency challenges of maize farmers in Ghana should be targeted more at improving technical efficiency.

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LIST OF ACRONYMS

AAEA	Agricultural and Applied Economics Association
AEAs	Agricultural Extension Agents
AUC	African Union Commission
CIMMYT	International Maize and Wheat Improvement Center
CEA	Cost Effective Analysis
CEE	Central and Eastern European Countries
COLS	Corrected Ordinary Least Squares
CRS	Constant Returns to Scale
CSIR	Council for Scientific and Industrial Research
DEA	Data Envelopment Analysis

EIU	Economist Intelligence Unit
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GSS	Ghana Statistical Service
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
MFC	Marginal Factor Cost
MFP	Multi-Factor Productivity
MiDA	Millennium Development Authority
ML	Maximum Likelihood
MLE	Maximum Likelihood Estimation
MLM	Multinomial logit model
MOFA	Ministry of Food and Agriculture
MPM	Multinomial probit model
MPSS	Most productive scale size
MRTS	marginal rates of technical substitution
MVP	Marginal Value Product
MVs	Modern Varieties
NAAD	National Agricultural Advisory Service
NEPAD	New Partnership for Africa's Development
NPK	Nitrogen Phosphorous Potassium
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares

PBA	Partial Budgeting Analysis
RTS	Rate of Technical Substitution
RECs	Regional economic communities
RoG	Republic of Ghana
SARI	Savannah Agricultural Research Institute
SFA	Stochastic Frontier Analysis
SFP	Single Factor Productivity
SSA	Sub-Saharan African
TFP	Total Factor Productivity
UBoS	Ugandan Bureau of Statistics
VIF	Variance Inflation Factor
WLS	Weighted Least Squares

CHAPTER ONE INTRODUCTION

1.1 Background

The importance of the contribution of agricultural growth to economic growth, poverty alleviation, GDP, employment and incomes in Sub-Saharan African (SSA) countries cannot be overestimated. Because agriculture is critical for the overall process of social and economic development of the region, it is crucial that SSA countries take steps to grow and develop the sector. For this objective to be achieved, governments, institutions and other stakeholders in SSA have devised strategies aimed at increasing agricultural production. And a very important factor that will help sustain an increase in agricultural production is an increase in agricultural productivity driven by use of agricultural production technologies and increase in economic efficiency. This is the more reason why improvement in agricultural productivity in SSA has been recognized in economic development, poverty alleviation and food security literature of the region (Ajao, 2011). Expected rise in demand for agricultural products coupled with population growth and increasing per-capita incomes needs a continuous rise in agricultural productivity. Agricultural productivity varies due to variations in technology employed, variations in the environment in which production takes place and differences in how efficient the production process is.

Maize is one of the important crops in the world especially in developing economies (including Ghana) which is a source of livelihood to millions of households (Tewodros, 2001). It is important, both as a source of food for man and animals and is also a source of raw materials for a great number of industrial products (James, 2003). With regard to area cultivated and total production, it is the most important cereal in the world after wheat and rice (James, 2003). With the growing economic importance of maize worldwide, it has become the number one staple and cash crop for a great number of farmers (Manyong et *al*, 2000). For over nine hundred (900) million poor people and over one-third of all malnourished children, maize is the number one staple. Added to this is the fact that the demand for maize in developing countries was projected to increase by 72% between 1997 and 2020. This increase in demand represented 213 million metric tonnes of maize for the period (James, 2003). Also by 2025, maize was projected to become the crop with the greatest production volume worldwide (CIMMYT and IITA, 2010).

From an African perspective, maize ranks first as a cereal grain of the greatest economic importance, ahead of wheat and rice ranking second and third places respectively (Thobatsi, 2009). At the Abuja Summit in December 2006 on Food Security in Africa, maize was identified among other crops[1], by Heads of State and Government in Africa as a commodity that can help achieve food security and also reduce poverty on the continent. The summit therefore urged countries in Africa, the African Union Commission (AUC), the New Partnership for Africa's Development (NEPAD) as well as regional economic communities (RECs) to assist in the promotion of maize production on the African continent so that selfsufficiency would be achieved by 2015 (AUC, 2006). For maize production to be given a boost in Africa, the summit realized the importance of understanding the variations in maize production on the continent. Therefore, an investigation into the factors that affect and streamline the changing patterns in maize production in sub-regions is critical to enacting policies that would improve the production and marketing of maize in Africa.

Notwithstanding the fact that natural conditions in Ghana favour agricultural production, domestic supply still lags behind demand, making the country food insecure (Wolter, 2008). It is therefore not surprising that Ghana still depends greatly on food imports (Wolter, 2008). Currently, Ghana's agricultural product supply according to the Ministry of Food and Agriculture, meets just 50% of domestic meat and cereal needs and 60% of domestic

[1] The other commodities of strategic importance include legumes, cotton, oil palm, beef, dairy, poultry and fish.

fish intake (MOFA, 2010). While Ghana is achieving self-sufficiency in starchy staples like plantain, yam and cassava, production of maize is nowhere near demand (EIU, 2007; RoG, 2007). With a greater proportion of maize supply going into food consumption in Ghana, an increase in its productivity is undoubtedly crucial for achieving food security in the country. As a major constituent of livestock and poultry feed, the productivity and development of the poultry and livestock industries depend on the maize value chain. In the medium term, the demand for maize in Ghana was expected to grow at an annual rate of 2.6% (MiDA, 2010). The unfortunate thing is that Ghana is self-insufficient in the production of this commodity crop. There is therefore, the urgent need for measures to be taken to improve productivity and aggregate production of maize so that Ghana's unending demand for maize would be met and food security in general would be improved (MiDA, 2010).

Empirical literature suggests that farmers in developing economies are not able to make use of the potential of a technology, thereby making inefficient decisions resulting from various reasons of which management capacity reigns paramount. Presently, policy makers have began believing that a crucial source of agricultural sector growth in every country is technological progress and increase in economic efficiency by farmers in response to improved access to education and information. Technological progress and improvement in economic efficiency are key to improving agricultural productivity especially in developing countries agriculture, where inputs are inadequate and opportunities for introducing and using improved technologies have currently began falling (Okoboi, 2011; Kuwornu et *al*, 2012).

1.2 Problem Statement

Accounting for over 50% of total cereal (maize, rice, sorghum and millet) production in Ghana, maize is the most important staple crop in the country (MiDA, 2010; MOFA, 2012). It is widely cultivated and serves as a major source of food and cash income in Ghana

(Tachie-Obeng et *al*, 2010). Maize is the number one crop in Ghana in terms of area planted (GSS, 2008; MOFA, 2013). For instance, the total area under maize cultivation in 2012 was about 1,042,000 hectares and production was estimated at 1,950,000 metric tons (MOFA, 2013). The crop is a major source of employment for many households in farming communities in the country. A nationwide survey carried out in 2005/2006 revealed that about 2.5 million households harvested maize in Ghana during the 2005 cropping season (GSS, 2008). Maize contributes significantly to consumer diets (Tahirou et *al*, 2009) as it is nutritious containing 80% carbohydrate, 10% protein, 3.5% fiber and 2% mineral (IITA,
2001; Khawar et *al*, 2007). With a wide variety of food such as porridges, 'kenkey', 'banku', 'tuo zaafi', etc, Ghanaians consume maize as a starchy base. The hunger gap after the dry season is filled by eating green maize which is fresh on the cob either roasted, boiled or baked. Starch from maize grain is a raw material for making noodles and confectioneries. Maize syrup which is rich in fructose can act as a sweetener and moisturizer for many kinds of foods.

In spite of the aforementioned economic importance of maize, productivity of its production is low. For instance, land productivity is estimated at a third of its potential yield per hectare (OECD, 2008 cited in Wolter, 2008). In the year 2010, the Crops Research Institute of Ghana also estimated the average yield of maize under rain fed conditions for smallholder maize farmers in Ghana to be 1.7 metric tonnes per hectare. This is less than 30% of the estimated potential yield of 6.0 metric tonnes per hectare for the same year (MOFA, 2010). With increasing population, demand for maize will continue to be on the higher side and expected rise in demand for maize requires a continuous increase in maize production fuelled by increase in maize productivity (CIMMYT and IITA, 2010). With maize production being a major source of food for most Ghanaians, a decline in maize productivity could threaten household food security in Ghana. This is because it was estimated that the shortfall between domestic production and domestic consumption would reach 267,000 metric tons by 2015 in case there is no productivity improvement (MiDA, 2010). Furthermore, beyond these projected figures for household consumption, there is considerable unfulfilled demand for processed maize uses and for the growing poultry and livestock feed sectors within Ghana (MiDA, 2010). If nothing is done about the status quo, maize productivity will continue to be low or even decline further. When that happens, it will aggravate the food insecurity and poverty situation among small holder farmers. Meanwhile agricultural productivity can be improved with improvements in farmer use of improved production technologies and economic efficiency (Addai, 2011; Kuwornu et *al*, 2012). Therefore, an empirical study to understand the key drivers of use of improved maize production technologies as well as technical, resource-use and scale efficiencies among small holder maize farmers in different agro-ecologies will provide relevant information that will help address maize productivity challenges in Ghana. This has given rise to the need to investigate measures that will help improve the productivity of maize production by smallholder maize producers in Ghana. Specifically, the main questions the study sought to answer included:

1. What are the levels of use of different maize technologies in Ghana and what factors influence the use of these technologies?
2. What is the technical efficiency of maize producers in Ghana and what factors influence the technical efficiency of maize producers in Ghana?
3. What are the efficiencies of use of resources in maize production in Ghana?
4. What is the scale efficiency of maize producers in Ghana and what factors influence the scale efficiency of maize producers in Ghana?

1.3 Objectives of the Study

The main objective of the study was to investigate the factors that influence use of productivity enhancing technologies and economic efficiency of maize farmers in Ghana. Specifically, the study sought:

1. To quantify the effects of the factors that influence use of productivity enhancing technologies by maize farmers in Ghana.
2. To estimate the technical efficiency and quantify the effects of the factors influencing the technical efficiency of maize farmers in Ghana.
3. To estimate the resource use efficiency among maize farmers in Ghana.
4. To estimate the scale efficiency and quantify the effects of the factors influencing the scale efficiency of maize farmers in Ghana.

1.4 Justification of the Study

Since maize is the main staple food in Ghana, high efficiency and productivity in its production are critical to ensuring food security in the country. The government has been investing in agricultural development but most households remain food insecure. That is, given the fact that domestic supply has not been able to meet up with domestic demand, there is the need to examine those factors that affect the efficiency and productivity of maize production so that appropriate policies could be made. Efficiency is also a very important factor of production growth in an economy where resources are scarce and opportunities for new technology are lacking. The study will provide information to government policy makers and other stakeholders in the maize sub-sector and will benefit small scale farmers not only in the study area, but in other areas as well. In this way, poverty and food insecurity will be reduced by encouraging even non-farmers to engage in maize production.

With economic efficiency being a possible source of productivity improvement, the current study sought to determine the efficiency of resource-use (Tambo and Gbemu, 2010). That is, the study contributes to the understanding of resource use efficiency in smallholder maize producing farms in Ghana, while contributing to the empirical literature with respect to African agriculture and Ghanaian agriculture in particular. Also, although the subject of technical and scale efficiencies is important, few studies have focused on these areas. Understanding the levels of inefficiency/efficiency can help address productivity gains if there are opportunities to improve socio-economic characteristics and management practices.

Low use of improved technologies is also often cited as the major reason for the above productivity gap. Since 1998, only four nationwide improved input use studies including Morris et *al* (1999), Doss and Morris (2001), Ragasa et *al* (2013) and Chapoto and Ragasa (2013) have been done on maize in Ghana. To determine improved input use levels and better understand the constraints and incentives for use of maize production technologies, there is the need to investigate the factors influencing use of productivity enhancing technologies in maize production.

Finally, this study is unique in the sense that unlike previous studies on productivity improvement which examined the different improvement components (improved inputs use and efficiency) independently, this study examined them together. It was also carried out across four agro ecological zones in Ghana (Northern savannah, Transitional, Forest and Coastal savannah zones). For example, Seidu (2008), Abatania et *al* (2012), Wongnaa and Ofori (2012), Kuwornu et *al* (2012), Shamsudeen et *al* (2013), Sienso et *al* (2013) and Kuwornu et *al* (2013) each examined efficiency in one agro ecology. Similarly, Yengoh et *al* (2010), Akudugu et *al* (2012) and Mohammed et *al* (2012) also concentrated on technology use in a single ecology. The current study therefore allowed for a comparison in improved inputs use, efficiency and productivity levels between maize farmers in different agro ecological zones which is very important for policy makers in their design of specific policies aimed at improving use of maize production technologies, efficiency and productivity in different agro ecological zones of Ghana.

1.5 Scope of the Study

The study was to investigate the reasons behind the low productivity of maize production in Ghana by investigating the determinants of use of productivity enhancing technologies and economic efficiency in maize production in Ghana. It covered four agroecological zones of Ghana namely northern savannah, Transitional, Forest and Coastal savannah zones. The target respondents were maize farmers of the selected districts in the aforementioned agro ecological zones.

1.6 Organization of the Study

This thesis is organized in five chapters. Chapter one provides the background information, problem statement, objectives of the study, justification of the study, scope of the study and organization of the study. Chapter two presents literature relevant to the study. It comprises use of agricultural productivity enhancing technologies, agricultural productivity, resource use efficiency in agriculture, technical efficiency among smallholder farmers and scale efficiency among smallholder farmers. The third chapter presents the characteristics of the study area, data collection and details of the methodology used to achieve each specific objective. Chapter four presents the results and discussions, while chapter five presents the summary, conclusions drawn from results discussed, and the recommendations resulting from the study.

CHAPTER TWO LITERATURE REVIEW

2.1 Introduction

This chapter presents literature relevant to the study. It begins with theory of agricultural technology use, agricultural productivity enhancing technologies and the factors influencing their use as well as a review of methods of analysing the determinants of use of improved inputs. Theory of agricultural productivity improvement as well as definition, measurement, determinants and analysis of agricultural productivity are also presented. This is followed by the concept of economic efficiency comprising resource use efficiency, technical efficiency and scale efficiency which concludes the chapter.

2.2.1 Theory of Agricultural Technology Use

The theory centers on the use of improved technologies and the dissemination of the technologies among farming communities. Agricultural productivity enhancing technologies comprise physical objects like herbicides, pesticides, seeds, fertilizer, etc as well as modern methods of farming. The production technology may not necessarily be new as such, but novel to the farmer. A new technology is defined as an idea, a production method, or an object that is perceived as novel to an individual or other user units (Rogers, 2003). From a farmer's perspective, Rogers (2003) finds two characteristics of technologies or innovations that excellently explain different rates of use of improved inputs. These include the perceived relative benefits derived from using the technology vis-à-vis existing technologies, and the perceived compatibility of the new technology with existing societal values, needs and experiences (Rogers, 2003). Also, Rogers observed that technologies or innovations are more likely to be used if they are less complex, give room for trialling and whose outcomes are noticeable by others.

According to Sunding and Zilberman (2001), technology use could be measured by making reference to either the timing or the extent of utilization of a new technology by individuals. Rogers (2003) however defined *diffusion* as the process in which a technology or innovation is disseminated or communicated through certain media or channels over time among the individuals of a social system. There are three levels involved in the timing of use of improved inputs and diffusion, viz: the farmer's decisions process (i.e whether or not to use a technology), the farmer's innovativeness with regard to when exactly to use in the diffusion process and the rate of use of technologies in the system (Rogers, 2003). The extent of use can also be measured by the intensity of cultivation with regard to number of farmers using a particular technology, total area cultivated as well as area within farms (CIMMYT, 1993).

Two studies on use of technologies have emerged (Marra et *al*, 2003). Sociologists have paid so much attention to the characteristics of the users, the users' perceptions of the technology or innovation, rates of use and channels of communication in the decision process. The seminal work by Zvi Griliches' of the dissemination or diffusion of hybrid maize was one of the pioneering economic studies in this field which shifted the emphasis towards economic variables as the most important factor influencing technology use (Griliches, 1957). Since the publication of the Griliches study, S-shaped diffusion curves have become prominent (Sunding and Zilberman, 2001). In this theory, technologies or innovations are first used by few early users. Then rates of use increase as the technology is used by the majority before it slows again as very few remaining members of the social system use the technology or innovation (referred to as laggards) (Rogers, 2003). That is, diffusion or dissemination studies have concentrated on the differences between early and late users of a technology or innovation, the perceived characteristics of a technology or innovation that influence its use rate and why many early users should be present for a technology or innovation to be popular among members of a social system.

It has been proven by experience that not all new technologies or innovations will be right in every situation, but rather their suitability depends on how well they fit the particular farming situation (CIMMYT, 1993). However, many improved input use studies concentrated on individual farmers (i.e farmers' socio-economic characteristics, such as landholding, wealth, education, etc) and the characteristics of the technologies or innovations, instead of the situation under which technology use and diffusion take place (Marra et *al*, 2003). Improved input use process is a dynamic one, not only with regards to the diffusion of new technologies or innovations over time and space, but also from the viewpoint of the individual member of the social system. Consequently, the willingness and ability to use new technologies or innovations, the relative magnitudes of the determinants and the concomitant needs for support may change over time (CIMMYT, 1993).

It is important to note that use of technologies or innovations is not necessarily a binary decision. Instead, use intensity may change over time. This may happen if farmers learn a lot about the technology or innovation in question and also if conditions are favourable such that farmers now have better access to production resources (CIMMYT, 1993). Evidence of a technological ladder can also be made mention of. Kaliba et *al* (2000) reported that most improved input use studies had reported that smallholder farmers have a tendency of using simple technologies or innovations first before considering more complex ones, while inexpensive technologies may be used before the more expensive ones. Moreover, researchers continue to recognize the need to view agricultural technologies as a package where smallholder farmers may use components at particular times and speeds (Feder and Umali, 1993).

2.2.2 Classification of Agricultural Productivity Enhancing Technologies

According to Knight et *al* (1972), agricultural productivity enhancing technologies could be classified into four main types, namely biological, chemical, mechanical and management. The study also grouped biological productivity enhancing technologies into new crop varieties like disease resistant varieties, high yielding varieties and varieties that are drought resistant. Chemical modern technologies include chemical fertilizer, fungicides, pesticides, herbicides and insecticides while mechanical technologies consist of farm machinery and implements for irrigation, tillage, weed control, disease and pest control as well as transport of inputs and outputs. In defining management as knowledge a farmer gets from decision-making, Knight et *al* (1972) argue that it should be considered a productivity enhancing technology even though its measurement may be difficult because it is known to accumulate over time. This is necessary since management actually puts together all the aforementioned technologies in their right proportions before the desired ouput could be produced. Also, effective management is associated with improved firm performance as it raises total factor productivity, profitability, growth and survival.

2.2.3 Determinants of use of Agricultural Productivity Enhancing Technologies

Langyintuo and Mekuria (2005) classify the determinants of use of productivity enhancing technologies as: characteristics of the farmer, institutional factors and input characteristics. Characteristics of the farmer include but not limited to age, gender, educational level and family size while institutional factors comprise being a member of a farmer group, area cultivated, access to production and marketing information, whether or not farmers received credit and access to road and storage infrastructures. According to Adesina and Zinnah (1993), input characteristics refer to the farmer's perception of the qualities of a particular input.

2.2.3.1 Farmer Characteristics that influence Agricultural Technology Use

Gender influences farmer use of productivity enhancing technologies like improved seeds and animal traction. Socio-economic conditions like restrictions on access to land and poverty, in which women find them selves influence their production patterns and their use of productivity enhancing technologies in agriculture (Appleton and Scott, 1994). Added to this is the finding of Appleton and Scott (1994) that female's notion of productivity enhancing technologies depends on their assessment of risk levels in such a way that if the risk is thought to be high, then use of productivity enhancing technologies will fall. Gender was therefore recommended by Langyintuo and Mekuria (2005) as one of the variables to be considered in improved input use research by noticing that provision of extension services which is critical in use of productivity enhancing technologies, is normally organized by men who are in most cases partial towards fellow men even though women dominate African agriculture. Making gender one of the variables in improved input use studies is important because women-headed farm families are relatively poor compared to male-headed ones (UBoS, 2010). Meanwhile, 72% of women who are employed and 90% of women living in rural areas work in agriculture (IFAD, 2000). Morris et *al* (1999), Doss (2001) and Asante (2013) stated that, in Ghana, even though no significant difference exists between rates at which men and women use productivity enhancing technologies in their maize farms, rates of use of row planting and improve maize varieties have been significantly lower among female farmers than among male farmers. Kassie et *al* (2010) and a review of literature on use of improve maize technologies by Kafle (2010) also revealed a positive relationship between gender (males) and use of productivity enhancing technologies. The review however added that it was very difficult to explain since not many studies had considered the gender variable. Studies by Doss and Morris (2001) in Ghana and Overfield and Fleming (2001) in Papua

New Guinea however revealed no significant influence of gender on use of improved inputs. Chirwa (2005) in Malawi also found similar results by concluding that the gender of the farmer is not a significant determinant of use of productivity enhancing technologies both with respect to improved maize varieties and inorganic fertilizers. The effect of gender on use of maize production technologies according to existing studies is therefore skeptical and further studies on the variable could clarify its direction.

Mixed results have been reported by studies that analyzed the influence of age on use of productivity enhancing technologies in agriculture. Whereas Adesina and Baido-Forson

(1995) in Burkina Faso and Guinea, Doss and Morris (2001) in Ghana as well as Etoundi and Dia (2008) in Cameroon reported direct relationships between age and use of agricultural technologies, Langyintuo and Mekuria (2008), Simtowe et *al* (2009), Cavane and Subedi (2009) and Kassie et *al* (2010) reported inverse relationships. Improved input use studies in Nigeria including Lawal and Oluyole (2008), Akramov (2009) and Tabi et *al* (2010) also reported an inverse relationship between age and use of productivity enhancing technologies. Reasons given for the varied results of the effect of age on use of productivity enhancing technologies are that under certain circumstances, young producers have lesser income and wealth, restricted access to extension services and credit and may encounter inadequate labour supply, all of which will likely make them unprepared to employ productivity enhancing technologies vis-a-vis older farmers, and as a result, making age being positively related to use of productivity enhancing technologies (Langyintuo and Mekuria, 2005). Conversely, Langyintuo and Mekuria (2005) reported that younger farmers are in most cases exposed to change and therefore are quite risk lovers who are willing to test new approaches to doing things, resulting in an inverse relationship between age and use of productivity enhancing technologies. Also, because younger farmers are more energetic, they tend to use labourintensive technologies such as compost manure application than their aged counterparts.

Both positive and negative influences of education on use of productivity enhancing technologies have been reported in the agricultural technology use literature. Positive relationships between education and use of improved inputs were reported by Nkonya et *al* (1997), Ntege-Nayeena et *al* (1997), Iqbal et *al* (1999), Morris et *al* (1999), Nkamleu and Adesina (2000), Langyintuo and Mekuria (2005), Nzomoi et *al* (2007), Paudel and Matsuoka (2008), Tabi et *al* (2010), UBoS (2010) and Asante (2013). The importance of education of farmers in their use of productivity enhancing technologies is discussed extensively in the literature. According to Langyintuo and Mekuria (2005) and Tabi et *al* (2010), farmers with many years of education are thought to have greater ability to notice, explain the meaning and respond to new information about productivity enhancing technologies than their counterparts with less number of years of education. Farmers who have received formal education are therefore able to access information from extension agents, which affect their use of production technologies. Furthermore, UBoS (2010) reported that educational level and the producer's economic status, that influence ability to purchase and use productivity enhancing technologies, are to a larger extent positively related, most especially for farmers in less developed economies. The implication is that educated farmers are expected to be more efficient to understand and obtain new technologies in a shorter period of time than uneducated ones. Also, Rogers (2003) notes that the complexity of a technology often poses a negative effect on improved input use and that education is thought to reduce the amount of complexity perceived in a technology thereby increasing its use. Conversely, negative influence of education was also observed in some studies. For instance, Tura et *al* (2010) stated that families headed by educated people were relatively less likely to use recommended maize varieties, given the fact that the relatively more educated household heads are youngsters and that land ownership among the youth is minimal thereby making them land constrained. It was similarly reported in Ethiopia that education influences timing of use but not whether to use an agricultural innovation (Weir and Knight, 2000b). Etoundi and Dia (2008) also observed that farmers having secondary education were less likely to use the improved maize seeds, CMS 8704. However, having a primary level of education was found to have a positive though not significant effect on the use of CMS 8704 improved maize seeds.

According to Kafle (2010), it is not easy to give a broad view of the effect of household size on agricultural technology use because both positive and negative influences have been noticed in previous studies. Whereas Amaza et *al* (2007), analyzing the influence of family size on the extent of use of maize productivity enhancing technologies reports an inverse correlation, Ntege-Nanyeena et *al* (1997), Perz (2003), Amaza et *al* (2007), Etoundi and Dia (2008), Tabi et *al* (2010) as well as Asante (2013) report a direct correlation. The reasons given for the inverse correlation was that large households especially those living in villages are impoverished and the little money they have are mostly expended on basic necessities of life, leaving little or no money for buying production inputs. Conversely, a large-size family may allow use of productivity enhancing technologies such as pesticides and fertilizer which are labour intensive (Perz, 2003). Therefore, if labour is supplied by the family member, use of productivity enhancing technologies is likely to be positive. However, Mohammed et *al* (2012) found no significant influence of household size on use of maize production technologies in Northern Ghana.

2.2.3.2 Institutional Factors that influence Agricultural Technology Use

The influence of institutional factors like area cultivated, access to credit, information and infrastructure as well as membership of a farmer association on farmers' use of productivity enhancing technologies has been greatly recognized. For bulky technologies like animal traction or tractor, farmers with huge acreages of land will likely employ them vis-avis those with small farms (Langyintuo and Mekuria, 2005). An improved input use study conducted by Doss and Morris (2001) in Ghana revealed a positive correlation between size of area cultivated and use of maize production technologies. The work of Mwinjilo (1994) revealed that not many Malawian farmers used a tractor for tillage since it needed at least three (3) hectares to be profitable and most of the farmers there had less than three hectare farms. Other studies that reported positive correlations between farm size and use of agricultural production technologies are Nkonya et *al* (1997) in Tanzania, Iqbal et *al* (1999) in India, Morris et *al* (1999) in Ghana, Langyintuo and Mekuria (2008) in Mozambique, Simtowe et *al* (2009) in Malawi, Tura et *al* (2010) in Ehiopia, Akudugu et *al* (2012) in Ghana and Asante (2013) in

Ghana. However, for other technologies like fertilizer, improve varieties, etc, Boahene et *al* (1999) in Ghana and Zhou et *al* (2010) in China reported negative correlations between use of agricultural technologies and area cultivated. Etoundi and Dia (2008) also explained that increasing farm size diminishes the probability of use of improved seed varieties. The reason was that a big sown area with maize requires much manpower and huge resources. The aforementioned studies therefore suggest mixed relationships between area cultivated and use of productivity enhancing technologies.

Generally, most agricultural technology use studies have reported positive relationships between access to credit and use of agricultural production technologies. For instance, improved input use studies conducted by Kaliba et *al* (2000) in Tanzania, Kamara (2004) in Kenya, Amaza et *al* (2007) in Nigeria, Nzomoi et *al* (2007) in Kenya, Langyintuo and Mekuria (2008) in Mozambique, Paudel and Matsuoka (2008) in Nepal, Tura et *al* (2010) in Ethiopia, Adejobi and Kassali (2013) in Nigeria and Akudugu et *al* (2012) in Ghana revealed positive relationships between access to credit and use of improved agricultural production technologies. This means that access to credit is important for use of agricultural production technologies. This is because access to credit is known to reduce the liquidity constraints that farmers normally face in purchasing production inputs and hence allows for timely application of production inputs thereby increasing overall productivity and farm income (Mpawenimana, 2005). Moreover, the work of Hailu et *al* (2014) showed that farm households who have credit access, keeping other things constant, have 9.9% and 24.5% higher probability of using chemical fertilizer and improved seeds respectively unlike farmers that are credit constrained. The study added that as a liquidity factor, the more farmers have access to sources of finance, the more likely they will adopt agricultural technologies that could possibly increase crop yield. MOFA (2010) also reported that high levels of poverty among farmers as well as poor access to credit make it very difficult for them to purchase and apply productivity enhancing technologies. This is especially so because the high cost of most improved technologies makes it difficult for most farmers, for instance those living in villages where poverty is widespread to be able to afford and use them (Benin et *al*, 2009).

In almost all improved input use studies, contact with agricultural extension service has been found to have a positive effect on use of agricultural technologies (Kaliba et *al*, 2000; Amaza et *al*, 2007; Langyintuo and Mekuria, 2008; Paudel and Matsuoka, 2008; Tura et *al*, 2010; Akudugu et *al*, 2012). Akudugu et *al* (2012) for instance, observed that access to extension services by farm households in Ghana would increase their probability of using modern agricultural technologies by 30.9%. The aforementioned studies explained that regular extension contact makes farmers aware of new improved technologies and how they are applied. Furthermore, a study by Yaron et *al* (1992) showed that extension contact can offset the negative effect of little or no formal education on use of some technologies, thereby positively impacting on technology use. There is no doubt that most agricultural technologies reach farmers through extension agents. According to Strauss et *al* (1991) as well as Langyintuo and Mekuria (2005), access to information on productivity enhancing technologies in agriculture by farmers through stakeholder financial support for extension programmes is important in assessing the benefits of using such technologies, and consequently, decreasing the biased uncertainty under certain circumstances and promoting greater use in other circumstances. Empirical research in this field including Strauss et *al* (1991) and Akromov (2009) among others also reported a positive correlation between access to extension services and use of productivity enhancing technologies. Asante (2013) however found mixed relationships between extension contact and use of irrigation technologies (manual pump, ground water motor pump and surface water motor pump) in a study into the use and profitability analysis of irrigation technologies in Ghana. The study found that whereas a 1% rise in extension contact would cause a 21.18% and 20.47% decline in uses of manual pump and ground water motor pump irrigation technologies respectively, a 1% increase in extension service would increase use of surface water motor pump irrigation technology by 36.46%.

It is an established fact that road and storage infrastructures play a key role in the agricultural production process. Roads play the role of facilitating access to input and output markets and storage facilities are needed to maintain the quality of harvested produce so that immediate sale could be deferred to a later date. According to Jansen et *al* (1990), Strasberg et *al* (1999), Ransom et *al* (2003) and Kamara (2004), access to the aforementioned infrastructures increases the probability of use of agricultural productivity enhancing technologies. In Bangladesh for instance, the work of Ahmed and Hossain (1990) revealed that improvement in rural infrastructure greatly increased the extent of use of agricultural productivity enhancing technologies like fertilizer, high yielding seed varieties and irrigation. Studies by Kafle (2010), Sserunkuuma (2005) as well as Langyintuo and Mekuria (2008) also revealed negative relationships between distance to the market and use of agricultural production technologies. For instance Langyintuo and Mekuria (2008), in assessing the influence of neighborhood effects on the use of improved agricultural technologies in developing agriculture, found that a 1% increase in the distance to inputs and output markets will decrease the probability of use of improved agricultural technologies by 0.4%. Salasya et *al* (2007) however found a positive relationship between market distance and use of hybrid maize in Kenya. The implication is that farmers do not necessarily buy production inputs from the nearest stockists.

2.2.3.3 Factor Input Characteristics that influence Technology Use

The features of production inputs have an effect on the perception of farmers and eventually the choice of production resources for the production of a particular crop. Characteristics put forward include: safety-risk features, consumptive qualities, farmer trials; and resources endowed by the farmer (Smale et *al*, 1995, 2001; Hintze et *al*, 2003). Smale et *al* (1995) observed that Malawian farmers preferred planting of traditional maize varieties vis-a-vis hybrid ones due to their ease of processing and on-farm storage features. Zeller et *al* (1998) reported that the productivity risk connected with use of certain seed varieties, for instance, their resilience to adverse climate, diseases and pest attack, has been proven to have a significant effect on farmers' use of the seeds. The study added that the risk attached to income connected with likeness of markets for certain qualities may also affect use of productivity enhancing technologies by farmers. If a technology is expensive or capital intensive, using it will likely have a negative effect on expected benefits of the production activity and therefore farmers will be reluctant in using such a technology. Adesina and Zinnah (1993) as well as Adesina and Baidu-Forson (1995) also observed that it was important to note the role of farmers' opinions of grain processing and cooking features of modern rice varieties on their use.

Five characteristics of an improved technology were identified by Rogers (2003) as the factors that influence the intensity of use of an improve technology. Those characteristics included: divisibility, relative advantage, complexity, compatibility and observability.

2.2.4 Estimation Methods for Improved Input Use Studies

Empirical studies that analyzed the factors influencing use of productivity enhancing technologies frequently used OLS and categorical choice regression estimation techniques. The estimation technique depends on whether the dependent variable is a categorical or a continuous variable. OLS regression is preferred if the dependent variable is a continuous variable. For a categorical dependent variable, probit, logit or tobit regression is generally used (Gujarati, 2004). According to Bekele and Drake (2003), the multinomial logit or multinomial probit models are usually employed when the parts of the dependent variable are put together in the consumption decisions of the consumers.

Kamara (2004) employed the OLS regression to examine the factors influencing farmers' use of inorganic pesticide, fertilizer and high yielding seed varieties in maize farming in Kenya. Nkamleu and Adesina (2000) used a probit model to analyze the influence of socioeconomic characteristics on the probability of farmers' use of inorganic fertilizer and pesticides in Cameroon. Nzomoi et *al* (2007) also used a logit model to examine the factors influencing technology use in horticultural export crops production in Kenya. The tobit model was also used by Strasberg et *al* (1999) to examine the determinants of farmers' use of inorganic fertilizers in Kenya. Kassie et *al* (2010) used the multinomial logit model to analyze the determinants of use of organic farming methods in Ethiopia. Doss and Morris (2001) applied the probit model to analyze how gender affects the use of agricultural innovations in Ghana. Also in Ghana, Asante (2013) used the probit model to study use of smallholder irrigation technologies in Ghana.

2.3.1 Definition and measurement of Agricultural Productivity

Productivity is generally defined as the ratio of output to input (OECD, 2001). Usually, inputs and outputs are measured in a standard unit. For agricultural productivity, it is the value of agricultural output per unit value of input(s) employed in production (OECD, 2001).

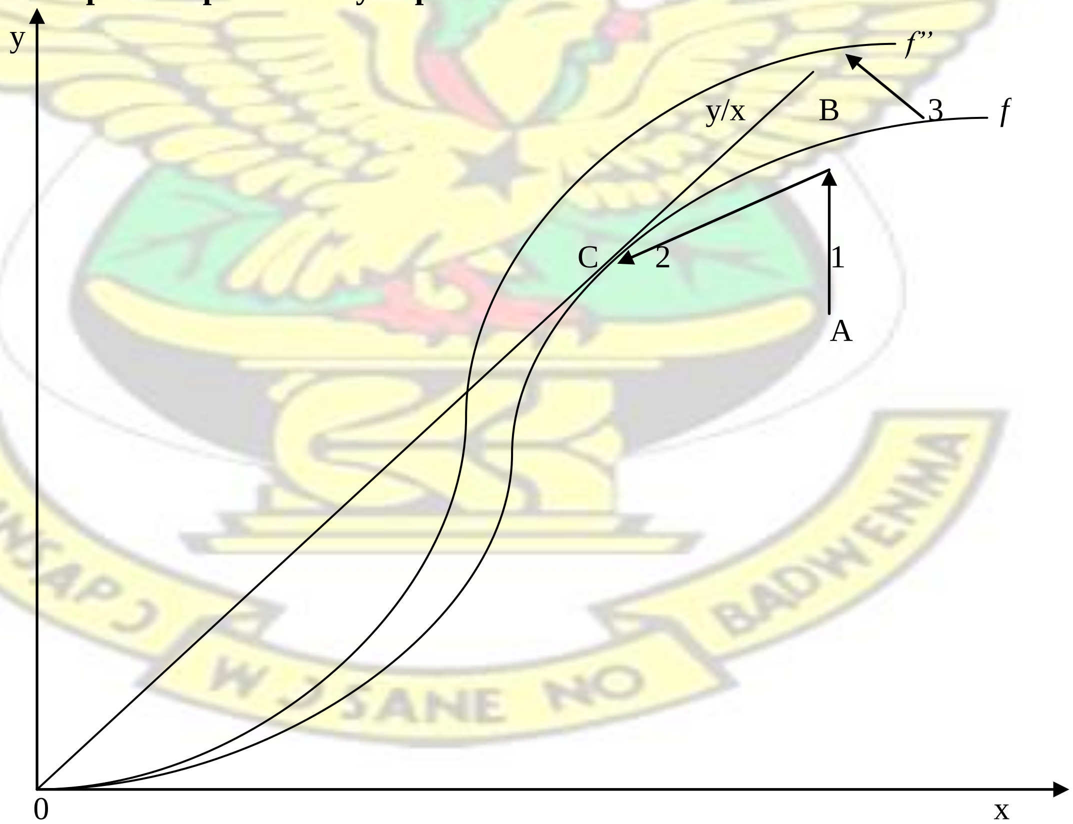
Agricultural productivity measures are twofold, viz: single factor productivity (SFP) and total factor productivity (TFP) measures (Wiebe et *al*, 2001; OECD, 2001). Single factor productivity measure is a measure of output to one input and total factor productivity is a measure of output to a collection of inputs (Wiebe et *al*, 2001). Land productivity is the most common indicator of agricultural productivity and is defined as the quantity of output per unit land area employed in the production of a given agricultural product (Wiebe et *al*, 2001). Conversely, labour productivity is the quantity of agricultural output per unit of labour used in production. Another important measure of agricultural productivity is gross profit although it is not very common in the literature because of unavailability of data required for its computation (Kelly and Murekezi, 2000).

2.3.2 Theoretical Framework for Productivity Improvement

Productivity improvement can be of three kinds, viz. efficiency increase, exploring economies of scale and technological progress.

In comparison with other firms, productivity improvement can result from optimal use of the existing technology. In figure 2.1, firm *A*, for example, would be able to use the same input to produce more output, that is to say it could use its input in a more efficient way. This is depicted by a movement from *A* towards the frontier *f*, parallel to the *y*-axis (movement 1). The movement could also be parallel to the *x*-axis and would correspond to a decrease in input use while the same output is produced.

Figure 2.1: Three possible productivity improvements for firms



Source: Based on Coelli et *al*, 2005.

A second productivity improvement for a firm when compared with other firms can be achieved by exploiting economies of scale. Potential economies of scale can be identified by the scale elasticity, calculated as the ratio of the proportionate increase in output to the proportionate increase in all inputs. At point *C* the elasticity of scale is one and therefore firm *C* has an optimal scale. Firm *B* by contrast has an elasticity of scale less than one and therefore exhibits diseconomies of scale, while a firm situated on the left of *C* would have scale elasticity greater than one and hence exhibit economies of scale. Exploiting economies or diseconomies of scale is therefore a productivity improvement, characterised by a movement on the frontier *f* (movement 2 for example).

The third possibility of productivity change refers to the long term and is called technological change. Technological progress, that is to say improvement in the state of technology, happens for example when a new and higher performing production or transformation process is available on the market. It results in an upward shift of the production frontier from *f* to *f* '(movement 3). This progress should be able to apply to all firms (assuming that they all have the same access to the new technology), and implies that they would be able to produce more using the same level of input. On the other hand, technological regress, for example due to a deterioration of worker qualifications, would imply a downward shift of *f* and therefore a decrease in the output produced per input used.

2.3.3 Factors that influence Agricultural Productivity

The factors influencing the productivity of a farmer can be divided into three, namely the physical inputs employed (capital, land and labour), characteristics of farm and farmers and factors that are external to the farmer such as climatic conditions as well as government and institutional policies (Wiebe et *al*, 2001). Capital inputs employed consist of herbicide, fertilizer, seed, pesticide as well as farm tools and implements. On the other hand, characteristics of the farm and farmer comprise factors such as topography and size of land cultivated, distance of farm from input and output markets, level of education, age, gender, family size, access to credit and extension contact. Soil conditions and weather factors including temperature, rainfall and humidity constitute the climatic conditions (Michele, 2001).

Fertilizer is one of the important inputs in crop production, especially maize. It has been confirmed by most studies in developing countries to have a positive significant effect on crop productivity (World Bank, 2007), even though there are mixed results on the influence of fertilizer on total revenue (Kelly, 2006). For instance, agricultural productivity studies by Reardon et *al* (1997), Evenson and Mwabu (1998), Strasberg et *al* (1999), Fan and Chan-Kang (2005) and Tittonell (2007) revealed that there was a positive relationship between fertilizer input and crop productivity. Productivity studies on maize by Addai (2011), Ragasa et *al* (2013), Sienso et *al* (2013) and Shamsudeen et *al* (2013) in Ghana also reported a positive effect of fertilizer on maize productivity. Addai (2011) and Sienso et *al* (2013) for instance reported a 1.4% and 16.2% respectively rise in maize output in Ghana for a 1% rise in fertilizer quantity. Kuwornu et *al* (2013) in their study of technical efficiency of maize production in the Eastern region of Ghana however reported a negative impact of fertilizer on the output of maize. Kelly and Murekezi (2000) also found that whereas use of fertilizer in some parts of Rwanda was unprofitable for certain crops such as cowpea and sorghum, it was profitable for potatoes and maize. The mixed results for the effect of fertilizer on profitability is not surprising since profit is influenced by other external factors such as market price of inputs and outputs whose determination is almost always beyond the farmer. Productivity could go up due to fertilizer use but when price of output is very low due to glut, profits will also be low. Indeed, some farmers who do not apply fertilizers at all can still have high profits especially when they produce during the lean season when food commodity prices are very high. So profitability depends on the crop in question and also on the market price of inputs and outputs.

The World Development Report of 2008 on Agriculture clearly states the importance of improved seed varieties on improving crop productivity in developing countries (World Bank 2007). Meanwhile, literature on the influence of improved seed varieties on labour productivity and profit is scanty. Japhether et *al* (2006) studied a comparison of the profit, yield and labour resources of farmers that used improved seed varieties to those that used traditional seed varieties in Kenya and found a significant higher productivity for farmers that used improved modern varieties but lower productivity of labour because of the labour intensive nature of application of fertilizer in use of improved modern seed varieties. However, significant difference in gross profit of the producers was not found by the study for producers using recycled hybrid seeds compared to those that used certified hybrid seeds.

A nationwide improved input use study conducted by Morris et *al* (1999) in Ghana reported that, of all the production inputs employed in agricultural production, none affects productivity more than improved certified seed. If farmers can obtain improved seeds that perform well under local conditions, the efficiency with which other inputs are converted into economically valuable outputs increases and productivity rises. Use of improved seeds therefore serves as the catalyst for use of improved crop management practices. This is the main reason why the Ghana Grains Development Project (GGDP) placed such a heavy emphasis on plant breeding research. CSIR trials have also proved that improved seeds have higher rates of germination and higher productivities than seeds saved by farmers. For instance, in 2005, certified Obatanpa seed resulted in a 7% to 9% higher productivity than farmer-saved seeds in Kwadaso and Ejura experimental plots of Ghana (CRI, 2005 cited in Ragasa, 2013).

Herbicides control weeds faster than manual weeding. When farmers weed manually, it takes them many weeks to control weeds. This leads to competition between weeds and crops, thereby reducing productivity. To reduce this competition, farmers have resorted to the use of herbicides which control weeds faster. Use of herbicides and fungicides in the management of weeds in Kenya for instance, led to an increase in the productivity of cowpea and maize vis-à-vis the use of the hoe (Muthamia et *al*, 2001). Studies by Kuwornu et *al* (2012), Shamsudeen et *al* (2013), Sienso et *al* (2013) and Oppong (2013) in Ghana as well as Sserunkuuma et *al* (2001) in Uganda have also given evidence of the positive influence of herbicides on crop productivity. Oppong (2013) for example reported that, in Ghana, a 1% increase in the amount of herbicide will cause maize productivity to increase by 0.091% *ceteris paribus*. North American Forestry empirical work also examined the influence of use of herbicides on forest productivity improvement and found a 30 to 300% rise in the productivity of wood for relevant marketable trees (Wagner et *al*, 2004). Notwithstanding the numerous benefits of herbicide use in crop production, its negative impact on human health and the environment has made its use in crop production a very controversial issue (Miller, 2002). Herbicides have had a positive significant influence on crop productivity in the short run by reducing pest damage, competition for plant nutrients and water from weeds as well as provision of many plant nutrients in a form that is easily absorbed by crops. In the long term, herbicide use can lead to serious soil infertility problems because the natural processes of decomposition of organic matter into plant nutrients by some beneficial microbes in the soil are disrupted as the microorganisms are gradually killed by herbicides. Also herbicides kill beneficial insects such as aphids and lady bugs that are normally used for biological control of pests in crop farms. Moths, spiders, butter flies and bees that play a key role in increasing agricultural productivity by pollinating crops are also sometimes killed by herbicides (Kughur, 2012). Moreover, some of the negative impacts of use of herbicides on humans include damage to the nervous, reproductive and immune systems, interference with hormone function as well as developmental abnormalities. Infants drinking breast milk normally ingest herbicide residues if their mothers eat vegetables and fruits that were sprayed with herbicides (Jurewicz and Hanke, 2008). Oladejo and Adetunji (2012) in

Nigeria however reported that herbicide usage does not have a significant impact on crop productivity.

Both positive and negative influences of farm size on productivity of crops, especially maize are found in the literature of agricultural productivity analysis. Studies conducted by Shamsudeen et *al* (2013), Sienso et *al* (2013), Oppong (2013) and Bempomaa and Acquah (2014) have reported significant positive impacts of size of land cultivated on the productivity of maize cultivation in Ghana. The works of Sienso et *al* (2013), Oppong (2013) and Bempomaa and Acquah (2014) for instance revealed 5.3%, 0.201% and 1.29%

respectively increases in maize outputs for the respective aforementioned studies in Ghana.

Fan and Chan-Kang (2005), in a study into farm size, productivity, and poverty in Asian agriculture as well as Goni et *al* (2007) in an analysis of resource-use efficiency in rice production in Nigeria also revealed positive correlations between farm size and agricultural productivity. The positive impact of land under crop cultivation on agricultural productivity is not surprising since farmers with large farms explore economies of scale. However, Pender et *al* (2004), Okoye et *al* (2008), Stifel and Minten (2008), Masterson (2007) as well as Byiringiro and Reardon (1996) reported that there is a negative relationship between area under crop production and productivity. Farmer's resources are scarce and may not be able to meet the requirements of large farm lands that they cultivate. Farmers are therefore unable to provide for and apply key production inputs such fertilizer, herbicides, pesticides, improve seeds, etc. thereby resulting in low productivity.

The impact of characteristics of the farm and farmer on agricultural productivity is recognized in the analysis of agricultural productivity. For instance, a direct influence of access to extension on agricultural productivity has been reported (Bravo-Ureta and Evenson, 1994; Evenson and Mwabu, 1998). These studies however found mixed results for the effect of educational level on productivity. Whereas Evenson and Mwabu (1998) found education to be positively related to yield, Aguilar (1988) cited in Evenson and Mwabu (1998) reported negative effects. Positive because educated farmers easily appreciate, understand and adopt improved technologies that are transferred to them thereby increasing crop productivity. The negative effect of education is also because education allows farmers to secure other jobs apart from farming which somehow draws their attention away from farming activities to non-farm activities. Meanwhile Bravo-Ureta and Evenson (1994) reported no statistical significance of education to crop productivity. Research attention has also been given to the influence of gender and household size on agricultural productivity. Agricultural productivity is positively related to household size (Bravo-Ureta and Pinheiro, 1997; and Iheke, 2008).

Udry (1996) reported that female farmers in Burkina Faso are less productive than their male counterparts. The study however found that the differences in productivity resulted from allocative instead of technical inefficiency of farms that were managed by women, given that farms managed by men had higher fertilizer and labour inputs. Insignificant positive effect of gender (male farmer) on productivity was also reported by Saito et *al* (1994) in Kenya. Empirical studies conducted by Dormon et *al* (2004) on the determinants of low crop productivity in Ghana also revealed other socio-economic causes of low productivity, including the level of producer prices paid to farmers, difficulties in accessing credit, high cost of labour, and high interest rates charged by money lenders

2.3.4 Estimation of Agricultural Productivity

According to Kumbhakar and Lovell (2002), Coelli and Prasda (2003) and Coelli et *al* (2005), approaches to estimating production functions is two fold namely, parametric and non-parametric approaches. Parametric method estimates production functions econometrically by specifying an appropriate production function while the non-parametric method applies a linear programming technique such as Data Envelopment Analysis to the estimation of production functions (Kumbhakar and Lovell, 2002).

Translog, Cobb-Douglas, stochastic frontier and quadratic functional forms are some of the parametric methods used in productivity studies. Prior to the 1980s, the Cobb-Douglas function was the major analytical tool for productivity studies and even today is still relevant notwithstanding its limitation concerning the restrictions to constant returns to scale and elasticity of substitution equal to one (Coelli et *al*, 2005). As a solution to the restrictions on the Cobb-Douglas functional form, the quadratic and translog functional forms were formulated. The major limitation of the latter models is that they are prone to multicollinearity problems and inadequate degrees of freedom because of the interaction terms they have (Coelli et *al*, 2005). Moreover, Abdulai and Huffman (2000) assert that the interaction terms in the translog production function have no economic meaning.

As a remedy to the challenges encountered by the Cobb-Douglas, translog and quadratic production functions, the stochastic frontier production function came into existence (Aigner et *al*, 1977; Meeusen and van den Broeck, 1977). This function has remained popular in productivity analysis since the latter part of the 1980s. There are two parts of the stochastic frontier production function, viz. the stochastic component and the inefficiency component. In this methodology, both the stochastic and inefficiency components can be estimated simultaneously using the maximum likelihood estimation procedure (Wang and Schmidt, 2002; Kumbhakar and Lovell, 2002). Earlier on, a two-step ordinary least squares procedure was employed to estimate the variables representing the stochastic components separately from the variables representing the inefficiency component. For instance, Bravo-Ureta and Pinheiro (1997) employed the ordinary least squares procedure to estimate the stochastic variables and the tobit model to estimate the inefficiency variables. The disadvantage of the two-step approach is that it is not consistent in its assumption concerning independence of the inefficiency effects. This is because the specification of the second stage regression in which the technical efficiency scores are hypothesized to be related to the explanatory variables, disagrees with the hypothesis that $u_i's$ are independently and identically distributed. Many agricultural productivity studies including Rahman (2003), Kolawole (2006), Oladeebo and Fajuyigbe (2007) as well as Hyuha et *al* (2007) among others, have employed the stochastic frontier analysis procedure and most especially, using the method of maximum likelihood. Shamsudeen et *al* (2013), Sienso et *al* (2013), Bempomaa and Acquah (2014) and Oppong (2013) also conducted technical efficiency studies in Ghana by employing the stochastic frontier analysis approach.

The stochastic frontier analysis procedure comes with its weaknesses and strengths when it is compared with the non-parametric Data Envelopment Analysis (DEA) procedure. In their book, "An Introduction to Efficiency and Productivity Analysis", Coelli et *al* (2005) presented the weaknesses and strengths of the stochastic frontier analysis procedure as follows:

Weaknesses

1. The selection of the distributional form for the inefficiency effects may be arbitrary, but generally, distributions such as the truncated-normal and gamma are the best.
2. The production technology must be specified by a particular functional form, for which the flexible functional forms are recommended.
3. The stochastic frontier approach is only well-developed for single output technologies, unless one is willing to assume a cost-minimizing objective.

Strengths

1. DEA assumes all deviations from the frontier are due to inefficiency. If any noise is present (e.g., due to measurement error, weather, diseases, etc), this may influence the

placement of the DEA frontier (and hence the measurement of efficiencies) more than would be the case with the stochastic frontier analysis.

2. Tests of hypothesis, regarding the existence of inefficiency and also regarding the structure of the production technology can be performed in a stochastic frontier analysis.
3. DEA approach produces biased estimates in the presence of measurement error and other statistical noise but this problem is absent in stochastic frontier analysis.

4. Stochastic frontiers are more appropriate than DEA in agricultural applications, especially in developing countries where the data are heavily influenced by measurement errors and the effects of weather, disease, etc.

2.4 Efficiency of Resources Use in Agriculture

For maize farmers to be helped to increase productivity, the focus should not only be on whether or not they have used productivity enhancing technologies but it is necessary to carefully examine whether they are even making maximum use of the technologies or inputs available to them. This will convince stakeholders in the maize subsector that the improved inputs they may have planned to introduce to the farmers will be utilized efficiently to help boost maize production in the country. Therefore, it is important to determine the efficiency of resource use in smallholder maize production in Ghana so that government and individuals interested in investing in maize production in Ghana will know the levels at which production inputs should be employed in order for them to achieve desired outputs (Tambo and Gbemu, 2010). This is because apart from studies conducted by Amankwah (1996) and Sienso et *al* (2013) on resource use efficiency in maize production in Ghana, no other economic study has considered the subject in the country even though it has been done for other crops (Tambo and Gbemu, 2010; Kuwornu, et *al*, 2012; Nimoh and Asuming-Brempong, 2012; Wongnaa and

Ofori, 2012; Danso-Abbeam et *al*, 2015), making literature on resource use efficiency in maize production in Ghana very limited.

However, resource-use efficiency in maize production is common in other parts of the world, especially neighbouring Nigeria. Jirgi et *al* (2007) in a study into the profitability and resource use efficiency in maize production in Kontagora Local Government Area, Niger State, Nigeria found that farm size, labour and fertilizer were over utilized, while other inputs and capital inputs were underutilized. Gani and Omonona (2009) studied the resource use efficiency among small-scale irrigated maize producers in Northern Taraba State of Nigeria. The empirical results showed that fertilizer, seeds, labour and land were underutilized whereas water (the key variable) was over utilized. Taiwo et *al* (2011) also analyzed the efficiency of resource use in hybrid and open-pollinated maize production in Giwa LGA of Kaduna State, Nigeria. The findings were that fertilizer and insecticides were underutilized whereas seeds, labour and herbicides were over utilized. In a similar study, Kehinde et *al* (2012) conducted a study into the resource-use efficiency in Quality Protein Maize (QPM) production in Kaduna State, Nigeria. In this study, the results showed that whereas fertilizer, family and hired labour were over utilized, land and seeds were underutilized. The allocative efficiency analysis by Rupasena (2014) in a study into the resource use efficiency of maize (*Zea mays L.*) production in Mahawali "H" Area of Sri Lanka showed that profitability can be increased by increasing land, seed and fertilizer as well as reducing use of agrochemicals and labour. Zongoma et *al* (2015) studying resource use efficiency in maize production among small-scale farmers in Biu Local Government Area, Borno State Nigeria observed that maize production can be improved if resources like fertilizer, labour and farm size are adequately utilized. Sanusi (2015) in optimization of resource use efficiency in small-scale maize production in Niger State, Nigeria reported under utilization of inputs such as farm size, improved seed, fertilizer and capital items.

Apart from the limited literature on the subject of resource use efficiency in maize production in Ghana, no study has analysed resource use efficiency in any crop at the national level, making literature on comparison of resource use efficiency in agricultural production in different agro ecological zones limited. This study, among other objectives, analyses and compares the resource use efficiencies of maize farmers in different agro ecological zones of Ghana.

2.5 Technical Efficiency among Smallholder Farmers

Technical efficiency is a component of economic efficiency and reflects the ability of a farmer to maximise output from a given level of inputs (e.g. output-orientation). One can trace back the beginning of theoretical developments in measuring technical efficiency to the works of Debreu (1959). Since then, however, there has been growing literature on the technical efficiency of smallholder agriculture. Notable works focusing on smallholders include Basnayake and Gunaratne (2002), Barnes (2008), Duvel et *al* (2003), Shapiro and Muller (1977) and Seyoum et *al* (1998).

Most studies have associated farmers` age, farmers` educational level, access to extension, access to credit, agro-ecological zones, land holding size, number of plots owned, farmers` family size, gender, tenancy, market access, and farmers` access to improved technologies such as fertilizer, agro-chemicals, tractor and improved seeds with technical efficiency. Farmers` age and education, access to extension, access to credit, family size and tenancy as well as farmers access to fertilizer, agrochemicals, tractors and improved seeds are reported by many studies as having a positive effect on technical efficiency (Amos, 2007; Ahmad et *al*, 2002; Tchale and Sauer, 2007; Basnayake and Gunaratne, 2002). The influence of educational level on the efficiency and productivity of cereals was also investigated by Weir (1999). The results of this study showed considerable importance of farmer education in enhancing efficiency and productivity even though a threshold of at least four years of schooling were required for significant influence on technical efficiency to be achieved. Weir and Knight (2000a) also studied the influence of education externalities on the productivity and technical efficiency of crop producers and found that education externalities resulted from use and dissemination of innovations that shifted out the production frontier. One shortcoming of the Weir (1999) and Weir and Knight (2000a) is that the level of formal education was investigated as the only source of variations in technical efficiency of smallholder farmers.

Studies by Amos (2007), Raghbendra et *al* (2005) and Barnes (2008) found the relationship between land holding size and technical efficiency to be positive. On the other hand, influence of the number of plots on technical efficiency has been reported by Raghbendra et *al* (2005) to be negative. This implies land fragmentation (as measured by number of plots) has a negative impact on productivity. There are conflicting results on the influence of socio-economic variables such as gender on technical efficiency. While some studies in Ghana (Kuwornu et *al*, 2013; Bempomaa and Acquah, 2014) reported that gender of the farmer has no significant influence on technical efficiency, other studies (Sienso et *al*, 2013; Shamsudeen et *al*, 2013; Oppong, 2013) found that gender plays an important role.

Technical efficiency and productivity of maize farmers in and outside a technology programme were studied and the performances of the aforementioned farmer groups were compared (Seyoum et*al*, 1998). The results of the study showed that farmers who participated in the programme were more technically efficient (94%) than those who did not participate in the programme (79%).

Townsend et *al* (1998) used DEA to analyse how returns to scale, farm size and productivity are related for South African wine farmers. These researchers found in the study that most producers operated under constant returns to scale even though the negative correlation between farm size and productivity was weak. Mochebelele and Winter-Nelson (2000) also analysed the influence of labour migration on the technical efficiency of crop producers in Lesotho. Their study revealed that households that supplied labour to mines in South Africa were less efficient than those that did not do that. Added to this is the fact that there was no statistical evidence of farm size or gender affecting efficiency of the crop producers. The authors provided evidence of the role of remittances in promoting agricultural production even though their study did not take cognizance of the influence of educational level, farming experience, access to credit facilities, contact with extension service and the extent of receipt of remittances by households that exported labour on the technical efficiency of crop producers.

Finally, the technical efficiency of rice producers in Côte d'Ivoire was studied by Sherlund et *al* (2002) and the results were that apart from the socioeconomic characteristics of farmers that influenced technical efficiency, the inclusion of environmental factors in the estimated production function caused changes in the results, with the mean technical efficiency increasing from 0.36 to 0.76. Binam et *al* (2004) analysed the determinants of technical efficiency of Cameroonian maize and groundnut producers and using a CobbDouglas production function, the authors estimated mean technical efficiencies of 77% and 73% respectively. The study also revealed the determinants of technical efficiency to be farmer's educational level, access to credit, contact with extension officers and road infrastructure. Addai (2011) also studied the Technical Efficiency of Maize Producers in three Agro Ecological Zones of Ghana and reported a mean technical efficiency of 64.1 % for maize producers in the chosen agro ecological zones. The study also found the determinants of technical efficiency of maize producers across the chosen agro ecological zones to be contact with extension agents, mono cropping, gender, age, land ownership and access to credit.

2.6.1 Scale Efficiency among Smallholder Farmers

Optimal scale of production describes a combination of resources in which elasticity of scale is one (1) and as a result, a farm exhibits constant returns to scale. That is the maximum output level that can be attained for the resources combination (Frisch, 1965). In DEA, the aforementioned definition considerably refers to the concept of MPSS (Banker, 1984). There are so many reasons why practically, farms do not exhibit constant returns to scale, viz. labour market constraints, constraints in disposing capital, land fragmentation, rigid markets for land, etc. The implication is that some degree of inefficiency can be observed in all farms.

In production, scale efficiency naturally relates to the returns to scale of the technology employed. According to Försund and Hjalmarsson (1979), scale efficiency measures the degree of closeness of a farm to optimal scale of production. Specifically, it is a reflection of Ray average productivity at the observed resource scale with respect to the optimal scale (Försund, 1996).

Estimation of scale efficiency in agriculture is common in agricultural economics literature. For many of these studies, scale efficiency is estimated non-parametrically within the DEA framework (Bravo-Ureta et *al*, 2007). Two (2) technical efficiencies are normally estimated in measuring scale efficiency by the non-parametric DEA approach, viz: technical efficiency calculated under constant returns to scale and technical efficiency calculated under variable returns to scale assumptions. From these technical efficiencies, scale efficiency is calculated by the ratio of technical efficiency calculated under constant returns to scale assumption to technical efficiency calculated under the assumption of variable returns to scale (Coelli, 1996). Scale efficiency therefore measures the importance of scale in technical efficiency determination.

Conversely, scale efficiency can be estimated parametrically by using the coefficients of the estimated function as well as scale elasticity estimations. Parametric estimation of scale efficiency is not common in the literature because a closed form measure which can be computed directly from the estimated model is not at the moment available for the more flexible functional forms, as translog specification. This is a considerable analytical limitation, notwithstanding the fact that, decades ago, Försund and Hjalmarsson (1979) proposed many scale efficiency measures within the generalised Cobb-Douglas production function framework. The approach that is normally followed in Data Envelopment Analysis cannot be transferred when a parametric method is employed (Orea, 2002; and Karagiannis and Sarris, 2005). Of course, nothing really shows that the variable returns-to-scale technology is enveloped from the constant returns-to-scale technology in the non-parametric framework.

Ray (1998) proposed a model that estimates scale efficiency by the parametric approach. By this method, a measure of scale efficiency is calculated from the parameters estimated in the production function under the variable returns to scale assumption and from scale elasticity estimations. The advantages of Ray's (1998) model are that econometrically, it is manageable and is especially appropriate for a translog production function.

Notwithstanding the advantages of Ray (1998) model, it has not been employed in most scale efficiency studies. Not long ago, this model was used by Karagiannis and Sarris (2005) to examine the Greek tobacco farms. They sampled tobacco farmers during 1991–95 and calculated technical and scale efficiencies for them. They found that, on average, the degree of technical efficiency (which varied from 64.7% to 76.2%) was lower than the degree of scale efficiency (from 90.1% to 95.9%). This would indicate that overall inefficiency may depend mainly on producing below the production frontier than on using an inefficient scale. Mo (2009) calculates scale efficiency of wheat farms in Kansas from parametric measures of technical efficiencies, but using the model illustrated by Featherstone et *al* (1997) suitable for cost functions measures and applied by the authors to non-parametric efficiency measures.

On the other hand, other studies calculated technical efficiency using both parametric and non-parametric approach, but estimation of scale efficiency is carried out exclusively using a non-parametric technique (Andreu and Grunewald, 2006; Vu, 2006; Bojnec and Latruffe, 2008). It is believed however, that scale efficiency measures obtained from parametric models might give relevant information as well as non-parametric measures about the role of scale in affecting productivity. From the foregoing, it is clear that parametric estimation of scale efficiency is not very common in agricultural production economics literature and therefore more scale efficiency studies that apply this methodology are needed to help develop the methodology.

2.6.2 Farm type, Size and Technical Efficiency

Agricultural economics debates have always concentrated on achievement of efficiency in the structure of the farm as well as area cultivated to a particular crop.

Efficiency studies that targeted Eastern European Countries were reviewed by Gorton and Davidova (2004). With regards to the studies that employed stochastic frontier analysis methodology, farms that were bigger than 150 hectares obtained higher profits (Curtiss, 2002), farms that were less than 15 hectares were inefficient (Munroe, 2001) and production scale was found to be positively related to technical efficiency (Morisson, 2000). Also, Curtiss (2002) confirmed the existence of improved technical efficiencies for individual sugar beet farms vis-a-vis company farms. Latruffe et *al* (2004) strengthened Munroe's findings by reporting that for agricultural production, farm size is positively related to efficiency. Not long ago, Alvarez and Arias (2004) also observed that area cultivated to a particular crop is positively related to the technical efficiency of the producers concerned.

2.7 The need for Economic Efficiency

Generally, efficiency has three components, namely technical efficiency, allocative efficiency and scale efficiency. Technical efficiency shows whether a firm is able to attain the maximum output from a given inputs bundle. Allocative efficiency of a firm reflects its ability to use inputs in their optimal proportions given their respective prices. That is, if its inputs maximize its profit or minimize its costs at given prices (Latruffe, 2010). Allocative efficiency implies technical efficiency, as in order to maximize its profits, the firm must first lie on the production frontier. However, technical efficiency does not necessarily imply allocative efficiency, since the combination of outputs and inputs can be optimal with respect to the production possibilities, but not be profit maximizing. By contrast, Scale efficiency explains whether or not the firm operates at an optimal size. Firms that are scale efficient operate under constant returns to scale (CRS) and have a scale elasticity of one, while scale inefficient firms could exploit scale economies or diseconomies (Coelli, 1996). Technical, scale and allocative efficiency scores multiplied by each other make up the economic efficiency of the firm (Latruffe, 2010). Therefore, it is important to note that a farmer may be technically efficient but not allocatively efficient, hence the need for economic efficiency.

2.8 Summary

Whereas extension contact as well as access to credit, road and storage infrastructures have a positive effect on farmer use of improved inputs, male gender, age, household size and educational level of farmer have mixed effects on use of maize production technologies (Doss, 2001; Langyintuo and Mekuria, 2005; Kassie et *al*, 2010; Asante, 2013). Most studies that analyzed farmer use of improved inputs employed categorical choice models such as binary logit and probit models as well as multinomial logit and probit models (Bekele and Drake, 2003; Gujarati, 2004; Kamara, 2004; Nzomoi et *al*, 2007; Kassie et *al*, 2010).

Also, whereas agricultural productivity is positively influenced by Gender (male farmer), household size, extension contact and use of improved seed varieties, its relationships with educational level as well as quantities of fertilizer, herbicide and farm size are mixed (Fan and Chan-Kang, 2005; Kelly, 2006; World Bank, 2007; Tittonell, 2007). Other socio-economic causes of low productivity include the level of producer prices paid to farmers, difficulties in accessing credit, high cost of labour and high interest rates charged by money lenders (Dormon et *al*, 2004). Analysis of efficiency and productivity of agricultural production employs either of two methodologies, viz. parametric Stochastic Frontier Analysis (SFA) or non-parametric Data Envelopment Analysis (DEA), the former being employed in the current study (Kumbhakar and Lovell, 2002; Coelli and Prasda, 2003; Coelli et *al*, 2005).

In most resource-use efficiency studies conducted in Ghana and other parts of the world, fertilizer, seeds, labour, herbicides and land were underutilized whereas water and capital inputs were over utilized (Amankwah, 1996; Taiwo et *al*, 2011; Kehinde et *al*, 2012; Sienso et *al*, 2013; Rupasena, 2014; Zongoma et *al*, 2015).

Farmers` age, educational level, access to extension, access to credit, family size, tenancy as well as farmers' use of fertilizer, agrochemicals, tractors and improved seeds are reported by many studies as having a positive effect on technical efficiency (Basnayake and Gunaratne, 2002; Ahmad et *al*, 2002; Amos, 2007; Tchale and Sauer, 2007). Also, whereas land fragmentation has a negative effect on technical efficiency, gender exerts mixed effects (Raghbendra et *al*, 2005). Addai (2011) also conducted a study into the technical efficiency of maize farmers in three agro ecological zones of Ghana and found the determinants of technical efficiency to include contact with extension agents, mono cropping, gender, age, land ownership and access to credit.

Most scale efficiency studies in agriculture have estimated scale efficiency nonparametrically within the DEA framework (Bravo-Ureta et *al*, 2007). Ray (1998) proposed an alternative parametric model within the stochastic frontier analysis framework that estimates scale efficiency. The advantages of Ray's (1998) model are that econometrically, it is manageable and is especially appropriate for a translog production function. The current study employs Ray's (1998) methodology in estimation of scale efficiency of maize farmers in Ghana.

CHAPTER THREE METHODOLOGY

3.1 Introduction

This chapter describes the study area and presents the methods of data collection and sampling procedure. It also describes the conceptual framework for economics of maize productivity improvement for the study. The chapter further presents the analytical framework for economic efficiency of maize production and the determinants of use of productivity enhancing technologies in maize production in Ghana.

3.2 The Study Area

3.2.1 Agro-ecological Zones, Climate and Soils of Ghana

Ghana is divided into six (6) agro-ecological zones. These are rain forest, deciduous forest, transitional, coastal savannah, sudan savannah and guinea savannah zones. The zoning depends on the vegetation, climate and soil characteristics of the area. Differences in amounts of rainfall and temperature depend on the interaction and movement of continental and maritime winds. Southern Ghana is made up of the rain forest, deciduous rain forest, transitional and coastal savannah zones. Rainfall patterns in these agro ecological zones are bimodal which allows for two growing seasons in the year. Northern Ghana also houses the Sudan and Guinea Savannah zones. In these zones, rainfall pattern is unimodal which allows for only one growing season in the year. Northern Ghana's one growing season is followed by the harmattan season, which refers to the hot, arid winds that blow from the northeastern part of the Sahara desert to Ghana and causes hot, arid days, and cold nights (Oppong-Anane, 2006).

Generally, annual rainfall amounts in Ghana range from 600mm to 2800mm. Annual rainfall normally decrease from the hot and moist southwest coast and north to the relatively hotter dry savannah. Meanwhile, the lowest annual rainfall occurs in the warm southeast coastal savannah zone (Oppong-Anane, 2006). Also, relative humidity appears to decline from south to north, which creates a general rise in evapotranspiration in the north relative to the south (Barry et *al*, 2005).

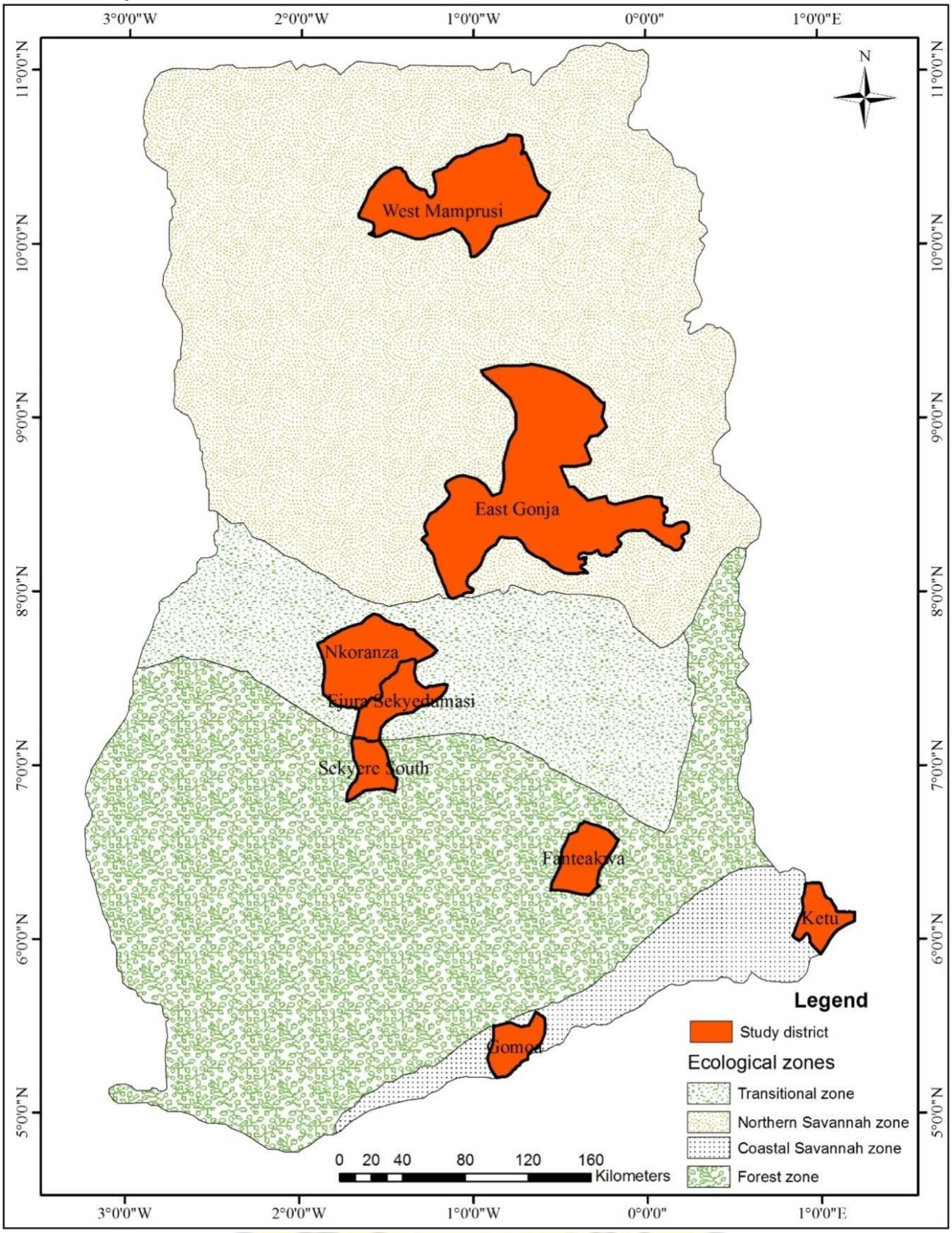
Variations in temperatures across the agro ecological zones and for that matter Ghana are however different vis-à-vis rainfall variations. As a result of Ghana's closeness to the equator as well as presence of low altitude areas, the average monthly temperature across the country seldom falls below 25^{o}C. With a mean annual temperature of 27^{o}C, the average annual minimum and maximum temperatures are 15^{o}C and 40^{o}C respectively.

Ghanaian soils originate from greatly weathered parent material (FAO, 2005). In almost all the agro ecological zones, alluvial and shallow soils are found. As a result of many human activities, naturally, most soils of Ghana are not fertile (Oppong-Anane, 2006). Southern Ghana has many Acrisols which contain large quantities of clay and aluminium and have low fertility (Bridges, 1997). Soils of the rainforest zone are dominated by Acrisols and Ferralsols and are associated with high kaolinite clay and metal oxides contents as well as low cation exchange capacity (Bridges, 1997). The southeastern part of Ghana contains different types of soils that are believed not to be suitable for crop production (Bridges, 1997). Northern Ghana has many Luvisols which is characterized by high nutrient content and good drainage (Bridges, 1997). Organic matter and nitrogen contents of soils of the savannah and transitional zones are relatively low.

3.2.2 The main study area

The main study area comprised four agro-ecological zones in Ghana, namely: Northern savannah (comprising Sudan and Guinea Savannah zones), Transitional zone, Forest zone (comprising the rain and deciduous forests) and Coastal Savannah zone. These zones are illustrated in Figure 3.1.

Figure 3.1: A Map of Various Agro Ecological Zones and District/Municipalities chosen for the study



Source: Geography Department, University of Ghana

3.2.2.1 Northern Savannah Zone

The northern savannah zone occupies most of the northern part of Ghana with a total land area of about 125,430 square kilometres. The tropical continental climate and Guinea

Savannah vegetation type strewn with several streams are seen in this area. Temperature is normally high above 35ºC with rainfall figures ranging from between 950-1300 millimetres, falling in a single rainy season beginning in April or May. The topology of the land is fairly undulating and lies entirely within the Voltaian sandstone basin with coarse lateritic upland soils and soft clay. Sorghum and millet dominate all the cereals in the northern savannah zone, but maize grown in association with small grains, groundnut, and/or cowpea is also important. Some fields are prepared by tractor, but most are prepared by hand. Maize is grown in permanently cultivated fields located close to homesteads, as well as in more distant plots under shifting cultivation (Morris et *al*, 1999).

3.2.2.2 Transitional Zone

The Transitional zone, which is located around the middle portion of the Brong Ahafo Region and the northern part of Ashanti Region, covers a total land area of about 2300 square kilometres. The climate of the place is the wet semi-equatorial type, while the vegetation is the Savannah woodland and a forest belt with several streams and rivers. The area is also characterized by soils developed over the Voltain sandstones and the topology is low lying and rises gradually. The population is about 127,000 people with rainfall figures ranging between 800-1200 millimetres, while the annual average temperature is 26ºC. The main food crops cultivated are maize, yams, vegetables, cassava, groundnut, cowpea, cocoyam and plantain. The importance of the transitioanal zone for commercial grain production cannot be overemphasized. This is because, the deep, friable soils and the relatively dispersed tree cover allows for more continuous cultivation and greater use of mechanized equipments.

Considering a trend that has been observed all over West Africa, the transitional zone has become progressively more important for maize production (Smith et *al*, 1994). This can be the results of a combination of factors, including the presence of favourable agro-ecological conditions, availability of improved productivity enhancing technologies, a relative abundance of underutilized land, and a well-developed road transport system. Maize in the transitional zone is planted in both the major and minor seasons, usually as a monocrop or in association with yam and/or cassava (Morris et *al*, 1999).

The transitional zone is an expanding zone along forest fringes where grassland is gradually replacing forest. Rainfall is in one peak in some years and two peaks in other years, although the double maximum is more common. This variation in the distribution of rainfall shows the transition nature of the zone: between the Guinea Savannah to the north and the Forest to the south. The vegetation is a degraded forest with a wide range of tall grasses. Among the surviving forest relics are *Antiaris, Phyllanthus* and *Elaeis* while *Borassus, Lophira, Daniellia, Lonchocarpus, Pterocarpus, Burkea* and *Parkia* represent the Savannah intrusions. Similarly, among the grasses, the humid zone representatives include *Pennisetum purpureum* and *Panicum maximum,* while the sub-humid zone species include *Andropogon gayanus, A. tectorum, Hyperthelia* and *Hyparrhenia* spp (Fianu et *al*, 2001).

3.2.2.3 Forest Zone

Just inland from the coastal savannah lies the forest zone. The zone, covering an area of about 135,670 km^2, is floristically divided into rain forest and semi deciduous forest and has a population of about 134,354. The climate of the place is the semi equatorial type while the vegetation is semi-deciduous forest zone with clay, sand and gravel deposits. High temperatures (20ºC to 32ºC), coupled with heavy rainfall of 1500-2200mm, which is well distributed throughout the year in the zone, promotes very rapid plant growth. The zone has an even tree canopy at 30-40 metres while emergents may attain 60 metres. Canopy trees may be deciduous in the dry season but the shrubs and trees are evergreen. A herbaceous layer which may include a few specialized grasses occurs over a variable portion of the forest floor. Compared to that of the Savannah zones, pasture resources in this zone are not very significant. Furthermore, ruminant livestock production is of minor importance as the area is not only dominated by food and tree crop farming but also associated, in some places, with heavy infestation of tsetse flies, the transmitter of sleeping sickness (trypanosomiasis). The main food crops produced are maize, yam, cassava, rice, cocoyam and plantain, while the cash crops consist of citrus, cocoa, oil palm and coffee. Maize in the forest zone is grown in scattered plots, usually intercropped with cassava, plantain, and/or cocoyam as part of a bush fallow system. Although some maize is consumed in the forest zone, it is not a leading food staple and much of the crop is sold. It is planted both in the major rainy season, beginning in March and in the minor rainy season, which begins in September (Morris et *al*, 1999).

3.2.2.4 Coastal Savannah Zone

The Coastal Savannah occupies about 20,000 km^2, and comprises the Ho-Keta Plains, the Accra Plains and a narrow strip tapering from Winneba to Cape Coast. The main climatic factor is rainfall, which comes in two peaks. March-July is the major season and SeptemberOctober, the minor rainy season. August is a dry but cloudy break during which bright sunshine may be less than two to four hours per day. Eight hours of sunshine per day occurs during the long dry season, except for the harmattan months of December to February when the haze of sand laden north-easterly winds from the Sahara prevail. The annual total rainfall is about 700 to 800mm in the Accra Plains, and slightly higher in the western half of the zone. Farmers in the coastal savannah zone mostly grow maize and cassava, in most cases as an intercrop, as their major staples. In this zone, maize is normally planted following the onset of the major rains that begin in March or April. The soils of this agro ecological zone are generally light-textured and infertile, so maize productivity is low (Morris et *al*, 1999).

In the past four decades, human activity, notably cultivation, firewood extraction and bush burning, has changed the tree cover of the Accra Plains from the forest relicts of *Ceiba, Bombax, Antiaris* and occasional *Triplochiton* and the introduced *Azadirachta*. There may also be a sprinkling of pockets of short trees and shrubs like *Albizia*, *Baphia*, *Milettia, Clausena, Lonchocarpus*, *Carissa*, *Dicrostachys* and *Xanthoxylon*. The grass cover is still dominated by *Vetiveria fulvibarbis*, but a high frequency of *Sporobolus* and *Imperata* or *Rhynchelytrum* along with *Ctenium newtonii* on lighter soils reveals the effects of overgrazing and cultivation, respectively. Gravelly soils carry *Ctenium newtonii, Brachiaria falcifera*, *Schizachyrium schweinfurthii* and *Andropogon canaliculatus* dominate grazing land in excellent condition. The more humid areas which line the northwestern boundary of the Accra Plains feature *Panicum maximum*, *Hyperthelia dissoluta* and an occasional *Andropogon gayanus* var. *bisquamulatus* as indicators of excellent grazing (Fianu et *al*, 2001).

3.3.1 Sample size determination

The research employed both primary and secondary data. The primary data employed was obtained through a cross-sectional survey conducted in the four main agro-ecological zones of Ghana (Northern Savannah zone, Transitional zone, Forest zone and Coastal Savannah zone). Farm level data for the 2014 rainy season were collected from 576 maize producers across the four agro-ecological zones of Ghana. The study used Bartlett et *al* (2001)'s sample size determination formula in the determination of the appropriate sample size. That is

$$n = \frac{t^2(p)(q)}{d^2} \qquad (3.1)$$

Where

n = sample size t = value for selected alpha level of 0.025 in each tail = 1.96 (the alpha level of 0.05 indicates the level of risk the researcher is willing to take that true margin of error may exceed the acceptable margin of error).

p = proportion of population engaged in maize production activities q = proportion of population who do not engage in maize production activities d = acceptable margin of error for proportion being estimated = 0.05 (error researcher is willing to accept).

According to the Ghana Living Standard Survey Report of the fith round (GLSS 5), 41.5% of households who harvested staple and or cash crops in the last twelve months before September, 2008 were maize farmers (GSS, 2008). Assuming 95% confidence level and 5% margin of error, the sample size was calculated as follows:

$$n = \frac{1.96^2 x 0.415 x 0.585}{0.05^2} = 373$$

These procedures result in the minimum returned sample size. If a researcher has a captive audience, this sample size may be attained easily. However, since many educational and social research studies often use data collection methods such as surveys and other voluntary participation methods, the response rates are typically well below 100%. Salkind (1997) recommended oversampling by 40%-60% to account for low response rate and uncooperative subjects". Fink (1995) stated that "Oversampling can add costs to the survey but is often necessary". Cochran (1977) stated that "A second consequence is that the variances of estimates are increased because the sample actually obtained is smaller than the target sample. This factor can be allowed for, at least approximately, in selecting the size of the sample". The sample size was therefore increased by 54.5% to correct all probable anomalies that might occur, increasing the sample size to 576 maize farmers.

3.3.2 Sampling technique and sampling procedure

Multi-stage sampling technique was employed in this study. In the first stage of the sampling design, two districts/municipalities were purposively selected from each of the four aforementioned agro-ecological zones of Ghana based on the level of maize production. The selected districts/municipalities were East Gonja and West Mamprusi (Northern Savannah zone), Nkoranza and Ejura Sekyedumase (Transitional zone), Fanteakwa and Sekyere South (Forest zone) and Gomoa and Ketu (Coastal Savannah zone). In the second stage, nine (9) villages or communities were randomly selected from each of the two districts/municipalities representing the agro-ecological zones. Table 3.1 presents the Villages or communities selected in the various districts selected for the study.

Table 3.1 Villages or communities selected in the various districts selected for the study
Source: Survey, 2015

East Gonja	West Mamprusi	Nkoranza	Ejura Sekyedumase	Fanteakwa	Sekyere South	Gomoa	Ketu
Makango	Walewale	Donkro Nkwanta	Sekyeredumase	Osino	Akrofonso	Ankamu	Akame
Salaga	Zoorini	Banofour	Ejura	Akyem Hemang	Jamasi	Nkran	Hatsukope
Masaka	Gbani	Bonsu	Ajamasu	Juaso	Abrakaso	Gomoa Amanfi	Agavedzi
Yankanjia	Porigu	Abountem	Juaho	Begoro	Agona	Bewadze	Denu
Kalande	Samani	Babiani	Tarkoso	Abompe	Bipoah	Simbrofo	Blekusu
Kpembe	Publini	Dotobiri	Durobo	Ayeikrom	Afamaso	Apam	Agbozume
Kayitypee village	Naasoro	Seseman	Asuogya	Dwenase	Hiamakyene	Takyiman	Klikor
Akyenteteyi	Tinkaya	Koforidua	Mbanaa	Saamang	Morso	Dago	Torkor
Yayayili	Yakurani	Nkoranza Zongo	Bisu	Nsutam	Wiamoase	Oguan	Viepe

Even though the proportion of maize farmers may vary for different agro-ecological zones/districts/villages, Ragasa et *al* (2013), in a study of the patterns of use of improved maize technologies in Ghana, randomly selected equal number of respondents (21) from each of 30 districts considered in the study. Stage three of the sampling procedure for the current study therefore involved systematically selecting eight (8) maize farmers from a list of maize farmers in each of the villages or communities with the aid of agricultural extension agents working in the villages or communities of the selected districts. This was done by selecting a maize farmer from the list at random and then selecting

every k^{th} (sampling interval) farmer in the list or frame. k was calculated by dividing the size of the population of maize farmers in a particular village or communty by the sample size (8).

The main data collection instruments employed in the study were the use structured questionnaires and interviews. The structured questionnaire consisted of both open-ended and closed-ended questions. The open-ended questions gave the respondents the chance to express themselves whereas the closed-ended questions on the other hand gave the respondents pre-coded responses in which the respondents selected the option they agreed most.

The questionnaire comprised four sections. The first section consisted of identification of the enumerator, the respondent as well as the district and operational area of the respondent. The second section included questions on maize producers' personal and household characteristics. The third section dealt with questions on inputs or resources employed in maize production, while the fourth section posed questions on the output of maize and its marketing.

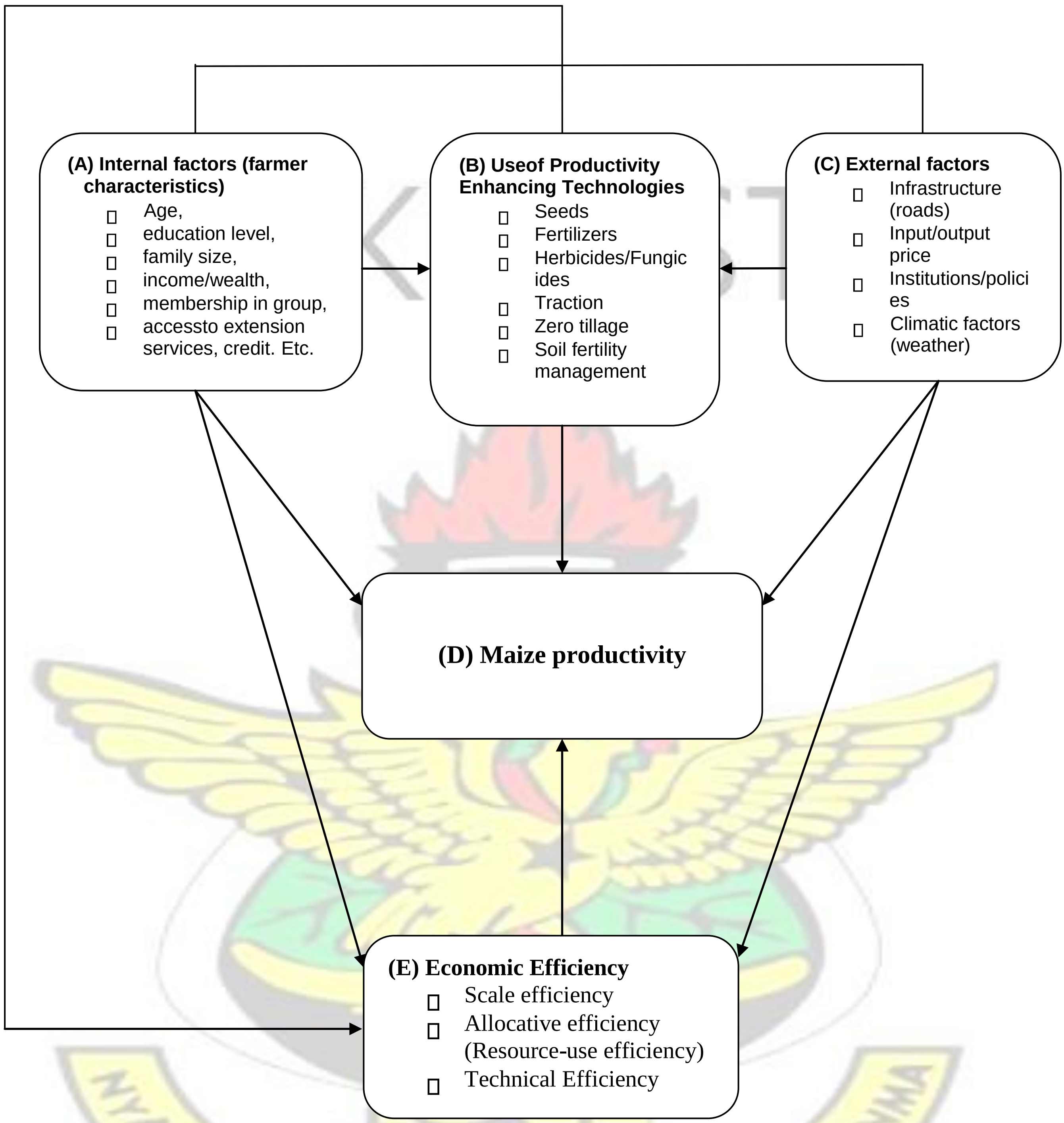
For the purpose of this project, secondary data on rainfall patterns and other relevant information were obtained from journals, books, reports, Ministry of Food and Agriculture, Ghana Meteorological Agency and the internet.

3.4 Conceptual Framework for Maize Productivity Improvement

Productivity can be defined as the ratio of value of output to the value of inputs used in producing it (Chavas *et al*, 2005). Productivity (D) growth arises from use of productivity enhancing technologies (B) and improvement in economic efficiency (E) (Latruffe, 2010; Kuwornu et *al*, 2012). As observed by Nkamleu et *al* (2003), many African farmers are still using low yielding agricultural technologies, which lead to low productivity. Also, it is always argued that, relevant question for agricultural policy makers, is whether the agricultural sector can be made more efficient, by achieving more output with the current input level, or achieving the current output with less input usage than is currently observed. An important step in answering this question is to identify the behaviour of productivity and its components.

Innovations in production systems by actors in the agricultural value chain depend on available technologies. Moser and Barrett (2003) as well as Minten and Barrett (2008) reported that Asia's Green Revolution presented the importance of use of productivity enhancing technologies in transforming present day agriculture and therefore use of improved technologies should be taken seriously by farmers in developing countries in order to boost productivity. Use of productivity enhancing technologies is reported to have significant positive effects on agricultural productivity improvement in developing countries (Nin et *al*, 2003). Agricultural transformation through the generation and application of agricultural production technologies is critical to enhancing agricultural productivity in developing countries (Mapila, 2011). The availability of new agricultural productivity enhancing technologies to farmers and the abilities of farmers to accept and use these technologies are also important. Regrettably, Ghana's agriculture is characterized by little or no use of productivity enhancing technologies and this according to MOFA (2010) is a major cause of low agricultural productivity in the country. This is a source of worry, since several attempts by successive governments have been made to encourage farmers to adopt agricultural production technologies. Addressing the problem of little or no use of technologies among producers requires the identification of the determinants of their decisions to use or not to use new agricultural productivity enhancing technologies. According to Langyintuo and Mekuria (2005), these factors are normally categorized into internal factors (A) and external factors (C). Examples of internal factors are educational level, age, gender and family size, while external factors comprise area cultivated, prices of inputs and outputs, climatic factors,

Figure 3.2: Conceptual framework of the linkage between Maize productivity Improvement, Economic Efficiency and Technology Use.



Source: Author's illustration based on theory

membership of a farmer association as well as access to credit, information and infrastructure like roads and storage facilities.

Productivity is also reinforced by economic efficiency (E). In production, efficiency can be defined in terms of resource use (that is, allocative efficiency), or achievement of the highest possible output level with a given set of inputs (technical efficiency). Economic efficiency then combines technical, allocative and scale efficiencies. With technical efficiency, a farmer must be on the highest production frontier whereas allocative efficiency denotes a balance or equality between marginal value product of input and product prices. Scale efficiency implies that firms are of appropriate size that no industry reallocation would improve output or earnings. According to Pingali and Rosegrant (1995), the factors that influence economic efficiency (E) can be grouped into improved inputs (Seeds, fertilizers, herbicides/fungicides, traction, zero tillage, soil fertility management practices) (B), internal factors (educational level, age, gender and family size) (A), external characteristics (area cultivated, input and output prices, climatic factors, membership of a farmer association as well as access to credit, information and infrastructures like storage facilities and roads) (C) and other factor inputs including land and labour. The aforementioned relationships are presented in figure 3.2. In this figure, the arrow directions illustrate the independent variabledependent variable relationships.

3.5 Analytical Framework for Maize Productivity Improvement

3.5.1 Method for Assessing Factors influencing Maize Technology Use

Several studies have analyzed determinants of farmers' use of agricultural technologies using binary choice models such as probit or logit regressions (Deininger and Okidi, 2001; Langyintuo and Mekuria, 2005; Sserunkuma, 2007 among others). However, the decision by farmers to use modern agricultural technologies like fertilizer in most cases depends on use of other complementary technologies like improved seed varieties. The implication is that the decision to use a collection of modern technologies is mutually dependent (Bekele and Drake, 2003). Use of improved seeds, fertilizer, row planting and herbicides by farmers in this study is considered and modelled as decisions that are mutually dependent.

Multinomial logit model (MLM) or multinomial probit model (MPM) is normally used to analyze mutually dependent unordered choice models (Gujarati, 2004; Greene, 2005). Bekele and Drake (2003) and Kassie et *al* (2010) are examples of studies that have used the multinomial logit model. The multinomial logit model is usually preferred by researchers to the multinomial probit model because computation of its probabilities is simple (Gujarati, 2004; Greene, 2005). The multinomial logit model is therefore used in this study to analyze the factors influencing maize farmers' use of improved seeds, fertilizer and row planting,

herbicides as well as a combination of all four technologies.

The multinomial logit model of multiple choices concerning modern technologies is stated according to Greene (2005) as: given Y_i to be a random variable which represents the preference of a production technology by famer *i*, then;

$$P_{ij} = E(Y_i = j \cdot x_i) = F(\alpha + \beta x_i), \quad j = 0,1, \ldots \ldots . .4 \qquad (3.2)$$

$$= \frac{1}{1+\sum_{j=1}^{3} e^{-z_i}}, where \ \ z_i = \alpha + \beta x_i \qquad (3.3)$$

$$= \frac{e^{z_i}}{1+\sum_{j=1}^{3} e^{z_i}} \qquad (3.4)$$

Where $P_{ij} = E(Y_i = j \cdot x_i)$ is the likelihood that maize farmer i employs production technology, *j*:*j* = 0 is the based category of not using the production technology, *j* = 1 is use of only improved seeds, *j* = 2 is use of only fertilizer and row planting, *j* = 3 is use of only herbicides and *j* = 4 is use of a combination of all four technologies. The $\beta's$ represent the coefficients of the parameters to be estimated and α is the constant term. The decision to choose j is influenced by several factors, x_i, which consist of internal factors and external factors. Using equation (3.4), the probability of not using production technology j is given by:

$$1 - P_{ij} = E(Y_i = 0 \cdot x_i) = \frac{1}{1+\sum_{j=1}^{3} e^{z_i}} \qquad (3.5)$$

The odds ratio, which is the ratio of the probability of use of the production technology to the probability of not using the technology, is given as:

$$\frac{P_{ij}}{1-P_{ij}} = \frac{\frac{e^{Z_i}}{1+\sum_{j=0}^{3} e^{Z_i}}}{\frac{1}{1+\sum_{j=1}^{3} e^{Z_i}}} = e^{Z_i} \tag{3.6}$$

The log-odds after normalizing the probabilities and adding the error term (ε) is also given as:

$$\ln\left(\frac{P_{ij}}{1-P_{ij}}\right) = z_i = \alpha + \beta x_i + \varepsilon_i \tag{3.7}$$

According to Greene (2005), by differentiating equation (3.4), we obtain the marginal effect as:

$$\delta_j = \frac{\partial P_i}{\partial x_i} = P_j\left[\beta_j - \sum_{k=o}^{J} P_k\beta_k\right] = P_j\left[\beta_j - \bar{\beta}\right] \tag{3.8}$$

The dependent variable in equation (3.7) is the ratio of log of likelihood of use of a given technology to the log of likelihood of not using the technology. For a comprehensive interpretation of the coefficients of the multinomial logit model, Gujarati (2004) and Greene (2005) suggested the derivation of the marginal effects of the independent variables. Using the conceptual framework (Figure 3.2) and emphasizing the correlation between production technologies and farmer and environmental factors, equation (3.7) can be written empirically as:

$$\begin{aligned}\ln\left(\frac{P_{ij}}{1-P_{ij}}\right) = {} & \alpha + \beta_1 \mathrm{GENDER}_i + \beta_2 HOSIZE_i + \beta_3 AGE_i + \beta_4 EDU_i + \beta_5 EXP_i \\ & + \beta_6 LANDSZ_i + \beta_7 NPLOTS_i + \beta_8 CAPgin_i + \beta_9 NOEXTVI_i + \beta_{10} MGROUP_i \\ & + \beta_{11} CREDIT_i + \beta_{12} PPRICE_i \\ & + \beta_{13} REDYMKT_i + \beta_{14} NOSAV_i + \beta_{15} TRASIT_i + \beta_{16} FOREST_i + u_i\end{aligned}$$

(3.9)

Where

The dependent variable in equation (3.9) included four (4) categories of use of improved inputs, namely, improved seeds, fertilizer and row planting, herbicides and a combination of all four technologies. If the farmer had used only improved seeds, then j = 1, 0 otherwise; j = 2 if the farmer used a combination of fertilizer and row planting technologies, 0 otherwise; j = 3 if the farmer used only herbicides, 0 otherwise; and j = 4 if the farmer used a combination of all four technologies.

GENDER = Gender of maize farmer, measured as a dummy (1 for male and 0 for female). Male farmers are less poor than female farmers (UBoS, 2006) and therefore are more likely to purchase and use production technologies. Moreover, female's perception and use of production technologies depends on their assessment of risk levels, in such a way that use of production technologies will be low if their perception of risk is high and vice versa (Appleton and Scott, 1994). Langyintuo and Mekuria (2005) also emphasized the importance of including gender in analyzing improved input use studies after observing that provision of extension services which aids use of production technologies is mainly given by men who are biased towards fellow men notwithstanding the dominance of women in African agriculture.

Male-gender is therefore expected to have a positive effect on use of productivity enhancing technologies.

HOSIZE = Household size, measured as number of family members living with maize farmer. Both small and large households may use improved inputs. This is because empirical studies like Akinola (1987) and Igodan et *al* (1988) that analyzed the influence of family size on the extent of use of production technologies reported an inverse correlation, whereas the works of Perz (2003) and Tabi et *al* (2010) reported a positive correlation.

AGE = Age of maize farmer, measured in years. Both old and young maize farmers may use productivity enhancing technologies in their maize production. This is because farmers who are old are less poor and therefore are more likely to purchase and use productivity enhancing technologies. Conversely, though less poor, farmers who are old may not be interested in using new technologies because of various reasons like inadequate knowledge (Langyintuo and Mekuria, 2005). Age of the farmer may also have an inverse relationship with use of productivity enhancing technologies because as a farmer ages, his/her ability to work hard tends to decline and this will likely adversely affect his/her use of improved inputs, especially the labour intensive ones.

EDU = Maize farmer's eduction, measured in number of years of schooling. According to UBoS (2006), more educated persons are less poor, hence are likely to purchase modern production inputs. Level of education is perceived to have a positive effect on use of productivity enhancing technologies because higher level of education allows the farmer to understand the new technology so that all doubts and uncertainties surrounding it would be cleared. The importance of education in use of productivity enhancing technologies has been discussed thoroughly in the literature. Farmers who are educated are assumed to have higher ability to notice, understand and accept new information about productivity enhancing technologies than their uneducated counterparts (Langyintuo and Mekuria, 2005; Tabi et *al*, 2010).

EXP = Maize farming experience, measured in number of years in maize farming. Farmers with many years of maize farming experience will more likely be familiar with productivity enhancing technologies in maize production and therefore are more likely to use improved inputs.

LANDSZ = Area cultivated with maize, measured in hectares. Maize farmers with large-sized farms are perceived to employ more productivity enhancing technologies. Area cultivated to maize is assumed to be positively related to use of production technologies because farmers who have devoted a greater portion of their land holdings to maize production will more likely have higher incomes which increase their purchasing power of productivity enhancing technologies.

NPLOTS = Land fragmentation, measured as a dummy (1 for owning more than one farm plot and 0 otherwise). It is expected to have an inverse relationship with use of productivity enhancing technologies in maize production even though some farmers may use it as a risk strategy.

CAPgin = Capital at the beginning of production, measured in Ghana Cedis (Gh¢). Farmers with enough capital will more likely be able to afford the cost of production technologies. Capital is therefore expected to have a positive effect on use of improved inputs.

NOEXTVI = Extension contact, measured in number of meetings of maize farmer with agricultural extension agents. Access to extension is expected to be positively related to use of maize production technologies. This is because extension agents remain the major medium of disseminating agricultural information in any country.

MGROUP = Membership of a farmer association, measured as a dummy (1 for membership of an association and 0 otherwise). This variable is expected to be positively related to technology use because farmers who belong to farmer associations have greater access to extension services (NAAD, 2005) and therefore are more likely to know about productivity enhancing technologies.

CREDIT = Access to credit, measured as a dummy (1 for access to credit and 0 otherwise). It is expected to have a positive influence on agricultural technology use because farmers with access to agricultural credit are more likely to buy and use productivity enhancing technologies.

SPMAIj12k = Selling price of maize in the previous season, measured in Ghana Cedis. Price of maize is predicted to be positively related to use of desired maize production technologies. This is because the higher the price of maize prior to the planting season, the higher the probability that farmers will be motivated to adopt usage of productivity enhancing technologies.

REDYMKT = Access to ready maize market, measured as a dummy (1 for available maize market and 0 otherwise). It is expected to have a positive influence on use of maize production technologies. This is because access to ready maize market motivates farmers to do whatever they can to increase their outputs. As a result, they are likely to purchase and use inputs that have proven to be productive.

NOSAV = Living in the northern savannah zone, measured as a dummy (1 for living in northern savannah zone and 0 for living in the coastal savannah zone). It may/may not increase/decrease use of productivity enhancing technologies.

TRASIT = Living in the transitional zone, measured as a dummy (1 for living in transitional zone and 0 for living in the coastal savannah zone). It may/may not increase/decrease use of productivity enhancing technologies.

FOREST = Living in the forest zone, measured as a dummy (1 for living in forest zone and 0 for living in the coastal savannah zone). It may/may not increase/decrease use of productivity enhancing technologies.

3.5.2 Method for Estimating Technical Efficiency and its Determinants

The stochastic frontier production function was employed to estimate the technical efficiency levels of maize farmers in Ghana. The function was also used to analyze the factors influencing the technical efficiencies of the farmers. Many years ago, econometricians estimated average production functions. As a way of bridging the gap between empirical work and theory, Farrell (1957) pioneered the possibility of estimating the frontier production functions (Aigner et *al*, 1977). Aigner et *al* (1977) and Meeusen and Van den Broeck (1977) independently proposed the stochastic frontier production function. The stochastic frontier production function is defined by;

$$y_i = f(x_i;\beta) + e_i \quad where\ i = 1,2,\ldots..,N \qquad (3.10)$$
$$e_i = v_i - u_i \qquad (3.11)$$

Where y_i represents the level of output of the ith maize farmer; $f(x_i;\ \beta)$ is an appropriate production function like Cobb-Douglas or translog production functions of vector, x_i, of inputs for the ith maize farmer and a vector, β, of parameters to be estimated. e_i is an error term which comprises two components: v_i which is a random error with zero mean,

$\mathrm{N}(0;\ \sigma^2 v,)$ and is specifically associated with random factors like measurement errors in production as well as weather factors that the maize farmer cannot control and it is assumed to be symmetric and independently distributed as $\mathrm{N}(0;\ \sigma^2 v,)$ random variables and is independent of u_i. Conversely, u_i is a *non-negative* truncated half normal, $\mathrm{N}(0;\ \sigma^2 v,)$ random variable and is linked to farm specific characteristics, which leads to the ith maize farm not achieving maximum production efficiency. u_i is therefore linked to the technical inefficiency of the maize farm and ranges from zero to one. However, u_i may have other distributions like exponential and gamma. N is the number of maize farmers that took part in the cross sectional survey.

Technical efficiency of a maize farmer is the ratio of observed output to the frontier output, given the quantity of resources employed by the farmer. Technical inefficiency therefore refers to the margin with which the level of output for the farmer falls below the frontier output.

$$\text{Technical Efficiency} = TE_i = \frac{y_i}{y_i^*} \qquad (3.12)$$
$$where\ \ y_i^* = f(x_i;\ \beta), highest\ predicted\ value\ for\ the\ ith\ farm$$

$$TE_i = Exp\,(-u_i) \tag{3.13}$$

$$\text{Technical inefficiency} = 1 - TE_i \tag{3.14}$$

According to Bravo-Ureta and Robert (1993), there are two ways of establishing the stochastic frontier production function. First, the function could be estimated using stochastic corrected ordinary least squares (COLS) if no clear distribution for the efficiency component is specified. On the other hand, if a clear distribution (exponential, half-normal or gamma) is specified, then the function is estimated by the maximum likelihood estimation (MLE) technique. According to Greene (2005), MLE makes use of the specific distribution of the disturbance term and this is more efficient than COLS. Previously, technical efficiency was estimated using a two-stage process. First, was to measure the level of efficiency/inefficiency using a normal production function. Second, was to determine socio-economic characteristics that determine levels of technical efficiency. This was done by using a probit model, with technical efficiency as the dependant variable and the socioeconomic characteristics as the independent variables. The disadvantage of the two-step approach is that it is not consistent in its assumption concerning independence of the inefficiency effects. This is because the specification of the second stage regression in which the technical efficiency scores are hypothesized to be related to the explanatory variables, disagrees with the hypothesis that $u_i's$ are independently and identically distributed. However, since 2000, the stochastic frontier and inefficiency models are jointly estimated using Limdep (Green, 2002) or Frontier computing packages, which apply MLE. Green (2002) outlines the Log likelihood estimation of the normal-truncated half-normal model. The log likelihood for the normal-truncated normal model is

$$\log L_i = -\frac{1}{2}\log 2\pi - \log\sigma - \log\Phi(\alpha\left(\sqrt{1+\lambda^2}\right) + \log\Phi\left(\alpha - \frac{\varepsilon_i\lambda}{\sigma}\right) - \frac{1}{2}(\frac{\varepsilon_i}{\sigma} + \sigma\lambda)^2 \tag{3.15}$$

Where

$$\varepsilon_i = y_i - \beta\,x_i$$

$$\lambda = \frac{\sigma_u}{\sigma_v}$$

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

$$\sigma = \sqrt{\sigma_u^2 + \sigma_v^2}$$

$$\alpha = \mu/(\lambda\sigma)$$

N represents the distribution function of the standard normal random variable. The parameter μ can be obtained from the result $\mu = \alpha\sigma\lambda$ after optimization. $\mu_i = \theta Z_i$ if there is heterogeneity in the mean,

Different forms of production functions are used in empirical studies, depending on the nature of data on hand. Therefore, the selection of functional form is vital in stochastic frontier production. In a number of studies, Cobb-Douglas functional form has been used to examine farm efficiency notwithstanding its well-known limitations (Thiam, et *al*., 2001). Kopp and Smith (1980) indicated that functional forms have a distinct but rather small impact on estimated efficiency. Ahmad and Bravo-Ureta (1996) in their study rejected the Cobb Douglas functional form in favour of the translog form, but concluded that efficiency estimates are not affected by the choice of the functional form (cited in Thiam et *al*, 2001). The Cobb-Douglas production function introduces severe restriction on the technology employed in the farm by limiting the elasticities of production to be fixed and the input substitution elasticities to unity (Wilson et *al*, 1998). The flexible translog functional form however, does not entail restrictions of fixed rate of technical substitution (RTS) value and an elasticity of substitution equivalent to one in the Cobb-Douglas form of the production function. Therefore, translog functional form is preferred over Cobb-Douglas functional. It is noted that the Cobb-Douglas functional form is nested within the translog form if all the square and interaction terms in translog turn out to be equal to zero. Diagnostically, the generalized likelihood ratio test was used to determine which of the two aforementioned functional forms fits the data collected from the maize farmers in this study better. The test allows evaluation of a restricted model with respect to an adopted model (Bohrnstedt and

Knoke, 1994). The statistic associated with this test is defined as:

$$\lambda = -2\left[\ln \frac{L(H_0)}{L(H_1)}\right] = -2[\ln L(H_0) - \ln L(H_1)] \tag{3.16}$$

where $L(H_0)$ and $L(H_1)$ are the log-likelihood values of the adopted and the restricted models respectively. The test statistic λ has approximately a chi-square distribution with a number of degrees of freedom equal to the number of parameters (restrictions), assumed to be zero in the null-hypothesis. Whenλ is lower than the correspondent critical value (for a given significance level), the null-hypothesis cannot be rejected. The main hypothesis tested here is to find out whether the Cobb-Douglas functional form is an adequate representation of the maize production data collected, given the specification of the translog functional form. The test results showed that the translog functional form was more appropriate. Therefore, the translog functional form is used in this study. Theoretically, the stochastic frontier translog production function is specified as:

$$\ln y_i = \beta_0 + \sum_{k=1}^{m} \beta_k \ln x_{ki} + \frac{1}{2}\sum_{k=1}^{m}\sum_{j=1}^{m} \beta_{kj} \ln x_{ki} \ln x_{ji} + v_i - u_i \tag{3.17}$$

Where

ln = Natural logarithm

y_i = Total quantity of output

x_i = Vector of inputs

ij = Positive integers $(i \neq j)$

β_S = Vector of parameters to be estimated v_i and u_i have their usual meanings.

The inefficiency model is also specified as:

$$u_i = \delta_0 + \sum_{m=1}^{N} \delta_m z_i \tag{3.18}$$

Where

z_i = Vector of farmer characteristics

δ = Vector of parameters

The variables z_i are the variables in the inefficiency variables. Limdep and stata provide a joint estimation of the parameters in the stochastic frontier production function and those of variables in the inefficiency model (Green, 2002). The joint model generates variance parameters, i.e, $\lambda = \sigma_u/\sigma_v$; variance of the model, σ, variance of the stochastic model, $\sigma^2_{v,}$ and variance of the inefficiency model, σ^2_u.

Empirically, the following stochastic frontier translog production function was estimated.

$$\ln OUTPUT \quad _i = \beta_0 + \beta_1 \quad \ln SED_i \quad + \beta_2 \ln \quad FET_i + \quad \beta_3 \ln PET \quad LAD_i \quad + \beta_6 \ln \quad LAB_i$$
$$+ \beta_7 \ln HEB \quad _i + \quad \beta_8 \ln CAP \quad + \beta_9 \ln \quad (SED \quad _{11}\ln(PET \quad) \quad _i \quad ^2$$
$$+ \beta_{12} ln \quad (MAN) \quad ^2{}_i + \beta_{13} \quad \ln(LAD \quad)^2{}_i + \beta \quad)^2 \quad _i$$
$$+ \beta_{16} \ln \quad (CAP)^2 \quad _i + \beta_{17} \quad (\ln SED \quad \times \ln FET \quad)_i \quad + \beta_{19} \quad (\ln SED$$
$$\times \ln MAN \quad)_i + \beta \quad _{20}(\ln SED \quad \times \ln \quad LAD + \quad + \beta_{22} \quad (\ln SED$$
$$\times \ln HEB \quad)_i + \beta \quad _{23}(\ln SED \quad \times \ln \quad CAP)_i + \quad _i + \beta_{25} \quad (\ln FET$$
$$\times \ln MAN \quad)_i + \beta \quad _{26}(\ln FET \quad \times \ln \quad LAD)_i \quad _i + \beta_{28} \quad (\ln FET$$
$$\times \ln HEB \quad)_i + \beta \quad _{29}(\ln FET \quad \times \ln \quad CAP)_i + \quad)_i + \beta \quad _{31}(\ln \quad PET$$
$$\times \ln LAD \quad)_i + \beta_{32} \quad \ln(PET \quad \times \ln LAB \quad)_i$$
$$+ \beta_{33} \ln \quad (PET \times \quad \ln HEB \quad)_i + \beta_{34} \quad (\ln PET \quad \times \quad \ln LAD \quad)_i$$
$$+ \beta_{36}(\ln \quad MAN \times \quad \ln LAB \quad)_i$$
$$+ \beta_{37}(\ln \quad MAN \times \quad \ln HEB \quad)_i + \beta \quad _{38}(\ln MAN \quad LAD \quad \times \ln LAB \quad)_i$$
$$+ \beta_{40}(\ln \quad LAB \times \quad \ln HEB \quad)_i + \beta_{41} \quad (\ln LAD \quad \times \quad \ln HEB \quad)_i$$
$$+ \beta_{43}(\ln \quad LAB \times \quad \ln CAP \quad)_i + \beta_{44} \quad (\ln HEB$$
$$_i + \beta_4 \quad \ln MAN \quad _i + \beta_5 \ln$$
$$)^2{}_i + \beta_{10} \quad \ln(FET \quad)^2{}_i + \quad \beta$$
$$_{14}\ln(LAB \quad)^2{}_i + \quad \beta_{15} \ln \quad (HEB$$
$$)_i + \beta \quad _{18}(\ln SED \quad \times \ln \quad PET$$
$$\beta_{21}(\ln SED \quad \times \quad \ln LAB) \quad _i$$
$$\beta_{24}(\ln \quad FET \times \quad \ln PET \quad)$$
$$+ \beta_{27}(\ln \quad FET \times \quad \ln LAB \quad)$$
$$\beta_{30}(\ln \quad PET \times \quad \ln MAN$$
$$\times \ln CAP \quad)_i + \quad \beta_{35}(\ln \quad MAN$$
$$\times \ln \quad CAP)_i \quad + \beta_{39}(\quad \ln$$
$$\times \ln CAP \quad)_i + \quad \beta_{42}(\ln \quad LAB$$
$$\times \ln CAP \quad)_i + \quad v_i - u \quad _i$$

(3.19)

Also, the following empirical inefficiency model was estimated.

$$\delta_5 HOSIZE_i + \delta_6 EXP_i$$
$$+ \delta_{10} INCOME_i + \delta_{11} NPLOTS_i$$
$$+ \delta_{15} PESTus + \delta_{16} SEDtyp$$
$$u_i = \delta_0 + \delta_1 ROAD_i + \delta_2 GENDER_i + \delta_3 AGE_i + \delta_4 EDU_i +$$
$$+ \delta_7 LANDSZ_i + \delta_8 MGROUP_i + \delta_9 CREDIT_i$$
$$+ \delta_{12} EXTSER_i + \delta_{13} REDYMKT_i + \delta_{14} FERTus$$
$$+ \delta_{17} NOSAV_i + \delta_{18} TRASIT_i + \delta_{19} FOREST_i$$

(3.20)

Where

OUTPUT = output of maize, measured in kilogramme per hectare (Kg/ha) and it is the dependent variable.

SED = Quantity of seed used, measured in Kilogramme per hectare (Kg/ha). Most recent improved seeds are high yielding and therefore use of large quantities of improved seeds may be positively related to the output produced of maize.

LANDSZ = Area of land cultivated with maize, measured in hectares. Maize farmers with large farm sizes are expected to use more productivity enhancing technologies and hence their outputs and technical efficiencies are expected to be higher. On the other hand, maize farmers with large farm sizes may be unable to meet improved input requirements of large farms and therefore will have low outputs and efficiencies (Pender et *al*, 2004; Okoye et *al*, 2008; Stifel and Minten, 2008). Farm size is therefore expected to have either positive or negative effect on the output and efficiency of maize farmers in Ghana.

LAB = Quantity of labour employed in maize production, measured in Man-days. Labour plays a very important role in maize production (most activities in the farm require the use of labour, e.g. land clearing, weeding, spraying, fertilizer application, harvesting, gathering, etc.) and its quantity is expected to be positively related to the output produced of maize.

CAP = Capital used in maize farm, measured as depreciated charges on farm tools and implements. Farm tools and implements are necessary for carrying out farm activities and therefore capital is expected to be positively related to the output produced of maize.

FET = Quantity of fertilizer used in maize production, measured in Kilogrammes per hectare (Kg/ha). The importance of fertilizer in increasing crop output has been proven by most research in developing countries (World Bank, 2007). For instance, a review report by Reardon et *al* (1997), of research undertaken in Senegal, Rwanda, Zimbabwe and Burkina Faso showed that fertilizer was positively related to crop output. Therefore in the current study, fertilizer is expected to have a positive influence on the output produced of maize.

MAN = Quantity of manure used in maize production, measured in Kilogrammes per hectare (Kg/ha). According to Tittonell (2007), application of manure would have a positive effect on crop output.

PET = Quantity of pesticides used in maize production, measured in litres per hectare (litres/ha). On-farm trials of use of pesticides revealed a positive relationship between pesticides use and maize output (Muthamia et *al*, 2001). Therefore pesticides use is expected to be positively related to the output produced of maize.

HEB = Quantity of herbicides used in maize production, measured in litres per hectare (litres/ha). Control of weeds with herbicides led to an increase in crop output vis-a-vis weeding with the hoe (Muthamia et *al*, 2001). Use of herbicides has also been found to have a negative impact on soil fertility and human health in the long-term (Miller, 2002; Jurewicz and Hanke, 2008; Kughur, 2012). Herbicides use is therefore expected to be either positively or negatively related to the output produced of maize.

ROAD = Access to good roads, measured as a dummy (1 for access to good road and 0 otherwise). Farmers with access to good roads will more likely buy and use productivity enhancing technologies and therefore will more likely have higher outputs. Access to good roads is therefore expected to have a positive influence on the output and efficiency of maize farmers in Ghana.

GENDER = Gender of maize farmer, measured as a dummy (1 for male and 0 for female). There are mixed results on the influence of gender on efficiency. Tchale and Sauer (2007) point out that, while some studies reported that gender of the farmer has no significant influence on efficiency, other studies found that gender plays an important role. Male farmers are wealthier than female ones (UBoS, 2006) and therefore are more likely to purchase and use productivity enhancing technologies and consequently have higher outputs and efficiency. Male-gender is therefore expected to have a positive effect on the output and efficiency of maize farmers in Ghana.

AGE = Age of maize farmer, measured in years. Both old and young maize farmers may use productivity enhancing technologies in their maize production. This is because older farmers are less poor, and therefore more likely to afford the cost of using productivity enhancing technologies. Conversely, though less poor, older farmers may not be enthusiastic about using productivity enhancing technologies because of inadequate knowledge of such technologies (Langyintuo and Mekuria, 2005). Use of improved inputs is expected to have a positive effect on output and efficiency. Therefore, age is expected to have either a positive or negative effect on the output and efficiency of maize farmers in Ghana.

EDU = Educational level of maize farmer, measured in years of schooling. Education enhances the managerial and technical skills of farmers. According to Battese and Coelli (1995), education is hypothesized to increase the farmers' ability to utilize existing technologies and attain higher efficiency levels. Therefore, education is expected to be positively related to the output and efficiency of maize farmers in Ghana.

HOSIZE = Household size, measured as number of family members living with maize farmer. Both small and large households may use improved inputs. Studies like Akinola (1987) and Igodan et *al* (1988) that analyzed the influence of family size on the extent of farmers' use of productivity enhancing technologies reported inverse relationships whereas those of Perz (2003) and Tabi et *al* (2010) reported positive relationships. Since use of improved inputs is directly related to maize output and technical efficiency, household size may have either positive or negative effect on the output and efficiency of maize farmers in Ghana.

EXP = Maize farming experience, measured in number of years in maize farming. Farmers with many years of maize farming experience will more likely be familiar with the required skills needed for maize production and therefore are more likely to have higher outputs and consequently more technically efficient. Maize farming experience is therefore expected to have a positive effect on the output and efficiency of maize farmers in Ghana.

MGROUP = Membership of a farmer association, measured as a dummy (1 for membership of an association and 0 otherwise). This variable is expected to be positively related to the output and efficiency of maize farmers in Ghana because farmers who are members of farmer groups have more access to extension services (NAAD, 2005) where output and efficiency enhancing practices are discussed, hence more likely to be productive and efficient than their counterparts who do not belong to any farmer association.

CREDIT = Access to credit, measured as a dummy (1 for access to credit and 0 otherwise). It is expected to have a positive influence on agricultural productivity and efficiency because farmers who get agricultural related credit are more likely to buy and use productivity and efficiency enhancing inputs.

INCOME = Previous year's maize income, measured in Ghana Cedis. This variable is expected to be positively related to the outputs and efficiency of maize farmers in Ghana because it allows farmers to be able to purchase productivity and efficiency enhancing inputs.

NPLOTS = Land fragmentation, measured as a dummy (1 for owning more than one plot and 0 otherwise). It is expected to have either a positive or negative effect on yield and efficiency of maize producers in Ghana. It may be positive because some farmers may use it as a risk strategy. Land fragmentation may also be the cause of inefficient use of resources and therefore reduce total returns to land. The reasons include but not limited to losses due to increased travel time, waste of border spaces, ineffective monitoring as well as inability to use farm machinery. Therefore land fragmentation may/may not increase/decrease technical efficiency (Raghbendra et *al*, 2005).

NOEXTVI = Extension contact, measured in number of meetings of maize farmer with agricultural extension agents. Access to extension is expected to have a positive effect on the output and efficiency of maize producers in Ghana. This is because extension agents constitute the main medium of technology transfer from research institutes to farmers. Maize farmers who seldom meet agricultural extension agents always lag behind when it comes to awareness and use of output and efficiency enhancing inputs and managerial practices.

REDYMKT = Access to ready maize market, measured as a dummy (1 for available maize market and 0 otherwise). It is expected to be positively related to productivity and efficiency of maize producers in Ghana. This is because access to ready maize markets motivates maize farmers to do whatever they can to increase their outputs and efficiency. As a result, they are likely to purchase and use inputs that have proven to be productive. Farmers are also motivated to practise all relevant cultural practices that have proven by research to be productive.

FERTus = Use of inorganic fertilizer, measured as a dummy (1 for use of inorganic fertilizer and 0 otherwise). This variable is expected to be positively related to output and efficiency of maize producers in Ghana because inorganic fertilizers improve the fertility of the soil by adding all required plant nutrients that may not be present in the soil.

PESTus = Use of pesticides, measured as a dummy (1 for use of pesticides and 0 otherwise). This variable is expected to be positively related to the output and efficiency of maize producers in Ghana because spraying of maize with pesticides kills most pests of maize, especially insects that chew the photosynthetic leaves of the crop.

SEDtyp = Seed variety planted by maize farmer, measured as a dummy (1 for improved variety and 0 for traditional variety). This variable is also expected to be positively related to the output and efficiency of maize producers in Ghana because most improved varieties released by agricultural research institutes worldwide have proven to be high yielding vis-a-vis traditional varieties.

NOSAV = Living in the northern savannah zone, measured as a dummy (1 for living in northern savannah zone and 0 for living in the coastal savannah zone). It may/may not increase/decrease output and efficiency of maize farmers in Ghana.

TRASIT = Living in the transitional zone, measured as a dummy (1 for living in transitional zone and 0 for living in the coastal savannah zone). It may/may not increase/decrease output and efficiency of maize farmers in Ghana.

FOREST = Living in the forest zone, measured as a dummy (1 for living in forest zone and 0 for living in the coastal savannah zone). It may/may not increase/decrease output and efficiency of maize farmers in Ghana.

Test for heteroscedasticity

A violation of one of the assumptions of ordinary least squares (OLS) is heteroscedasticity, also referred to as the existence of non-constant error variance. Heteroscedasticity leads to the estimation of coefficients that are unbiased and inefficient. The variances may be too small or too large, resulting in Type I or II errors, OLS is not BLUE.

Heteroscedasticity is common in cross-sectional data set like the data employed in this study. The causes of heteroscedasticity are: increasing variance caused by increasing levels of dependent variable, changing variance of dependent variable caused by changes in independent variables and outliers in the data set. Analysis of the heteroscedasticity condition in a stochastic frontier model reveals the presence or absence of double heteroscedasticity. This comes from variance in the normal error term (*v*), represented by heteroscedasticity from *v* (*hfv)* and from variances in the truncated half normal error term (*u*) represented by heteroscedasticity from *u* (*hfu)*. A statistically significant t-statistics for the functions *hfu* and *hfv* indicate the presence of heteroscedasticity. The Breusch Pagan test was employed to test for the presence or absence of heteroscedasticity. This was performed by squaring the error term e_i^2 and dividing each error term squared by the mean error term to obtain v_i^2. Then, v_i^2 is regressed against all the independent variables and R^2 is obtained. Since this is a large sample, the product of R-squared and the sample size follows a Chi-square distribution. If the computed chi-square is greater than the critical value, the null hypothesis of homoscedasticity is rejected and we conclude that there is heteroscedasticity.

Heteroscedasticity can be corrected by transforming data into natural logarithms and also by the generalized least squares (GLS), also known as the weighted least squares (WLS). In the weighted least squares method, $1/\sigma_i$ which is the weighting function is calculated by obtaining an inverse of the variance (σ), i.e. the square root of σ_i^2, from the regression of v_i^2 against all the independent variables. All the variables in the stochastic frontier model are then multiplied by this function. Orthogonalized forms of the transformed variables are employed in subsequent analysis. Precision of the beta coefficients and estimated mean technical efficiency improve when heteroscedasticity is corrected.

Test for multicollinearity

Multicollinearity occurs when two or more variables in a regression model are highly correlated. This means that some variables can be linearly predicted from others with a non-trivial degree of accuracy. This allows the coefficients of the regression model to change randomly as a result of small variations in the data. Multicollinearity does not necessarily lessen the predictive power of the model but only influences computations concerning unit predictors. The implication is that a multiple regression model containing predictors that are correlated indicates how well the entire combination of predictors predicts the dependent variable, but may not give acceptable results about individual predictors. For perfect multicollinearity, the predictor matrix cannot be inverted because it is singular. In such situations, the OLS estimator $\hat{\beta} = (X'X)^{-1}X'y$ does not exist. In this study, the variance inflation factor (VIF) was used to test

for the presence or absence of multicollinearity in the model. The variance inflation factor (VIF) was calculated as follows:

$$VIF_j = \frac{1}{1-R_j^2} \tag{3.21}$$

Where R_j^2 is the coefficient of determination of a regression of explanator j on all the other explanators. If $VIF_j \geq 10$, then there is a problem with multicollinearity.

3.5.3 Method for estimating efficiency of resources use in maize production

According to Kabir Miah et *al* (2006) and Tambo and Gbemu (2010), for maize farmers to be efficient in their use of production resources, their resources must be used in such a way that their marginal value product (MVP) is equal to their marginal factor cost (MFC) under perfect competition Therefore, the resource use efficiency parameter was calculated using the ratio of MVP of inputs to the MFC. According to Fasasi (2006) and Goni et *al* (2007) the efficiency of resource use is given as;

$$r = \frac{MVP}{MFC} \quad (3.22)$$

r = Efficiency coefficient

MVP = Marginal Value Product

MFC = Marginal Factor Cost of inputs

$$MFC = P_x \quad (3.23)$$

Where

P_{xi} = Unit price of input, say X

$$MVP_x = MPP_x . P_y \quad (3.24)$$

Where

Y = Mean value of output and

X = Mean value of input employed in the production of a product.

MPP_x = Marginal Physical Product of input X

P_y = Unit Price of maize output

If β_x = output elasticity of input X

From the translog production function (equation 3.17) in section 3.5.2,

$$\beta_x = \frac{\partial lnY}{\partial lnX} = \frac{\partial Y}{\partial X} . \frac{X}{Y}$$

$$MPP_x = \frac{\partial Y}{\partial X} = \beta_x \frac{Y}{X} \quad (3.25)$$

MPP_x = Marginal Physical Product of input X and is a measure of technical efficiency of input X.

Therefore

$$MVP = \frac{\partial Y}{\partial X} . P_y = \beta_x \frac{Y}{X} . P_y \quad (3.26)$$

Marginal Value Product (MVP) of a particular input is therefore calculated by the product of output elasticity of that input, the ratio of mean output to mean input values and the unit output price. On the other hand, Marginal Factor Cost (MFC) of an input was obtained from the data collected on the unit price of that input. To decide whether or not an input is used efficiently, the following convention is used. If

$r = 1$, it implies the input was used efficiently

$r > 1$, it implies the input was underutilized and therefore output would be increased if more of that input is employed.

$r < 1$, it implies the input is over utilized and therefore both output and profit would be maximized if less of that input is employed (Mbanasor, 2002; Eze, 2003; Okon, 2005).

3.5.4 Method for Estimating Scale Efficiency and its Determinants

Ray (1998) suggested a parametric approach (alternative to DEA) to estimating scale efficiency from the estimated coefficients of the stochastic frontier production function and from estimation of scale elasticity. For instance for a stochastic frontier translog production function:

$$\ln y_i = \beta_0 + \sum_{k=1}^{m} \beta_k \ln x_{ki} + \frac{1}{2} \sum_{k=1}^{m} \sum_{j=1}^{m} \beta_{kj} \ln x_{ki} \ln x_{ji} + v_i - u_i$$

(3.27)

and with the assumption of output-oriented approach to estimating technical efficiency, farm level scale elasticity is given by:

$$E_i = \sum_{k=1}^{m} \left(\beta_k + \sum_{j=1}^{1} \beta_{kj} x_{ji} + \beta_{ji} \right)$$

(3.28)

Referring to Ray (1998) for a comprehensive explanation of the parametric methodology, farm level scale efficiency (SE^0) can be calculated as follows:

$$SE_i^0 = exp\left[\frac{(1-E_i)^2}{2\beta}\right] \qquad (3.29)$$

Where:

$$\beta = \sum_{k=1}^{m}\sum_{j=1}^{m}\beta_{kj} \qquad (3.30)$$

with β, which is hypothesized to be negative definite in order to be sure that $0 < SE_i^0 \leq 1$. It is however important to note that even though negative definiteness of β is a sufficient condition, it is not a necessary condition (Ray, 1998). The aforementioned output-oriented scale efficiency assesses the importance of scale in shaping technical efficiency. For a resource combination that does not exhibit constant returns to scale, the average productivity of a farm differs from those of optimum levels. The implication, according to Karagiannis and Sarris (2005) is that scale efficiency corresponds to the relative expansion in output by operating efficiently. That is, from the Frisch's definition, scale efficiency estimates the distance to maximum efficieny.

According to Ray (1998), scale efficiency (equation 3.29) and scale elasticity (equation 3.28) are both equal to one only at the most productive scale size (MPSS). That is, at the point where there is constant returns to scale. There may also be variations in their values and SE_i^0 <1 no matter $E_i < or > 1$. This implies that, away from the MPSS, scale elasticity does not reveal anything about SE_i^0 levels.

It is important to note that the sub-optimal scale corresponds to increasing returns to scale. With increasing returns to scale, $E_i > 0$ and SE_i^0 rises with a rise in output. That is, the output level should be expanded in order to operate in an optimal scale. Conversely, for a farm that exhibits decreasing returns to scale or supra-optimal scale ($E_i < 0$), there should be a contraction in output in order for optimal scale to be achieved.

For farm level scale efficiency variations to be explained, a two-stage methodology was used by Karagiannis and Sarris (2005). Firstly, equation (3.27) was used to estimate SE_i^0s which was followed by a regression of SE_i^0 scores against a vector of explanatory variables in the second stage. In the second stage of the parametric approach, the stochastic frontier function is estimated by the maximum likelihood technique (Reinhard et *al*, 2002) according to the following equations:

$$\ln SE_i^0 = m_i + \varepsilon_i \quad \text{with} \qquad (3.31a) \quad m_i = Z(z_i, \rho) \quad \text{and}$$

(3.31b)

$$\varepsilon_i = v_i^* - u_i^* \qquad i = 1,2, \ldots \ldots \ldots N \qquad (3.31c)$$

where z_i comprises the inefficiency variables in technical efficiency estimation (equation 3.20), ρ are the parameters that will be estimated, ε_i is the error term which is twofold, viz: v_i^* which stands for statistical noise and is identically and independently distributed with $N(0, \sigma_{v^*}^2)$ random variable is truncated at $-m_i$ and u_i^* which stands for the conditional scale inefficiency that remains even after variation in the z_i has been taken into consideration $(u_i^* \sim N(-m_i, \sigma_{u^*}^2))$.

The following empirical model was estimated.

$$\begin{aligned} \ln SE_i^0 = {} & \delta_0 + \delta_1 ROAD_i + \delta_2 GENDER_i + \delta_3 AGE_i + \delta_4 EDU_i + \delta_5 HOSIZE_i \\ & + \delta_6 EXP_i + \delta_7 LANDSZ_i + \delta_8 MGROUP_i + \delta_9 CREDIT_i \\ & + \delta_{10} INCOME_i + \delta_{11} NPLOTS_i + \delta_{12} NOEXTVI_i + \delta_{13} REDYMKT_i \\ & + \delta_{14} FERTus + \delta_{15} PESTus + \delta_{16} SEDtyp + \delta_{17} RAINamt \\ & + \delta_{18} NOSAV_i + \delta_{19} TRASIT_i + \delta_{20} FOREST_i \end{aligned}$$

(3.32)

Where $RAINamt$ is the amount of rainfall recorded in the area where maize farmer lives (expected to have a positive effect on scale efficiency) and all other variables have their usual meanings as explained in section 3.5.2 for determinants of technical efficiency. Many authors including Battese and Coelli (1995), Kumbhakar and Lovell (2000) among others have criticized the two-stage approach for estimating technical efficiency because it is not consistent in its assumption concerning independence of the inefficiency effects. This is because the specification of the second stage regression in which the technical efficiency scores are hypothesized to be related to the explanatory variables, disagrees with the hypothesis that u_i's are independently and identically distributed.

Nonetheless, it is possible to use a two-stage approach on condition that the efficiency scores are estimated from the parameter estimates of the first stage regression rather than estimating it econometrically in stage one (Reinhard et *al*, 2002). For the scale efficiency estimation procedure explained above, there is no such assumption made about the dependent variable SE_i^0 because SE_i^0 scores are calculated from the estimated parameters and the estimated scale elasticity of the first stage regression. The two-stage approach was therefore recommended by Reinhard et *al* (2002) for farm level scale efficiency estimations.

CHAPTER FOUR RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the results and discussions of the study. It begins with the description of the variables used in the study. The empirical results which comprise analyses of use of productivity enhancing technologies, technical efficiency, resource use efficiency and scale efficiency are also presented and discussed.

4.2 Descriptive Analysis

Table 4.1 and 4.2 present the distribution and descriptive statistics of characteristics of farmers interviewed for the study. The pooled results show that 77.4% of maize farmers in Ghana are males, while 22.6% are females, an indication of active male involvement in maize production than females in Ghana. Similar results were recorded in the four agro ecological zones considered in the study. For instance, in the Northern Savannah zone, 88.2% of the farmers were males while 11.8% were females. The transitional zone also recorded 76.4% for males and 23.6% for females. As shown in Table 4.1, similar results were found in the Forest and Coastal Savannah zones of Ghana. These results are consistent with those of Sadiq et *al* (2013) who studied the Profitability and Production Efficiency of Small-Scale Maize Production in Niger State, Nigeria and found that 67% of maize farmers in the state were males, while the remaining 33% were females. Oladejo and Adetunji (2012) also studied the Economic analysis of maize (*Zea mays L.*) production in Oyo state of Nigeria and found similar results. They found

Table 4.1: Location and characteristics of farmers interviewed

Variable	Pooled Sample		Northern Savannah		Transitional		Forest		Coastal Savannah	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Description of Operational area										
Rural	485	84.2	128	88.9	114	79.2	118	81.9	125	86.8
Urban	91	15.8	16	11.1	30	20.8	26	18.1	19	13.2
Total	576	100	144	100	144	100	144	100	144	100
Sex of maize farmer										
Male	446	77.4	127	88.2	110	76.4	113	78.5	96	66.7
Female	130	22.6	17	11.8	34	23.6	31	21.5	48	33.3
Total	576	100	144	100	144	100	144	100	144	100
Age group of farmers (Years)										
18-45	328	56.9	93	64.6	76	52.8	69	47.9	90	62.5
46-60	180	31.2	28	19.4	53	36.8	56	38.9	43	29.9
Greater than 60	68	11.8	23	16	15	10.4	19	13.2	11	7.6
Total	576	100	144	100	144	100	144	100	144	100
Educational level of maize farmer										
No formal education	207	35.9	98	68.1	24	16.7	15	10.4	70	48.6
Primary school	84	14.6	8	5.6	33	22.9	23	16	20	13.9
Middle school/JSS/JHS	200	34.7	19	13.2	69	47.9	67	46.5	45	31.2
SSS/SHS	69	12	13	9	13	9	36	25	7	4.9
Training college/Tertiary	16	2.8	6	4.2	5	3.5	3	2.1	2	1.4
Total	576	100	144	100	144	100	144	100	144	100
Number of plots										
One plot	454	78.8	99	68.8	107	74.3	122	84.7	126	87.5
More than one plot	122	21.2	45	31.2	37	25.7	22	15.3	18	12.5
Total	576	100	144	100	144	100	144	100	144	100
Association membership										
No	436	75.7	92	63.9	103	71.5	128	88.9	113	78.5
Yes	140	24.3	52	36.1	41	28.5	16	11.1	31	21.5

Source: Survey, 2015

Table 4.1: Continued

Variable	Pooled Sample Freq	%	Northern Savannah Freq	%	Transitional Freq	%	Forest Freq	%	Coastal Savannah Freq	%
Total	576	100	144	100	144	100	144	100	144	100
Ready market last year										
No	70	12.2	30	20.8	26	18.1	9	6.3	5	3.5
Yes	506	87.8	114	79.2	118	81.9	135	93.7	139	96.5
Total	576	100	144	100	144	100	144	100	144	100
Access to extension										
No	331	57.5	76	52.8	86	59.7	125	86.8	44	30.6
Yes	245	42.5	68	47.2	58	40.3	19	13.2	100	69.4
Total	576	100	144	100	144	100	144	100	144	100
Access to credit										
No	475	82.5	116	80.6	118	81.9	120	83.3	121	84
Yes	101	17.5	28	19.4	26	18.1	24	16.7	23	16
Total	576	100	144	100	144	100	144	100	144	100
Source of credit										
ADB	4	4			4	15.4				
GCB	4	4	3	10.7	1	3.8				
Rural bank	22	21.8	5	17.9	2	7.7	6	25	5	21.7
Savings and Loans	13	12.9	1	3.5	4	15.4	3	12.5	3	13.1
Credit unions	16	15.8					1	4.2		

Informal sources(friends, etc)	42	41.5	19	67.9	15	57.7	14	58.3	15	65.2
Total	101	100	28	100	26	100	24	100	23	100

Source: Survey, 2015

Table 4.1: Continued

Variable	Pooled Sample		Northern Savannah		Transitional		Forest		Coastal Savannah	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Access to good roads										
Tarred with potholes/Rough and marshy	292	50.7	100	69.4	43	29.9	61	42.4	88	61.1
Asphalt/Tarred but not asphalt/ Rough and smooth	284	49.3	44	30.6	101	70.1	83	57.6	56	38.9
Total	576	100	144	100	144	100	144	100	144	100
Access to adequate rains										
No	172	30.6	84	58.3	37	25.7	17	11.8	38	26.4
Yes	400	69.4	60	41.7	107	74.3	127	88.2	106	73.6
Total	576	100	144	100	144	100	144	100	144	100

Source: Survey, 2015

Table 4.2: Descriptive statistics of Farmers' characteristics

	M	SD	M	SD	M	SD	M	SD	M	SD

Farmer's Age (Years)	18		45.15	11.61	20	75	43.22	14.33	21	72	44.77	11.7	18	78	47.12	10.8	27	71	45.49	18
Education(Years)	0	18	5.96	4.976	0	18	3.979	6.031	0	17	7.181	3.864	0	15	8.313	3.67	0	15	4.368	0
Experience (Years)	1	50	14.07	10.83	1	50	18.64	13.34	1	50	13.9	10.37	1	45	7.931	7.58	3	40	15.83	1
Farm size (ha)	0.2	70	2.862	12.71	0.4	11.6	2.742	1.707	0.4	70	3.408	4.732	0.2	54.5	3.34	24.9	0.4	7.2	1.96	0.2
Number of farm plots	0.4	50	1.579	2.164	1	5	1.549	0.737	1	5	1.931	4.123	0.4	5	1.392	0.7	0.8	7	1.443	0.4
Extension visits	0	26	2.727	4.833	0	4	1.229	1.481	0	20	2.167	3.717	0	13	0.965	2.92	0	26	6.549	0
Amount of credit received (Gh¢/ha)	0	4500	162	466	0	1711	133	341	0	4500	181	530	0	4500	150	489	0	2100	183	0
Size of household	2	34	7.611	4.719	0	32	9.743	6.494	0	34	7.792	5.081	1	25	6.486	3.07	1	15	6.424	2
Average rainfall for 2013 (mm)	109	1750	1084	446	1010	1075	1044	32.61	1111	1320	1216	104.9	1400	1750	1575	176	109	900	505	109

Source: Survey, 2015

Variable	**Pooled**		**Northern Savannah**		**Transitional**		**Forest**		**Coastal Savannah**	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
		78								

that 70.9% of maize farmers in the Oyo state were males. Even though the results of the current study and those of previous studies have shown that maize production is dominated by males, it could also be inferred from these studies that both men and women can take maize production as a business and a source of employment.

The ages of the respondents ranged from 18 to 78 years with a mean age of 45.2 years for the pooled sample (Table 4.2). Also, Table 4.1 shows that majority of maize farmers in Ghana (56.9%) are within the age bracket of 18-45 years, while 31.2% are from 46 to 60 years and 11.8% are above 60 years of age. The results found in the four agro ecological zones are not different from the pooled results. For example, the mean ages obtained in the Northern Savannah, Transitional, Forest and Coastal Savannah zones of Ghana are 43.2, 44.7, 47.1 and 45.5 respectively. The mean age shows that generally, maize producers in Ghana are old and this could affect their use of productivity enhancing technologies and economic efficiency of maize production. This corroborates the results of Ojiako and Ogbukwa (2012) that revealed a mean age of 44.8 years for farmers. The results also agree with the results of Akpan (2010) in a study into how the youth could be encouraged to go into agricultural production and processing that reported that most farmers in Nigeria are old.

The results of educational level of the farmers presented in Table 4.1 show that 35.9% of maize farmers in the pooled sample received no formal education, 14.6% had up to primary education, 34.7% got to middle school, Junior Secondary School (JSS) or Junior High School (JHS), 12% ended in the Senior Secondary School (SSS) or Senior Higher School (SHS) and only 2.8% received tertiary education. Table 4.2 also shows that, on average, maize farmers in Ghana have 6 years of schooling. The highest number of years of schooling of 8 was found in the forest zone and the lowest of 4 was recorded in the northern savannah zone of the country. The results suggest that majority of maize farmers in Ghana (64.1%) received formal education. With the exception of the northern savannah zone where majority of the maize farmers (68.1%) were illiterates, similar results were obtained in the transitional, forest and coastal savannah zones. This corroborates the findings of Oladejo and Adetunji (2012) that most maize farmers in Oyo state of Nigeria (82.3%) were literates.

With a mean of 7.61, the household size ranged from 2 to 34 for the pooled sample (Table 4.2). Similarly, maize farmers in the northern savannah, transitional, forest and coastal savannah zones recorded mean family sizes of 9.74, 7.79, 6.49 and 6.42 respectively. These results corroborate those of Oladejo and Adetunji (2012) that found an average household size of 8 among maize farmers in Oyo state of Nigeria. Also, Table 4.2 shows that on average, farmers in Ghana had about 14 number of years of experience in maize farming. With the exception of maize farmers in the forest zone where farmers had an average of seven (7) years of farming experience, similar high levels of farming experience where found in the northern, transitional and coastal savannah zones of the study area. With high levels of farming experience, the yields of maize farmers in the northern, transitional and coastal savannah zones are expected to be on the higher size given that such farmers are supplied with the required productivity enhancing technologies.

The results in Table 4.1 show that 57.5% of maize farmers in the pooled sample had no access to extension service, while 42.5% had access. That is a greater proportion of the respondents had no contact with extension agents. With the exception of maize farmers in the coastal savannah zone where 69.4% of the farmers had access to extension service, most maize farmers in the northern savannah, transitional and forest zones also had no access to extension service. For example, as high as 86.8% of maize farmers in the forest belt never had access to agricultural extension service. This could cause little or no use of productivity enhancing technologies since farmers will likely be unaware of these technologies because those who are suppose to disseminate the technologies to them (i.e, extension agents) are far from them. For those who had access to extension service, the average number of times extension agents visited them were calculated to be 3, 1, 2, 1 and 7 times for the pooled sample, northern savannah, transitional, forest and coastal savannah zones respectively, an indication of poor provision of extension service to the farmers (Table 4.2). Also 75.7% of maize farmers for the pooled sample did not belong to any farmer association as against 24.3% that were members of farmer associations (Table 4.1). This runs through all the agro ecological zones, especially in the forest zone where only 11.1% of the sampled maize farmers belonged to a farmer association. This could be the reason why many of the farmers probably were not aware of some of the recommended technologies since extension agents are used to disseminating technologies through farmer based organizations.

In fact, most of the respondents in all the agro ecological zones considered in this study had no maize production credit from any financial source be it formal or informal. For example, 83.3% and 84% of maize farmers in the forest and coastal savannah zones respectively never received credit from any financial source. For those who received credit in the pooled sample, 21.8% got it from rural banks, 12.9% received it from savings and loans companies, 15.8% had it from credit unions, while the remaining 41.5% got it from informal sources such as friends and relatives (Table 4.1). The results show that maize farmers in all four agro ecological zones who received credit had it from informal financial sources. The average amount of loans received by maize farmers per hectare in the study area were calculated to be Gh¢162.00, Gh¢133.00, Gh¢181.00, Gh¢150.00 and Gh¢183.00 in the pooled sample, northern savannah, transitional, forest and coastal savannah zones respectively (Table 4.2). This is quite minuscule looking at the total cost of production per hectare of maize. Few maize farmers in Ghana received production credit probably because of the reluctance of most financial institutions to support agricultural production with credit facilities. According to Awunyo-Vitor (2012), out of the eleven (11) universal banks that were studied, only Agricultural Development Bank (ADB) offered production credit to maize farmers. Also, about 18% of universal banks considered credit for only a registered agricultural business concern with well-structured financial statement and appropriate records on their operations. Meanwhile, the results of the current study show that maize production activities in Ghana are on a small scale ranging from 0.2ha to 70ha with a mean of 2.86ha (Table 4.4). Obviously, farmers will find it difficult meeting the loan requirements of most universal banks, hence the low credit access received by farmers in the country.

With the exception of farmers in the northern savannah zone that had inadequate rains, maize farmers in the transitional, forest and coastal savannah zones remarked rainfall was not a problem (Tables 4.1 and 4.2). Adequate rains in the production season together with use of CSIR/MOFA recommended productivity enhancing technologies is expected to increase maize productivity. A greater number of maize farmers in the transitional (70.1%) and forest (57.6%) zones remarked they had access to good roads (Asphalt/Tarred but not asphalt/Rough and smooth) as against those of northern (69.4%) and coastal (61.1%) savannah zones that reported dilapidated nature of their roads (Tarred with potholes/Rough and marshy) (Table 1). Out of the 576 maize farmers who were interviewed in all agro ecological zones, 72.1% of them stored their harvested maize in the traditional crib or hut, 23.4% stored them in an ordinary room with no state of the art equipment, 4.3% used the services of public silos and 0.2% stored theirs in other crude structures (Table 4.3). The situation was not different for farmers in all four agro ecological zones because a greater percentage of the farmers in the chosen areas stored their maize in the crude traditional crib. Okoboi (2011) emphasized the importance of road and storage infrastructures in the agricultural production and marketing process. According to the study, roads are needed for regular access to inputs and output markets and storage is essential in preserving crops quality so that current sales could be deferred to a later date. Many previous improved input use studies have also shown that access to the aforementioned infrastructures would increase the probability of use of productivity enhancing technologies (Jansen et *al*, 1990; Ransom et *al*, 2003; Langyintuo and Mekuria, 2005 among others).

The average yield of maize grain produced in Ghana according to the results of the pooled sample was 1800kg/ha (1.8 metric tonnes/ha) (Table 4.4). This is in line with a report by the Ministry of Food and Agriculture (MOFA) that the average yield of maize was 1.7 metric tonnes/ha instead of a potential of 6.0 metric tonnes/ha (MOFA, 2010). Also, the average yield of maize grain estimated in this study for maize farmers in the northern savannah, transitional, forest and coastal savannah zones were 1375kg/ha, 2375kg/ha, 1075kg/ha and 1725kg/ha respectively. These yields show that maize production is most productive in the transitional zone of Ghana. This is followed by production in the coastal savannah, northern savannah and forest zones respectively. Morris et *al* (1999) also reported a less than 2 metric tonnes/ha of maize grain for maize farmers in the coastal savannah and forest zones of Ghana.

4.3.1 Use of production technologies among maize farmers in Ghana

A number of technologies aimed at increasing maize productivity were promoted by CSIR and MOFA. These technologies were use of modern seed varieties, use of fertilizer, fungicides/pesticides use, Herbicides use, Row planting, Zero tillage and other soil fertility management practices such as application of animal manure, ploughing in crop residues, practicing ridging, intercropping with nitrogen-fixing crops, intercropping with any crop, planting in mulch as well as practicing relay cropping or crop rotation. Table 4.3 shows that 78.8% of maize farmers in the pooled sample did not ensure zero tillage in their maize production activities while only 21.2% ensured it. The result is not different for maize farmers in the northern, transitional, forest and coastal savannah zones of Ghana. For instance, in the coastal savannah zone, 87.5% of the sampled farmers did not use zero tillage technology in their maize production activities, while 12.5% of them used it. The implication is that zero tillage is not a common activity practised by maize farmers in Ghana. This result supports the findings of

Ragasa et *al* (2013) who found that only 4% of maize farmers in Ghana ensured zero tillage. Also, the work of Ekboir et *al* (2002) showed that only 300,000 small-scale farmers in Ghana used zero tillage technology in 2001. According to Mensah-Bonsu et *al* (2011), close to 50% of maize farmers in Ghana do not burn when preparing land for maize production, and 38% ensured no-tillage even though the definition of zero tillage was not clarified in their study. Meanwhile, zero tillage is one of the productivity enhancing technologies proven and promoted under the Sasakawa Global 2000 agricultural program in Ghana. The onus therefore lies on stakeholders in the maize industry to devise strategies aimed at re-educating maize farmers on the benefits of practising zero tillage in their production activities.

The study revealed that 60.1% of the respondents used traditional maize seeds, while 39.9% used improved seeds (Table 4.3). Similar results were obtained for the distribution of the type of maize seeds used by maize farmers in the various agro ecological zones. For instance,

72.9% of maize farmers in the transitional belt planted traditional varieties, while only 27.1%

Table 4.3:Distribution of maize farmers according to technologies and storage facilities used

Variable	Pooled Sample		Northern Savannah		Transitional		Forest		Coastal Savannah	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Fertilizer use										
No	207	35.9	28	19.4	32	22.2	84	58.3	63	43.8
Yes	369	64.1	116	80.6	112	77.8	60	41.7	81	56.2
Total	576	100	144	100	144	100	144	100	144	100
Pesticides use										
No	560	97.2	138	95.8	137	95.1	141	97.9	144	100
Yes	16	2.8	6	4.2	7	4.9	3	2.1	0	0
Total	576	100	144	100	144	100	144	100	144	100
Herbicides use										
No	203	35.2	52	36.1	59	41	64	44.4	28	19.4
Yes	373	64.8	92	63.9	85	59	80	55.6	116	80.6
Total	576	100	144	100	144	100	144	100	144	100
Seed variety planted										
Traditional	346	60.1	83	57.6	105	72.9	77	53.5	81	56.2
Improved	230	39.9	61	42.4	39	27.1	67	46.5	63	43.8
Total	576	100	144	100	144	100	144	100	144	100
Improved maize varieties used										
Obatampa	192	83.4	40	65.6	24	61.5	66	98.5	58	92.1
Odomfo	2	0.9			2	5.2				
Nwanwa	14	6.1								
Mamaba (Hybrid)	17	7.4	3	4.9	8	20.5	1	1.5	5	7.9
Dadaba (Hybrid)	5	2.2	18	29.5	5	12.8				
Total	230	100	61	100	39	100	67	100	63	100

Source: Survey, 2015

Table 4.3: Continued

Variable	Pooled Sample		Northern Savannah		Transitional		Forest		Coastal Savannah	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Manure use										
No	551	95.7	142	98.6	139	96.5	127	88.2	143	99.3
Yes	25	4.3	2	1.4	5	3.5	17	11.8	1	0.7
Total	576	100	144	100	144	100	144	100	144	100
Farmer ensured zero tillage										
No	454	78.8	99	68.8	107	74.3	122	84.7	126	87.5
Yes	122	21.2	45	31.2	37	25.7	22	15.3	18	12.5
Total	576	100	144	100	144	100	144	100	144	100
Choice of technologies										
No use	84	14.6	24	16.7	26	18.1	17	11.8	17	11.8
Improved seed	78	13.5	13	9	26	18.1	15	10.4	24	16.7
Fertilizer and Row planting	281	48.8	92	63.9	63	43.8	48	33.3	78	54.2
Herbicides	109	18.9	10	6.9	18	12.5	62	43.1	19	13.2
All technologies	24	4.2	5	3.5	11	7.6	2	1.4	6	4.2
Total	576	100	144	100	144	100	144	100	144	100
Type of storage facilities used										
Traditional Crib (hut)	415	72.1	91	63.2	97	67.4	101	70.1	127	88.2
Ordinary room	135	23.4	53	36.8	33	22.9	36	25	13	9
Public Silos and drying facilities	24	4.3			14	9.7	7	4.9	3	2.1

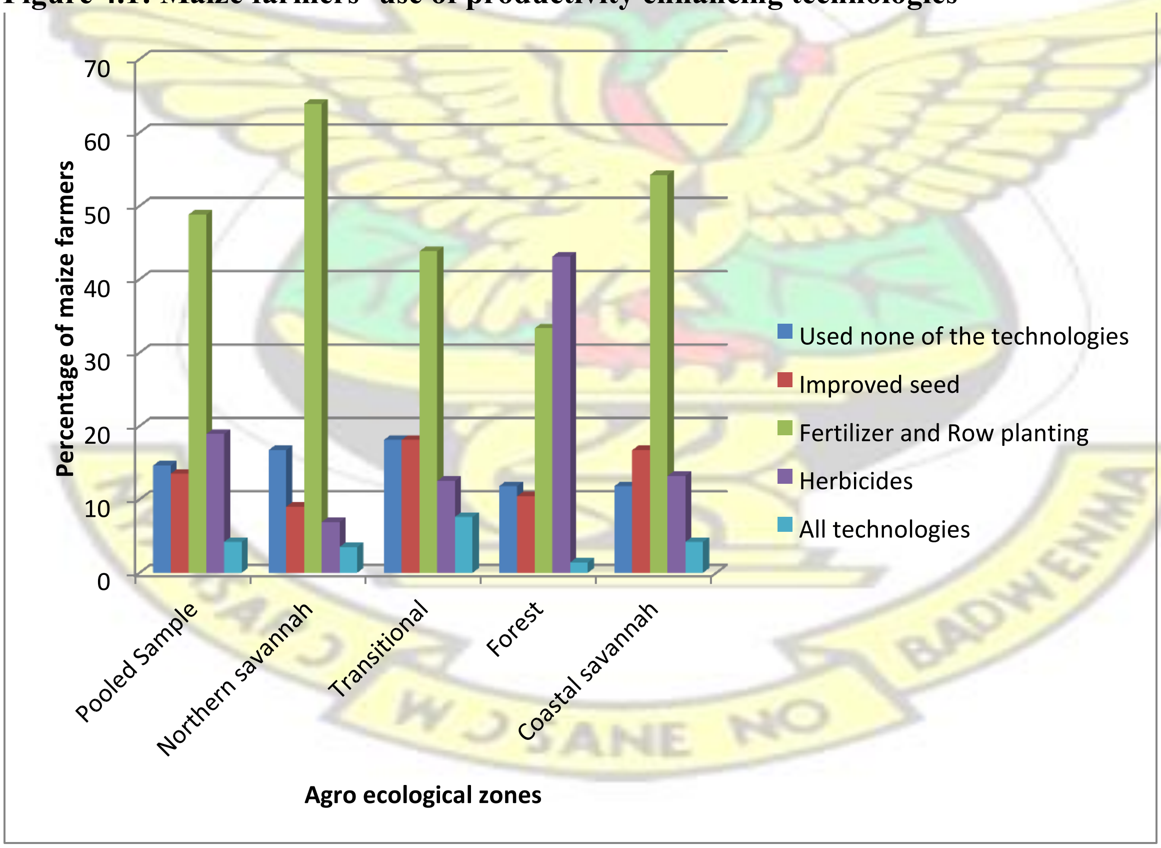
Others	1	0.2							1	0.7
Total	576	100	144	100	144	100	144	100	144	100

Source: Survey, 2015

used improved varieties. Traditional varieties are usually preferred by most smallholder farmers because of the quality of maize flour produced through the traditional system, fewer demands on fertilizers and ease in storage. Also, they are not susceptible to pests and they can be recycled as seed. The results suggest a higher usage of traditional maize varieties by maize farmers in Ghana as against the results of Ragasa et *al* (2013) that found that 61% of maize farmers planted improved varieties just that only 15% of them used certified seed. Out of the 230 farmers that used improved maize varieties in their production, as high as 83.4% of them planted Obatampa, a 1992 IITA/CIMMYT variety, 7.4% planted Mamaba, a 1996 CIMMYT hybrid variety, 2.2% planted Dadaba, 0.9% planted Odomfo and only 6.1% planted Nwanwa**,** a 2012 IITA variety which is hybrid yellow maize that is suitable for human, poultry and livestock consumption. The results corroborate the findings of Ragasa et *al* (2013) that Obatanpa is still the most popular variety and has even overshadowed the newer varieties. The average quantity of seed used per hectare for all the sampled maize farmers is 37.34kg (Table 4.4).This is quite high but, given that most farmers used traditional varieties, seeds were not difficult to come by since they could get it from their previous season.

With the issue of choice of technologies, the results presented in Table 4.3 show that 14.6% of the respondents in the pooled sampled did not adopt any of the technologies (improved seeds, fertilizer and row planting, herbicide), 13.5% of them used only improved seeds, 48.8% used fertilizer and row planting only, 18.9% used only herbicides and only 4.2% used all the technologies. With the exception of the forest zone, fertilizer and row planting remain the predominant productivity enhancing technology employed by most maize farmers in Ghana (Table 4.3). The current study asserts that few farmers in Ghana employ all the CSIR/MOFA recommended productivity enhancing technologies in the production of maize. Meanwhile, according to Ragasa et *al* (2013), the sluggish growth in the productivity of maize in Ghana is the result of no or poor use of maize productivity enhancing technologies. These technologies include but not limited to use of modern seed varieties, fertilizer, herbicides, pesticides as well as husbandry practices like row planting, green manuring, planting in mulch, etc. Figure 4.1 shows that few of the farmers in all agro ecological zones used all technologies, indicating that farmers used either a single technology, a combination of some of them or none. Moreover, 14.6%, 16.7%, 18.1%, 11.8% and 11.8% of maize farmers in the pooled sample, northern savannah, transitional, forest and coastal savannah zones respectively reported not to have used any of the technologies (i.e, improved seed, fertilizer, row planting and herbicides). Farmers used different

Figure 4.1: Maize farmers' use of productivity enhancing technologies



Source: Survey, 2015

categories of productivity enhancing technologies in maize production. Use of a combination of fertilizer and row planting was practiced by majority of the respondents in almost all agro ecological zones, indicating that farmers appreciate its importance in maize production as a means of improving maize productivity. That is, with the exception of the forest zone where herbicide was most used, the aforementioned combination was most used in the rest of the agro ecological zones, as 48.8% of maize farmers in the pooled sample, 63.9% of maize farmers in the northern savannah zone, 43.8% of maize farmers in the transitional zone and 54.2% of maize farmers in the coastal savannah zone used only fertilizer and row planting technologies combination. Herbicide was most used in the forest zone because the lands there are not good for using the plough because of the presence of many trees. Therefore, the maize farmers in this zone preferred chemical control of weeds instead of the use of the plough. For farmers in the forest zone to plough, they have to spend so much felling trees and removing stumps which is uneconomical, hence the popularity of herbicide use in this agro ecological zone.

With the exception of farmers in the forest belt, most farmers in the other three agro ecological zones used fertilizer (NPK and Sulphate of ammonia or Urea) in their maize production. For instance, 80.6% of maize farmers in the northern savannah zone used fertilizer in their maize production activities. Added to this is the fact that the pooled results also showed a 64.1% use of fertilizer (Table 4.3). Fertilizer use is therefore quite high in the study. This corroborates the results obtained by Ragasa et *al* (2013) that use of fertilizer greatly exceeds earlier reports, even though the extent of use was 50% of the recommended rate. The results presented in Tables 4.3 and 4.4 show that both the use and intensity of fertilizer are highest in the northern savannah zone and lowest in the forest zone. This is not surprising since forest farm lands are generally fertile than savannah ones and therefore required little or no application of

Table 4.4: Descriptive statistics of quantities and prices of inputs and outputs

Variable	Pooled				Northern Savannah				Transitional				Forest				Coastal Savannah			
	Min	Max	M	SD	Min	Max	M	SD	Min	Max	M	SD	Min	Max	M	SD	Min	Max	M	SD
Farm size (ha)	0.2	70	2.862	12.71	0.4	11.6	2.742	1.707	0.4	70	3.408	4.732	0.2	54.5	3.34	24.9	0.4	7.2	1.96	0.2
2012 maize price (Gh¢/Kg)	0	1.5	0.779	0.235	0	1.3	0.488	0.16	0.2	1.2	0.854	0.19	0.1	1.5	0.929	0.19	0.6	1.2	0.865	0
Fertilizer quantity (Kg)	0	6000	350	556	0	6000	481	644	0	4000	465	649	0	1250	141	254	0	2800	313	0
Herbicide quantity (Litres)	0	60	5.164	7.445	0	48	6.222	8.145	0	60	4.875	7.94	0	60	4.479	8.51	0	24	5.08	0
Pesticide quantity (Litres)	0	11	0.111	0.889	0	6	0.118	0.724	0	11	0.229	1.373	0	3	0.021	0.25	0	1	0.007	0
Quantity of seed (Kg)	6	720	37.34	46.04	0	117	28.39	19.05	0	720	59.66	79.22	2.5	120	22.33	17.9	6	144	39.08	6
Quantity of labour (man-days)	9	1096	69.07	97.16	0	1020	75.64	106.5	0	1096	80.78	139.2	0	380	48.44	51	9	363	71.57	9
Quantity of manure (Kg)	0	6000	29.25	272.7	0	6000	41.67	500	0	750	9.375	75.25	0	500	40.97	124	0	1400	25	0
Capital (Ghana Cedis)	40	10000	558	766	100	3500	697	637	150	10000	899	1232	0	3000	328	322	0	2000	307	40
Price of fertilizer (Gh¢/Kg)	0.4	3.1	1.069	0.862	0	3	0.5	0.778	0.2	2.2	1.344	0.797	0	3.1	1.5	0.78	0	2.15	0.851	0.4
Price of pesticide(Gh¢/Litre)	5	18	10.1	65	0.1	22	9.2	2.808	0	25	11.1	4.262	0	15	10.3	1.25	0	14	9.5	5
Price of herbicide (Gh¢/Litre)	4.5	45	9.453	7.903	5	45	10.34	9.215	6.5	25	8.129	7.745	0	25	8.068	7.81	0	25	11.27	4.5
Price of maize seed (Gh¢/Kg)	0	15	2.823	1.496	1.5	15	3.637	1.832	1.8	8	2.209	1.431	1.00	5	2.758	1.16	1	5.5	2.688	0
Price of labour (Gh¢/Man-day)	4.5	20	11.97	8.175	3.5	44	7.058	6.263	5.4	21	12	10.97	0	20	10.29	5.43	8	20	11.69	4.5
Price of manure (Gh¢/Kg)	0	1	0.012	0.066	0	0.1	0.005	0.022	0	0.1	0.004	0.02	0	0.2	0.019	0.05	0	1	0.019	0
Price of land (Gh¢/ha)	0	267	30.39	33.19	0	250	13.93	32.47	0	267	47.09	32.19	0	150	28.26	32.3	0	90	32.26	0
Price of capital (Gh¢)	5.6	42.33	12.92	5.724	0	30.8	11.83	5.802	0	40	12.78	7.091	0	42.33	13.29	5.33	7	27	13.79	5.6
Output of maize (Kg)	10	40000	2753	3435	50	8600	2230	1644	200	40000	4190	5429	150	6000	1130	959	10	11700	3461	10
Maize yield (Kg/ha)	10	2200	1800	1145	12	1845	1375	1847	600	2900	2375	2000	15	1600	1075	1200	98	2100	1725	1400
2013 price of maize (Gh¢/Kg)	0.4	1.7	0.97	0.24	0.5	1.5	0.796	0.196	0.4	1.5	0.91	0.168	0.6	1.7	1.179	0.27	0.5	1.6	1.011	0.4

Source: Survey, 2015

fertilizers. Use of pesticides was not very common in maize production in the various agro ecological zones as 97.2% of the farmers did not apply pesticides (Table 4.3). With the exception of few occasions of army worms and stem borer infestation as well as *streak virus* infection, maize is not normally affected by diseases and pests. This probably, could have contributed to the low pesticide usage recorded in the production of maize in the study area. It could also be that most farmers planted improved disease and pest resistant varieties that needed no spraying with pesticides. With minimum and maximum quantities of 0 and 11 litres of pesticides used in the pooled sample, its intensity was highest in the transitional zone (mean quantity of 0.229 litres) and lowest in the coastal savannah zone (mean quantity of 0.007) (Table 4.4). Farmers in the transitional zone had to apply more pesticides because of army worm infestation. The popularity of use of herbicides currently in Ghana is the result of the influx of low-cost formulations of herbicides imported from China (Ragasa et *al*, 2013). The results of the current study show that a greater percentage of maize farmers in all agro ecological zones used herbicides (Table 4.3). Examples of herbicides used in Ghana by maize farmers are *Adwumawura*, *Sunphosate*, *Gramazon*, *Atrazine*, *Condem*, *Caliherb*, *herbazal* and *power*. The average quantity of these herbicides used by maize farmers in Ghana was also calculated to be 5.16 litres per hectare (Table 4.4). The aforementioned results also agree with those of Ragasa et *al* (2013) that about 73% of maize farms in Ghana used herbicides at an average rate of 9.2 litres per hectare for those who applied it, which is higher than the recommended rates.

4.3.2 Factors influencing use of maize production technologies in Ghana

The estimated coefficients of the multinomial logit model for the pooled data, along with the levels of significance and marginal effects are presented in Table 4.5. Those of the northern,

Table 4.5: Parameter estimates and marginal effects of the multinomial logit model for determinants of use of maize technologies for the pooled sample of maize farmers in Ghana

Independent Variable	Improved Seed		Fertilizer/Row Planting		Herbicides		All technologies	
	Coeff/SE	dy/dx	Coeff/SE	dy/dx	Coeff/SE	dy/dx	Coeff/SE	dy/dx
Constant	-4.162 (1.482)		-0.2836233 (0.912532)		-0.0974494 (1.039482)		-5.483077 (2.170445)	
HOSIZE	1.015 (0.607)	0.046078*	0.4348166 (0.3804489)	0.006701***	0.060983 (0.424183)	0.003081**	0.7331031 (0.7946723)	0.004443
SEX	0.366 (0.503)	0.0055513	0.3298469 (0.3508734)	0.0172541	0.6336044 (0.402972)	0.0015268	0.4377763 (0.6453362)	0.002115
AGE	-0.0263781 (0.0207)	-0.000437	-0.0243 (0.0144663)	-0.001980*	-.0247001 (0.0166166)	-0.000015	0.0202272 (.0259176)	0.0007119
EDU	0.079837 (.047081)	0.002258*	0.0589003 (0.035586)	0.0019141	0.0582716 (0.0423386)	$8.9\text{x}10^{-06}$	.0721129 (0.0632778)	0.0002638
EXP	0.028241 (.0259276)	0.003099	.0100192 (0.0161161)	0.0050249	0.0172659 (0.0199573)	0.000107	0.0863 (0.0393545)	0.001523**
LANDSZ	-0.1625801 (0.119146)	-0.014858	0.0083169 (0.0184601)	0.0140109**	0.0004908 (0.0198757)	0.0000492*	.004465 (0.1505964)	0.000079***
NPLOTS	-0.606 (0.29954)	-0.0116**	-0.492 (0.161419)	-0.00398***	0.0710929 (0.1024621)	0.0028502	-2.0006 (0.7972486)	-0.025599**
CAPgin	0.0007 (0.0003282)	0.000014**	0.00059 (0.000272)	0.0000385**	-0.0005114 (0.0003921)	$-5\text{x}10^{-06}$	0.0003038 (0.0005196)	$-4.\text{x}10^{-06}$
NOEXTVI	0.697 (0.1315091)	0.027528***	0.415 (0.1245699)	0.002066***	0.1480422 (0.1425718)	-0.001352	0.662 (0.1385987)	0.004216***
MGROUP	0.279724	0.0089517*	0.3679794	0.1427418*	13.9382	0.138886**	0.1312444	0.00072

	(0.6625257)		(0.5557325)		(389.8082)		(0.8033682)	

Source: Survey, 2015

Note: Coeff = Coefficient, SE=Standard errors are in parentheses. The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%. dy/dx represents marginal effects.

Table 4.5: Continued

Independent Variable	Improve Seed		Fertilizer/Row Planting		Herbicides		All technologies	
	Coeff/SE	**dy/dx**	**Coeff/SE**	**dy/dx**	**Coeff/SE**	**dy/dx**	**Coeff/SE**	**dy/dx**
CREDIT	2.896 (0.8525722)	0.11652***	1.965 (0.7884721)	0.03052**	1.273219 (0.908442)	0.002940	2.558 (0.9677492)	0.011086***
SPMAIj12k	0.9859134 (0.7851234)	0.0486533	0.4221495 (0.5129629)	-0.049220	0.3511417 (0.5494837)	-0.000676	2.806 (1.278565)	0.0392722**
REDYMKT	1.675 (0.6682139)	0.029898**	1.554 (0.3839164)	0.17092***	0.54242 (0.4582554)	-0.005377	0.6571802 (0.7311412)	-0.014423
NOSAV	2.697 (0.8303644)	0.246689***	.678728 (0.4762094)	0.272255**	.457251 (0.6109705)	0.005461*	3.558 (1.17435)	0.0942287***
TRASIT	2.395 (0.7285025)	0.309686***	-.0146937 (0.4511752)	-0.347557	-.2850218 (0.5309237)	-0.003175	2.749 (0.9851135)	0.0742649***
FOREST	1.841 (0.8012241)	0.208186**	0.1635342 (0.4826165)	-0.183584	0.971 (0.5281144)	0.003212*	0.4665411 (1.231217)	0.0008767
Number of Observations				571				
LRchi2 (64)				429.51				
Prob> chi2				0.000				

Pseudo R2	0.2792
Log likelihood	-554.423

Source: Survey, 2015

Note: Coeff = Coefficient, SE=Standard errors are in parentheses. The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%. dy/dx represents marginal effects.

transitional, forest and coastal savannah zones are also presented in Appendices I – IV. The standard errors in each model are also presented in the table and appendices in parenthesis. The likelihood ratio statistic, as indicated by chi-square statistic, is highly significant at the 1% significance level for each model, suggesting the robustness of the models. The marginal effects represented by dy/dx measure the expected change in probability of a particular choice being made with respect to a unit change in an explanatory variable. In all cases, the estimated coefficients of the explanatory variables are compared with the base category of non-use of productivity enhancing technologies in maize production.

The coefficient and the marginal effect of age in the pooled sample are negative for use of fertilizer and row planting and this is significant at the 10% significance level. That is a unit increase in the age of a maize farmer would result in a 0.198% decrease in the chances of the farmer using fertilizer and row planting technologies. Similarly, the coefficients and marginal effects of age are negative for use of improved seeds, herbicides as well as fertilizer and row planting in the forest zone of Ghana and these are significant at 5%, 10% and 10% significant levels respectively. A year increase in the age of a maize farmer in the forest zone has the effect of decreasing the likelihood of the farmer using improved seeds, herbicides as well as fertilizer and row planting by 0.0822%, 0.0373% and 0.0448% respectively. The reasons for the inverse relationship between age and use of improved inputs were the conservative nature of older farmers and the fact that younger farmers were more risk-loving than elderly ones. This finding confirms those of many improved input use studies that age constitutes one of the human capital variables that are known to be negatively related to use of productivity enhancing technologies (Simtome et *al,* 2009; Langyintuo and Mekuria, 2008; Cavane and Subedi, 2009). Conversely, the coefficient and the marginal effect of age are positive for use of all technologies (Improved seeds, fertilizer and row planting, herbicides) in the northern savannah zone, indicating a positive correlation between farmer's age and use of the aforementioned technologies. The coefficient of age is statistically significant for use of all technologies in the northern savannah zone at the 10% significance level. An increase in the age of a maize farmer by one year would increase the probability that the farmer would employ all the productivity enhancing technologies by $2x10^{08}$%. The implication is that older maize farmers are more likely to use productivity enhancing technologies than young farmers. This finding corroborates the findings of Etoundi and Dia (2008) that reported a positive and significant relationship between age group and use of improved maize variety, CMS 870 in Cameroon. The study found that early users of CMS 8704 were mostly adults and the highest user rate was that of farmers aged between 46 and 60 years (58.18%).

As can be seen in Table 4.5, farming experience is positive and statistically significant for use of all technologies at the 5% significant level for the pooled data. That is, a year increase in maize farming experience will increase the probability of maize farmers in all agro ecological zones using all technologies by 0.15%. This result was consistent across three of the four agro ecologies in Ghana. For instance, a unit increase in maize farming experience would cause a 0.022% rise in the probability of a maize farmer using improved seeds in the northern savannah zone (Appendix I). Farming experience was also found to be statistically significant and positively related to herbicide as well as fertilizer and row planting technologies in the forest and coastal savannah zones respectively (Appendices III and IV). This finding agrees with Amaza et *al* (2007) that reported a positive influence of farming experience on use of improved inputs in the Guinea Savannas of Nigeria.

The coefficients and marginal effects of the variable representing farm size are positive for use of all technologies, herbicides as well as fertilizer and row planting for the pooled sample and these are significant at 1%, 10% and 5% respectively (Table 4.5). For this sample, an increase in land under maize cultivation by one hectare would increase the probability of a maize farmer using all technologies, herbicides as well as fertilizer and row planting by 7.91×10^{-3}%, 4.92×10^{-3}% and 1.4% respectively. The results also revealed a positive relationship between farm size and use of improved seeds and herbicides in the transitional zone (Appendix II). In this zone, a rise in farm size by one hectare has the effect of increasing use of improved seeds and herbicides by 0.28% and 3.9×10^{-5}% respectively. The coefficient and marginal effect of farm size are however negative for use of improved seeds in the pooled sample. It is also negative for use of each technology category for maize farmers in the northern savannah zone. Results from farmers in the transitional zone also showed that there is a negative correlation between farm size and use of fertilizer and row planting (Appendix II). The negative relationships observed could be the result of inadequate funds to meet the demands of large farms so even though farmers may have the desire to adopt these technologies they probably lack the ability to purchase the technologies. From the foregoing, it would be very difficult to tell whether farm size has a positive or negative effect on use of productivity enhancing technologies. This is consistent with mixed effects of farm size on technology use observed in previous studies. For instance, in the studies conducted by Nkonya et *al* (1997), Iqbal et *al* (1999), Morris et *al* (1999), Simtowe et *al* (2009), Langyintuo and Mekuria (2008) and Tura et *al* (2010), land holding size was found to have a positive and significant effect on use of maize production technologies, indicating that households with larger land holdings allocated more land to improved maize technologies.

Inconsistent with this finding, Etoundi and Dia (2008) point out that increasing land area diminishes the likelihood of use of the improved seed variety, CMS 8704. The reason was that a big sown area with maize requires much manpower and huge resources.

The results of the pooled regression show that the number of extension visits received by the maize farmer is positively related to use of improved seeds, all required technologies as well as fertilizer and row planting. It was however found to be negatively related to use of herbicide. The variable is statistically significant at the 1% significance level for use of improved seeds, all technologies as well as fertilizer and row planting and insignificant for use of herbicide. This result is consistent with apriori expectation since increase in the number of extension visits received by the farmer enhances his/her knowledge of existing production technologies. An increase in extension contact by one visit would increase the likelihood of a maize farmer using improved seeds, all technologies as well as fertilizer and row planting by 2.8%, 0.42% and 0.21% respectively (Table 4.5). Similar results were also found in almost all the agro ecological zones only that none of the variables was statistically significant in the northern savannah and forest zones. For instance, results from the transitional zone revealed positive relationships between maize farmer's contact with extension officers and use of improved seeds, all technologies as well as fertilizer and row planting and insignificant for use of herbicide. In this agro ecological zone, increasing extension contact by one visit has the effect of increasing the probability of a maize farmer using improved seeds, all technologies as well as fertilizer and row planting by 1.4%, 0.49% and 1.95% respectively (Appendix II). Each of these coefficients was found to be statistically significant at 1%. A number of previous studies have also reported a positive influence of extension contact on use of agricultural technologies (Kaliba et *al*, 2000;

Amaza et *al*, 2007; Langyintuo and Mekuria, 2008; Paudel and Matsuoka, 2008; Tura et *al*, 2010). These studies explained that regular extension contact makes farmers aware of new improved technologies and how they are applied. Furthermore, a study by Yaron, et *al* (1992) showed that extension contact can offset the negative effect of little or no formal education on use of some technologies, thereby positively impacting on technology use.

The influence of male-gender is positive for use of each of improved seeds, a combination of fertilizer and row planting, herbicides as well as a combination of all four technologies although the variable is not statistically significant for either of them in the pooled sample. Being a male farmer has the effect of increasing the probability of using the aforementioned technologies by 0.56%, 1.73%, 0.15% and 0.22% respectively (Table 4.5). In the northern savannah zone, with the exception of the response of use of herbicides to male-gender which was negative, positive relationships were observed between male maize farmers and use of improved seeds, a combination of fertilizer and row planting as well as a combination of all four technologies. In this agro ecological zone, the implication is that male farmers will more likely adopt improved seeds, a combination of fertilizer and row planting as well as a combination of all four technologies than females. That is being a male farmer will increase the likelihood of a maize farmer in the northern savannah zone using improved seeds, a combination of fertilizer and row planting as well as a combination of all four technologies by 0.06%, 5.5% and $7x10^{-6}$% respectively (Appendix I). In the transitional zone, the effect of male-gender was positive for use of improved seeds and herbicides and negative for use of a combination of fertilizer and row planting as well as a combination of all four technologies. That is, being a male farmer in the transitional zone will 5.6% and $3.4x10^{-06}$% more likely increase use of improved seeds and herbicides respectively than females (Appendix II). Conversely, in this transitional zone, males will 2.4% and 3.2% more likely see a decrease in their ability to use a combination of fertilizer and row planting as well as a combination of all four technologies. With the exception of use of a combination of fertilizer and row planting, the effect of male-gender on improved input use was also positive on all the technology categories in the forest zone (Appendix III). Finally, in the coastal savannah zone, gender was negatively related to use of improved seeds. It was however positively related to use of a combination of fertilizer and row planting, herbicides and a combination of all four technologies. The positive effect of gender could be attributed to the crucial roles women performed in the domestic and economic life of society which affected their use of improved inputs. This comprises the unmeasured noneconomic activities such as child care, cooking, cleaning, etc, performed by females in the household. The results reveal a mix effect of gender on use of agricultural technologies. The results of previous studies also revealed conflicting evidence concerning the diverse roles men and women play in use of productivity enhancing technologies. The findings of the works of Doss and Morris (2001) as well as Overfield and Fleming (2001) revealed insignificant effects of gender on improved input use. Chirwa (2005) also confirmed this by concluding that the gender of the farmer is not a significant determinant of technology use both with respect to inorganic fertilizers and improved maize varieties.

The positive effects of education, measured in years of schooling on use of improved seeds, a combination of fertilizer and row planting, herbicides and a combination of all four technologies in the pooled sample are expected. The variable is statistically significant at the 10% significance level for use of improved varieties but insignificant for the other technology categories. An increase in the level of education by one more year will increase the likelihood of a maize farmer's use of improved seeds, a combination of fertilizer and row planting, herbicides and a combination of all four technologies by 0.23%, 0.19%, 8.9×10^{-4}% and 0.026% respectively (Table 4.5). In the northern savannah zone, education was found to be positively related to use of fertilizer and row planting and this was statistically significant at the 5% significance level. That is, one more year of education to a maize farmer in the northern savannah zone will increase the likelihood of the farmer using fertilizer and row planting by 1.7% (Appendix I). In this agro ecological zone, even though the effect of years of education was negative on uses of improved seeds and a combination of all technologies, none of them was significant. In the transitional zone, the effect of education was equally positive for uses of improved seeds, fertilizer and row planting as well as a combination of all four technologies. The effect of education was statistically significant at the 5% significance level for improved seeds as well as a combination of fertilizer and row planting. It was however statistically significant at the 1% significance level for a combination of all four productivity enhancing technologies (Appendix II). The results show that an increase in the level of education by one year will increase the probability that a maize farmer in the transitional zone will use improved seeds, fertilizer and row planting as well as a combination of all four technologies by 0.27%, 0.97% and 0.7% respectively. The effect of years of formal education on use of improved inputs was however not significant for any of the technologies (improved seeds, fertilizer and row planting, herbicides as well as a combination of all four technologies) in the forest and coastal savannah zones. The results in general reveal a positive relationship between years of formal education and use of productivity enhancing technologies and this corroborate those of a large number of improved input use studies (Nkonya et *al*, 1997; Ntege-Nayeena et *al*, 1997; Iqbal et *al*, 1999; Morris et *al*, 1999; Paudel and Matsuoka, 2008). The implication is that educated farmers are expected to be more able to understand and use new technologies in a shorter period of time than uneducated ones. Also, Rogers (2003) notes that the complexity of a technology often poses a negative effect on its use and that education is thought to reduce the amount of complexity perceived in a technology thereby increasing its use. Conversely, negative influence of education was also observed in some studies. For instance, Tura et *al* (2010) stated that families headed by educated people were relatively less likely to adopt and use recommended maize varieties, given the fact that the relatively more educated household heads are youngsters and that land ownership among the youth is minimal thereby making them land constrained. It was similarly reported in Ethiopia that education influences timing of use but not whether to use an agricultural innovation (Weir and Knight, 2000b). Etoundi and Dia (2008) also observed that farmers having secondary education were less likely to use the improved maize seeds, CMS 8704. However, having a primary level of education was found to have a positive though not significant effect on the use of CMS 8704 improved maize seeds.

Considering the pooled sample, the coefficients and the marginal effects of the variable representing household size are positive and statistically significant for use of improved seeds, fertilizer and row planting as well as herbicides, indicating a positive correlation between maize farmers' family size and use of maize production technologies. The variable is statistically significant at the 10% significance level for use of improved seeds, 1% significance level for use of fertilizer and row planting and 5% significance level for use of herbicides (4.5). The results in Table 4.5 further show that an increase in the household size of a maize farmer by one person would increase the probability that the farmer will adopt improved seeds, fertilizer and row planting and herbicides by 4.6%, 0.67% and 0.31% respectively. The results from farmers in the transitional zone also showed positive significant relationships between household size and use of improved seeds, fertilizer and row planting as well as a combination of all four productivity enhancing technologies. In this zone, one more person added to the maize farmer's family would cause a 5.7%, 8% and 2.3% increase in the likelihood of the maize farmer using improved seeds, fertilizer and row planting as well as a combination of all four productivity enhancing technologies respectively (Appendix II). The situation was not different for maize farmers in the coastal savannah zone of Ghana. In this zone, maize farmers recorded positive significant relationships between household size and uses of improved seeds and herbicides. A unit increase in family size for maize farmers in this agro ecological zone will lead to a rise in the probability that a farmer will use improved seeds and herbicides by 9.2% and 0.25% respectively. The variable was statistically significant at the 5% significance level for improved seeds and 1% significance level for herbicides. The implication is that maize farmers with large family sizes are more likely to use productivity enhancing technologies than those with small families. In the forest zone of the country, the effect of household size was found to be negatively related to use of improved seeds and positively related to use of herbicides and these were statistically significant at the 10% and 5% significance levels respectively. Specifically, the results in this agro ecological zone show that a unit increase in household size will decrease the probability of use of improved seeds by 0.22% but will increase the probability of use of herbicides by 3.2%. The coefficients and the marginal effects of family size for use of improved seeds as well as fertilizer and row planting in the northern savannah zone of Ghana are however negative and statistically significant at the 5% and 10% significance levels respectively, indicating the probability that a maize farmer will use improved seeds as well as fertilizer and row planting will fall with an increase in the household size of the farmer. Magnitude wise, a unit increase in the household size of a maize farmer will therefore result in a 4.8% and 20.7% decrease in the chances of the farmer using improved seeds as well as fertilizer and row planting technologies respectively. The results of the effect of household size so far discussed reveal mixed effects of family size on use of various maize productivity enhancing technologies. That is why Kafle (2010) reported that it is not easy to give a broad view of the effect of household size on agricultural technology use because both positive and negative influences have been noticed in previous studies. The implication is that family members may or may not give support to improved input use programmes. Use of most improved technologies is labour intensive (Feder et *al*, 1985). Therefore, if labour is supplied by the family member, use of productivity enhancing technologies is likely to be positive. Consistent with the notion of Feder et *al* (1985), use of hired labour was found to be positive in most studies (Ntege-Nanyeena et *al*, 1997; Amaza et *al*, 2007 and Etoundi and Dia, 2008). However, Amaza et *al* (2007) stated that it is likely that farmers with larger families attach greater importance to nonfarm activities than those with smaller households.

Membership to a group or farmer association was found to be positively related to use of improved seeds, fertilizer and row planting as well as herbicides for the pooled sample. For this sample, farmers who belong to farmer associations will more likely have their probabilities of using the aforementioned groups of agricultural technologies increased by 0.9%, 14.3% and 13.9% respectively. The variable was significant at 10% for improved seeds, 10% for fertilizer and row planting and 5% for herbicides. The results found in each of the four agro ecological zones considered in this study support those of the pooled sample. For instance, in the northern savannah zone, positive significant effects of membership of a farmer association on use of improved seeds, fertilizer and row planting as well as a combination of all four technologies were obtained. Specifically, in this zone, belonging to a farmer association will increase the likelihood of a maize farmer using improved seeds, fertilizer and row planting as well as a combination of all four technologies by 2.1%, 1.2% and 0.01% respectively. These margins are statistically significant at the 5%, 1% and 10% significance levels respectively. Similarly, in the coastal savannah zone, maize farmers belonging to farmer associations will more likely have their probabilities of using improved seeds, fertilizer and row planting as well as herbicides increased by 22.2%, 13.2% and 9.1% respectively than those who do not belong to any farmer association. Farmers who belong to farmer associations therefore easily use productivity enhancing technologies than those who do not belong to any such association. This is because agricultural technologies are normally disseminated through farmer associations and therefore farmers who belong to such associations will more likely have access to and knowledge of suggested technologies than those who are not members of such associations. Consistent with this finding are the results of the works of Bonabana-Wabbi (2002), Amaza et *al* (2007) and Mohammed et *al* (2012) that found a positive influence of group or association membership on use of agricultural technologies.

The coefficient of the variable representing access to credit has a positive effect on use of improved seeds, fertilizer and row planting as well as a combination of all four technologies for the pooled sample and these are statistically significant at 1%, 5% and 10% respectively. The results showed that access to credit would increase the odds that a maize farmer will use improved seeds, fertilizer and row planting as well as a combination of all four technologies by 11.6%, 3.1% and 1.1% respectively. Also, in the northern savannah zone, the effect of credit was found to be positively related to use of improved seeds as well as fertilizer and row planting. The results further showed that increasing access to credit will cause a rise in the odds of using improved seeds as well as fertilizer and row planting by 2.9% and 12% respectively. These margins are statistically significant at 5% and 10% respectively. In the transitional, forest and coastal savannah zones, positive relationships between access to credit and use of improved seeds, fertilizer and row planting, as well as a combination of all four technologies were found, just that the variable was not significant for any of the technology categories. The implication is that access to credit is crucial to use of maize production technologies. This is because access to credit reduces liquidity constraints that maize farmers normally face in purchasing agricultural inputs and hence paves the way for timely application of inputs thereby increasing the overall productivity and farm income (Mpawenimana, 2005). The results of the current study is also in line with those of Hailu et *al* (2014) that found that farm households who have credit access, keeping other things constant, have 9.9% and 24.5% higher probability of using chemical fertilizer and improved seeds respectively unlike farmers that are credit constrained. The study added that, as a liquidity factor, the more farmers have access to sources of finance, the more likely they will use agricultural technologies that could possibly increase crop output. The results of the current study are also in line with MOFA (2010) report that high levels of poverty among farmers as well as poor access to credit make it very difficult for them to purchase and apply productivity enhancing technologies. This is especially so because of the high cost of most improved technologies which makes it difficult for most farmers, for instance those living in villages where poverty is widespread to be able to afford and use them (Benin et *al*, 2009).

The effect of the variable for access to ready market was found to be positively related to use of improved seeds as well as fertilizer and row planting for the pooled sample. The results show that maize farmers who have access to ready market will more likely have their odds of using improved seeds as well as fertilizer and row planting increased by 3% (significant at 5%) and 17.1% (significant at 1%) respectively. For farmers in the northern savannah zone, the effect of access to ready market was also significantly positive for use of improved seeds and herbicides. In this zone, access to ready market allows maize farmers to have their probabilities of use of improved seeds and herbicides increased by 0.86% and 0.35% respectively. The variable is significant at 10% for use of improved seeds and 5% for use of herbicides. The effect of access to ready market on improved input use in the transitional zone was positive and statistically significant for improved seeds, fertilizer and row planting as well as a combination of all four productivity enhancing technologies. Market accessibility in this agro ecological zone will 1.8% (significant at 1%), 3.8% (significant at 1%) and 5.6% (significant at 10%) more likely increase the likelihood of use of improved seeds, fertilizer and row planting as well as a combination of all four productivity enhancing technologies than no market access. Similar significant positive effects of access to ready market on use of improved inputs were obtained for maize farmers in the forest and coastal savannah zones. For instance, in the forest zone, the effect was positive on use of fertilizer and row planting as well as herbicides. Appendix III shows that access to ready market by maize farmers in the forest zone of Ghana will increase their probabilities of use of fertilizer and row planting as well as herbicides by 3.9% (significant at 10%) and 3.6% (significant at 5%) respectively. In the coastal savannah zone, the effect of access to ready market by maize farmers was significantly positively related to use of fertilizer and row planting. Market accessibility in this zone has the effect of increasing the likelihood of use of fertilizer and row planting by 2.5% and this is significant at the 10% significance level. The results corroborate those of previous studies (Jansen et *al*, 1990; Strasberg et *al*, 1999; Ransom et *al*, 2003; Kamara, 2004).

The variable representing the previous year's price of maize has a positive significant relationship with use of a combination of all four technologies in the pooled sample. Table 4.5 shows that an increase in the previous year's price of maize by one Ghana Cedi will increase the odds of a maize farmer using a combination of all four technologies by 3.9% and this was significant at the 5% significance level. Similarly, the previous year's price variable was found to be positively related to use of improved seeds and a combination of all four technologies in the northern savannah zone. A unit increase in the previous year's price of maize will increase the likelihood that a maize farmer in the northern savannah zone will use improved seeds and a combination of all four technologies by 2.3% (significant at 1%) and $2x10^{-4}$% (significant at 1%) respectively. In the transitional zone, the effect of previous year's price of maize is positive for use of each of the technology categories considered in the study and significant for use of improved seeds as well as fertilizer and row planting. The results revealed that a unit rise in the previous year's price of maize will cause an increase in the odds of a maize farmer in the transitional zone using improved seeds as well as fertilizer and row planting by 6.7% and 5.5% respectively. The variable is significant at 5% for use of improved seeds and 10% for use of fertilizer and row planting. An increase in the previous year's price will let maize farmers have confidence in the maize production business and this allows them to go the extra mile to employ all possible productivity enhancing technologies in their production plans (Jack, 2013).

Finally, the coefficients of the variable representing maize farmers living in the northern savannah zone of Ghana are positively related to use of all the technologies considered in the study (i.e. improved seeds, fertilizer and row planting, herbicides, all technologies). Maize farmers living in the northern savannah zone will more likely have their chances of using improved seeds, fertilizer and row planting as well as a combination of all four technologies increased by 24.7%, 27.2%, 0.55% and 9.4% respectively (Table 4.5). The variable is statistically significant at 1% for use of improved seeds, 5% for use of fertilizer and row planting together, 10% for herbicides and 1% for use of a combination of all four technologies. The higher user rates recorded in the northern savannah zone could be one of the positive impacts of the Savannah Accelerated Development Authority (SADA) project that supplied production inputs to farmers in the northern part of the country. Living in the transitional zone variable was also found to be positive and statistically significant for use of improved seeds and a combination of all four technologies (1% for each technology). Living in the transitional zone will cause maize farmers to have their odds of using improved seeds and a combination of all four technologies by 31% and 7.4% respectively. This is due to availability of improved imputs and a well-developed road transport system considering the importance of maize production in the transitional zone (Smith et *al*, 1994; Morris et *al*, 1999). The variable for farmers living in the forest zone was also positive and statistically significant for use of improved seeds and herbicides. Living in the forest zone has the effect of increasing the likelihood of use of improved seeds and herbicides by 20.8% and 0.32% respectively. The variable was significant at 5% for use of improved seeds and 1% for use of herbicides. This is due to the fact that maize farmers in the forest zone received the highest number of years of formal education (Table 4.2). This is because educated farmers are assumed to have higher ability to notice, understand and accept new information about productivity enhancing technologies than their uneducated counterparts (Langyintuo and Mekuria, 2005; Tabi et *al*, 2010).

4.4.1 Determinants of maize output in various agro ecological zones

Maximum likelihood estimates of the stochastic frontier production function and the inefficiency model were estimated simultaneously using the computer program STATA. Estimates for the preferred frontier model were obtained after testing various null hypotheses in order to evaluate suitability and significance of the adopted model using the generalized likelihood ratio statistic. The test results for data collected from each of the four agro ecological zones and that of the pooled sample showed that the rather popular but inflexible Cobb-Douglas functional form should be rejected since at least one of the interaction terms is statistically different from zero (Table 4.6).

Table 4.7 presents the variance parameters for the stochastic frontier production function for maize farmers in Ghana. The gamma (Υ) values of 0.999999, 1, 0.999999,1 and 1 for maize farmers in the pooled sample, northern savannah zone, transitional zone, forest zone and coastal savannah zone lie between 0 and 1 with a value equal to 0 implying that technical inefficiency is absent and the ordinary least square estimation would be an adequate representation and a value close or equal to 1 implying that the frontier model is appropriate (Piesse and Thirtle, 2000). The values of gamma mean that about 99.9%, 100%, 99.9%, 100% and 100% of total variance of composed errors of the production functions for maize farmers in the pooled sample, northern savannah, transitional, forest and coastal savannah zones respectively are explained by the variance of the technical inefficiency terms of the respective production functions. This also means that about 99.9%, 100%, 99.9%, 100% and 100% of the total variations in outputs for maize farmers in the pooled sample, northern savannah, transitional, forest and coastal savannah zones were as a result of factors within the control of the farmer and that variations in maize outputs could be attributed to inefficiency. That is the differences between actual (observed) and frontier output had been dominated by technical inefficiencies. The results therefore suggest that about 0.1%, 0%, 0.1%, 0% and 0% of the variations in maize outputs for maize farmers in the pooled sample, northern savannah, transitional, forest and coastal savannah zones are due to random shocks outside the farmer's control. Examples of these random shocks include bad weather, diseases, topology, bushfires as well as statistical errors in measuring data. This therefore represents the importance of incorporating technical inefficiency in the production function. Lambda (λ) is the ratio of the U and V error terms and is far greater than one (1) for

Table 4.6: Results of hypotheses test for the used model

Restriction	Pooled				Northern Savannah				Transitional				Forest				Coastal Savannah			
	L(H_0)	λ	χ_2	**D**	**L(H_0)**	λ	χ_2	**D**	**L(H_0)**	λ	χ_2	**D**	**L(H_0)**	λ	χ_2	**D**	**L(H_0)**	λ	χ_2	**D**
$H_0: \beta_{ij} = 0$	-98.2	38.2	23.3	R	-85.3	24.2	23.3	R	-99.4	52.5	23.3	R	-81.3	44.1	23.3	R	-112.2	62.8	23.3	R
$\delta_m = 0$	-148.7	28.4	10.1	R	-178.3	45.8	10.1	R	-83.4	31.2	10.1	R	-94.8	21.7	10.1	R	-138.7	34.4	10.1	R

Critical values are at 5% significance level and are obtained from χ^2 distribution table. *L(H₀)* = Log likelihood function,   = Test statistic, *D* = Decision on whether hypothesis accepted or rejected, *R* = Hypothesis is rejected, *NR* = Hypothesis is not rejected. β_{ij} = Parameters in the square and cross terms and δ_m = Parameters in the inefficiency term.

Variable		**Pooled Sample**	**Northern Savannah**	**Transitional**	**Forest**	**Coastal Savannah**
		Coeff	**Coeff**	**Coeff**	**Coeff**	**Coeff**
Sigma squared	$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.72206*	0.361***	0.21**	0.257**	0.37133*
Gamma	$\gamma = \sigma_u^2/\sigma^2$	0.999999	1***	0.99***	1***	1***
Lambda	$\lambda = \sigma_u/\sigma_v$	3764018***	1007194***	1438535***	52521.56***	153917.1***
Log likelihood		-246.316	17.71978	21.18604	32.206377	64.88732
Likelihood ratio stat		52.5***				
Number of farmers		548	139	135	135	139
Wald		$3.1\text{x}10^{10}$***	$8.37\text{x}10^{8}$***	1629.3***	$3.40\text{x}10^{7}$***	$8.61\text{x}10^{8}$***
Mean VIF		1.2519	1.4586	2.1456	1.736	2.5461
Breusch Pagan stat		0.5664	0.9147	0.4851	0.6145	0.9545

Table 4.7: Variance parameters for the stochastic frontier production function

Source: Survey, 2015

Note: The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%.

the production functions representing farmers in the pooled sample and in each agro ecological zone, indicating that the one sided error term U dominates the symmetric error term V, so variation in actual output comes from the difference in farmers' specific factors rather than the random variability. The values of lambda (λ) for maize farmers in the pooled sample and in each of the four agro ecological zones exceeded one in value and are statistically different from zero at the 1% level of significance. The values of λ and the fact that they are significantly different from zero implies good fits and the correctness of the specified distributional assumptions. The estimated sigma square (σ^2) parameters in the stochastic frontier production functions representing maize farmers in the pooled sample and in each of the four agro ecological zones are also significantly different from zero (each significant at 10% significance level), indicating good fits of the models and the correctness of the specified distributional assumptions. The aforementioned results reveal the existence of inefficiencies among maize farmers in Ghana and hence the appropriateness of the application of the stochastic frontier production function in modeling technical efficiencies of the farmers.

Table 4.7 also presents statistically significant Wald chi-square statistics of $3.1\text{x}10^{10}$ ($p<0.1$), $8.37\text{x}10^{8}$ ($p<0.01$), 1629.3 ($p<0.05$), $3.40\text{x}10^{7}$ ($p<0.05$) and $8.61\text{x}10^{8}$ ($p<0.1$) for maize farmers in the pooled sample, northern savannah, transitional, forest and coastal savannah zones respectively. This shows that each model was jointly significant. The variables included in each model were tested for multicollinearity using Variance Inflation Factor (VIF). The mean VIF calculated for the models representing maize farmers in the pooled sample, northern, transitional, forest and coastal savannah zones were 1.2519, 1.4586, 2.1456, 1.736 and 2.5461 respectively (Table 4.7). The VIFs are small and indicate the absence of multicollinearity in the models (Edriss, 2003). In addition, Breusch Pagan (BP) tests revealed safety of heteroskedasticity as justified by statistically insignificant values of 0.5664, 0.9147, 0.4851, 0.6145 and 0.9545 for the models representing maize farmers in the pooled sample, northern savannah zone, transitional zone, forest zone and coastal savannah zone respectively.

Table 4.8 presents the results of the maximum likelihood estimation of the stochastic frontier production functions for maize production in four agro ecological zones of Ghana comprising northern Savannah zone, transitional zone, forest zone and coastal savannah zone. The results of the pooled regression have also been presented. Fertilizer, herbicide, labour, land and pesticides were observed to have significant effects on the output of maize in the pooled sample and therefore, in general, are the determinants of maize output in Ghana. Fertilizer, herbicide, pesticides and land were found to be positively related to the output of maize and were statistically significant at 10%, 1%, 5%, and 1% respectively. The signs of the coefficients of these inputs reflect a priori expectations. Table 4.9 presents the production elasticities of these inputs employed in maize production in the four agro ecological zones considered in the study. The results show that in general, land is the most important input in maize production since it gave the highest elasticity value. The elasticity value shows that if land increases by 1%, the output of maize would increase by 1.14%. Previous similar studies suggested that the high elasticity of farm size is envisaged with the occurrence of small size farms because land could be described as a quasi-fixed production input (Alvarez and Arias, 2004; Madau, 2012). Similarly, if quantities of fertilizer, herbicide and pesticides increase by 1%, maize output will increase by 0.49%, 0.18% and 0.003% respectively. The aforementioned results corroborate the results of Goni et *al* (2007) that reported that a 1% rise in farm size and fertilizer would cause 127.2% and 20.5% respectively increases in the output of rice. The work of Imoudu (1992) also revealed area

Table 4.8: Maximum likelihood estimates of stochastic frontier production function

Variable	Pooled Sample		Northern Savannah		Transitional		Forest		Coastal Savannah	
	Coeff	**Std. Err**	**Coeff**	**Std. Err**	**Coeff**	**Std. Err**	**Coeff**	**Std. Err**	**Coeff**	**Std. Err**
Constant	6.141105		6.841003	0.372580	10.2804***	0.504657	11.17572		9.15365	
lnFET	0.035808*	0.019983	0.1750***	0.022727	0.03187***	0.00809	0.027614**	0.011885	0.0767***	0.014738
lnHEB	0.28478***	0.083703	0.358414	0.04581	-0.3852***	0.074561	1.54886**	0.7704192	0.190057	0.198616
lnPET	0.009152**	0.00412	0.044383*	0.004325	0.19185***	0.048105	0.011650**	0.010795	0.00097*	0.002184
lnSED	0.025144	0.016284	-0.03039	0.047987	-0.1009***	0.017815	2.60684***	0.782539	0.06954***	0.00961
lnLAB	-0.2874***	0.076363	-0.363206	0.00478	-0.183314	0.00125	0.12322	0.466467	-1.6165***	0.199892
lnMAN	-0.0047556	0.004164	0.0448***	0.008839	0.15013***	0.040132	0.0112006	0.010984	0.05021***	0.002524
lnLAD	0.72564***	0.14299	0.7081***	0.16138	0.54767**	0.24389	2.6582***	0.33904	-0.506815	0.35138
lnCAP	-0.04421	0.030529	-0.295***	0.05213	-0.1994***	0.063465	-0.46054	0.57687	-0.2173**	0.09144
lnFETxlnFET	-0.0075***	0.001945	-0.013***	0.00329	-0.0216***	0.002596	-0.00082	0.004654	0.04972***	0.002405
lnPETxlnPET	0.008695	0.017164	-0.07198	0.06256	-0.0001757	0.01268	-0.0689***	0.019458	-0.0850***	0.008085
lnHEBxlnHEB	-0.0376***	0.011096	-0.215***	0.02261	-0.1473***	0.043013	0.063244	0.047104	0.06409***	0.005691
lnSEDxlnSED	-0.0975***	0.00871	-0.055***	0.0207	-0.08168**	0.031974	0.31401	0.26333	-0.0995**	0.045588
lnLABxlnLAB	-0.01556**	0.00757	0.010438	0.013473	-0.0316***	0.006632	-0.06179**	0.026870	0.2212***	0.01251
lnMANxlnMAN	-0.00523**	0.002116	-0.002***	0.00542	-0.0529***	0.00639	-0.00759**	0.003421	-0.0192***	0.001114
lnLADxlnLAD	0.017689	0.02085	0.09869**	0.047355	-0.130492	0.109445	0.12861**	0.063587	-0.5811***	0.10124
lnCAPxlnCAP	-0.0099***	0.00264	0.00933**	0.004254	-0.00315*	0.001723	0.00124	0.005166	-0.0176***	0.003795
lnFETxlnPET	0.03589***	0.010018	-0.0189**	0.009622	0.008472	0.010975	0.012239	0.010410	-0.0962***	0.003208
lnFETxlnHEB	-0.002079	0.00348	-0.014***	0.004229	0.002466*	0.001418	0.001148	0.004547	-0.0194***	0.000665
lnFETxlnSED	0.006614	0.005298	0.0506**	0.023578	-0.0422**	0.012523	0.07479***	0.01197	-0.0838***	0.01372
lnFETxlnLAB	-0.003543	0.002891	0.007739	0.024842	0.03175**	0.013008	-0.0046***	0.001529	-0.0375***	0.007852
lnFETxlnMAN	-0.00449**	0.002187	-0.053***	0.007784	0.01553***	0.003138	0.016538**	0.0075467	0.00646***	0.002148
lnFETxlnLAN	0.002772**	0.002519	-0.099***	0.022025	0.0014967	0.002146	0.005584**	0.0025122	0.01369***	0.0100438

Source: Survey, 2015

Note: The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%.

Table 4.8: Continued

Variable	Pooled Sample		Northern Savannah		Transitional		Forest		Coastal Savannah	
	Coeff	**Std. Err**	**Coeff**	**Std. Err**	**Coeff**	**Std. Err**	**Coeff**	**Std. Err**	**Coeff**	**Std. Err**
lnPETxlnCAP	0.0054***	0.00166	0.0145***	0.00103	0.03465***	0.005773	-0.006589	0.004553	-0.0105***	0.000334
lnPETxlnHEB	-0.032***	0.00901	0.026197*	0.014204	0.10956***	0.008242	-0.018149	0.011623	-0.0187***	0.002534
lnSEDxlnLAB	-0.0435**	0.020435	0.034966	0.025683	-0.0825***	0.013409	0.087217	0.171794	0.122379	0.085089
lnSEDxlnMAN	-0.011104	0.019845	0.10878***	0.014806	-0.1109***	0.017004	-0.0213**	0.010197	-0.011737	0.031934
lnSEDxlnLAD	-0.164***	0.034314	0.0279385	0.038550	0.10532***	0.052402	-0.5182**	0.227153	0.76307***	0.090151
lnSEDxlnCAP	-0.005622	0.007020	0.03791***	0.011298	0.09979***	0.028195	0.217141	0.191402	0.20479***	0.052284
lnSEDxlnHEB	0.0464***	0.01499	0.015265	0.018626	0.12410***	0.010839	0.481467*	0.249946	0.16959***	0.0109921
lnLABxlnMAN	0.0258***	0.008313	0.08590***	0.025521	-0.0550***	0.013295	-0.031326	0.022692	0.07133***	0.0099319
lnLABxlnLAD	0.0408982	0.015034	0.0422048	0.02145	0.27249***	0.022815	-0.015275	0.187254	-0.3206***	0.06463
lnLABxlnCAP	-0.009154	0.009142	0.040584**	0.018089	-0.0143427	0.009182	-0.006047	0.015752	-0.048493*	0.0288037
lnLABxlnHEB	-0.104***	0.010646	-0.0989***	0.012854	-0.001735	0.017726	0.0565443	0.048151	0.0254605	0.0502706
lnMANxlnLAD	0.0119***	0.022958	0.3336275	0.01258	0.30923***	0.108282	0.0017101	0.032323	-0.0152***	0.003247
lnMANxlnCAP	0.0020805	0.002654	0.0789***	0.007592	0.015541**	0.006513	0.0017397	0.002055	0.03265***	0.010022
lnMANxlnHEB	0.01491**	0.005952	0.11092***	0.012383	-0.0215***	0.003740	-0.003340	0.016207	-0.007176	0.0049037
lnLADxlnCAP	0.0130063	0.008294	-0.0034273	0.013983	-0.1054***	0.02838	-0.232661	0.166305	-0.0615291	0.0396392
lnLADxlnHEB	-0.006***	0.001830	-0.0047***	0.000558	-0.0930***	0.013409	-0.5329**	0.272449	-0.3431***	0.0430171
lnCAPxlnHEB	-0.004569	0.001371	0.0020112	0.002272	-0.0115499	0.000724	-0.0113**	0.004636	-0.1267***	0.0105443
lnFETxlnCAP	-0.002860	0.002089	-0.00499**	0.002464	-0.0174***	0.001817	-0.0405**	0.012058	0.01438***	0.0030404
lnPETxlnSED	-0.0037**	0.001425	-0.0119***	0.002634	-0.0144***	0.000682	-0.008***	0.001232	-0.00085*	0.0004659
lnPETxlnLAB	0.0005474	0.000422	0.00348***	0.000975	0.00390***	0.000515	-0.00199*	0.001180	0.00197**	0.00097
lnPETxlnMAN	0.0056727	0.006087	0.036786	0.056539	0.13751***	0.007320	-0.042***	0.014998	-0.0478***	0.0027876
lnPETxlnLAD	0.0008757	0.003021	-0.0175456	0.043479	-0.0208***	0.002648	0.01251**	0.004909	0.00681***	0.001544

Source: Survey, 2015

Note: The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%.

Table 4.9: Input elasticities

	Elasticity				
Variable	**Pooled**	**Northern Savannah**	**Transitional**	**Forest**	**Coastal Savannah**
Fertilizer	0.485	0.519	0.588	0.668	0.934
Herbicide	0.177	0.435	0.746	0.550	0.017
Pesticide	0.003	0.004	0.009	0.001	$2.1x10^{-5}$
Seed	0.734	0.019	1.672	0.151	0.361
Labour	0.245	0.893	0.598	0.786	0.830
Manure	2.045	0.064	0.004	0.081	0.015
Land	1.145	0.142	3.553	4.158	0.012
Capital	0.493	0.214	0.424	0.301	0.021
Scale elasticity	**5.327**	**2.29**	**7.594**	**6.696**	**2.19**

Source: Survey, 2015

cultivated to maize to be an important determinant of the output of maize in Ondo-State of Nigeria. Ohajianya (2006) as well as Onyenweaku et *al* (1996) also had similar results.

Labour input, statistically significant at 1%, was however negatively related to the output of maize. The implication is that a rise in quantity of labour would cause a decline in output and this agrees with the results of Stephen et *al* (2004) that reported a negative correlation between quantity of labour input and the output of cowpea. This could be as a result of diminishing marginal productivity resulting from excess labour supplied by the household (Table 4.2). Most of the square and interaction terms for the translog model were statistically significant with some having positive and others negative signs (Table 4.8). This is also an indication of the translog production function being an appropriate functional form for the stochastic frontier production function. Fertilizer squared, herbicide squared, seed squared, capital squared, fertilizer and pesticide, pesticide and capital, pesticide and herbicide, seed and land, labour and manure, labour and herbicide, manure and land as well as land and herbicide were statistically significant at 1%. Labour squared, manure square, fertilizer and manure, fertilizer and land, seed and labour, manure and herbicide, as well as pesticide and seed were also found to be statistically significant at the 5% significance level. The coefficients of fertilizer squared, seed squared, manure squared, herbicide squared, labour squared and capital squared in the pooled sample are negative and imply that continuously increasing the quantities of each of fertilizer, seed, manure, herbicide, labour and capital by 1% would at a point decrease output by 0.75%, 9.7%, 0.52% and 0.1% respectively. This is because maize as a crop has biological features and therefore reacts differently to different levels of applied production inputs. For instance, output of maize will, in practice, initially respond positively to fertilizer use but may also respond negatively to excess application of fertilizer due to the possibility of excess fertilizer causing acidity of the soil. Similarly, excess application of seeds will lead to over crowding of plants, competition for plant nutrients, difficulty in carrying out cultural practices, etc, and consequently a reduction in output.

The signs of the coefficients of the other interaction terms indicate whether the two production input variables in question are substitutes or complements. For instance, fertilizer and pesticide, pesticide and capital, seed and herbicide, labour and manure, manure and land, land and fertilizer as well as manure and herbicide have positive effects on the output of maize and therefore are all complements. Fertilizer and herbicide, fertilizer and labour, fertilizer and manure, pesticide and capital, pesticide and herbicide, seed and labour, seed and land, seed and capital, labour and capital, labour and herbicide, manure and herbicide, land and herbicide as well as pesticide and seed however have negative effects on maize output and therefore are all substitutes. The results of the current study agree with the results of Shamsudeen et *al* (2013) that fertilizer squared has a negative significant effect on the output of maize and that farm size and fertilizer are complements whereas seed and farm size are substitutes.

In the northern savannah zone of Ghana, fertilizer, pesticide, manure, land and capital inputs were observed to have significant effects on the output of maize and therefore are the determinants of maize output in the northern savannah zone. Table 4.8 shows that these inputs are significant at 1%, 10%, 1%, 1% and 1% respectively. The signs of the coefficients of these inputs with the exception of capital met their a priori expectations. The coefficients of the variables representing each of fertilizer, pesticide, manure and land are positively related to the output of maize, indicating farmers will record higher output levels when higher amounts of these inputs are employed in their maize production. For example the elasticity values shown in Table 4.9 show that a 1% rise in the levels of fertilizer, pesticide, manure and land in the northern savannah zone has the effect of increasing output levels by 0.52%, 0.004%, 0.064% and 0.14% respectively. This corroborates the results of Goni et *al* (2007) that reported that a 1% rise in seed, farm size and fertilizer levels would cause 12.6%, 127.2% and 20.5% increases in the output of rice respectively. Similar results were also reported by Imoudu (1992), Onyenweaku et *al* (1996) and Ohajianya (2006) in Nigeria. Conversely, labour input, though insignificant, had a negative coefficient which implied that a rise in labour would cause a decrease in output and this corroborates Stephen et *al* (2004) that reported a negative correlation between quantity of labour input and the output of cowpea. The effect of capital on the output of maize was found to be significantly negative. The implication here is that most farmers in the northern savannah zone have idle production resources that are yet to be employed.

For maize farmers in the transitional zone of Ghana, fertilizer, pesticide, land, manure, herbicide, seed and capital inputs were observed to have significant effects on the output of maize and therefore are the determinants of maize output in the transitional zone. These inputs were found to be statistically significant at 1%, 1%, 5%, 1% 1%, 1% and 1% respectively (Table 4.8). Whereas fertilizer, pesticide, land and manure were found to be positively related to the output of maize, herbicide, seed and capital were found to be inversely related to maize output. The coefficients of the variables representing each of fertilizer, pesticide, land and manure show that farmers will record higher output levels when higher amounts of these inputs are employed in their maize production. The elasticity values presented in table 4.9 show that a 1% increase in the levels of fertilizer, pesticide, land and manure in the transitional zone of Ghana will increase the output levels of smallholder maize farmers by 0.59%, 0.009%, 3.6% and 0.004%

respectively. This finding also agrees with the results of previous similar studies (Onyenweaku et *al*, 1996; Ohajianya, 2006; Goni et *al*, 2007). In this agro ecological zone too, labour, though insignificant, had a negative coefficient indicating that an increase in labour will lead to a decrease in output and this corroborates the findings of Stephen et *al* (2004). The effects of herbicide, seed and capital on the output of maize were also found to be significantly negative. The current study again asserts that the negative effect of capital input on the output of maize could imply that most farmers in the transitional zone have idle production resources that are yet to be employed.

In the forest zone, maize production inputs that were found to be significant comprised fertilizer, herbicide, pesticide, seed and land. These therefore constituted the determinants of maize output in the forest zone of Ghana. Fertilizer, herbicide and pesticide were each found to be statistically significant at the 5% significance level while seed and land were significant at 1% (Table 4.8). All the aforementioned determinants were found to be positively related to the output of maize. Though manure and land inputs were statistically insignificant, they had the expected positive signs. The coefficients of each of fertilizer, herbicide, pesticide, seed and land inputs show that farmers will record higher output levels when higher amounts of these inputs are employed in their maize production. A 1% increase in the levels of fertilizer, herbicide, pesticide, seed and land inputs in the forest zone of Ghana will increase the output levels of farmers by 0.67%, 0.55%, 0.001%, 0.15% and 4.2% respectively (Table 4.9). The results obtained in this zone are also in agreement with those of Ohajiany (2006) and Goni et *al* (2007).

The results from the forest zone present contrasting views of the effect of labour on maize production as compared to the results obtained in the pooled as well as the northern savannah and transitional zones. In the current study, though labour was found to be statistically insignificant, it was found to be positively related to maize output. This however contradicts the findings of Stephen et *al* (2004) that reported a negative correlation between quantity of labour and the output of cowpea. The effect of capital on the output of maize was also found to be negative but was not significant. As has already been explained, the negative effect of capital input on the output of maize could imply that most farmers in the forest zone have idle production resources that are yet to be employed in their production activities.

Finally, the coastal savannah zone of the country also recorded very interesting results about the determinants of maize output. In this zone, fertilizer, pesticide, seed, manure, labour and capital inputs were observed to have significant effects on the output of maize and therefore are the determinants of maize output in the coastal savannah zone. Statistically, these inputs are significant at the 1%, 10% 1%, 1%, 1% and 5% significance levels respectively. The signs of the coefficients of these inputs with the exception of labour and capital met their a priori expectations. The coefficients of the variables representing each of fertilizer, pesticide, seed and manure are positively related to the output of maize, indicating farmers will see an increase in output levels when higher amounts of these inputs are employed in their maize farms. Specifically, the elasticity values for the various production inputs presented in table 4.9 show that a 1% increase in the levels of fertilizer, pesticide, seed and manure inputs by maize farmers in the coastal savannah zone has the effect of increasing their output levels by 0.93%, 2.1×10^{-5}%,

0.36% and 0.015% respectively. This result confirms those of Goni et *al* (2007) that found that a 1% rise in seed and fertilizer levels would cause 12.6% and 20.5% increases in the output of rice respectively. Quantity of labour input employed however had a significant negative coefficient, implying that a rise in labour would cause a decline in the output of maize. This could be due to excess supply of labour from the household (Table 4.2) which causes diminishing marginal productivity. The result confirms the findings of Stephen et *al* (2004) that found a negative correlation between labour input and the output of cowpea. The effect of capital on the output of maize was also found to be significantly negative, an indication of the possibility of idle resources that are yet to be used in maize farms in the coastal savannah zone of Ghana.

4.4.2 Technical efficiency of maize farmers in various agro ecological zones

Table 4.10 presents the minimum, maximum, mean and standard deviation of technical efficiency scores for maize farmers in the overall sample and the various agro ecological zones considered in the current study. The mean technical efficiency estimate for the sampled maize

Table 4.10: Technical Efficiency scores of Maize Farmers in Ghana

Pooled/Zone	Minimum	Maximum	Mean	Standard Deviation
Pooled	0.6	99.9	58.1	23.5
Northern Savannah	11.8	99.9	61.2	26.8
Transitional	7.3	99.9	70.2	22
Forest	10.3	99.9	49.9	25
Coastal Savannah	0.6	99.9	66	20.3

Source: Survey, 2015

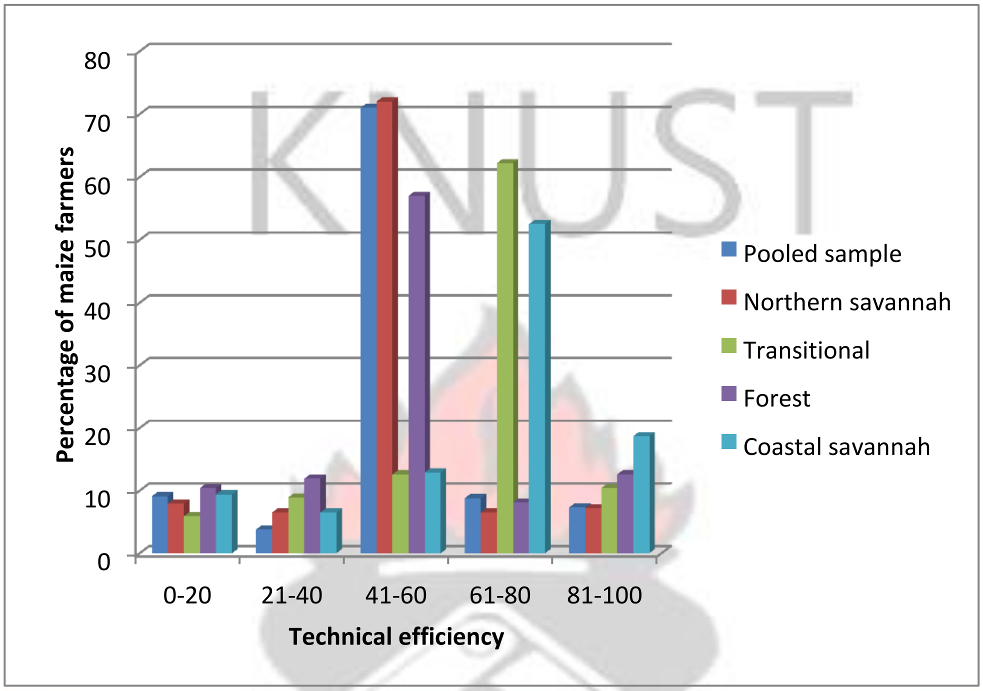
farmers in the pooled sample was 58.1%, with a standard deviation of 23.5% and 0.6% and 99.9% as the minimum and maximum respectively, indicating that maize farmers in Ghana produce below the frontier with 41.9% of potential maximum output (6.0 metric tonnes per ha) lost to inefficiency. It could therefore be inferred from the results of the current study that maize farmers in Ghana are on average 58.1% technically efficient in the use of the technologies available to them. With technical efficiency scores estimated as output-oriented measures, the results imply that the outputs of maize farmers in Ghana can be increased by 42% if they are able to use the resources available to them more efficiently. Specifically, the mean technical efficiency of maize farmers in the northern savannah zone of Ghana was calculated to be 61.2% with a standard deviation of 26.8%

and minimum and maximum scores of 11.8% and 99.9% respectively. The implication is that maize farmers in the northern savannah zone of Ghana are 61.2% efficient in using their technologies and that such farmers can increase their outputs by about 38.8% by employing their production resources more efficiently. Similarly, for maize farmers in the transitional zone, the average technical efficiency was calculated to be 70.2% with a standard deviation of 22% as well as minimum and maximum scores of 7.3% and 99.9% respectively. That is, maize farmers in the transitional zone of Ghana are 70.2% efficient in the use of their technologies with 29.8% of potential output lost to inefficiency. In a related development, the technical efficiency of maize farmers in the forest zone of Ghana was calculated to be 49.9% with a standard deviation of 25% and minimum and maximum values of 10.3% and 99.9% respectively. This means that maize farmers in this agro ecological zone had over 50% of their potential output lost to inefficiency. Finally, Table 4.10 shows that maize farmers in the coastal savannah zone of Ghana had a mean technical efficiency of 66% and a standard deviation of 20.3% with minimum and maximum values of 0.6% and 99.9%

respectively. The results are in line with previous similar studies in Ghana and other developing African countries. For instance, Shamsudeen et *al* (2013) obtained a mean technical efficiency estimate of 74% with minimum and maximum values of 12% and 98% respectively in a study into the technical efficiency of maize production in Northern Ghana. The results of the current study is also in line with the results of Addai (2011) in a study into the technical efficiency of maize producers in three agro ecological zones of Ghana where the mean technical efficiency of the sampled maize producers across the three agro ecological zones was found to be 64.1%. However, with the exception of the results obtained for the forest belt of Ghana, the rest of the results contradict the results of Chirwa (2007) that found smallholder maize farmers in Malawi to be overly inefficient with an average technical efficiency score of 46.23%. It could be inferred from the current study that maize farmers in the transitional zone are more technically efficient in their use ofproduction resources available to them than those in other agro ecological zones. This is followed by maize farmers in the coastal savannah zone, northern savannah zone and the forest zone respectively. The observed technical efficiency scores across the various agro ecological zones indicate that maize farmers in Ghana still produce below optimal output levels and therefore can improve their outputs with efficient use of resources and technologies available to them.

The distribution of technical efficiency scores among maize farmers in each of the agro ecological zones considered in this study is also presented in Figure 4.2. The figure shows that 71% of maize farmers in the pooled sample have technical efficiencies ranging from 41% to 60%. The implication is that most maize farmers in Ghana have at least 40% of their potential output lost to inefficiency. Also, very few maize farmers in the sample (3.8%) had their technical efficiencies in the range of 21%-40%. The figure also shows that whereas the mean technical efficiency of farmers in the northern savannah zone fell within the range of 41% to 60% that of farmers in the transitional zone lies in the range of 61% to 80%. In the northern savannah zone, most of the maize farmers (72%) also have their technical efficiencies in the 41%-60% range, indicating that, at least 40% of their potential output is lost to inefficiency. Over 60% of the respondents in the transitional zone however had their technical efficiencies in the range of 61%80%, implying that at least 20% of farmers' potential maize output is lost to factors that the farmer can control. Finally, the mean technical efficiencies of maize farmers in the forest and coastal savannah zones were in the ranges of 41% to 60% and 61% to 80% respectively. The distribution of technical efficiencies of the farmers in the forest zone is similar to those of the pooled and the northern savannah zones, as 57% of the farmers in this zone had their technical efficiencies in the 41%-60% range. For maize farmers in the coastal savannah zone, over half of

Figure 4.2: Distribution of predicted technical efficiencies in agro ecological zones



Source: Survey, 2015

the respondents (52.5%) had their technical efficiencies in the range of 61%-80%, while only 9.4% obtained the lowest technical efficiencies in the range of 0%-20%. The implication is that most maize farmers in the Coastal Savannah zone of Ghana have at least 20% of their potential outputs lost to inefficiency. A critical analysis of the means locations of technical efficiencies of maize farmers in the transitional and coastal savannah zones shows that the percentage of maize farmers in the transitional zone whose technical efficiencies fell in the 61% to 80% range is more than that of those of the coastal savannah zone, an indication of a possibility of higher technical efficiency estimate in the transitional zone. This is because, the deep, friable soils, and the relatively dispersed tree cover in the transitional zone allows for more continuous cultivation and greater use of mechanized equipments (Smith et *al*, 1994). Other factors include the presence of favourable agro-ecological conditions, availability of improved production technologies, a relative abundance of underutilized land and a well-developed road transport system (Morris et *al*, 1999).

4.4.3 Sources of technical efficiency of maize farmers in various agro ecological zones

From the inefficiency model presented by Table 4.11, a negative coefficient implies an increase in the variable concerned would increase technical efficiency and productivity and vice versa. The coefficients of the dummy representing use of fertilizer by farmers in the pooled sample and in each of the four agro ecological zones have the expected negative signs and are statistically significant at the 10%, 1%, 1%, 5% and 1% levels in the pooled, northern savannah, transitional, forest and coastal savannah zones respectively. This suggests that maize farmers who used fertilizer produced maize more efficiently. The implication is that fertilizer plays an important role in ensuring technical efficiency of maize farmers in all the maize growing areas of Ghana. This makes the results of Bravo-Ureta and Evenson (1994) that found significant positive relationship between fertilizer use and technical efficiency in developing country agriculture still relevant.

Even though the effects of household size on technical efficiency by maize farmers in the overall sample and the northern savannah zone were not significant, they had the expected positive signs. The negative signs of the coefficients of this variable for maize farmers in the transitional, forest and coastal savannah zones are however statistically significant at the 5%, 10% and 1% levels. The negative sign indicates that the larger the household size, the greater the technical efficiency. One of the major reasons for the negative sign is that large farm families

Table 4.11: Sources of technical efficiency among smallholder maize farmers

Variable	Pooled Sample		Northern Savannah		Transitional		Forest		Coastal Savannah	
	Coeff	Std. Err	Coeff	Std. Err	Coeff	Std. Err	Coeff	Std. Err	Coeff	Std. Err
Constant	-0.288562	0.476968	18.3668	11.89757	3.722822	3.174472				
ROAD	0.478476	0.209379	-0.5245398	0.565751	3.35395	0.4775973	-0.815672	0.515379	1.66398	0.570661
NOSAV	-0.6422***	0.274989								
TRASIT	-0.2342197	0.3177233								
FOREST	-0.88106**	0.3993664								
SEX	-0.22193**	0.1637183	-2.877***	0.739977	-1.08329***	0.4102854	-0.22472*	0.513564	-1.5889 ***	0.336601
AGE	0.007146	0.007019	-0.03510**	0.017747	-0.10617***	0.018317	0.004052	0.02851	-0.15852***	0.032815
EDU	-0.0443***	0.015667	-0.046939	0.038084	-0.062296**	0.052576	-0.013881	0.067279	-0.15039***	0.039668
HOSIZE	-0.012306	0.016180	-0.055539	0.034262	-0.004571**	0.047171	-0.07866*	0.099168	-0.29065***	0.095838
EXP	-0.00349**	0.0086328	-0.0606***	0.022284	-0.043319**	0.021208	-0.1096**	0.049283	-0.11481***	0.030027
LANDSZ	0.0135495*	0.0072586	0.41781***	0.136437	0.364353***	0.0390488	-1.509***	0.345056	-0.358239**	0.162361
NPLOTS	0.007409*	0.0330892	328436**	0.449164	0.0293568	0.0305377	1.0400**	0.429744	0.23428***	0.179359
INCOME	-0.0001***	0.0000236	-0.0003***	0.000111	-0.00362***	0.0003621	-0.002***	0.000109	-0.00156***	0.000220
NOEXTVI	-0.301949*	0.177144	-1.29781**	0.596022	-0.49678***	0.0951196	-1.39494	1.033366	-1.00701**	0.460074
MGROUP	-0.20243**	0.2002509	-0.104914*	0.753458	-1.53559***	0.4716871	-2.838***	0.904472	-1.9286 ***	0.717837
CREDIT	-0.057534	0.197045	-3.6039***	0.668188	-6.47137***	0.549414	-1.2719**	0.608811	0.5669898	0.599426
REDYMKT	-0.294598	0.202662	-0.651297	0.578592	-2.9097 ***	0.4173649	-0.932518	0.768077	-2.25182***	0.778272
FERTus	-0.193379*	0.180209	-1.9089***	0.728059	-1.7921 ***	0.501014	-1.6332 **	.6981899	-1.7354***	0.475388
PESTus	-0.4314514	0.4018594	-2.5667***	0.931166	-2.9938 ***	0.823485	-0.714608	0.001489	0.018947	0.458941
SEDtyp	-0.5286***	0.142917	-1.24682**	0.51738 8	-6.32304***	0.7106904	-1.239287	0.502351	0.058237	0.460167

Source: Survey, 2015

Note: The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%.

ensure availability of enough family labour for farm operations like sowing, weeding, fertilizer application, harvesting, dehusking, etc, to be performed on time. This result is in full agreement with the work of Chukwuji et *al* (2007) that concluded that large families enable farm activities to be completed on time in Nigeria. This however contradicts the work of Addai (2011) and Coelli et *al* (2002) that concluded that larger families are clearly a cause of lower efficiencies in the less labour intensive season, when surplus labour is a problem.

The coefficients of the variable for maize farming experience with negative signs for farmers in the pooled sample and in all four agro ecological zones are expected and are statistically significant at the 5%, 1%, 5%, 5% and 1% levels in the overall sample, northern savannah zone, transitional zone, forest zone and the coastal savannah zone respectively. The implication is that experience maize farmers are more technically efficient in the production of maize than inexperienced ones. This is because farmers with many years of maize farming experience will more likely be familiar with the required skills needed for maize production and therefore are more likely to have higher outputs and consequently more technically efficient. This agrees with the findings of Isaac (2011) that found the number of years in maize farming to have a negative effect on technical inefficiency. The results of the current study also agrees with the findings of Shamsudeen et *al* (2013) that concluded that farmers with many years of experience were more technically efficient than those with fewer years.

The age variable was found to be positively related to inefficiency for maize farmers in the pooled sample and the forest zone only that it was not significant for any of the samples. If this is anything to go by, the positive signs observed in these samples could be attributed to the conservative nature of aged farmers which makes it difficult for them to accept new agricultural technologies and innovations thereby preventing such farmers from operating on higher production frontiers. The coefficients of age variable are however negatively related to technical inefficiency for maize farmers in the northern savannah, transitional and coastal savannah zones and are expected. They are statistically significant at the 5%, 1% and 1% levels for the aforementioned agro ecological zones respectively. This means that an increase in a maize farmer's age will cause the farmer to produce maize more efficiently than younger ones. Age is also sometimes known to be a proxy for experience of the farmer. This is because, as a farmer ages in the farming business, the greater experience he/she acquires. This can be explained by the fact that farming is done under risky environmental conditions such as erratic rainfall, therefore, farmers who have cultivated the same crop over a long period of time are able to make accurate predictions on when to sow, the inputs to use, the quantity to use as well as the timing of the use of these inputs and are therefore more efficient in the use of these inputs as compared to younger farmers (Sienso et *al*, 2013).

The coefficient of the dummy representing membership to a farmer association is negatively related to technical inefficiency and statistically significant at 5% for maize farmers in the pooled sample. The variable is also statistically significant at the 10%, 1%, 1% and 1% levels for maize farmers in the northern, transitional, forest and coastal savannah zones respectively. This implies that maize farmers who belonged to farmer associations in all agro ecological zones of Ghana were more technically efficient than those who did not belong to any farmer association. The reason was that most agricultural technologies and new methods of farming are normally disseminated through farmer based organizations so it is likely that it is only farmers who are members of such associations that will have access to improved technological packages. Added to this is the fact that most seminars and workshops aimed at improving maize productivity are normally organized for only farmers who belong to farmer based associations. It is therefore not surprising that farmers who are members of farmer based associations are more productive and efficient in their production activities. This finding is in agreement with NAAD (2005) that stated that farmers who are members of farmer groups are more efficient and productive because they have more access to extension services.

The effect of the dummy for improved seeds on technical inefficiency for maize farmers in each of the pooled sample, northern savannah zone as well as transitional zone is negative and is expected. The variable is statistically significant at 1% for maize farmers in the pooled sample, 5% for maize farmers in the northern savannah zone and 1% for maize farmers in the transitional zone. Maize farmers in the forest zone of the country also experienced a negative effect of improved seed use on inefficiency just that it was not significant. The implication is that maize farms with improved maize seeds are more efficient than farms using local seeds.

The effect of education on technical efficiency was positive and significant for maize farmers in the pooled sample, transitional and coastal savannah zones. Education was significant at 1% for maize farmers in the overall sample, 5% for maize farmers in the transitional zone and 1% for maize farmers in the coastal savannah zone. Though the effect of education on technical inefficiency was insignificant for maize farmers in the northern savannah and forest zones, it had the expected negative sign. The results show that educated farmers produced maize more efficiently than illiterate farmers. This is true since human capital represented by educational level, enhances the managerial and technical skills of farmers. According to Battese and Coelli (1995), education is hypothesized to increase the farmers' ability to utilize existing technologies and attain higher efficiency levels. Owour and Shem (2009) however indicated that educational level is negatively correlated to technical efficiency of farmers. The explanation given was that scientific skills in agriculture, for instance in developing economies are more affected by practical training in modern agricultural methods than just formal education. Another school of thought has it that technical inefficiency tends to increase after 5 years of schooling. This could probably be explained by the fact that high education attenuates the desire for farming and therefore, the farmer probably concentrates on salaried employment instead (Kibaara, 2005).

Ultimately, this reduces labour availability for farm production thereby lowering efficiency. Nevertheless, it could be argued that access to better education enable farmers to manage resources in order to sustain the environment and produce at optimum levels.

The effect of male-gender on technical efficiency was negative for farmers in the pooled sample and in each of the four agro ecological zones. The variable was significant at 5% for maize farmers in the pooled sample, 1% for maize farmers in the northern savannah zone, 1% for maize farmers in the transitional zone, 10% for maize farmers in the forest zone and 1% for maize farmers in the coastal savannah zone. The results show that males are more technically efficient in maize production than females. This corroborates the findings of Shamsudeen et *al* (2013) in a study into technical efficiency of maize production in northern Ghana that found a negative relationship between male-gender and technical inefficiency. The negative effect of male-gender on inefficiency could be attributed to the crucial roles women performed in the domestic and economic life of society which affected their technical efficiency. This comprises the unmeasured non-economic activities such as child care, cooking, cleaning, etc, performed by females in the household. Added to this is the fact that some customs, traditions, religious beliefs, and social norms placed restrictions on women's activities both on-farm and off-farm and hence their inability to access new information and use technologies. The findings of the present study also agree with the findings of Solís et *al* (2006) that reported lower technical efficiencies for female-headed households vis-a-vis male-headed ones.

The variable for land exerts mixed effects on the technical inefficiency of maize farmers in Ghana. The variable was positive and significant at 10% for maize farmers in the pooled sample, 1% for maize farmers in the northern savannah zone and 1% for maize farmers in the transitional zone. This means that an increase in farm size by maize farmers in the pooled sample, northern savannah zone and the transitional zone will cause a decline in the technical efficiency of such farmers. The reason is that most farmers are poor and may not have the required resources to meet the production demands of large farms. Conversely, farm size is negatively related to technical inefficiency for maize farmers in the forest and coastal savannah zones. It is significant at 1% and 5% for maize farmers in the forest and coastal savannah zones respectively. Maize farmers in the forest and coastal savannah zone will therefore produce close to the production frontier if their farm sizes are adjusted upwards. This is because farmers have some production resources, especially capital inputs which as at now have not been employed because of their small farm sizes. With an increase in farm size, farmers' resource endowment will be proportionate to their scale of production. The results of the current study confirm existing knowledge about the effect of land holding on the technical efficiency of farmers. That is, as reported by Kalaitzadonakes et *al* (1992), the influence of farm size on technical efficiency is inconclusive, even though Raghbendra et *al* (2005), Amos (2007) and Barnes (2008) reported a positive correlation between farm size and technical efficiency.

The influence of land fragmentationon on technical inefficiency is positive for maize farmers in the pooled sample, northern savannah, forest and coastal savannah zones. The variable is statistically significant at 10% for maize farmers in the pooled sample, 5% for maize farmers in the northern savannah zone, 5% for maize farmers in the forest zone and 1% for maize farmers in the coastal savannah zone. The variable was also positively related to inefficiency for maize farmers in the transitional zone only that it was not significant. This means that owning many farm plots by maize farmers in Ghana causes inefficiencies in maize production. This is in line with the results of Raghbendra et *al* (2005) that reported an inverse correlation between land fragmentation and efficiency of agricultural production. Land fragmentation is therefore inversely related to agricultural productivity.

Access to extension was found to be positively related to technical efficiency of maize farmers in the overall sample, northern savannah zone, transitional zone and coastal savannah zone. This was significant at 10%, 5%, 1% and 5% for maize farmers in the pooled, northern savannah, transitional and coastal savannah zones. The implication is that access to extension service will increase the efficiency of maize farmers in Ghana. This is because agricultural production technologies developed by research institutes reach farmers through agricultural extension officers. Extension therefore allows maize farmers to be abreast with the latest recommended farming methods and technologies that are believed will enhance agricultural productivity and efficiency. Several studies including Ahmad et *al* (2002), Basnayake and Gunaratne (2002), Amos (2007) as well as Tchale and Sauer (2007) among others have also reported a positive relationship between access to extension service and technical efficiency of farmers.

With the exception of maize farmers in the coastal savannah zone, positive relationships between access to farm credit and technical efficiency were observed among maize farmers in the pooled sample, northern savannah, transitional and forest zones. Access to credit was statistically significant at 1% for maize farmers in the northern savannah zone, 1% for those in the transitional zone and 5% for maize farmers in the forest zone. This means that maize farmers who have access to production credit are more technically efficient than those without credit.

This is because access to production credit reduces the liquidity constraints of farmers and allows them to be able to purchase required production inputs. This corroborates the results of Tchale and Sauer (2007) that also found a positive relationship between access to farm credit and efficiency of agricultural production.

The influence of pesticides on the efficiency of maize production was found to be positive for maize farmers in the overall sample and in all the agro ecological zones except the coastal savannah zone. Pesticide use was found to be significant at 1% for maize farmers in the northern savannah and transitional zones which mean that use of pesticides will increase the technical efficiency of maize production. This is because pesticides kill pests of maize thereby increasing productivity and efficiency. The results of the current study confirm those of Amos (2007) that reported a negative relationship between use of pesticides and inefficiency of food crop production.

The effect of the variable representing access to ready market on the technical efficiency of maize production was found to be positive for maize farmers in all four agro ecological zones and was particularly significant at 1% for farmers in the transitional and coastal savannah zones. The implication is that presence of a ready market will increase the technical efficiency of maize farmers in Ghana. This is because presence of a ready market has the effect of boosting the morale of farmers in general which allows them to apply required methods and technologies in their production activities as they are assured of markets for their produce. Access to ready market also increases access to inputs and credit hence improving farm technical efficiency. The results agree with those of Sibiko et *al* (2012) that reported a positive relationship between access to input markets and the technical efficiency of smallholder common bean farmers in Eastern Uganda.

Finally, the influence of the variables representing maize farms in the northern savannah, transitional and forest zones on the technical inefficiency of maize production were negative, indicating that improvement in technical efficiency of maize production is independent of agro ecological zone. The variable representing maize farms in the northern savannah zone was significant at the 1% significance level while that of maize farms in the forest zone was significant at the 5% significance level. The results suggest that maize producers in all agro ecological zones have equal chances of increasing their technical efficiencies and that maize production is not specifically possible in any one agro ecological zone. The result is in line with the results of Addai (2011) in a study into the technical efficiency of maize producers in three agro ecological zones of Ghana that revealed positive relationships between variables representing various agro ecological zones and the efficiency of maize production in Ghana.

4.5 Resource use efficiency by maize farmers in various agro ecological zones

The returns to scale parameters presented in Table 4.9 for maize farmers in the pooled sample and each of the four agro ecological zones, which were calculated as the sum of individual production inputs' elasticities showed increasing returns to scale for the farmers. The implication is that maize production in each of the four agro ecological zones and Ghana in general during the 2014 rainy season was in stage one of the production function. The returns to scale calculated for the pooled sample, northern savannah zone, transitional zone, forest zone and the coastal savannah zones were 5.327, 2.29, 7.594, 6.696 and 2.19 respectively. The results suggest that maize farmers in the pooled sample, northern savannah zone, transitional zone, forest zone and the coastal savannah zone should enlarge their production scale by about 5.3%, 2.3%, 7.6%, 6.7% and 2.2% respectively on average, in order to adequately expand productivity, given their disposable resources. That is maize farmers in Ghana in general and in each of the four agro ecological zones can increase their maize output by employing more of the resources (fertilizer, herbicide, pesticide, seed, labour, land, manure and capital) employed in maize production. This confirms the results of

Goni et *al* (2007) that reported that it was possible for farmers to increase their output by increasing quantities of fertilizer, seed, labour as well as size of cultivated area. The increasing returns to scale finding agrees with those of Uchegbu (2001) and Ajibefun (2002), even though it contradicts the finding of Obasi (2007). Table 4.12 presents the estimates of resource use efficiency parameters for the pooled sample and each of the four agro ecological zones considered in the study. The marginal productivities revealed that maize farmers in the pooled sample, transitional zone and forest zone utilized land more efficiently visà-vis the other resources. This suggests that if more lands were cultivated, it would have led to an increase in maize output by 1101kg, 4368kg and 1407kg among the farmers in the pooled sample, transitional zone and forest zone respectively. Similarly maize farmers in the northern savannah and coastal savannah zones were more efficient in the use of herbicide and labour respectively. The implication is that if more herbicides were used in the northern savannah zone, maize output would have increased by 156kg. In the coastal savannah zone, maize output would have increased by 40.1kg if maize farmers there had used more labour in their production activities. Capital had the least MPP in the pooled sample and most especially in the northern savannah, forest and coastal savannah zones, an indication of inefficiency in the use of capital in these areas. Manure however had the least MPP in the transitional zone of Ghana. This means that maize farmers in this agro ecological zone were more inefficient in their use of manure than any other production input. These results also corroborate those of Goni et *al* (2007).

Considering the technologies available to farmers as well as inputs and output prices, resource use efficiency was determined at the level where Marginal Value Product was equal to

Table 4.12: Ratio of Marginal Value Product to Marginal Factor Cost across different agro-ecologies in Ghana

Variable	Pooled				Northern Savannah				Transitional				Forest				Coastal Savannah			
	MPP	MVP	MFC	r	MPP	MVP	MFC	R	MPP	MVP	MFC	R	MPP	MVP	MFC	R	MPP	MVP	MFC	r
Fertilizer	3.8	3.7	1.1	3.4	2.4	1.92	1.5	1.3	5.3	4.8	1.3	3.7	5.4	6.3	0.6	10.5	10.3	10.4	0.85	12.3
Herbicide	94.4	91.6	9.5	9.6	156	124	10.3	12	641	583	8.1	72	139	164	8.1	20.2	11.6	11.7	11.3	1.04
Pesticide	74.4	72.2	10.1	7.1	75	60.2	0.5	120	165	150	0.9	167	53.8	63.4	0.104	610	10.4	10.5	0.1	108
Seed	54.1	52.5	2.8	18.7	1.49	1.19	3.6	0.3	117	107	2.2	49	7.64	9	2.8	3.2	32	32.3	2.7	12
Labour	9.8	9.5	12	0.79	26.3	21	7.1	3	31	28.2	18.9	1.5	18.3	21.6	10.3	2.1	40.1	40.6	11.7	3.5
Manure	193	187	0.01	15558	3.4	2.7	0.005	545	1.8	1.6	0.01	400	2.2	2.6	0.019	138.6	2.1	2.2	0.02	114
Land	1101	1068	30.4	35.2	116	91.9	13.9	6.6	4368	3975	47.1	84	1407	1659	28.26	58.7	21.2	21.4	32.3	0.66
Capital	2.43	2.36	12.9	0.18	0.68	0.55	11.8	0.05	1.98	1.8	12.8	0.1	1.04	1.22	13.29	0.09	0.24	0.24	13.8	0.02

Source: Survey, 2015

Note: *MPP* = Marginal Physical Product, *MVP* = Marginal Value Product, *MFC* = Marginal Factor Cost, *r* = Efficiency Coefficient

Table 4.13: Adjustments in MVPs for optimal resource use (% divergence).

	EG	%D	EG	%D	EG	%D	EG	%D	EG	%D
Fertilizer	2.6	70.3	0.42	21.9	3.5	72.9	5.7	90.5	9.55	91.8
Herbicide	82.1	89.6	113.7	91.7	574.9	98.6	155.5	95	0.43	3.7
Pesticide	62.1	86	59.7	99.2	149.1	99.4	63.3	99.8	10.4	99.1
Seed	49.7	94.7	2.41	66.9	104.7	97.9	6.2	68.9	29.6	91.6
Labour	2.5	20.8	13.9	66.4	9.35	33.2	11.31	52.4	28.9	71.2

Variable	Northern Savannah		Transitional		Forest		Coastal Savannah		Pooled Sample	
Manure	186.69	99.9	2.69	99.6	1.596	99.75	2.58	99.3	2.18	99.1
Land	1037.6	97.2	78	84.8	3927.91	98.8	1630.7	98.3	10.86	33.7
Capital	10.54	81.7	11.3	95.3	10.98	85.9	12.1	90.8	13.55	98.3

Source: Survey, 2015

Note: *EG* = Efficiency gap, *D* = Divergence from optimal levels

Marginal Factor Costs. That is, a resource is efficiently utilized if marginal value product and marginal factor cost are the same. Table 4.12 shows that the ratios of the marginal value product to the marginal factor cost for maize farmers in the pooled sample were greater than unity (1) for fertilizer, herbicide, pesticide, seed, land and manure. The ratios for labour and capital were however found to be less than unity. The implication is that the farmers were not efficient in the allocation of any of the resources available to them. That is, fertilizer, herbicide, pesticide, seed and manure were underutilized, while labour and capital (farm tools) were over utilized. Maize output in Ghana in general could have therefore increased if more of such inputs like fertilizer, herbicide, pesticide, seed and manure were employed while quantities of labour and capital were reduced.

Table 4.12 also presents the ratios of the MVP to MFC for maize farmers in the northern savannah zone of Ghana. The results revealed that the ratios were greater than unity (1) for fertilizer, herbicide, pesticide, labour, manure and farm size. The ratios for seed and capital were however found to be less than unity. That is, none of the inputs was efficiently allocated by the maize farmers. This means that fertilizer, herbicide, pesticide, labour, manure and farm size were underutilized, while seed and capital were over utilized. Maize output in the northern savannah zone could have therefore increased if more of such inputs like fertilizer, herbicide, pesticide, labour, manure and farm size were employed while quantities of seed and capital were reduced.

For farmers in the transitional zone of Ghana, the results revealed that the ratios were greater than unity (1) for fertilizer, herbicide, pesticide, seed, labour, manure and farm size. The only input with a ratio less than unity was capital. That is, none of the inputs was efficiently used by the maize farmers. That is fertilizer, herbicide, pesticide, seed, labour, manure and farm size were underutilized, while capital was over utilized. Maize farmers in the transitional zone could have therefore increased their outputs if more of such inputs like fertilizer, herbicide, pesticide, seed, labour, manure and farm size were employed while quantity of capital was reduced.

The efficiencies of use of resources by maize farmers in the forest zone are similar to those calculated for maize farmers in the transitional zone. The ratios calculated for maize farmers in the coastal savannah zone were greater than unity (1) for fertilizer, herbicide, pesticide, seed, labour and manure. Those of land and capital were however found to be less than unity. The inference is that none of the inputs was efficiently utilized by maize farmers in the coastal savannah zone of the country. Specifically, fertilizer, herbicide, pesticide, seed, labour and manure were underutilized, whereas land and capital were over utilized. Maize farmers in the coastal savannah zone of Ghana could have therefore had higher outputs if more of such inputs like fertilizer, herbicide, pesticide, seed, labour and manure were employed while quantities of land and capital were reduced. Eze et *al* (2010) also reported similar results.

The adjustments in marginal value products (MVPs) for optimal resource use (% divergence) by maize farmers in the pooled sample shown in Table 4.13 and Appendix V indicate that for resources to be efficiently utilized, more than 70.3%, 89.6%, 86%, 94.7%, 99.9% and 97.2% increase in fertilizer, herbicide, pesticide, seed, manure and land respectively were required. Labour and capital inputs were over used and therefore needed 20.8% and 81.7% respectively decline for efficient use in maize production. For optimal resource use by farmers in the northern savannah zone, more than 21.9% increased in fertilizer, 91.7% rise in herbicide, 99.2% increase in pesticide, 66.4% increase in labour, 99.6% increase in manure would be required. On the other hand, quantities of seed and capital would be expected to decline by 66.9% and 95.3% respectively. Optimal resource use adjustment by maize farmers in the transitional zone also comprises 72.9% rise in fertilizer quantity, 98.6% rise in herbicide quantity, 99.4% rise in pesticide quantity, 97.9% rise in seed, 33.2% rise in man days of labour, 99.75% rise in manure and 98.8% rise in farm size. Farmers in this agro ecological zone however required 85.9% reduction in capital for optimal output levels to be achieved. For maize farmers in the forest zone, an increase by 90.5%, 95%, 99.8%, 68.9%, 52.4%, 99.3% and 98.3% of fertilizer, herbicide, pesticide, seed, labour, manure and land respectively as well as a decline in capital input by 90.8% would be required for optimal resource use to be achieved. Finally, optimal adjustment towards optimal use of resources by maize farmers in the coastal savannah zone of Ghana requires 91.8% increase in fertilizer input, only 3.7% rise in herbicide, 99.1% rise in pesticide input, 91.6% increase in seed quantity, 71.2% rise in man days of labour and 99.1% rise in manure input levels even though 33.7% decline in farm size as well as 98.3% decrease in capital inputs would be needed. Eze et *al* (2010) as well as Wongnaa and Ofori (2012) obtained similar results in their resource use efficiency studies. The above results show great divergence from optimal levels of use of manure (underutilized) in all the agro ecological zones than any other input. This is followed closely by divergence from optimal levels of use of pesticides in all agro ecological zones. Divergence of manure use from optimal levels was greater in the transitional zone whereas that of pesticide was greater in the forest zone of the country. Even though it is uncommon for maize farmers to apply pesticides to their crops (except under especially army worms infestation), the results of the current study raises concern about inadequate use of pesticides in maize farms.

4.6.1 Scale efficiency of maize farmers in various agro ecological zones of Ghana

Table 4.14 presents the results of the estimated scale elasticities and scale efficiencies of maize farmers in Ghana. The table shows that the overall mean scale efficiencies are 87.7%,

Table 4.14: Estimated scale elasticity and scale efficiency in agro ecological zones of Ghana

Type of Scale	Pooled Sample		Northern Savannah		Transitional		Forest		Coastal Savannah	
	E	SE	E	SE	E	SE	E	SE	E	SE
Supra-optimal scale	0.609008	0.908918	0.569493	0.894787	0.712946	0.952151	0.58864	0.899498	0.543967	0.880592
Optimal scale	1	1	1	1	1	1	1	1	1	1
Sub-optimal scale	1.54234	0.846257	1.598854	0.82171	1.462852	0.869951	1.478323	0.875832	1.559374	0.842523
Maximum	6.961194	0.999998	2.961194	0.9999948	8.74859	0.999998	7.496631	0.9999935	2.760078	0.9999609
Minimum	-0.38011	0.2034403	-0.31469	0.203440	0.1823844	0.281999	-0.38011	0.395607	-0.35509	0.277332
Mean	5.327	0.8769669	2.29	0.8571164	7.594	0.909432	6.696	0.8856926	2.19	0.8552129
Std. Dev	0.594485	0.1614981	0.657873	0.1808911	0.5111749	0.142594	0.570311	0.145848	0.628569	0.169363

Source: Survey, 2015

Note: *E* = Scale elasticity and *SE* = Scale efficiency

Table 4.15: Distribution of maize farmers according to scale efficiency

Type of Scale	Pooled Sample		Northern Savannah		Transitional		Forest		Coastal Savannah	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Supra-optimal scale	192	33.33	50	35.71	51	37.5	50	35.46	40	27.78
Optimal scale	52	9.03	12	8.58	10	7.35	7	4.97	8	5.56
Sub-optimal scale	332	57.64	78	55.71	75	55.15	84	59.57	96	66.66
Total	576	100	140	100	136	100	141	100	144	100

Source: Survey, 2015

85.7%, 90.9%, 88.6% and 85.5% for maize farmers in the pooled sample, northern savannah zone, transitional zone, forest zone and coastal savannah zone respectively. The implication is that observed maize farms in the aforementioned samples could have further increased their outputs by about 12.3%, 14.3%, 9.1%, 11.4% and 14.5% respectively if they had used an optimal scale. The above results show that maize farmers in the transitional zone of Ghana are more scale efficient than maize farmers in the other agro ecological zones. Similarly, the results from Table 4.14 shows that the average elasticities are 5.327, 2.29, 7.594, 6.696 and 2.19 for maize farmers in the pooled sample, northern savannah, transitional, forest and coastal savannah zones respectively. This also means that maize farmers in the transitional zone are more productive than any other agro ecological zone in Ghana. This explains why the largest maize farms found in the current study were located in the transitional zone (Table 4.2).

Table 4.15 and appendix VI present the scales distribution of respondents in different agro ecological zones of Ghana. The results showed that 57.64% of maize farmers in the pooled sample exhibited increasing returns to scale, 33.33% exhibited decreasing returns to scale while only 9.03% were operating under constant returns to scale. For maize farmers in the northern savannah zone, the results showed that 55.71% of them exhibited increasing returns to scale,

35.71% exhibited decreasing returns to scale whereas only 8.58% operated under optimal scale. Results from the transitional zone of Ghana also revealed that 55.15%, 37.5% and 7.35% of maize farmers in that zone exhibited increasing returns to scale, decreasing returns to scale and constant returns to scale respectively. Similarly, the percentages of maize farmers in the forest belt of the country that operated under sub-optimal, supra-optimal and optimal scales were 59.57%, 35.46% and 4.97% respectively. The situation was not all that different for maize farmers in the coastal savannah zone as 66.66%, 27.78% and only 5.56% of maize farmers in that zone exhibited increasing returns to scale, decreasing returns to scale and constant returns to scale respectively. It could be deduced from the foregoing that most maize farmers in Ghana operate under a sub-optimal scale, indicating that their outputs fall below efficient levels and therefore they should be increased for optimal scales to be reached. This is because the scale elasticity calculated for the farmers in each agro ecological zone is above unity (Table 4.14). Table 4.14 also shows that in these farms, scale efficiencies cannot be greater than the averages 84.6%, 82.2%, 87%, 87.6% and 84.3% for maize farmers in the pooled sample, northern savannah, transitional, forest and coastal savannah zones respectively.

However, the mean scale efficiencies of maize farmers operating in supra-optimal scales (90.9% for the pooled sample, 89.5% for the northern savannah zone, 95.2% for the transitional zone, 89.9% for the forest zone and 88.1% for the coastal savannah zone) suggest that the margins that separate such farmers from the optimal scale are not that wide. This also gives evidence of the assertion by this study that observed scale inefficiencies result from the maize farms producing under sub-optimal scales and these sub-optimal scale maize farms should increase their outputs higher than the supra-optimal ones. The aforementioned results of the current study corroborate those of previous studies including Coelli et *al* (2002), Karagiannis and Sarris (2005), Latruffe et *al* (2005), Cisilino and Madau (2007), Madau (2010) and Madau(2012) that concentrated on small land holdings and reported that most small scale farmers operate under increasing returns to scale. These small-sized farms are generally adversely affected with capital, structural and infrastructural challenges in the form of huge land fragmentation, use of simple farming implements, inadequate knowledge of modern production technologies as well as insignificant availability of land markets. As a result, these farmers do not reach their efficient sizes. According to Thiele and Brodersen (1999), the aforementioned structural and market challenges constitute the factors that prevent most farmers from producing efficiently.

4.6.2 Determinants of scale efficiency of maize farmers in various agro ecological zones

Table 4.16 presents the maximum likelihood estimates of the stochastic frontier scale efficiency function. The coefficient of the variable representing age is negatively related to scale efficiency and statistically significant at the 5%, 10%, 1% and 10% levels for maize farmers in the pooled sample, northern savannah zone, transitional zone and coastal savannah zone respectively. This means that younger maize farmers are more scale efficient than older ones. This is because younger farmers are more aware of current technology and tend to acquire more knowledge about technical advances (Weersink et *al*, 1990). This result however disagrees with the findings of Karagiannis and Sarris (2005) and Madau (2012) that reported that older farmers are more scale efficient than farmers who are relatively young. Madau (2012) further stated that the small value of the coefficient of farmers' age implies the variable does not have much influence on the observed variations in scale efficiency and therefore even though significant, the variable does not really explain the magnitude of scale efficiency. The coefficients of age for the current study are even lower than that of Madau (2012) and therefore its effect in this study cannot be taken seriously.

The coefficients of education is positive and significant at the 5%, 10%, 5% and 1% levels for maize farmers in the pooled sample, northern savannah zone, forest zone, and the coastal savannah zone respectively. This means that acquisition of one more year of education by a maize farmer has the effect of making the farmer operate close to an optimal scale. This is because education will give farmers adequate knowledge of a balanced input mix required for producing at optimal levels. The relationship between household size and scale efficiency

Table 4.16: Maximum likelihood estimates of stochastic frontier scale efficiency function

Variable	Pooled Sample		Northern Savannah		Transitional		Forest		Coastal Savannah	
	Coeff	**Std. Err**	**Coeff**	**Std. Err**	**Coeff**	**Std. Err**	**Coeff**	**Std. Err**	**Coeff**	**Std. Err**
Constant	0.00035		-0.3843772		0.0979175		.0129004		-0.0427835	
ROADS	0.0008927*	0.0000111	0.022325**	0.0103945	0.0145723	0.0065403	0.0006949*	0.000034	0.0000861***	0.002856
NOSAV	0.00070***	0.0000132								
TRASIT	0.00134**	0.0000159								
FOREST	0.0008875*	0.0000112								
SEX	-0.000373	2.89x10^{-6}	0.046026	0.015876	-0.010041	0.0049532	0.002121	0.0000222	-0.0069391	0.0362751
AGE	-0.0000256	1.64x10^{-7}	-0.000812	0.0000706	-0.000257	0.0009138	0.000027	2.25x10^{-6}	-0.0001794	0.0008271
EDU	0.000037**	2.68 x10^{-7}	-0.00170*	0.00222	0.000387	0.0002805	0.00044**	2.78x10^{-6}	0.00066***	0.0000751
HOSIZE	0.000050*	1.69 x10^{-7}	0.001964**	0.0000423	0.003973*	0.0004346	0.000136	3.20x10^{-6}	0.003499**	0.0003834
EXP	9.4x10^{-6}**	8.14 x10^{-7}	0.00028**	0.000544	0.000656	0.000852	0.00017***	3.23x10^{-6}	0.000371**	0.001212
LANDSZ	-0.000202*	1.43x10^{-6}	-0.00761	0.008219	0.00600*	0.0007888	-0.00038**	6.55x10^{-7}	-0.00389**	0.0045404
NPLOTS	-0.000307	9.24x10^{-6}	-0.00548**	0.0135823	-0.00005*	0.000242	0.000922	0.0000149	-0.00606**	0.0098731
NOEXTVI	7.9x10^{-6}**	4.79 x10^{-7}	0.00362***	0.0221803	0.006727	0.0015531	0.017275*	0.0000407	0.0017753*	0.0018697
MGROUP	0.00127***	8.38x10^{-6}	-0.003741*	0.0168814	0.029712	0.0014322	0.01889**	0.0000907	0.020597*	0.0118407
CREDIT	0.000056*	3.20x10^{-6}	0.003709*	0.0338653	0.008043**	0.014341	0.004227	0.000059	0.014412**	0.0078618
REDYMKT	0.000197**	1.93x10^{-6}	0.002531	0.0048648	0.0024233*	0.0110822	0.002024	0.0000306	0.091382	0.0108283
RAINamt	4.57x10^{-7}*	4.74x10^{-9}	0.000361**	0.0000185	0.000038	0.0000294	0.000011*	5.14x10^{-08}	-0.000016	0.0000162
FERTus	0.000392**	1.55x10^{-6}	0.004087	0.0231058	0.011629**	0.0003683	0.002508*	0.0000398	0.002795**	0.0257106
PESTus	0.002336**	0.0000117	0.0002887*	0.0065025	0.001994**	0.001868	0.001383	0.000051	0.007835**	0.0014004
SEDtyp	0.000117**	6.22x10^{-6}	0.0054102	0.0259803	0.05659***	0.0007163	0.000159*	0.0000411	0.0042003	0.0109965

Source: Survey, 2015

Note: The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%.

is positive and is significant at the 10%, 5%, 10% and 5% levels for maize famers in the pooled sample, northern savannah zone, transitional zone and coastal savannah zone respectively. The implication is that maize farm families with many members experience less scale inefficiencies as compared to those with few members. This is because large household sizes will increase the labour available to such farm families which will make them operate close to an optimal scale. An increase in labour input is required since at least 55% of maize farmers in the pooled sample and in each of the agro ecological zones have been found to exhibit increasing returns to scale (Table 4.15). That is most farmers operate below the optimal scale.

Farm size, with positive coefficients and statistically significant at the 10%, 10%, 5% and 5% levels for maize farmers in the pooled sample, transitional zone, forest zone and coastal savannah zone are expected. This means that maize farmers who cultivated large farm plots have higher levels of scale efficiencies than those with small land holdings. This result is in line with the findings of Madau (2012) that reported that scale efficiency improvement is mostly conditioned by variations in farm size. Karagiannis and Sarris (2005) also observed that notwithstanding the fact that no solid correlation between technical efficiency and area cultivated can be statistically established, a statistically significant positive correlation is obtained between scale efficiency and area cultivated. According to the study, farmers with small farm sizes normally have financial challenges and therefore have inadequate access to production resources, which according to Thiele and Brodersen (1999) are part of the major factors causing scale inefficiencies in agriculture. Also, farmers operating small farms may have other sources of income, which to them, are more important and therefore little effort is put into farming compared with farmers with larger farms (Coelli and Battese, 1996). It is worthy of note that the influence of cultivated area on scale efficiency is still being argued. This is because, according to Hallam and Machado (1996), larger farms appear more scale efficient by exploiting scale economies. Conversely, larger farms may also have challenges in undertaking their activities at the optimal time and therefore will not be efficient in the use of the resources available to them (Amara et *al*, 1999).

Use of fertilizer in maize production in the pooled sample, transitional zone, forest zone and coastal savannah zone is positively related to scale efficiency and is significant at the 5%, 5%, 10% and 5% levels respectively (Table 4.16). This means that maize farmers who used fertilizer in their maize production achieved higher scale efficiency scores than those who did not use fertilizer. Therefore use of fertilizer will make farmers operate close to an optimal scale. The influence of use of pesticides on the scale efficiency of maize farmers in the pooled sample and in each of the agro ecological zones is positive and statistically significant at the 5% significance level for each zone. This means that the scale efficiencies of farmers who used pesticides are higher than those who did not use pesticides. Notwithstanding the fact that none of the respondents complained of army worm infestation, positive relationships were found between pesticides and scale efficiency of maize farmers in all the agro ecological zones considered in the study. This could be due to the presence of some unknown pests of maize that farmers are not aware of. This therefore calls for research in this area that will help identify such unknown pests so that stringent measures would be devised to control their infestation. The relationship between seed variety and scale efficiency is positive and is statistically significant at the 5%, 1% and 1% significance levels for maize farmers in the pooled sample, transitional zone and forest zone. The implication is that maize farmers who used improved varieties are more scale efficient than those who used traditional varieties. This is because most improved seeds are high yielding and this will give users of such varieties higher outputs than non-users. Access to good road has a positive effect on the achievement of optimal scale and is statistically significant at the 10%, 5%, 10% and 1% levels for maize farmers in the pooled sample, northern savannah zone, forest zone and coastal savannah zone respectively. This means that maize farmers with good roads leading to their farms are less scale inefficient and vice versa. This is because good road network around maize farms allows free flow of inputs and outputs. The net result is that farms are timely and adequately supplied with required production inputs and farm outputs do not go bad as they reach consumers on timely basis.

The coefficients of the variable for land fragmentation is inversely related to scale efficiency and is significant at 5%, 10% and 5% for maize farmers in the northern, transitional and coastal savannah zones respectively. This means that maize farmers who farm on more than one plot of land are less scale efficient than those farming on single lands. This is because, even though land fragmentation may be used as a risk strategy by maize farmers, it increases cost of production and farm monitoring is very poor. For instance, transportation cost will definitely increase because farmers have to be moving from farm plot to farm plot that may be far apart. The coefficients of the variable representing contact with extension service is positively related to scale efficiency and is statistically significant at 5%, 1%, 10% and 10% for maize farmers in the pooled sample, northern savannah zone, forest zone and coastal savannah zone respectively. This implies that an increase in number of extension visits will let maize farmers produce close to an optimal scale. This is because extension allows maize farmers to know and learn new production technologies as well as the correct combination of production inputs in production. The effect of the variable representing membership of a farmer association on scale efficiency is positive and statistically significant at 1%, 10%, 5% and 10% for maize farmers in the pooled sample, northern savannah zone, forest zone and coastal savannah zone respectively.

That is, scale inefficiency of the farmer would be reduced if the farmer belonged to a farmer association. The reason is that members of such associations benefit through the provision of credits and subsidies on production inputs by the association. Added to this is the fact that agricultural extension agents mostly disseminate agricultural production technologies through seminars organized for members of farmer based organizations.

Access to farm credit was also found to have a positive influence on the scale efficiency of maize farmers and is statistically significant at 10%, 10%, 5% and 5% significance levels for maize farmers in the pooled sample, northern savannah, forest and coastal savannah zones respectively. This means that maize farmers with access to credit are more scale efficient than those with no access to credit. Acquisition of credit by maize farmers reduces their liquidity constraints and allows them to purchase required production inputs for their input mixes. Consequently, farmers approach optimal levels of output. Finally the results of northern, transitional and forest zones dummies were positive and significant at 1%, 5% and 10% respectively using coastal savannah zone as a base category. This implies that maize producers in northern, transitional and forest zones are more scale efficient than those in the coastal savannah zones. The magnitude of the coefficients in Table 4.16 shows that maize farmers in the transitional belt are more efficient in their scale of production than any other agro ecological zone.

CHAPTER FIVE

SUMMARY, CONCLUSION AND IMPLICATIONS FOR POLICY AND RESEARCH

This chapter presents a summary of the background information, statement of the problem, the objectives and the main findings of the study. In addition, it presents conclusions and policy implications as well as areas for further research.

5.1 Summary

Maize is considered the most important cereal crop in Ghana because it is widely cultivated and the number one crop in terms of area planted, serves as a major food and cash crop and the most common staple crop contributing significantly to consumer diets with maize-based foods constituting a significant proportion of household expenditure. In spite of the aforementioned relative importance of maize in Ghana, the industry is characterized by low productivity challenges resulting from no or low use of production technologies and economic inefficiency. The main objective of this study was to investigate the determinants of use of productivity enhancing technologies and economic efficiency in maize production in Ghana. Specifically, the study investigated resource use efficiency in maize production and the factors influencing technical efficiency, scale efficiency and use of productivity enchancing technologies in maize production.

The research largely employed primary data obtained from a cross section of 576 maize farmers in eight (8) districts across all the four (4) agro ecological zones in Ghana for the rainy season of 2014 calendar year using a structured questionnaire. Descriptive statistics in the form of percentages, means, frequency tables and bar charts were employed in the qualitative analyses. For the quantitative analyses, whereas the multinomial logit model was employed in the analysis of the determinants of use of productivity enhancing technologies, the stochastic frontier production function was employed in the economic efficiency analyses. STATA/IC 11.0 statistical package was used in the analysis.

The results of the multinomial logit model on factors influencing use of productivity enhancing technologies revealed that, in Ghana, educational level, capital at the beginning of production, contact with agricultural extension agents, membership of a farmer association, availability of ready maize market, access to credit, experience in maize farming and previous year's price of maize have significant positive effect on the likelihood of use of productivity enhancing technologies in maize production. Also, whereas land fragmentation was significantly negatively related to the odds of using maize production technologies, mixed effects of household size and age of farmer on improved input use were found.

The results of the stochastic frontier translog production function analysis revealed that the mean technical efficiency estimate for the sampled maize farmers in the pooled sample was 58.1%, indicating that maize farmers in Ghana produce below the frontier with 41.9% of potential maximum output lost to technical inefficiency. Specifically, the mean technical efficiency of maize farmers in the northern savannah, transitional, forest and coastal savannah zones were estimated to be 61.2%, 70.2% , 49.9% and 66% respectively. The analysis of the inefficiency model revealed that, generally, educational level, maize farming experience, income, contact with agricultural extension agents, male gender, membership of a farmer association, access to credit, household size, availability of ready maize market as well as uses of fertilizer, pesticides and improved seeds exert positive effect on the technical efficiency of maize producers in Ghana. Also, whereas land fragmentation was found to be negatively related to technical efficiency, land input was found to have mixed effects.

The results of the resource use efficiency analysis show that fertilizer, herbicide, pesticide, labour, manure and land were under utilized in the northern savannah zone. Seed and capital were however over utilized. For maize farmers in the transitional zone, fertilizer, herbicide, pesticide, seed, labour, manure and land were underutilized whereas only capital was over utilized. Apart from capital inputs, all other inputs including fertilizer, herbicide, pesticide, seed, labour, manure and land were underutilized in the forest zone of Ghana. Finally, for maize farmers in the coastal savannah zone, with the exception of land and capital that were over utilized, all other inputs including fertilizer, herbicide, pesticide, seed, labour and manure were underutilized. Generally, the results of the resource use efficiency analysis show that maize farmers in Ghana underutilized the amounts of fertilizer, herbicides, pesticides and manure whereas capital input was over utilized.

The results of the parametric estimation of scale efficiency showed that the overall mean scale efficiencies were 87.7%, 85.7%, 90.9%, 88.6% and 85.5% for maize farmers in the pooled sample, northern savannah zone, transitional zone, forest zone and coastal savannah zone respectively**.** That is, maize farmers in Ghana are not optimal in their scale of operation. The results also showed that 57.64% of maize farmers in the pooled sample exhibited increasing returns to scale, 33.33% exhibited decreasing returns to scale while only 9.03% were operating under constant returns to scale. For maize farmers in the northern savannah zone, the results showed that 55.71% of them exhibited increasing returns to scale, 35.71% exhibited decreasing returns to scale whereas only 8.58% operated under optimal scale. Results from the transitional zone of Ghana also revealed that 55.15%, 37.5% and 7.35% of maize farmers in that zone exhibited increasing returns to scale, decreasing returns to scale and constant returns to scale respectively. Similarly, the percentages of maize farmers in the forest belt of the country that operated under sub-optimal, supra-optimal and optimal scales were 59.57%, 35.46% and 4.97% respectively. The situation was not all that different for maize farmers in the coastal savannah zone as 66.66%, 27.78% and only 5.56% of maize farmers in that zone exhibited increasing returns to scale, decreasing returns to scale and constant returns to scale respectively. Generally, the results of the pooled sample revealed educational level, maize farming experience, extension contact, access to good roads, household size as well as uses of fertilizer and improved seeds to have positive significant effects on the scale efficiency of maize producers in Ghana. Also, whereas land fragmentation was found to be the only factor that exerted negative influence on the scale efficiency of maize farmers in Ghana, farm size and membership of a farmer association were found to exert mixed effects.

5.2 Conclusions

Generally, it can be concluded from the multinomial logit results that an increase in educational level, capital at the beginning of production, credit, extension contact, maize farming experience, previous year’s price of maize as well as membership of a farmer association and availability of ready market would increase Ghana's maize farmers' use of productivity enhancing technologies. However, increasing land fragmentation will decrease maize farmers' use of improved inputs.

The results of the stochastic frontier production function analysis showed that maize farmers in Ghana are technically inefficient which means that they can increase their output levels by employing their production inputs efficiently. The inefficiency model revealed that educational level, maize farming experience, income, extension contact, male-gender, farmer's age, membership of a farmer association, access to credit, household size, availability of ready maize market as well as uses of fertilizer, pesticides and improved seeds would increase the technical efficiency of maize producers in Ghana. Also, whereas land fragmentation would decrease technical efficiency of Ghana's maize farmers, farm size may/may not increase/decrease it.

It can be concluded from the results of the resource use efficiency analysis for maize farmers in the northern savannah zone that for them to be optimal in their productivity levels there is the need for them to increase levels of fertilizer, herbicide, pesticide, labour, manure as well as farm size and reduce seed and capital inputs. For maize production in the transitional zone, levels of fertilizer, herbicide, pesticide, seed, labour, manure and farm size should be increased whereas capital inputs should be reduced. Apart from capital inputs, all other inputs including fertilizer, herbicide, pesticide, seed, labour, manure and land should be increased for optimal productivity levels in the forest zone of Ghana. Finally, for maize farmers in the coastal savannah zone, with the exception of land and capital that should be reduced, all other inputs including fertilizer, herbicide, pesticide, seed, labour and manure should be on the higher side. Generally, the results of the resource use efficiency analysis allow this study to conclude that maize farmers in Ghana use less than optimum amounts of fertilizer, herbicides, pesticides and manure whereas more than optimum amount of capital was employed.

Finally, the results of the parametric estimation of scale efficiency revealed that maize farmers in Ghana are scale inefficient and this observed scale inefficiency is mainly due to the maize farms operating in a sub-optimal scale and these sub-optimal scale maize farms should increase their output levels higher than the supra-optimal ones by employing their production inputs efficiently. The results further showed that an increase in educational level, maize farming experience, access to good roads, extension contact, household size as well as uses of fertilizer and improved seeds would increase the scale efficiency of maize producers in Ghana. Also, whereas an increase in land fragmentation would decrease the scale efficiency of maize farmers in Ghana, an increase in farm size and membership of a farmer association may/may not increase/decrease scale efficiency.

5.3 Policy Implications

Given that increase in formal education would increase use of productivity enhancing technologies and efficiency, technology dissemination and efficiency improvement programmes by stakeholders in the maize industry could target literate maize farmers. Stakeholders, especially the Ministry of Food and Agriculture (MOFA) could also liaise with the Non-Formal Education Division of the Ministry of Education to provide maize farmers who do not have formal education with special training in at least reading, writing and numeracy prior to introducing new maize production technologies to such farmers.

Also, extension officers should encourage maize farmers to join Farmer Based Organizations in places where there are established ones by presenting to the farmers the benefits of joining such organizations. In places where there are no established ones, extension officers should assist maize farmers to team up and form such organizations. This is because agricultural technologies are normally disseminated through farmer associations and therefore farmers who belong to such associations will more likely have knowledge of suggested technologies than those who are not members of such associations.

Key stakeholders in the maize industry comprising the government and nongovernmental organizations could assist farmers to increase their use of fertilizer, manure, pesticides and improved seeds by supporting them with production capital with which they can purchase the inputs or subsidizing the inputs to make them affordable to the maize farmers. This is because use of these inputs in maize production enhances the output which further increases productivity. Government could also set up an agricultural fund that would provide farmers with credit through which production inputs, especially those mentioned above would be purchased. Moreover, government could liaise with financial institutions to come out with measures that would make loan acquisition by maize farmers very easy.

Given that the scale efficiency of maize farmers is higher than their technical efficiency, agricultural productivity improvement policies such as assisting farmers to purchase and use improved inputs aimed at addressing the efficiency challenges of maize farmers in Ghana should be targeted more at improving technical efficiency than scale efficiency.

The finding on the number of times extension officers visited maize farmers suggests that policy makers through the Ministry of Food and Agriculture should analyse the problems extension officers face in the discharge of their duties. This will pave the way for the provision of appropriate incentives to extension officers by government and other stakeholders in the maize industry that will help improve their commitment to delivery of agricultural extension services to the maize farmers. This is because access and number of contacts with extension agents would create opportunities for maize farmers to be updated with new and cost effective productivity enhancing technologies.

Improvement in especially road infrastructure by government is also indispensable to achieving maize farm efficiency since production inputs would be delivered to farms on time and farm products will also reach consumer markets without them going bad.

Finally, Maize farmers should as much as possible have their farm at one place instead of holding many plots of land so that they would be able to deal with the adverse effects of land fragmentation. For maize farmers that may use land fragmentation as a risk strategy, the study recommends the development of agricultural insurance policies by both government and nongovernmental organizations that will be made available and accessible to the farmers so that the safety of their investments in maize production would be guaranteed.

5.4 Contribution to body of literature

This study is unique in the sense that unlike previous productivity studies that examined use of improved inputs and economic efficiency seperately, this study examined them together. This is necessary because the study paves the way for easy comparison of productivity improvement via increasing improved inputs use and economic efficiency. This will inform policy makers about the best source of maize productivity improvement. Also, it was carried out across four agro ecological zones in Ghana which allows comparison in productivity levels between maize farmers in different agro ecological zones.

Furthermore, following a proposal by Ray (1998) about the possibility of estimating scale efficiency parametrically (an alternative to the DEA approach), very few studies on scale efficiency estimations have used this methodology. The current study adds to the literature on parametric approach to scale efficiency estimations.

Finally, in parametric analysis based on a frontier production function, usually the scale elasticity rather than scale efficiency level is reported. The current study has reported scale efficiency from the stochastic frontier production function.

5.5 Areas of Further Research

There is no doubt that the current study was not without challenges. The study therefore suggests the following for consideration by future research in agricultural productivity improvement and most especially in the maize industry.

Firstly, the current study mainly used cross-sectional data. It did not use farm-level panel data. Cross-sectional data analysis is fraught with challenges, such as inability to trace the dynamics of performance of farmers over a period. Therefore, the current study suggests that future research should undertake agricultural productivity analysis using farm-level panel data in order to be able to track the dynamics of farmer performance over time.

Secondly, the focus of the current study was on maize. Similar farm level analysis can be done for other crops. Even two or more crops or livestock can be included in the study. That is multi-product analysis, which is possible in small scale crop and animal production.

Finally, the improved input use studies considered in the current study focused on whether or not in general, maize farmers used productivity enhancing technologies. Future improved input use, efficiency and productivity researchers are encouraged to consider specific technologies in different agro-ecological zones to pave the way for analyzing the effect of technology gaps across agro-ecological zones. Studies on intensities of use of productivity enhancing technology are also crucial.

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LIST OF APPENDICES

Appendix I: Parameter estimates and marginal effects of the multinomial logit model for determinants of use of maize technologies for the Northern Savanna Zone

Independent Variable	Improved Seed		Fertilizer/Row Planting		Herbicides		All technologies	
	Coeff/SE	dy/dx	Coeff/SE	dy/dx	Coeff/SE	dy/dx	Coeff/SE	dy/dx
Constant	-6.02945		-2.216557		3.897683		-8.629089	
	(3.379718)		(1.924401)		(4.228164)		(4.79201)	
HOSIZE	-20.252	-0.0481**	-1.545	-0.20743*	1.003654	0.0000126	-19.09252	-2x10^{-06}
	(7619.937)		(0.8357473)		(1.492581)		(11502.44)	
SEX	0.4919064	0.000574	0.4535235	0.0549078	-2.086881	-0.00002	(0.755739)	7x10$_{-08}$
	(1.505401)		(1.004083)		(2.090071)		(1.813539)	
AGE	0.0011657	-0.00005	0.0116646	0.0012987	-0.0910986	-2x10^{-07}	0.0895913	2x10^{-08}*
	(0.0454863)		(0.0281786)		(0.0712732)		(0.0525461)	
EDU	0.1095502	-0.00017	0.1578	0.017092**	0.1606609	4.5x10^{-08}	0.0866504	-1x10^{-08}
	(0.0900668)		(0.0699501)		(0.1126311)		(0.1232421)	
EXP	0.03856	0.00022**	0.0002523	0.0001668	0.0277819	5.5x10^{-08}	0.0908694	2x10$_{-08}$
	(0.0514927)		(0.0319924)		(0.0657904)		(0.0843545)	
LANDSZ	-0.3734101	-0.00101	-0.2261935	-0.023405	-0.5972028	-8x10^{-07}	-0.8331447	-2x10^{-07}
	(0.4216985)		(0.1902822)		(0.6942346)		(0.7917144)	
NPLOTS	0.5370287	-0.00042	0.6958884	0.0751015	1.322582	1.4x10^{-06}	0.0216442	-1x10^{-07}
	(0.7010502)		(0.6172867)		(.8284412)		(1.071434)	
CAPgin	0.0004306	7.5810^{-07}	0.0003412	0.000036	-0.0004251	-2x10^{-09}	-0.0011972	-3x10^{-10}
	(0.0009164)		(0.0006276)		(0.0014614)		(0.0024201)	
NOEXTVI	0.5309595	0.0007629	0.4546645	0.0481579	0.7265983	6.5310^{-07}	0.5534125	4x10$_{-08}$

	(0.4075463)		(0.3108457)		(0.5494364)		(0.5716107)	
MGROUP	3.732 (1.888647)	0.0206**	0.06506 (0.9928148)	0.011886***	16.93485 (2367.516)	0.0008	17.13824 (2629.803)	0.0001*

Source: Survey, 2015

Note: Coeff = Coefficient, SE=Standard errors are in parentheses. The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%. dy/dx represents marginal effects.

Appendix I: Continued

Independent Variable	Improved Seed		Fertilizer/Row Planting		Herbicides		All technologies	
	Coeff/SE	**dy/dx**	**Coeff/SE**	**dy/dx**	**Coeff/SE**	**dy/dx**	**Coeff/SE**	**dy/dx**
CREDIT	4.149258 (1.702785)	0.029188**	2.09691 (1.160726)	0.1197528*	-14.6585 (3347.015)	-0.000048	-13.45157 (3213.886)	-4x10^{-06}
SPMAIj12k	5.122283 (3.06782)	0.0229652*	1.299527 (2.312085)	0.1194202	1.918195 (3.709135)	1.5x10^{-06}	8.360062 (4.828271)	2x10^{-06}*
REDYMKT	2.99685 (1.696688)	0.0085611*	0.7134465 (0.7265103)	0.0825302	3.041 (1.506553)	.0035**	1.902268 (1.901303)	2x10$_{-07}$
Number of Observations				140				
LRchi2 (52)				104.28				
Prob> chi2				0.000				
Pseudo R2				0.3426				
Log likelihood				-100.0304				

Source: Survey, 2015

Source: Survey, 2015

Note: Coeff = Coefficient, SE=Standard errors are in parentheses. The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%. dy/dx represents marginal effects.

Note: Coeff = Coefficient, SE=Standard errors are in parentheses. The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%. dy/dx represents marginal effects.

Appendix II: Parameter estimates and marginal effects of the multinomial logit model for determinants of use of maize technologies for the Transitional Zone

Independent Variable	**Improved Seed**		**Fertilizer/Row Planting**		**Herbicides**		**All technologies**	
	Coeff/SE	**dy/dx**	**Coeff/SE**	**dy/dx**	**Coeff/SE**	**dy/dx**	**Coeff/SE**	**dy/dx**
Constant	-5.050042 (3.42048)		-1.145127 (2.00627)		-.5934001 (1.984616)		-3.049395 (3.353355)	
HOSIZE	4.532 (1.934456)	0.057182**	0.7568069 (0.8465773)	0.080043*	0.3087092 (0.9128438)	1.9×10^{-06}	1.769113 (1.341107)	0.022868**
SEX	1.969468 (1.788483)	0.0558114	-1.267422 (0.8459287)	-0.024026	0.2692539 (0.9281453)	3.4×10^{-06}	-2.043169 (1.264029)	-0.03179
AGE	-0.000428 (0.0510524)	0.0008118	-0.0313162 (0.0316021)	-0.00159	-0.0108356 (0.0332363)	5.8×10^{-08}	-0.0052906 (0.0486946)	0.0007761

EDU	0.364	0.002703**	0.2562	0.009747**	-0.0850692	$-1x10^{-06}$	0.4875	0.0070464***
	(0.1603713)		(0.1170796)		(0.120091)		(0.1807606)	
EXP	0.1085338	0.00276	0.005508	0.00348***	0.0028705	$1.9x10^{-08}$	0.0317949	0.00072
	(0.0747779)		(0.0354574)		(0.0360814)		(0.0676815)	
LANDSZ	0.0469773	0.0027851	-0.0569306	-0.003506	0.073416	$3.9x10^{-07}$	-0.030609	(0.0007205)
	(0.2137462)		(0.107166)		(0.0650055)		(0.2810803)	
NPLOTS	-2.503	-0.0391***	-1.000	0.0906376**	0.1138318	$3.8x10^{-06}$	-2.7129	-0.051548**
	(0.9597935)		(0.5095011)		(0.1073872)		(1.293493)	
CAPgin	0.001282	3.8110^{-06}*	0.00115	$1.9x10^{-06}$**	-0.0004599	$-5x10^{-09}$	0.0009643	$-6x10^{-06}$
	(0.0007323)		(0.0004975)		(0.0005373)		(0.0007504)	
NOEXTVI	2.0999	0.014620***	1.553	-0.0195***	-1.285039	$-9x10^{-06}$	1.7288	0.0049345***
	(0.5749759)		(0.5524125)		(1.409005)		(0.5708789)	
MGROUP	19.816	0.003070*	19.87952	0.046605	0.113312	0.000927	21.12639	0.0519596
	(2561.959)		(2561.959)		(3918.47)		(2561.959)	
CREDIT	20.0018	0.1496925	17.53689	0.203438	-16.37676	$-3x10^{-06}$	18.91721	0.0538618
	(3350.559)		(3350.559)		(3350.559)		(3350.559)	

Appendix II: Continued

Independent Variable	Improved Seed		Fertilizer/Row Planting		Herbicides		All technologies	
	Coeff/SE	dy/dx	Coeff/SE	dy/dx	Coeff/SE	dy/dx	Coeff/SE	dy/dx
	(3350.559)		(3350.559)		(3350.559)		(3350.559)	
SPMAIj12k	2.36854	0.0674**	0.111043	0.05506*	1.294986	3.8610^{-06}	0.4364516	0.0122441

Source: Survey, 2015

Note: Coeff = Coefficient, SE=Standard errors are in parentheses. The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%. dy/dx represents marginal effects.

	(1.583127)		(1.028457)		(1.139117)		(1.575352)	
REDYMKT	4.366 1.498885	0.0180166***	3.5832 1.030651	0.0383475***	0.0113554 0.8397711	-0.00005	2.383 1.313138	0.056227*
Number of Observations				144				
LRchi2 (52)				196.64				
Prob> chi2				0.000				
Pseudo R2				0.4754				
Log likelihood				-108.489				

Source: Survey, 2015

Note: Coeff = Coefficient, SE=Standard errors are in parentheses. The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%. dy/dx represents marginal effects.

Appendix III: Parameter estimates and marginal effects of the multinomial logit model for determinants of use of maize technologies for the Forest Zone

Independent Variable	Improved Seed Coeff/SE	dy/dx	Fertilizer/Row Planting Coeff/SE	dy/dx	Herbicides Coeff/SE	dy/dx	All technologies Coeff/SE	dy/dx
Constant	4.132874 (7.867496)		4.104014 (2.633844)		2.180794 (2.480995)		-77.79739 (17151.69)	
HOSIZE	-0.344114 (1.613986)	-0.00223*	-0.1280322 (1.04328)	-0.02963	0.1788795 (0.965077)	0.0318622**	12.65884 (5322.994)	3×10^{-19}
SEX	3.544239 (4.217628)	0.0149311	1.036233 (0.9048096)	-0.04698	1.418507 (0.8818814)	0.0320509	37.79142 (6671.258)	2×10^{-20}
AGE	-0.16305 (0.0819427)	-0.0008**	-0.077353 (0.042947)	-0.00037*	-0.0735766 (0.0398099)	-0.000448*	0.5199061 (148.5928)	2×10^{-20}
EDU	0.2001755 (0.2329349)	0.0021375	-0.0474975 (0.1110468)	-0.02285	0.1723662 (0.1171153)	0.020711	-1.440337 (595.6393)	0.001
EXP	0.0794735 (0.1094721)	0.000831	0.0161116 (0.0445198)	0.0082323	0.0625329 (0.0473601)	0.007401*	0.6134264 (178.1162)	2×10^{-20}
LANDSZ	-0.1423383 (1.300144)	-0.001410	0.0065599 (0.0508053)	0.0022343	-0.0036857 (0.0610139)	-0.000823	0.1028872 (134.7072)	3×10^{-21}
NPLOTS	-7.3212 (3.998098)	-0.05483*	-1.7308 (0.6772119)	-0.087956**	-0.2937438 (0.4667092)	0.1427863	-17.60015 (2937.273)	0.002
CAPgin	-0.0004636 (0.0035102)	-0.000022	0.0024474 (0.002354)	0.0005204	-0.0028067 (0.00237)	-0.000498	-0.0811464 (20.25883)	0.004
NOEXTVI	14.35117	0.0156939	12.73513	0.011105	12.47155	-0.026796	18.39265	8×10^{-19}

Source: Survey, 2015

Note: Coeff = Coefficient, SE=Standard errors are in parentheses. The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%. dy/dx represents marginal effects.

	(2478.862)		(2478.861)		(2478.862)		(2528.223)	
MGROUP	18.96744 (11251.23)	0.0017193	19.48357 (11251.23)	0.549218*	1.33569 (14884.53)	0.550936**	1.242429 (15089.09)	3x10$_{-23}$
CREDIT	0.3029278 (2.286336)	0.0082229	0.4310615 (1.34556)	0.05623	-0.0260242 (1.531956)	-0.048007	4.671225 (9222.759)	5x10$_{-22}$

Appendix III: Continued

Independent Variable	Improved Seed		Fertilizer/Row Planting		Herbicides		All technologies	
	Coeff/SE	**dy/dx**	**Coeff/SE**	**dy/dx**	**Coeff/SE**	**dy/dx**	**Coeff/SE**	**dy/dx**
SPMAIj12k	3.917048 (2.622134)	0.040362	-0.3006359 (1.164753)	-0.025787	-0.4079768 (1.088721)	-0.014574	37.88799 (8872.916)	3x10$_{-18}$
REDYMKT	2.542049 4.881803	0.0034707	2.066489 1.116983	0.039343*	2.507572 1.083475	0.0358742**	-8.240854 15345.42	-1x10^{-19}
Number of Observations				143				
LRchi2 (52)				166.53				
Prob> chi2				0.000				
Pseudo R2				0.4552				
Log likelihood				-99.6671				

Source: Survey, 2015

Note: Coeff = Coefficient, SE=Standard errors are in parentheses. The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%. dy/dx represents marginal effects.

Appendix IV: Parameter estimates and marginal effects of the multinomial logit model for determinants of use of maize technologies for the Coastal Savanna Zone

Independent Variable	Improved Seed Coeff/SE	dy/dx	Fertilizer/Row Planting Coeff/SE	dy/dx	Herbicides Coeff/SE	dy/dx	All technologies Coeff/SE	dy/dx
Constant	-3.465299		2.563372		2.629482		-5.75636	
	(7.471086)		(5.175107)		(5.602191)		(5012.425)	
HOSIZE	0.66929	0.0923171**	0.3693876	0.090248	1.1326	0.002524***	.6841044	0.0003046
	(1.561511)		(1.216934)		(1.546402)		(1.960789)	
SEX	-0.3282479	-0.071429	0.6379374	0.0708746	0.7762822	0.0008115	0.8470322	0.0000595
	(1.016567)		(0.7563037)		(0.8626164)		(1.410381)	
AGE	(0.0438748)	(0.0069144)	-0.0657607)	-0.006839	-0.0785706	-0.000078	-0.1773168	-0.000025
	(0.0833602)		(0.0512797)		(0.0595567)		(0.1635583)	
EDU	-0.0665764	-0.002865	-0.0208022	0.0031506	-0.0895649	-0.000256	-0.2168393	-0.000042

Source: Survey, 2015

Note: Coeff = Coefficient, SE=Standard errors are in parentheses. The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%. dy/dx represents marginal effects.

	(0.118087)		(0.0841047)		(0.0960414)		(0.1975462)	
EXP	0.1150323 (0.0920327)	0.009776	0.0399811 (0.0504132)	0.009668***	0.0745703 (0.0581606)	0.000176	0.2125084 (0.2747924)	0.000053*
LANDSZ	0.2792562 (0.5278478)	-0.001765	0.3071744 (0.4101165)	0.0016893	0.3568373 (0.4098877)	0.0002013	0.442158 (0.79496)	0.0000298
NPLOTS	-0.8686731 (0.8129409)	0.0208572	-1.202075 (0.760941)	-0.023125	-0.4085629 (0.7942087)	0.0030056	-7.317899 (18.10776)	-0.001339
CAPgin	0.0040318 (0.0027663)	0.000028	0.003598 (0.0016589)	-0.000018**	0.0013197 (0.0017558)	$-9x10^{-06}$	0.004912 (0.0057174)	$2.8x10^{-07}$
NOEXTVI	0.9668 (0.2809337)	.0129705***	0.762449 (.2747071)	-.011628***	.5237077 (0.279149)	-.000982*	.934372 (0.2922585)	.000035***
MGROUP	0.603048 (1.977824)	0.2219835**	1.422918 (1.75082)	0.132326**	16.3256 (1665.515)	0.090502**	1.474932 (3.962636)	0.000040
CREDIT	15.29609 (1527.38)	0.0012165	15.28222 (1527.38)	0.0037836	15.27135 (1527.38)	-0.000026	17.12383 (1527.384)	0.0008625

Appendix IV: Continued

Independent Variable	**Improved Seed**		**Fertilizer/Row Planting**		**Herbicides**		**All technologies**	
	Coeff/SE	**dy/dx**	**Coeff/SE**	**dy/dx**	**Coeff/SE**	**dy/dx**	**Coeff/SE**	**dy/dx**
SPMAIj12k	-4.343293 (7.702823)	-0.056598	-3.451696 (6.06584)	0.0505825	-2.461774 (6.307184)	0.0040844	-2.865389 (8.409464)	0.0001398
REDYMKT	2.994884 (3.218328)	0.0026994	2.98135 (1.557197)	0.0248844*	1.106234 (1.611572)	-0.019593	19.41162 (5012.382)	0.000386
Number of Observations				144				
LRchi2 (52)				139.94				

Prob> chi2	0.000
Pseudo R2	0.3788
Log likelihood	-114.726

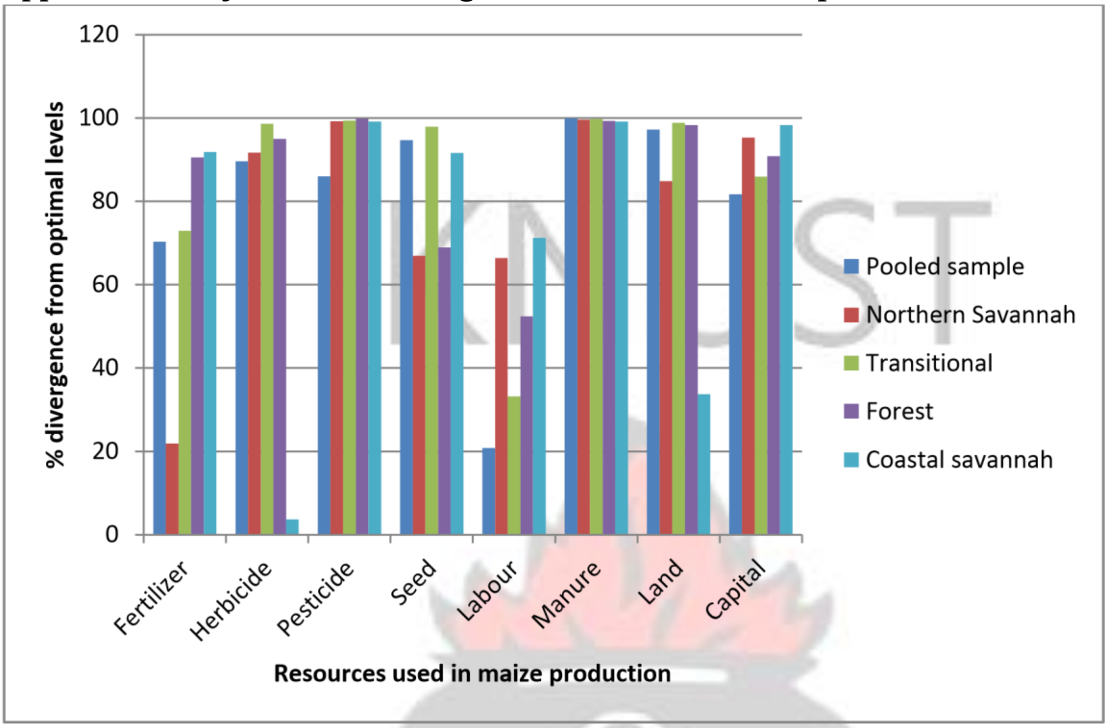
Source: Survey, 2015

Note: Coeff = Coefficient, SE=Standard errors are in parentheses. The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%. dy/dx represents marginal effects.

Source: Survey, 2015

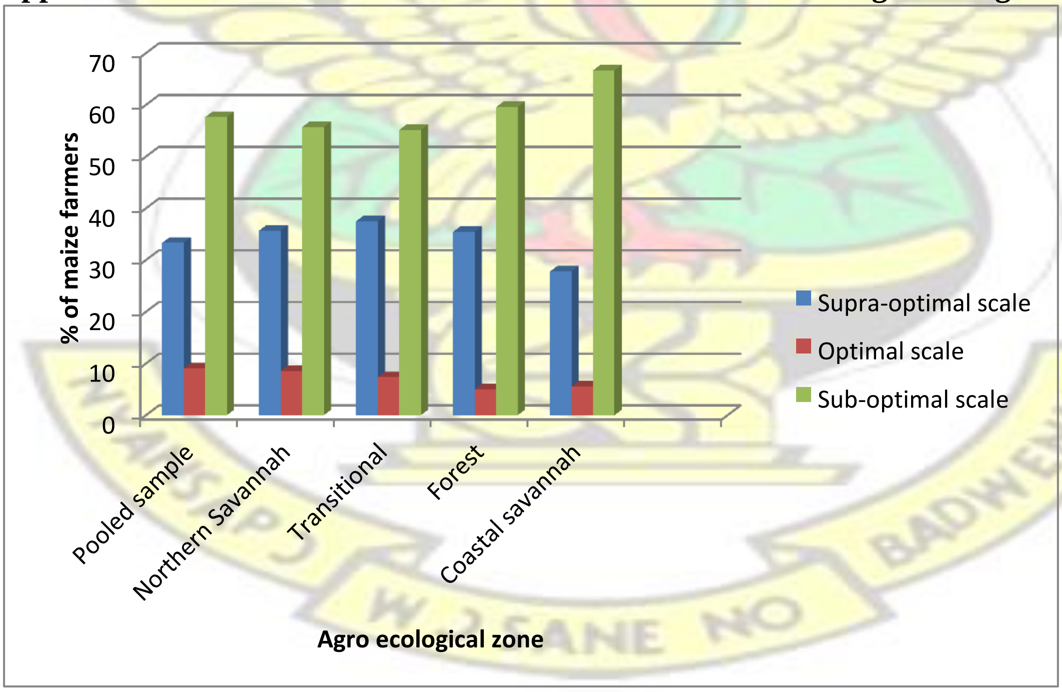
Note: Coeff = Coefficient, SE=Standard errors are in parentheses. The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%. dy/dx represents marginal effects.

Appendix V: Adjustments in Marginal Value Products for optimal resource use



Source: Survey, 2014

Appendix VI: Scales distribution of maize farmers in different agro ecological zones



Source: Survey, 2014

Appendix VII: Survey questionnaire

STRICTLY CONFIDENTIAL SURVEY OF MAIZE FARMERS IN GHANA ABOUT ECONOMIC EFFICIENCY AND PRODUCTIVITY OF MAIZE PRODUCTION IN GHANA

A: IDENTIFICATION

A1. Name of Enumerator…………………………………………..............Phone No…………

A2. Name of Respondent ……………………………………………..Phone No……………

A3. Agro-ecological zone (Please tick)
1. Northern Savannah
2. Transitional
3. Forest
4. Coastal Savannah

A4. District/Municipality (Please tick)
1. West Mamprusi
2. East Gonja
3. Nkoranza
4. Ejura Sekyedumase
5. Fanteakwa
6. Agona
7. Gomoa
8. Ketu

A5. Operational area (Farm location)………………………………

A6. Description of operational area. Urban = 1 Rural = 2

B. DEMOGRAPHIC CHARACTERISTICS AND SOME CULTURAL PRACTICES

B1. Gender Male = 1 Female = 2

B2. Age of respondent (years)……… (1=18-45 years; 2=46-60 years; 3= more than 60years)

B3. Educational Level………. 1= No Formal Education; 2= Primary School; 3=Middle/JSS/JHS; 4=SSS/SHS; 5= Training College/Tertiary

B4. Actual Number of years of formal education (schooling)………………………………

B5. Size of household………………………..

B6. Marital status: Single = 1 Married = 2

B7. Number of years in Maize farming……………………………

B8. What was your total capital at the beginning of the production season? Gh¢…………

B9. Size of your maize farm last year in acres…………………………………..

B10 Number of plots of land last year……………………………………………….

B11. How much did you spend for renting an acre of land last year? Gh¢.............................

B12. What was the average total income from your maize farm last year? Gh¢......................

B13. Were you engaged in other income generation activity apart from maize farming last year? Yes = 1 No = 2

B14. If you engaged in other income (economic) activities last year, which of the following is applicable? (Select only one)

1. Artisan (carpentry, fitting, dress making, etc);
2. Trading;
3. Food processing:
4. By day labourer
5. Public Servant
6. Others (Please Specify)…………………………………………………………

B15. If you engaged in other income (economic) activities please indicate your average total income from other income generation activities for last year? Gh¢........................

B16. Did you adopt any productivity enhancing technology in your maize production last year? Yes = 1 No = 2

B17. Did you ensure zero tillage (slashing, no burning, no ploughing, use herbicide and planting with mulch) in your maize production last year? Yes = 1 No = 2

B18 Did you have access to tractor services?
Yes = 1 No = 2

B19. Did you employ row planting technology in your maize production last year?
Yes = 1 No = 2

B20. If row planting technology was applied last year, what was the planting distance used in centimetres?……………………………………………………………………

B21. Apart from the use inorganic fertilizer, did you ensure other soil fertility management practices in your maize production last year? Yes = 1 No = 2

B22. If you ensured other soil fertility management practices in your maize production last year, which of the following management practices were ensured?

1. Applied animal manure

2. Ploughed in crop residues
3. Practiced ridging
4. Intercropped with nitrogen-fixing crops
5. Intercropped with any crop
6. Planted in mulch
7. Practiced relay cropping or crop rotation
8. All the above
9. Others (Please specify)………………………………………………………………

B23. Why did you plant the variety you planted last year?

1. It was very cheap
2. It was the only one available
3. It was the only known variety
4. That was what customers preferred
5. It is high yielding
6. It matures early
7. Others (Please Specify)………………………………………………………………

B24. Which **one** of the following groups of productivity enhancing technologies did you employ in your maize production last year? Please tick.

1. Improved seeds + fertilizer use + fungicides/pesticides use+ Herbicides use + Row planting + Zero tillage + Other soil fertility management practices
2. Some of the technologies mentioned in (1) above but not all
3. Only one of the technologies mentioned in (1) above

B25. Did you have access to extension service last year? Yes = 1 No = 2

B26. If you had access to extension service last year, how many times did you receive this service?...

B27. Were you a member of any farmer association last year? Yes = 1 No = 2

B28. Did you have access to farm credit last year? Yes = 1 No = 2

B29. If you had access to farm credit last year, which of the following was your source of credit.

1. ADB;
2. GCB;
3. Rural Bank;
4. Savings and Loans
5. Credit Unions
6. Informal Sources
7. Others (Please Specify)………………………………………………………………

B30. If you had access to farm credit last year, please indicate the amount of credit received. Gh¢……………………………………………………………………………

B31. What was the nature of the road linking your village to the main maize market in your district last year?

1. Asphalt
2. Tarred but not asphalt
3. Tarred with pot holes
4. Rough but smooth
5. Rough and marshy
6. Others (Please Specify)……………………………………………………………

B32. Did you get adequate rains last year? Yes = 1 No = 2

C. RESOURCES/INPUTS USED IN MAIZE PRODUCTION

C1. **Variable Resources/inputs used in Maize Production.**

For each of the inputs listed in the table below indicate whether or not it was used in your maize production last year and if it was used, indicate the quantity used, unit cost and the total cost per acre.

NO.	VARIABLE INPUT	WHETHER OR NOT USED (Tick)		QUANTITY USED	UNIT COST (GH¢)	TOTAL COST (GH¢)
		Yes	**No**			
1	**Fertilizer (Kilogramme)**					
a	NPK					
b	Sulphate of Ammonia					
c	Urea					
d	Manure					
2	**Fungicides (Litres)**					
a						
b						
c						
d						
3	**Pesticides (Litres)**					
a						
b						
c						
d						
4	**Herbicides (Litres)**					
a						
b						
c						
d						

e						

NO.	VARIABLE INPUT	WHETHER OR NOT USED (Tick)		QUANTITY USED	UNIT COST (GH¢)	TOTAL COST (GH¢)
		Yes	No			
5	**Seed (Kilogramme)**					
a	Obatampa					
b	Mamaba(hybrid)					
c	Dada-ba (hybrid)					
d	Cida-ba (hybrid)					
e	Etubi (Hybrid)					
f	Aseda					
g	Opeaburoo					
h	Tintim					
i	Nwanwa					
j	Odomfo					
k	Enibi (hybrid)					
l	Traditional Variety					
	Others(Please specify)					
m						
n						
o						
p						
6	**Labour (Man-days)**					
a	Land Clearing					
b	Felling of trees					
c	Burning					
d	Sowing					
e	Refilling					
f	Thinning					
g	NPK fertilizer application					
h	Ammonia fertilizer application					
i	Urea fertilizer application					
j	Manure fertilizer application					
k	First weeding					

l	Second Weeding					
m	Herbicide application					
n	Fungicide/insecticide application					
o	Slashing					
p	Harvesting					
q	Gathering					
r	Loading					
s	Unloading					

NO.	**VARIABLE INPUT**	**WHETHER OR NOT USED (Tick)**		**QUANTITY USED**	**UNIT COST (GH¢)**	**TOTAL COST (GH¢)**
		Yes	**No**			
t	Dehusking					
u	Threshing					
v	Bagging					
w	Ridging					
	Others (Please specify)					
7	**Ploughing**					
8	**Ridging**					
9	**Fuel**					
	Others (Please specify)					

C2. **Fixed Resources/inputs used in Maize Production.**

If you used any of the inputs listed in the table below in your maize production last year, please indicate the time of purchase, number used per acre, unit cost, total cost and resale value.

No.	Fixed Input	Economic Life Span	Time Of Purchase		Number Used	Unit Cost (Gh¢)	Total Cost (Gh¢)	Resale Value (Gh¢)
			Month	*Year*				
1	Cutlass							
2	Hoe							
3	Mattock							
4	Basket							
5	Pan							
6	Sacks(81kg)							
7	Storage Structure							
8	Garden Line							
9	Knapsack sprayer							
10	Willington boots							
11	Nose Mask							
12	Gloves							
13	Protective Clothing							
14	Rake							
15	Mist Blower							
16	Axe							
	Others (Please specify)							

C3. **Summary of unit costs/price of key production variables**

No.	Production Variable	Cost/Price (Gh¢)
1	Average price of maize per **Kg**	
2	Average cost of rent of land per **hectare**	
3	Average price of labour per **man-day** (wage rate)	
4	Average price of seed per **Kg**	
5	Average price of fertilizer per **Kg**	

6	Average price of herbicide per **litre**	
7	Average price of insecticides per **litre**	
8	Average price of Fungicides per **litre**	
9	Average price of pesticides per **litre**	
10	Average price of farm tools per **one**	
11	Average price of manure per **Kg**	

C4. **Other production Costs per acre**

NO.	**COST ITEM**	**COST (GH¢)**
1	Repairs of farm implements	
2	Transportation	
3	First Aid	
4	Storage	
	Others (Please specify)	

D. OUTPUT OF MAIZE AND MARKETING

D1. Output of Maize (For all land cultivated to maize) and selling price

YEAR	**SEASON**	**TOTAL MAIZE FARM SIZE (Acres)**	**TOTAL OUTPUT**		**SELLING PRICE (Gh¢/Bag)**
			No. of bags	**Weight (Kg)**	
2013	Major				
	Minor				
2012	Major				
	Minor				

D2. Did you make profit by selling your maize at the price mentioned in the table above?
Yes = 1 No = 2

D3. Did consumers prefer the varieties you planted last year? Yes = 1 No = 2

D4. Where did you sell your maize last year?
1. Farm gate
2. Community maize markets
3. Maize processing firms
4. Others (Please Specify)……………………………………………………………………

D5. Was there ready market for your produce last year? Yes = 1 No = 2

D6. Did you have access to maize storage facilities after harvesting your maize last year?
Yes = 1 No = 2

D7. If you had access to maize storage equipments last year, please indicate which of the following types of storage facilities was used.
1. Traditional Crib (hut)
2. Ordinary room with no state of the art storage equipment
3. Cold Room with state of the art storage equipment
4. Public Silos and drying and warehouse facilities
5. Others (Please Specify)……………………………………………………………