TECHNICAL EFFICIENCY OF MAIZE PRODUCERS IN THREE AGRO ECOLOGICAL ZONES OF GHANA

By

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DECLARATION

I, Kwabena Nyarko Addai, do hereby declare that this submission is my own work towards the MPhil (Agricultural Economics) and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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DEDICATION

This work is dedicated to my sweet mother, Lofty Akosua Yalley, for all her struggle and toil in bringing me to this level. I also dedicate it to my lovely sister, Rebecca Sraku; the Yalley family and the Aikins family for the support and encouragement in my academic pursuit.

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ABSTRACT

This study analyses the technical efficiency of maize producers in three agro ecological zones of Ghana. To carry out this analysis, a translog stochastic production frontier function, in which technical inefficiency effects are specified to be a function of socioeconomic, institutional and environmental variables, is estimated using the maximum likelihood method. Cross sectional data was collected for 2009 crop year from a sample of 453 maize farmers from the Bekwai Municipality, Nkoranza South District and Gushiegu District of the Forest Zone, Transitional Zone and Savannah Zone respectively. Then, the constraints ranked by farmers were analysed using the Kendall's coefficient of concordance to test for degree of agreement in ranking. The results show increasing returns to scale in maize production.

The mean technical efficiency of the sampled maize producers across the three agro ecological zone is 64.1%. The mean technical efficiency of maize producers in the forest, transitional and savannah zone are 79.9 %, 60.5% and 52.3% respectively. The results reveal that extension, mono cropping, gender, age, land ownership and access to credit positively influence technical efficiency. High input price, inadequate capital and irregularity of rainfall are the most pressing problems facing maize producers in the forest, transitional and savannah zones respectively.

The study therefore recommends that policies that would improve extension service delivery, access to credit and the development of hybrid seeds should be pursued.

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AE	Allocative Efficiency
CD	Cobb-Douglas
DEA	Data Envelope Analysis
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
MOFA	Ministry Of Food and Agriculture
MLGRD	Ministry of Local Government and Rural Development
MLE	Maximum Likelihood Estimation
OLS	Ordinary Least Square
RTS	Rate of Technical Substitution
SRID	Statistical, Research and Information Directorate
TE	Technical Efficiency
Translog	Transcendental Logarithmic

CHAPTER ONE

INTRODUCTION

1.1 Background

The idea arising out of Schultz (1964) hypothesis that smallholder farmers are reasonably efficient in allocating their resources and respond positively to price incentives has triggered much attention, particularly in Sub-Saharan Africa. Indeed, the level of efficiency of smallholder farmers has important implications for the choice of development strategy; reason being that most Sub-Saharan countries derive over 60 percent of their livelihoods from agriculture and rural economic activities (Owuor and Shem, 2009).

If farmers are sufficiently efficient then increases in productivity require new inputs and technology to shift the production possibility frontier upward. But, on the other hand, if there are significant opportunities to increase productivity through more efficient use of farmer's resources and inputs with current technology, a stronger case could be made for improvement through eliminating the factors or determinants of inefficiency.

Ghana' population of 6.7 million in 1960 grew to 18.7million in 2000(Ghana Statistical Service, 2002), registering a three –fold increase. The high population growth has been mainly due to a moderately declining fertility and mortality since 1970. Thus rapid population growth has had consequences for food crop production in Ghana (Benneh and Agyepong, 1990). One way of solving the problem of food shortage being created by the widening gap between food output growth and population growth is through increasing agricultural productivity.

The productivity of a farmer does not only depend on physical resources and technology available, but also on the prevailing environmental production conditions such rainfall and temperature. Sherlund *et al* (2002) argue that the presence of inefficiency among small scale farmers could partly be due to consistent omission of the variables representing environmental production conditions in numerous efficiency studies conducted over the years.

Other studies examining efficiency of farmers in developing countries place production efficiency levels within the range of 60-82% irrespective of crop types and regions (Battese and Coelli, 1995 and Rahman, 2003).

1.2 Problem Statement

Maize is a major staple for many Ghanaians that also acts as a substitute for other cereals when in short supply. Despite the increase in maize production over the years in Sub-Sahara Africa, Ghana has a supply deficit of maize and makes up for this shortage through imports (Codjoe, 2007). This is not surprising as demand for maize for various domestic and industrial purposes keep increasing. This shortfall can easily be addressed with local production, as there is enormous potential for maize cultivation in Ghana (Codjoe, 2007).

Maize is produced in almost all the agro-ecological zones in Ghana either under mono-crop or an intercrop system. It is grown on 846,300 hectares and has an annual production of 1,470,000 metric tonnes. However domestic production has been fluctuating for the past two decades, which threatens food security and incomes sources (MOFA -SRID, 2009). The success of the agricultural sector in Ghana is therefore critical for raising the standard of living, food self sufficiency and sustainable livelihood for the population. Production outputs of maize producers depend largely on the combination of productive resources in order to maximise output.

Ghana is divided into three main agro-ecological zones, namely the forest, transitional and savannah zones. The food production potentials of these agro ecological zones have been recognised for years, where new agricultural technologies have been introduced. These technological packages are often very similar, yet they are targeted at farms and communities in different ecologies and at different levels of development of infrastructure and human capital. Consequently, they perform differently in different locations and the overall outcomes fall short of the potential (Alemu *et al.,* 2002). In the dissemination of new technologies, farmers in the agro ecological zones are treated as though their constraints and opportunities are similar. Such an approach is also adopted in applied research, where a majority of farm productivity studies generally stratify farms only by farm characteristics, e.g., farm size, tenure and level of income and measure efficiency for the average farm. Such methods presume that all farms produce under similar environmental conditions and as such the differences in the output and productivity among farms are mostly due to the scale of operation. This is not the case, however, traditional smallholder agriculture, which relies heavily upon the underlying agro ecological (environmental) conditions that vary markedly over time and space affect productivity and efficiency in resource use as witnessed by Okike *et al*, (2004) in a study a savannah zone.

This raises a number of research questions including the following; Are there differences in the technical efficiencies of maize producers in the three agro ecological zones of Ghana? What factors influence the technical efficiency of maize producers in the three agro ecological zones of Ghana? Are there increasing returns to scale in the maize production in Ghana? What constraints do maize farmers face in the three agro ecological zones of Ghana?

These are the pertinent issues that the study seeks to address.

1.3 Objectives of the Study

The main objective of the study is to assess the technical efficiency of maize producers in three agro ecological zones of Ghana. The specific objectives are as follows:

1) To estimate technical efficiency scores of maize farmers in the three agro ecological zones of Ghana.

2) To identify the factors which influence the technical efficiency of maize farmers in the three agro ecological zones of Ghana.

3) To estimate returns to scale in maize production industry.

4) To identify the major constraints faced by maize producers in the three agro-ecological zones of Ghana.

1.4 Justification of the Study

It is widely acknowledged that the scope for agricultural production can be expanded and sustained by peasant farmers within the limits of existing resource base and available technology if farm productivity is raised by efficient use of resources (Udoh, 2000).

The efficient allocation of resources at the farm levels has great implication for overall national development. It will also lead to a rise in Gross Domestic Product (GDP) and per capita income will increase. The following reasons could be brought forward for measuring efficiency on the farm. Firstly, technical efficiency is a success indicator, and performance measure. Secondly, it is only by measuring efficiency and separating its effects from the effects of the production environment that one can explore hypotheses concerning the sources of efficiency differentials (Ajibefun and Daramola, 2003). When the sources of inefficiency are identified, policy formulations to improve farmers' performance can be effectively tackled. Thirdly, the ability to quantify efficiency helps decision-makers to monitor the performance of systems under study. In some cases, the use of theory does not give a clearer picture of the impact of some factors on the performance level. The use of empirical measurement provides both qualitative and quantitative evidence (Coelli, 1995).

More studies on technical efficiency in Ghana have focussed only on farmers in the savannah zone with little attention to the other agro ecological zones (Abdulai and Huffman, 2000; Okike *et al*., 2004 and Al-hassan, 2008). Restricting technical efficiency estimates to only one agro ecological may lead to inadequate information due to spatial agro ecological variations. As noted by Alemu *et al*, (2002) farmers in different agro-ecological zones may face different challenges in terms of resource endowments. Moreover, a one-fit-all approach to efficiency measurement may not be optimal because of agro ecological differences. Accelerated and sustainable agriculture can be achieved if we take into account agro ecological variations and identify appropriate development strategies which will take advantage of the development opportunities in each agro ecological zone and implement them accordingly.

1.5 Organisation of Study

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

Chapter Two gives an overview of literature relevant to the study. Chapter Three outlines the methodology employed to achieve the objectives of the study. In particular, it describes the study area, discusses the conceptual framework on stochastic frontier, and the sampling techniques adopted for the data collection.

In Chapter Four, the descriptive and empirical results are provided and conclusions from the study are distilled in Chapter Five.

CHAPTER TWO

LITERATURE REVEIW

This chapter presents literature on studies related to the maize industry, maize production and technical efficiency analysis. It begins with the maize economy of Ghana, maize cropping systems and production technologies and production trend of maize in Ghana. The concept of economic efficiency and the frontier and the methods of measuring efficiency are also reviewed. It concludes with empirical literature on the factors that influence technical efficiency.

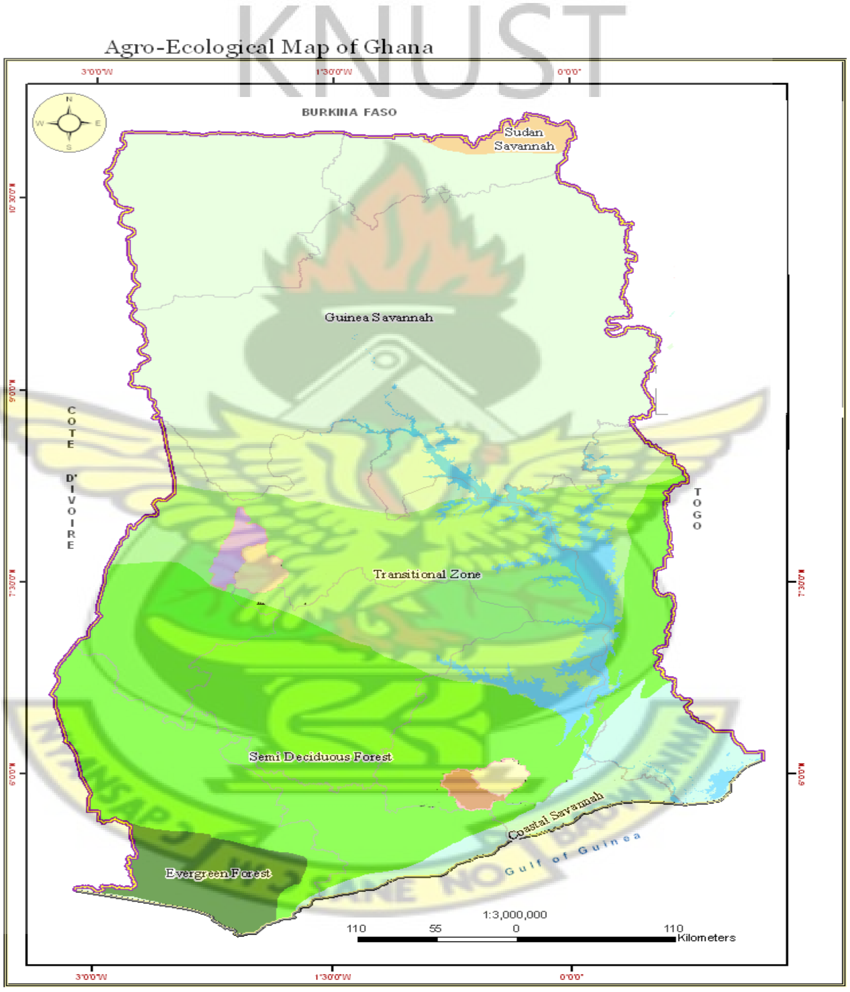
2.1 The Maize Economy of Ghana

Maize has been cultivated in Ghana for several hundreds of years. According to Morris *et al*, (1999) since the introduction of maize in the 16th century, it has established itself as an important food crop in the country. In no time, maize also attracted the attention of commercial farmers, even though it never achieved economic importance as compared to traditional plantation crops, such as oil palm and cocoa. Over time, the eroding profitability of many plantation crops (attributable mainly to increasing disease problems in cocoa, deforestation and natural resource degradation, and falling world commodity prices) served to strengthen interest in commercial food crops, including maize (Morris *et al*, 1999). According to Al-Hassan and Jatoe (2002) maize is currently Ghana's most important cereal crop. It is grown by the vast majority of rural households in almost all parts of the country except for the Sudan Savannah Zone of the North.

2.1.1 Maize Cropping Systems and Production Technologies

The cropping systems and production technologies of maize vary between the different agro-ecological production zones namely the coastal savannah zone, forest zone, transitional zone and the Guinea savannah zone. These zones are illustrated in Figure 2.1.

Figure 2.1: A Map of the Various Agro Ecological Zones of Ghana



Source: Geography Department, University of Ghana

The coastal savannah zone includes a narrow belt of savannah that runs along the coast and widening toward the eastern part of Ghana. Farmers in this zone grow maize and cassava, often intercropped, as their principal staples. The annual rainfall, which is bimodally distributed, totals only 800 mm, so maize could be planted at the onset of the major rains beginning in March or April. The soils in this zone is generally light and low in fertility, hence their output tend to be low (Morris *et al*, 1999).

Immediately inland from the coastal savannah lays the forest zone. Most of Ghana's forest is semi-deciduous, with a small proportion of high rain forest remaining only in the South-western part of the country near the border with Côte d'Ivoire. 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 (Morris *et al*, 1999). Although some maize is consumed in the forest zone, it is not a leading food staple and much of the crop is sold (Morris *et al*, 1999). The major cash crop in the forest zone of Ghana is cocoa. The annual rainfall in the forest zone averages about 1,500 mm and maize is planted both in the major rainy season (March) and in the minor rainy season (September) (Morris *et al*, 1999).

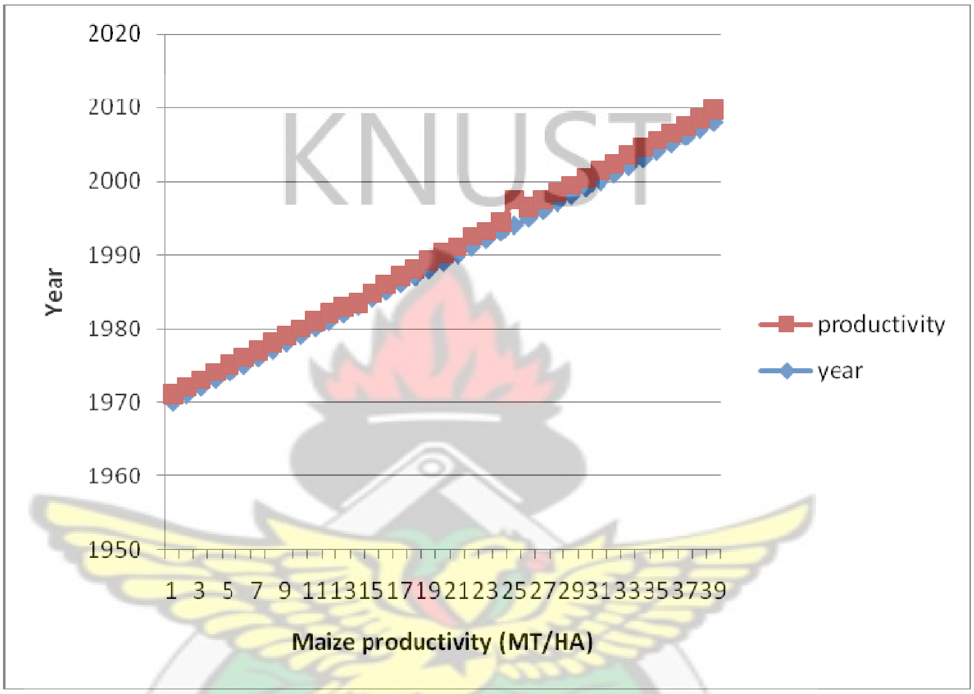
Moving further north of Ghana, the forest zone gradually gives way to the transition zone. The exact boundary between the forest and savannah zone is in dispute, this is not surprising considering that the boundary area is characterized by a constantly changing patchwork of savannah and forest plots. What is certain, however, is that the transition zone is an important region for commercial grain production (Morris *et al*, 1999). Much of the transition zone has deep, friable soils, and the relatively sparse tree cover allows for more continuous cultivation (and greater use of mechanized equipment). Rainfall is bimodal and averages about 1,300 mm per year. Maize is planted in both the major and minor seasons in the transition zone, usually as a mono crop or in association with yam and or cassava (Morris *et al*, 1999). The light raining season is considered the major season in the transitional zone because of the favourable growing conditions.

The Guinea savannah zone occupies most of the northern part of the country. Annual rainfall totals about 1,100 millimetres, falling in a single rainy season beginning in April or May. Sorghum and millet are the dominant cereals in the Guinea savannah, but maize grown is intercropped with small grains, groundnut, and/or cowpea is also important. Some fields are prepared by tractor, but most are prepared manually. 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).

2.1.2 Production Trend of Maize in Ghana

According to MOFA- SRID (2009), maize area cultivated annually in Ghana averages about 846,300 hectares. In Ghana maize is intercropped with other crops, particularly in the coastal savannah and forest zones, so planting densities are generally low. Average grain yields of maize are modest when expressed per unit land area, averaging less than 2 t/ha. Total annual maize production is currently over 1,470,000 metric tonnes (MOFA- SRID 2009). The two key determinants of maize production (area planted and yield) have increased over the years, although the upward trends have been characterized by high year-to year variability typical of rain fed crops (MOFA SRID 2009). Productivity gains indicated in figure 2.2 in maize production in spite of government investment in the agricultural sector suggest little improvement and the goal of self-sufficiency in food production at the national level in Ghana remain a long term target coupled with the ever increasing population.

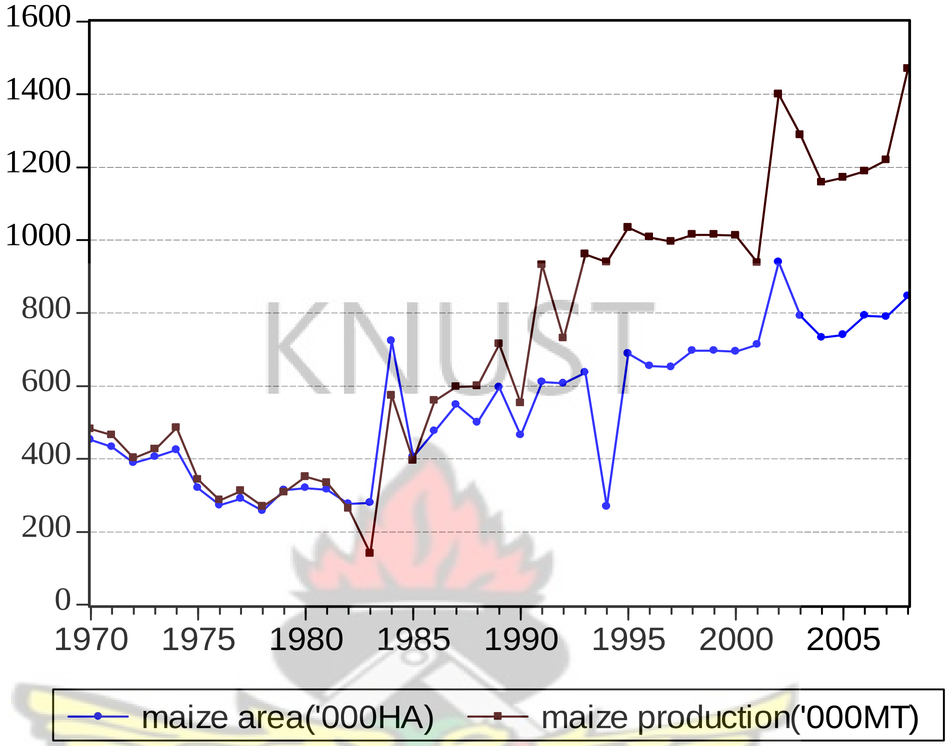
Figure 2.2: Maize productivity in Ghana (1970-2008)



Source: MOFA-SRID (2009)

Figure 2.3 shows no systematic trend in maize production. Maize production declined from 1970-1983. In 1983, the decline was as a result of the adverse weather conditions in the form of drought. Since then, maize production improved marginally until 1985, but then declined thereafter until 1986 when the oscillating pattern was more evident. Even though maize area being cultivated has increased marginally the corresponding effect in production is not being witnessed. This has led to maize import in order to meet the national demand.

Figure 2.3: Maize Area and Production in Ghana (1970-2008)



Source: MOFA-SRID (2009)

2.2 The Concept of Economic Efficiency and the Frontier

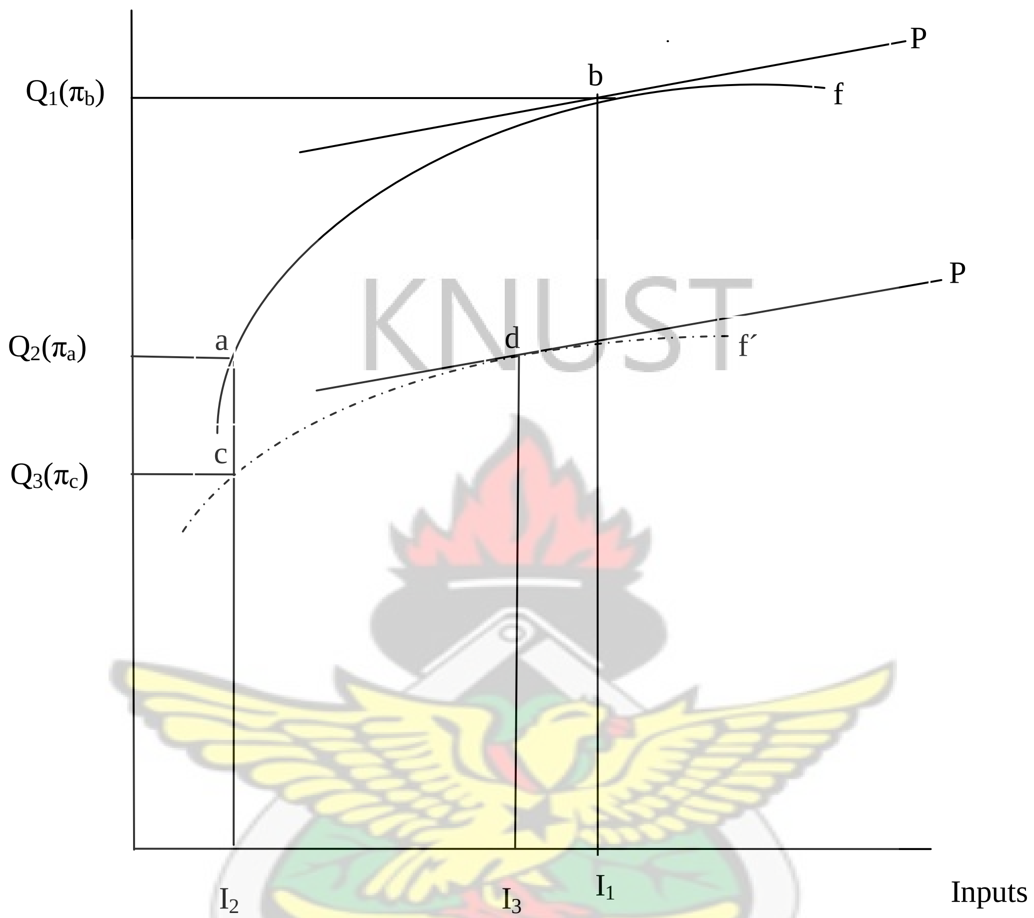
Economic efficiency is described by its component parts: technical efficiency and allocative (price) efficiency. A farmer is more technically efficient than his counterpart if he produces a higher output from a similar bundle of inputs. Allocative efficiency (AE) is reached when the marginal cost of input is equal to the value of the marginal product of output. (Khanna, 2006)

The concept of economic efficiency is intimately linked with Farell's (1957) work, and has been subsequently applied by Aigner and Chu (1968), Afriat (1972), Aigner *et al* (1977), Meeusen and van der Broeck (1977) and Kumbhakar and Lovell (2000). The concept of production frontiers and efficiency can be illustrated with the aid of Figure 2.4, using output (Y axis) and inputs (X axis). Here an output oriented measure of efficiency is described following Kalirajan and Shand, (1999). The production frontier for a firm using best practice techniques is shown by frontier f, which in the context of this study represents the stochastic production frontier.

A firm operating at point b on the frontier receives profit π_b, where the price line p is tangential to its production frontier. At this point the firm is economically efficient and there is neither technical nor allocative inefficiency. If on the other hand, the firm operates at point a on the frontier, it receives lower profits π_a, arising due to allocative inefficiency given by π_b / π_a.

In reality however, firms do not operate at their best practices output curve f but rather at a lower frontier f' due to various constraints such as inappropriate or outdated production methods, organizational constraints and non-price factors such as information glitches. These factors can cause a firm to operate at a point such as c, using an input bundle I_2 and receiving lower profit π_c. At point c, the firm experiences both allocative and technical inefficiency. A movement to point production at d, would leave the firm allocatively efficient but still technically inefficient as output levels could be raised further to levels at frontier f. In terms of output loss, a firm operating at c, experiences a shortfall in output given by Q1-Q3. Of this total shortfall, Q2-Q3 is attributable to technical inefficiency and Q1-Q2 is attributable to allocative inefficiency.

Figure 2.4: Production frontier: Output oriented



Source: Kalirajan and Shand, 1999

2.3 Measurement of Efficiency

There are various approaches to measuring efficiency, which can be categorised into parametric and non-parametric methods. The difference between the two lies in the specification of a functional form, *a priori*. While parametric methods are restricted to a functional form, non-parametric methods rely solely on sample observations that are used to construct a production frontier.

Non-parametric methods, as originally conceived by Farell (1957), used the unit input output space to create a frontier isoquant within the production possibility set (Khanna, 2006). The frontier was determined by a single or a convex combination of efficient units which were then compared against inefficient units to calculate the extent of inefficiency. This method was later applied to the multiple input output case (Murillo-Zamorano, 2004). Parametric techniques are further classified into deterministic and stochastic methods. Deterministic methods date back to Farell's (1957) seminal work, where he introduced the idea of parametric methods using the Cobb-Douglas production function to estimate a convex hull of observed input and output ratios.

Farell's (1957) suggestion was further developed and tested by Aigner and Chu (1968), Afriat (1972), and Richmond (1974). Both Aigner *et al* (1977) and Meeusen and van der Broeck (1977) independently introduced stochastic production frontiers, where each firms' frontier is bounded above but is allowed to vary across firms. Hence, each firm's efficiency is measured relative to its own frontier rather than to some industry wide frontier. In essence, the difference between deterministic and stochastic methods lies in the treatment of the error term.

In deterministic methods, the error is implicitly assumed and makes no distinction between unobserved variables that lie outside the control of the agent and those that lie within it. Stochastic models decompose the error term into purely statistical noise (that lies outside the control of the production agent), and inefficiency (a one-sided error term).

Parametric methods such as the stochastic production frontier method offer an opportunity to researchers to test their hypotheses, but restrict them to certain production relations assumed by the functional forms employed.

Several estimation techniques exist to estimate or calculate the efficiency frontiers. These are mathematical programming techniques or econometric estimation methods. Deterministic parametric methods employ either mathematical programming techniques (Aigner and Chu, 1968) or econometric estimation techniques.

Stochastic parametric methods employ only econometric techniques such as Maximum Likelihood Methods or Corrected Ordinary Least Squares that is used to estimate rather than calculate the efficiency frontier (Kumbhakar and Lovell, 2000). Non-parametric methods such as the Data Envelope Analysis (DEA) rely on mathematical programming applied to sample observations to construct a production frontier and which are used to calculate efficiency scores.

The advantage of the DEA method lies in its flexibility as it requires no specification of a functional form. However, it is entirely data driven and extremely sensitive to outliers. Also, it does not allow the estimation of shadow prices nor does it allow testing of hypotheses (Khanna, 2006).

2.4 Empirical Literature on Efficiency

There are various socio-economic, demographic, institutional, environmental factors and non-physical factors that affect efficiency (Kumbhakar and Bhattachury, 1992). These factors include gender, age, educational level, household size, experience in farming, hybrid seed, access to credit, off-farm work, membership of a farmer based organisation, mono cropping, land tenancy and so on (Tesfay *et al*, 2005; Nchare, 2007; Abdulai and Eberlin, 2001; Rahman and Hassan, 2006). Abdulai and Eberlin (2001) pointed out that, the level of schooling represented human capital, access to formal credit and farming experience contribute positively to production efficiency, whiles farmer's participation in off- farm employment tends to reduce production. Sherlund *et al* (2002) further emphasized that variables such as farm size, cropping experience, gender, age and rainfall also affect the technical efficiency of farmers.

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

A farmer' age which is believed can serve as proxy for farming experience also influence efficiency. This is so since farming experience increases with an increase in age. Coelli (1996b) pointed out that the age of the farmer could have a positive or negative effect upon the size of the inefficiency effects. He concludes that older farmers are to have had more farming experience and hence less inefficiency. It is also possible that older farmers could be more traditional and conservative and therefore show less willingness to adopt new practices. Another school of thought also suggest that ageing farmers would be less energetic to work on farm. Hence, this will lower technical efficiency.

Also ownership of land also influence the technical efficiency of farmers (Helfand and Levine, 2004; Giannakas *et al*, 2001; Reddy, 2002; Coelli *et al*, 2002). Empirical results on ownership of land on inefficiency are mixed. A positive relationship is consistent with the hypothesis that longer years of leasing motivate farmers to work harder to meet their contractual obligations (Helfand and Levine, 2004; Coelli *et al*, 2002). A negative relationship on the other hand is linked to the agency theory, reflecting monitoring problems and adverse incentives between the parties involved in diminishing business performance (Giannakas *et al*, 2001; Reddy, 2002).

The size of farmers' household is another factor that influences the efficiency of farmers. Abdulai and Eberlin (2001) pointed out that although large household size puts extra pressure on farm income for food and clothing, but at times ensure availability of enough family labour for farming activities to be performed on time. Opposite to this is that farmers with surplus labour force are likely to use the rest of the family labour, and hence operate inefficiently or farmers with bigger household size would have to allocate more financial resources to health, education and so on for members of the household and thus affect production (Nchare, 2007).

As far as the impact of off-farm work on technical efficiency is concerned, literature offers mixed results. Some argue that off-farm labour supply curtails farming efficiency (Abdulai and Huffman, 2000). Others contend that the additional income generated by other household members who engage in off-farm work, can more than compensate for the constraints caused by reduced farm labour availability. Tesfay *et al*, (2005) found a positive impact of off-farm work on technical efficiency. It may also be hypothesized that managerial input may be withdrawn from farming activities with increased participation of the educated in off-farm work, which leads to lower efficiency. Abdulai and Eberlin (2001) found higher inefficiency of production with the involvement of farmer households in off-farm activities. In any case, the effect of off-farm work on production efficiency may not be determined beforehand.

Another important factor that affects efficiency is access to extension services. A farmer' regular contact with extension workers facilitates the practical use of modern technologies and adoption of agronomic norms of production. Owen *et al* (2001) in analysing the impact of extension services on agricultural production in Zimbabwe found that farmer's access to extension services increases the value of output by 15%. Alemu *et al* (2002) on the other hand had opposite results. Their results revealed that neither extension visits nor visits and trainings could bring about significant reductions in inefficiency levels. This could be due to the fact that the development agents remain at the edge, never reaching the farmer and that the training packages may not fit the agro ecological settings. Again it is not extension services in terms of visits but appropriateness of extension message or training.

Farming experience is gleaned from the act of agricultural production-that is conscious accumulation of know-how from farming practices. Rahman (2003) found that experience in growing modern rice varieties pay-off well. That is farmers with more than three years of experience in growing modern rice varieties earned significantly higher profit, incurred less profit loss and operate at significantly higher level of profit efficiency.

The gender of the farmer also influences technical efficiency. Kibaara (2005) observed that male farmers decrease technical inefficiency. This could probably be explained by the fact that men have greater access to credit, probably because of cultural prejudice and hence men are closer to the frontier. In addition men are most likely to attend agricultural extension training seminars (Kibaara, 2005). The FAO estimates that, in Sub-Saharan Africa as a whole, 31 percent of rural households are headed by women, mainly because of the tendency of men to migrate to cities in search of wage labour. Despite this substantial role, women have less access to land than men. When women do own land, the land holding tends to be smaller and located at marginal areas. Rural women also have less access to credit than men, which limits their ability to purchase seeds, fertilizer and other inputs needed to adopt new farming techniques (FAO, 2002).

Dolisca and Jolly (2008) studying the situation in Haiti had contrasting result that being a male farmer increases technical inefficiency. This may be explained by the fact that after land preparations women normally carry out the remaining activities involved in production process at the farm and this is more evident in Africa.

Rainfall being an environmental variable also influences technical efficiency. Rainfall enhances efficiency as it improves the soil's capacity and enables it to use the fertilizer and other inputs effectively (Tchale and Suaer, 2007). Tchale and Suaer (2007) points out that higher variation in the water requirement index lowers the production efficiency especially in hybrid maize seed, which is very susceptible both to intensity and intra-seasonal distribution of rain. On the other hand excessive rainfall can cause flooding and lower efficiency.

Access to credit improves liquidity and enhances use of agricultural inputs in production as it is often claimed in development theory. Nchare (2007) pointed out that access to credit has negative influence on technical inefficiency. He explained that, it actually reduces the financial difficulties farmers face at the beginning of the crop year, thus enabling them to buy inputs.

CHAPTER THREE

METHODOLOGY

This chapter presents the study area, conceptual framework, statement of hypotheses and the empirical model. It concludes with, data collection, an overview of the questionnaire design and data analysis.

3.1 The Study Area

In table 3.1, we compare three agro ecological zones in Ghana being the forest, Transitional and Savannah zones representing the study areas. The forest zone is located on the southern part of Ashanti Region with a total land area of 633 square kilometres. The forest has a population of about 134,354 and records a rainfall of between 1600-1800 mm with a temperature ranging between 20^0 C and 32^0 C. The climate of the place is the semi equatorial type while the vegetation is semi-deciduous forest zone with clay, sand and gravel deposits. The area is also underlain by three geological formations.

The Transitional zone which is located around the middle portion of the Brong Ahafo Region, covered 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. The area is characterized by soils developed over the Voltain sandstones. The population is about 127,000 people with rainfall figures ranging between 800-1200 millimetres while the annual temperature is 26^0 C.

The third agro ecological zone being compared is the Savannah. It is located along the North eastern corridor of the Northern Region with a total land area of about

125,430 square kilometres. The tropical continental climate and Guinea Savannah vegetation type are seen in this area. Temperature is normally high above 35^0 C with rainfall figures ranging from between 950-1300 millimetres.

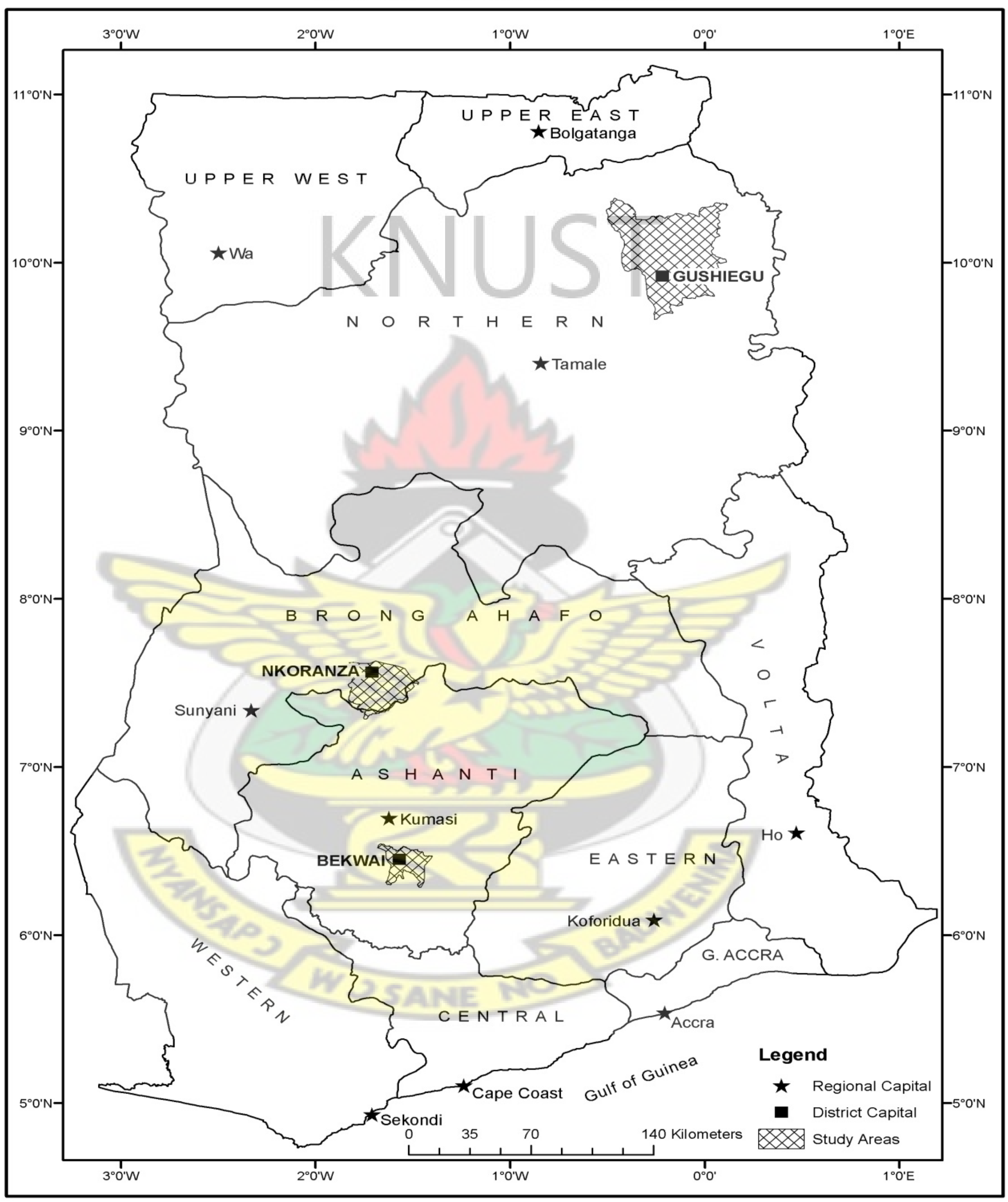
Table 3.1: A General Description of the Characteristics of the Various Study Areas

GENERAL CHARACTERISTICS	FOREST (BEKWAI MUNICIPAL)	TRANSITIONAL (NKORANZA SOUTH DISTRICT)	SAVANNAH (GUSHEGU DISTRICT)
LOCATION	Southern part of Ashanti Region	Middle portion of the Brong Ahafo region.	Northeastern corridor of Northern Region.
TOTAL LAND AREA	633sqkm	2300sqkm	5796sqkm
TOPOLOGY	Within the forest dissected plateau.	Low lying and rising gradually.	Fairly undulating.
CLIMATE	Semi-equatorial type.	Wet semi-equatorial region	Tropical continental climate.
VEGETATION	Semi-deciduous forest zone	Savannah woodland and a forest belt.	Guinea savannah type.
RIVERS /DRAINAGE	Drained by the Oda River and its tributaries.	Fairly drained by several streams and rivers.	Strewn with several streams.
GEOLOGY	Underlain by three geological formations.	Characterized by soils developed over Voltain sandstones.	Lies entirely within the Voltaian sandstone basin
SOILS	Clay, sand and gravel deposits	The geological feature together with vegetation influences and gives rise to two distinct soil categories.	Coarse lateritic upland soils and soft clay.
RAINFALL	1600– 1800mm.	800-1200mm.	950-1300mm
TEMPERATURE	Fairly high and uniform temperature	Average annual temperature is about 26°C.	Normally high above 35^0C

	ranging between 32ºC in March and 20º C in August.		
POPULATION (2000)	134,354	127,000	125,430
CROPS	Major food crops produced include cassava, maize, rice, yam, cocoyam and plantain, while the cash crops include cocoa, citrus, coffee and oil palm.	Main food crops cultivated are maize, yams, vegetables, cassava, groundnut, cowpea, cocoyam and plantain.	Major traditional crops cultivated include maize, sorghum, millet, groundnuts, cowpeas, cassava, rice and yam.
ECONOMIC ACTIVITIES	It includes textile based industry, agro- based industry, craft, metal based industry and service. Professionals such as teachers, nurses etc are also present.	Activities of economic importance are agro-based industry, and include farming, and trading in foodstuff and few small-scale industries. Professionals such as teachers, nurses etc are also here.	Economic activities in the district are agro-based and include farming, agro-processing and trading in foodstuff. There are few small-scale industries such as welding and mechanic shops. Professionals such as teachers, nurses etc are also present.

Source: MLGRD (2006)

Figure 3.1: A map of the study areas in national context



Source: Geography Department, University of Ghana

3.2 Conceptual Framework

This study employs the stochastic frontier model proposed by Aigner *et al* (1977), and extended by Battese and Coelli, (1995).

$$Y_i = f(x_i, \beta)\exp(V_i - U_i) \qquad i = 1, 2....., n \tag{3.1}$$

Here V_i is the random error, associated with random factors not under the control of the farmer and U_i is the inefficiency effect. The possible production Y_i is bounded by the stochastic quantity, $f(x_i, \beta)\exp(V_i - U_i)$, hence the name stochastic frontier. The random error V_i is assumed to be independently and identically distributed as $N(0, \sigma_V^2)$ random variables independent of $U_i s$, which are assumed to be non-negative truncations of the $N(0, \sigma_V^2)$ distribution (i.e. half-normal distribution) or have exponential distribution.

The technical inefficiency effects are expressed as:

$$U_i = \delta z_i + w_i \tag{3.2}$$

Here z_i is a vector of observable explanatory variables and δ is a vector of unknown parameters and w_i are unobserved random variables which are assumed to be independently distributed and obtained by truncation of normal distribution with zero mean and constant variance.

A number of studies (Helfand and Livine, 2004; Nyemeck *et al*., 2001) have estimated the production frontier (equation 3.2) and the determinants of inefficiency (equation 3.3) separately. According to their two-stage procedure, the production frontier is first estimated and then the technical inefficiencies are derived. The predicted inefficiencies are subsequently regressed upon a set of firm (or farm) specific variables (z_i) in an attempt to determine reasons for differing efficiencies. In the second stage the predicted inefficiency scores are assumed to be a function of several firm (or farm) specific factors, which implies that they are not identically distributed unless all the coefficients of the factors are simultaneously equal to zero (Coelli *et al*., 1998).

In addition, using Ordinary Least Square (OLS) in the second stage regression fails to capture the fact that the dependent variable (U_i) is restricted to be non-negative. The two-stage procedure is unlikely to provide estimates which are as efficient as those that are obtained from the one-step estimation procedure (Coelli, 1996b). For these reasons, the Battese and Coelli (1995) model is, therefore, applied in this study and allows for a simultaneous estimation of the parameters of the stochastic frontier and the inefficiency model using the single-stage, maximum likelihood (MLE) method. The likelihood function is expressed in terms of the variance parameter σ^2 and γ , where $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$

Technical efficiency (TE) = Y_i / Y_i^*

$$= f(x, \beta) \exp(V_i - U_i) / f(x, \beta) \exp(V_i)$$

$$= \exp(-U_i)$$

$$= \exp(-z_i\delta - W_i) \tag{3.3}$$

Where Y_i is the observed output and Y_i^* is the frontier output.

3.3 Empirical model

Farm technical efficiency is the ability of a farmer to maximize output with given quantities of inputs and a certain technology (output-oriented) or the ability to minimize input use with a given objective of output (input-oriented). However, the output-oriented technical efficiency is commonly used.

3.3.1 Specification of Empirical Model

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 (CD) 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 transcendental logarithmic (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 imposes a severe prior restriction on the farm's technology by restricting the production elasticities to be constant and the elasticities of input substitution to unity (Wilson, *et al*., 1998).

The flexible functional form 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 CD form of the production function. Therefore, translog functional form is preferred over CD functional. It is noted that the CD is nested within the translog form if all the square and interaction terms in translog turn out to be equal to zero. Therefore, the translog functional form is adopted in this study. The empirical model is specified as:

$$
\begin{aligned}
\ln Y_i = {} & \beta_0 + \beta_1 \ln LAB + \beta_2 \ln FSIZ + \beta_3 \ln SED + \beta_4 \ln FERT + \beta_5 \ln(LAB)^2 + \beta_6 \ln(FSIZ)^2 \\
& + \beta_7 \ln(SED)^2 + \beta_8 \ln(FERT)^2 + \beta_9 \ln(LAB) \times \ln(FSIZ) + \beta_{10} \ln(LAB) \times \ln(SED) \\
& + \beta_{11} \ln(LAB) \times \ln(FERT) + \beta_{12} \ln(FSIZ) \times \ln(SED) + \beta_{13} \ln(FSIZ) \times \ln(FERT) \\
& + \beta_{14} \ln(SED) \times \ln(FERT) + (V_i - U_i)
\end{aligned}
\tag{3.4}
$$

Here Y_i denotes maize yield (kg / ha), $FERT$ denotes quantity of fertilizer used (kg / ha), LAB denotes labour (man-days/ha), SED denotes quantity of seed planted (kg / ha), $FSIZ$ denotes maize area cultivated (ha), β_ks are unknown parameters of the production functions, $v_i s$ are random errors assumed to be independent and identically distributed $N(0, \sigma_v^2)$, $u_i s$ are non-negative random variables, assumed to be independently distributed, such that the technical inefficiency effect for the producer, u_i

, is obtained by truncation (at zero) of the normal distribution with zero mean u_i and constant variance, σ^2. Specifically the inefficiency model is specified as:

$$\begin{aligned}
U_i = \delta_0 &+ \underset{(-)}{\delta_1 GEND} + \underset{(+/-)}{\delta_2 AGE} + \underset{(+/-)}{\delta_3 HHS} + \underset{(-)}{\delta_4 EDU} + \underset{(+/-)}{\delta_5 LTEN} + \underset{(-)}{\delta_6 MCRP} + \underset{(-)}{\delta_7 HMAV} \\
&+ \underset{(-)}{\delta_8 EXT} + \underset{(-)}{\delta_9 ATC} + \underset{(+)}{\delta_{10} OFW} + \underset{(-)}{\delta_{11} RAIN} + \underset{(+/-)}{\delta_{12} FOREST} + \underset{(+/-)}{\delta_{13} TRANSITIONAL} \\
&+ \underset{(+/-)}{\delta_{14} SAVANNAH}
\end{aligned}$$

Here $GEND$ denotes dummy variable 1 if farmer is male, 0 otherwise, AGE denotes age of maize producer in years , HHS denotes number of people living in farmers' household, ATC denotes dummy variable 1 if farmer has access to credit, 0 otherwise, EXT denotes dummy variable 1 if farmer had access to extension services, 0 otherwise, OFW denotes dummy variable 1 if farmer engages in off-farm work, 0 otherwise, $MCRP$ denotes dummy variable 1 if farmer practice mono cropping, 0 otherwise, EDU denotes number of years of schooling, $HMAV$ denotes dummy variable 1 if farmer cultivates hybrid maize variety, 0 otherwise , $LTEN$ denotes dummy variable 1 if landowner, 0 otherwise, $RAIN$ denotes annual mean rainfall (mm) , $FOREST$ denotes dummy variable 1 if farmer is located in the forest zone, 0 otherwise, $TRANSITIONAL$ denotes dummy variable 1 if farmer is located in the transitional zone, 0 otherwise, $SAVANNAH$ denotes dummy variable 1 if farmer is located in the savannah zone, 0 otherwise, $\delta's$ are unknown parameters to be estimated.

Since the dependent variable of the inefficiency model represents the mode of inefficiency, a positive sign of an estimated parameter implies that the associated variable has a negative effect on efficiency but positive effect on inefficiency and vice versa. It is assumed that some farmers produce on the production frontier and others do not produce on the frontier. Therefore, the need arises to find out factors causing technical inefficiency. The technical inefficiency model incorporates farm and farmer specific characteristics, institutional and environmental factors.

3.3.2 Measurement of Variables

Yield of maize is measured as the quantity of maize produced in kg per ha during the 2009 cropping season.

Fertilizer refers to the quantity of chemical fertilizer applied on maize plot in kg per ha during the 2009 cropping year. Fertilizer is expected to have a positive effect on yield.

Seed is a measure of the quantity of maize seeds in kilograms (kg) cultivated. The quantity of seeds per ha determines the plant population which has an influence on yield. This variable was averaged over the cropped area.

Farm size is the area of land in hectares of maize cultivated. The variable was used to investigate the influence of farm size on output. Farm size was measured in acre and summed over plots.

Labour is measured as the man-days spent on the farm from land preparation to harvesting on a hectare of plot. This is made up of both family and hired labour.

Education variable was measured as the number of years of schooling of a farmer. It represents the managerial ability of the farmer. Education as a human capital variable is a relevant factor in technology adoption. Educated farmers easily adopt improved farming technology and therefore should have higher technical efficiency than farmers with low level of education (Seyoum *et al*, 1998). The expected sign for education is positive.

Access to Credit is a binary variable used to capture the effect of credit on the efficiency of farmers. This variable is measured as a dummy, 1 if farmer had access to credit, 0 otherwise during the 2009 cropping season. A farmer having access to credit include both partial and adequate credit level needed received. The availability of credit will enable farmers to purchase inputs in a timely manner and hence is supposed to increase efficiency. The coefficient estimate is expected to be positive as indicated by Owuor and Shem (2009) and Chukwuji *et al* (2007).

Household Size measures the number of people (adult men and women and children) who were living with the farmer during the 2009 cropping year. The expected sign for household size is mixed. A positive sign indicates that the larger the household size, the greater is the technical inefficiency. A reason for a positive sign is allocation of financial resources to family members for their education and health (Coelli *et al*, 2002). On the other hand, larger household size might benefit from being able to use labour resources at the right time (Dhungana *et al*, 2004).

Age in years is used as a proxy for farming experience in the inefficiency model (Owuor and Shem, 2009). Since, farming experience increases with increase in age, it is expected that the age of the farmer would have a positive effect on technical inefficiency. This is the case even though older farmers could be more traditional and conservative and hence show less willingness to adopt new practices (Coelli, 1996b).

Hybrid Maize Variety is a variable capturing special crop species (genetically modified) with shorter gestation period, drought/pest resistance and high-yielding. It is a dummy variable indicating 1 if the farmer cultivates hybrid seed and 0 otherwise. Sherlund *et al* (2002) argue that hybrid rice varieties tend to increase technical efficiency of farmers and therefore would be positively related to technical efficiency.

Land Tenancy is a variable included in the inefficiency model to examine the effect of land tenure on technical inefficiency. This variable is measured as a dummy, 1 if farmer is land owner, 0 otherwise. Being a tenant includes all forms of tenancy agreement excluding being a land owner. The empirical result of land tenure on efficiency is mixed. A positive relationship with efficiency is consistent with the hypothesis that with a higher lease payment requirement, farmers are expected to work harder to meet their contractual obligations (Coelli *et al*, 2002). A negative relationship on the other hand is linked with agency theory, reflecting monitoring problems and adverse incentives between the parties involved in diminishing business performance and preventing long term investments (Giannakas *et al*, 2001; Reddy, 2002).

Mono cropping is a binary variable used to capture the effect of practicing mono cropping on the efficiency of farmers. It is a dummy indicating 1 if the farmer practiced mono cropping and 0 otherwise. A positive relationship with efficiency is expected as mono cropping not only enables farmers to work tirelessly, but also saves the maize crop from competition that might occur among various crops in the case of mixed cropping for the use of input available at the farm level (Nchare, 2007). Even in the presence of complementary crops output will not be the optimum.

Gender variable measures the effect of gender on technical efficiency. It is a dummy indicating 1 if the farmer is male and 0 otherwise. The anticipated sign of the coefficient of gender is however indeterminate because of the argument that men and women farmers are both efficient in resource use (Adesina and Djato, 1997).

Extension variable indicates whether the farmer had access to extension services during the 2009 cropping year. This variable is measured as a dummy, 1 if farmer had access to extension service and 0 otherwise. Extension agents are responsible for teaching farmers new and improved methods of farming. If farmers receive visits by extension agents they learn more about the farm operations and the farm business. The expected sign for extension is positive.

Off-farm work variable measures whether farmer engaged in any other business aside the farming during the 2009 cropping year. It is a dummy indicating 1 if the farmer engages in off-farm work and 0 otherwise. The impact of off-farm work on technical efficiency is mixed. Some argue that off-farm labour reduces farming efficiency (Abdulai and Huffman, 2000). Others also contend that the additional income generated by other household members who engage in off-farm work, can more than compensate for constraints caused by reduced availability of labour (Abudulai and Eberlin, 2001).

Rainfall as a biophysical factor is included since agriculture in Ghana is mostly rain fed. Annual mean rainfall in each agro ecological zone is measured in millimetres. Rainfall enhances efficiency as it improves the soil's capacity and enables it to use fertilizer and other inputs effectively (Tchale and Suaer 2007). Tchale and Suaer (2007) again point out that higher variation in the water requirement index lowers production efficiency especially for hybrid maize, which is very susceptible to both the intensity and intra-seasonal distribution of rain. A positive relationship with efficiency is expected.

Agro-Ecological Zone Specific Effects: Three dummy variables representing Savannah, Transitional and Forest zone were included to control for unobserved heterogeneity due to agro-ecological zone-specific characteristics (Tong and Chan, 2003). The forest zone variable is given a dummy of 1, 0 otherwise; transitional zone 1, 0 otherwise and savannah zone 1, 0 otherwise. Their expected signs are mixed.

3.4 Statement of Hypotheses

The following null hypotheses would be validated:

1) Farmers are technically efficient in maize production in the three agro ecological zones of Ghana.

2) Technical efficiency of maize producers are positively affected by socio economic such as gender, age, household size and education and environmental factor such as rainfall in the three agro ecological zones of Ghana.

3) Technical efficiency of maize producers are positively affected by institutional factors such as mono cropping, hybrid seed, extension and access to credit and

negatively by non-physical factors such as off-farm work, land tenancy and zonal disparity in the three agro ecological zones of Ghana.

3.5 Data Collection

This section presents a discussion on how the data employed in the study was collected. It is presented in two main parts. The first part discusses the survey design and the sampling procedure whiles the second part discusses the questionnaire design for the study.

3.5.1 Survey Design and Sampling Method

The research employed both primary and secondary sources of data. The primary data employed was obtained through a cross-sectional survey conducted in three different agro-ecological zones in Ghana. Farm level data were collected from 453 maize producers across the three agro-ecological zones of Ghana in the 2009 calendar year. The choice of the whole calendar year is on the premise that maize can be produced throughout the year. This is base on the premise that depending on the rainfall duration, length of fall and distribution maize can be produced throughout the year.

In the second stage of the sampling design, a district each was selected from each of the three agro ecological zones purposively. The districts are Gushiegu District (Savannah zone), Nkoranza South District (Transitional zone) and Bekwai Municipality (Forest zone). These districts were selected based on their agricultural potential, accessibility and high level of maize production in their agro-ecological zone. Maize yields are estimated at 1.2 mt/ha, 2.4 mt/ha and 1.45 mt/ha for Bekwai Municipality, Nkronza South District and Gushiegu District respectively (MOFA- SRID 2009). In the third stage, villages or communities from operational areas of MOFA were randomly selected from each of the districts representing the agro-ecological zones. Table 3.2 shows the communities that were sampled for the study.

The final stage involved random selection of maize farmers proportionately according to the size or the number of maize producers in the various communities. A total of 151 maize farmers were sampled in the Savannah zone (Gushiegu District), 151 maize farmers were sampled in the Transitional zone (Nkoranza South District) and 151 maize farmers were sampled in the Forest zone (Bekwai Municipality).

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

Table 3.2: Communities sampled for the study.

District	Communities	Number of maize farmers sampled
Bekwai municipal	Bekwai	31
	Amoafo	15
	Abodom	15
	Nampasa	15
	Dwumako	15
	Sanfo	15
	Dadease	15
	Esumja	15
	Denyase	15
Nkoranza South District	Nkoranza	46
	Breman	15
	Nkwabeng	15
	Domase	15
	Brahoho	15
	Donkro Nkwanta	15
	Barnofou	15
	Akuma	15

Gushiegu District	Gushiegu	31
	Nausugali	15
	Machele	15
	Zanteli	15
	Lunlua	15
	Kpatili	15
	Nawuni	15
	Bonboayili	15
	Kpatinga	15

3.5.2 Questionnaire Design

The structured questionnaire was used to solicit information directly from the farmers. 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 or the option to specify otherwise.

The questionnaire comprised of eight sections. The first section included questions on maize producer's personal and household characteristics. The second section consisted of questions on farm characteristics, whereas the third section included questions on farm input use. Questions on investments in land improvement constituted the fourth section. The fifth part composed of questions on technical services and credit. The final part of the questionnaire solicited information on maize producers' production constraints and how they are coping with them. The likert scale was used to rank the constraints. The responses were coded into five classes from very high to none (1=very high, 2=high, 3=low, 4=very low and 5=none).

3.6 Data Analyses

Both descriptive and inferential analyses were used to achieve the objectives of study. Descriptive analysis such as means and standard deviation were first used to describe the data. The stochastic frontier production function and the inefficiency model are simultaneously estimated with the maximum likelihood method using the FRONTIER 4.1 Econometric software (Coelli 1996a).

Constraints to maize production during the 2009 crop year were ranked. The responses were coded into five classes from very high to none (1=very high, 2=high, 3=low, 4=very low and 5=none). The responses from the constraints were averaged to obtain the mean rank for each constraint. The constraint with the least mean is ranked the most pressing problem with highest mean being the least pressing. The agreement in the ranking of the constraints was also tested.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

This chapter presents the results and discussion of the study. It begins with the description of the variables used in the study. The empirical results which entail the maximum likelihood estimates, partial elasticities and returns to scale and the distribution of technical efficiency in three agro ecological zones are also discussed. It concludes with the discussion of technical efficiency and environmental variables of maize production, equality of means and the analysis of maize producer’s constraints in each agro ecological zone.

4.1 Descriptive Results

The average yield is 1725.79. This is obtained by using 455.43 man-days per ha of labour, 3.12 kg per ha of seed, 1.71 ha farm size and 17.48 kg per ha of chemical fertilizer.79 percent of the maize producers were males with the average age of the farmers being 43.

The average number of people in a maize producing farmer household is 9 and 5 years being average number of years of schooling. 48%, 43% and 45% out of a total of 453 maize farmers are land owners, practiced mono cropping and cultivated hybrid maize seeds respectively. The percentage that received extension service and credit are 46 and 29 respectively. In addition, 18 percent of the respondents engage in off-farm work. The annual mean rainfall is 1471.37 mm.

Finally, 33 percent of the respondents are in forest zone, 33 per cent in transitional zone and 33 per cent in the savannah zone. Descriptive statistics for the variables used in the study for the different agro ecological zones are shown in appendix E

Table 4.1: Descriptive statistics for the variables used in the Study

Variable	Variable Definition	Mean	Std deviation	Min	Max
Yield	Yield in kg per ha	1725.79	1216.99	33.33	18000
Labour	Labour in man-days per ha	455.43	436.67	3.75	4249
Seed	Seed in kg per ha	3.12	0.79	0.4	4.8
Farm size	Farm size in ha	1.71	1.39	0.2	10
Fertilizer	Fertilizer in kg per ha	17.48	15.25	0	60
Gender	1 if farmer is a male, 0 otherwise	0.79	0.41	0	1
Age	Age of farmer in years	43.18	10.84	20	75
Household size	Household size in number	9.25	6.21	1	40
Education	Number of years of schooling	4.86	3.72	0	9
Land tenancy	1 if farmer is the landowner, 0 otherwise	0.48	0.50	0	1
Mono cropping	1 if farmer practiced mono cropping, 0 otherwise	0.43	0.50	0	1
Hybrid seed	1 if farmer cultivated hybrid seed, 0 otherwise	0.45	0.50	0	1
Extension	1 if farmer had access to extension service , 0 otherwise	0.46	0.50	0	1
Access to credit	1 if farmer had access to credit, 0 otherwise	0.29	0.45	0	1

Off-farm work	1 if farmer engaged in off-farm work, 0 otherwise	0.18	0.39	0	1
Rainfall	Annual mean rainfall in millimetres	1475.37	423.73	1152.2	2073.3
Forest zone	1 if forest zone, 0 otherwise	0.33	0.47	0	1
Transitional zone	1 if transitional zone, 0 otherwise	0.33	0.47	0	1
Savannah zone	1 if savannah zone, 0 otherwise	0.33	0.47	0	1

Source: Survey, 2010

4.2 Empirical Results

4.2.1Maximum-Likelihood Estimates

The maximum likelihood estimates of the parameters of the stochastic frontier production function and the inefficiency model with and without environmental variables are presented in Table 4.2. The estimated sigma square (σ_s^2) parameter (0.614) in the stochastic frontier production is significantly different from zero, indicating a good fit of the model and the correctness of the specified distributional assumptions. The estimated gamma (γ) parameter (0.930) is significant at 1% which means that the technical inefficiency effects are significant in determining the level and variability of maize yield.

With regard to the sources of efficiency differentials among the sampled maize producers across the three agro-ecological zones, the estimates of technical inefficiency model provide some important insights. The parameter estimates in Table 4.2 have the relevant signs, indicating the impact of explanatory variables on technical (in) efficiency. Explanatory variables with a large impact should be the main focus in an effort to improve efficiency in maize production in the three agro-ecological zone of Ghana, since these can be influenced relatively easily.

The result of the coefficient of gender variable indicates that, being a male maize producer reduces technical inefficiency than being a female. This result is in agreement with the findings of Kibaara (2005) that being a male farmer decreases technical inefficiency. . This could be explained by the fact that men have greater access to credit, probably because of cultural prejudice, and hence men are closer to the production frontier. In addition, men are most likely to attend agricultural extension training seminars (Kibaara, 2005). The FAO estimates that, in Sub-Saharan Africa as a whole, 31 percent of rural households are headed by women, mainly because of the tendency of men to migrate to cities in search of wage labour. Despite this substantial role, women have less access to land than men. When women do own land, the land holding tends to be smaller and located in more marginal areas. Rural women also have less access to credit than men, which limits their ability to purchase seeds, chemical fertilizers and other inputs needed to adopt new farming techniques. Only 5 percent of the resources provided through extension services in Africa are available to women, although in some cases, particularly in food production, African women handled 80 percent of the work (FAO, 2002). However, Onyenweaku and Effiong (2005) and Dolisca and Jolly (2008) had a contrasting result that being a male farmer increases technical inefficiency. This study therefore contributes to the debate on the role of gender in farmers' level of efficiency.

Age is included to estimate the impact of age on the level of technical inefficiency. It is commonly believed that age can serve as a proxy for farming experience. This is because as a farmer ages in the farming business the greater experience one has. From the estimates age has a negative effect on technical inefficiency, indicating that as the age of the maize producer's increases, technical inefficiency declines.

The coefficient of household size has a positive sign for the maize producers. The positive sign indicates that the larger the household size, the greater the technical inefficiency. One of the major reasons for the positive sign is the allocation of financial resources to household members. Large household size of the farmer puts extra pressure on farm income, even though it may does ensure availability of enough family labour for farm operations to be performed on time. This has been the case as maize production has become less labour intensive as people resort to the use of other alternatives like using herbicides in controlling weeds. This result is in full agreement with 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. This however contradicts the work of Chukwuji *et al.* (2007) that concluded that large families enables farm activities to be completed on time in Nigeria.

The coefficient for years of schooling is negative as expected but not significant. This result is consistent with the work of Kibaara in Kenya (2005).

Land tenancy has significant impact in explaining technical inefficiency differentials among maize farmers. The estimated coefficient for owner dummy variable has a positive sign and statistically significant at 10%. The significant effect of land owner on efficiency is the flexibility in the use of inputs such as land and the fact that it promotes easy access to the credit market. Ownership of land enables households to access credit market for investment in production. This result is in agreement with Helfand and Levine (2004) who concluded that renters are somewhat more efficient than owners in the Brazilian Centre-West. The reason is that renters were a more homogenous group of market-oriented farmers relative to owners who are the majority. On the contrary Giannakas *et al*. (2001) and Reddy (2002) showed that tenants operated farms are less efficient because of lack of security preventing long term investments on farms.

There is also a negative correlation between technical inefficiency and the practice of mono cropping. This is also significant at 1% level of significance. This result may be explained by the fact that practising mono cropping not only enable farmers to work tirelessly, but also saves the maize plant from competition that might occur among various crops in case of mixed cropping for use of inputs available at the farm level. This result is in agreement with the findings of Nchare (2007).

A negative sign on the dummy variable for hybrid seed indicates that use of hybrid seed for maize production decreases technical inefficiency, yet 45 percent of the total maize producers used hybrid seeds. This is probably because of the high cost of hybrid seeds, making them unaffordable to most subsistence maize producers. Again local seeds are usually preferred by most smallholder farmers because of the quality of maize flour produced through the traditional system, lower demands for fertilizer and ease in storage- it is not susceptible to pests and can easily be recycled as seed (Chirwa, 2003).

The coefficient of extension service is negative but not significant. It indicates the involvement of extension agent tends to reduce the technical inefficiency for maize production. This result is consistent with Owens *et al*., (2001) who showed that access to agricultural extension services, defined as receiving one or two visits per agricultural year raises the value of crop production by about 15%.

The negative relationship between access to credit and inefficiency suggest the farmers who face credit constraint for the purchase of inputs experience higher inefficiency. Credit access indicates liquidity, which is a prerequisite for flexibility in the purchase of improved inputs. Thus the finding points at the case in the allocation of purchased factors such as fertilizer, improved planting materials and hired labour in circumstances where credit is available. This result leads credence with the findings of Owuor and Shem (2009) and Chukwuji *et al*. (2007).

The result of the coefficient estimation shows that off-farm work positively and significantly affects inefficiency. This result is consistent with the findings of Abdulai and Huffman (2000) who argued that non- farm labour supply curtails farming efficiency.

The coefficient for rainfall has the expected sign and is statistically significant. Rainfall enhances efficiency as it improves the soils capacity and enables it to use fertilizer and other inputs effectively. This result leads credence with the findings of Tchale and Suaer (2007).

Finally, the coefficient of the dummy variable for the forest zone is negative and is statistically significant. This suggests that producers in this zone are efficient and closer to their production frontier. On the other hand, the dummy variable for the transitional zone is negative but not statistically significant, indicating that maize producers in this zone are less inefficient. The savannah zone had a negative sign and is also not statistically significant indicating that maize producers there are not all that inefficient.

Table 4.2: Maximum likelihood estimates of stochastic frontier production function and inefficiency model

Variable	Parameter	With environmental Variables		Without environmental Variables	
		Coefficient	t-ratio	Coefficient	t-ratio
<u>Stochastic frontier</u>					
Constant	β_0	7.548	9.746***	7.168	8.728***
lnlabour	β_1	-0.196	-0.924	-0.098	-0.445
lnfarmsize	β_2	-0.114	-0.501	-0.070	-0.312
lnseed	β_3	0.395	0.695	0.469	0.792
lnfertilizer	β_4	0.209	-1.479*	0.204	-1.449*
lnlabour^2	β_5	0.039	1.927**	0.032	1.657**
lnfarmsize^2	β_6	0.042	1.218	0.044	1.306*
lnseed^2	β_7	0.111	0.699	0.132	0.901
lnfertilizer^2	β_8	-0.001	-0.022	-0.008	-0.336

lnlabour × lnfarmsize	β_9	-0.044	-1.246	-0.051	-1.518**
lnlabour × lnseed	β_{10}	-0.078	-0.590	-0.083	-0.631
lnlabour × lnfertilizer	β_{11}	0.056	3.307***	0.509	3.426***
lnfarmsize × lnseed	β_{12}	0.122	0.997	0.096	0.778
lnfarmsize × lnfertilizer	β_{13}	0.026	1.024	0.031	1.222
lnseed × lnfertilizer	β_{14}	-0.103	-1.309*	-0.115	-1.882*
Inefficiency model					
Constant	δ_0	-31.089	-1.309*	0.731	1.704**
Gender	δ_1	-0.253	-1.286*	-0.474	-0.232
Age	δ_2	-0.017	-2.123**	-0.026	-2.682***
Household size	δ_3	0.035	2.642***	0.049	3.385***
Education	δ_4	0.008	0.404	-0.021	-0.913
Land tenure	δ_5	0.165	1.284*	0.260	1.572*
Monocropping	δ_6	-0.362	-2.720***	-0.368	-2.247**
Hybrid seed	δ_7	-0.026	-0.147	-0.411	-1.889**
Extension	δ_8	-0.244	-1.387*	-0.480	-2.136**
Access to credit	δ_9	-0.152	-1.330*	-0.442	-1.968**
Off-farm work	δ_{10}	0.491	2.497***	0.522	2.457***
Rainfall	δ_{11}	0.028	1.312*		
Forest zone	δ_{12}	-28.361	-1.364*		
Transitional zone	δ_{13}	-2.180	-1.062		
Savannah zone	δ_{14}	-0.547	-0.490		

Variance parameters					
$\sigma_s^2 = \sigma^2 + \sigma_v^2$	σ_s^2	-0.614	4.266***	0.691	3.961***
$\gamma = \sigma^2 / \sigma_s^2$	γ	0.930	46.984***	0.937	48.691***
Log likelihood function		-250.566		-261.676	
LR test of one sided error		177.664		155.445	
Mean efficiency		0.641		0.642	

Source: Survey data, 2010. ***, ** and * indicate that coefficients are statistically significant at 1%, 5% and 10% respectively.

4.2.2 Partial Elasticities and Returns to Scale

Considering that some individual coefficients of the variables of the translog stochastic frontier production function are not directly interpretable because of the presence of second order coefficients, partial elasticities of yield with respect to inputs are estimated because they permit the evaluation of the effect of changes in the amount of an input on yield.

Table 4.3 shows the results obtained. The partial elasticity values obtained indicate the relative importance of every factor used in maize production. The scale coefficient is 1.311. This value is greater than one, indicating increasing returns to scale in maize production. The implication of such a result is that a proportional increase of all the factors of production leads to a more than proportional increase in production. The results further reveals that maize farmers can benefit from economies of scale linked to increasing returns in order to boost production. These results lead credence to the work by Ajibefun and Daramola (2003) in Nigeria.

Table 4.3: Partial elasticity and returns to scale of maize inputs

Variable	Partial elasticity	
	With environmental variables	Without environmental variables
Labour	0.223	0.196
Farmsize	0.410	0.267
Seed	0.447	0.857
Fertilizer	0.231	0.113
Returns to scale	1.311	1.433

4.2.3 Distribution of Technical Efficiency in the Three Agro-Ecological Zones

The technical efficiency scores of the individual farmers are shown in appendix B, C and D. The distribution of technical efficiency scores is given in Table 4.5 and Figure 4.1. The estimated technical efficiency for maize producers in the forest zone ranges from 0.173 to 0.941 with a mean of 0.797.

Even though the value of the mean indicates that producers are technically efficient, it also suggests that there exist some potential to increase maize yield with the current technology. The estimated technical efficiency score for maize producers in the transitional zone varies from 0.100 to 0.960 with an average score of 0.605.

The estimated technical efficiency score for maize producers in the savannah zone ranges from 0.122 to 0.918 with an average score of 0.523. This wide disparity noted in this zone can be attributed to a number of factors that makes them constrained in maize production. Notable among them are irregular rainfall, high temperatures and poor soil characteristics among the lot.

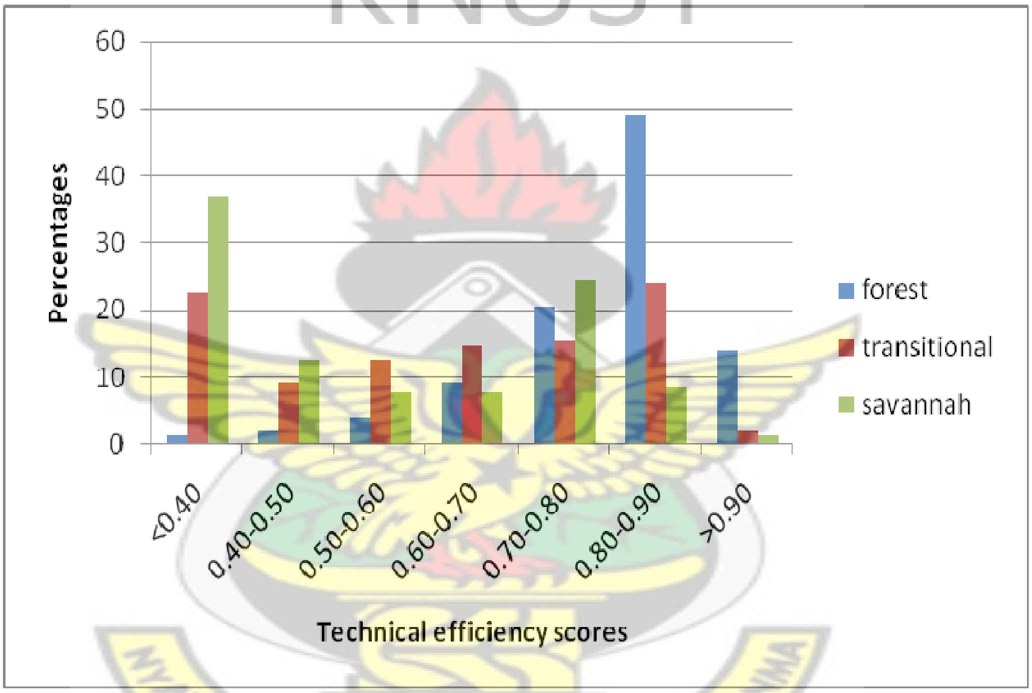
Table 4.4: Distribution of technical efficiency of maize farmers in the three agro-ecological zones

Technical efficiency scores	Forest zone	Transitional zone	Savannah zone
<0.40	2 (1.32)	34 (22.52)	56 (37.09)
0.40-0.50	3 (1.99)	14 (9.27)	19 (12.58)
0.50-0.60	6 (3.97)	19 (12.58)	12 (7.95)
0.60-0.70	14 (9.27)	22 (14.57)	12 (7.95)
0.70-0.80	31 (20.53)	23 (15.23)	37 (24.50)
0.80-0.90	74 (49.01)	36 (23.84)	13 (8.61)
>0.90	21 (13.91)	3 (1.99)	2 (1.32)
Mean	0.797	0.605	0.523

Minimum	0.173	0.100	0.122
Maximum	0.941	0.960	0.918
Standard deviation	0.127	0.217	0.218

Source: Survey data, 2010. Figures in parentheses are percentages

Figure 4.1: Distribution of technical efficiency of maize farmers in the three agro-ecological zones



Source: Survey data, 2010

4.3 Technical Efficiency and Environmental Variables of Maize Production

The assumption underlying inclusion of environmental production conditions in estimating parameters of the production frontier is that they are exogenously determined. Furthermore if these variables are asymmetrically distributed, then their omission will lead to upward bias in the estimates of producer specific technical efficiency. From table 4.2 the maximum likelihood estimates with and without environmental variables clearly confirm the importance of this assumption. The omission of the environmental variables led to higher parameter estimates and significant estimates. This is in agreement with the findings of Rahman and Hassan (2006) that the omission of environmental variables affect parameter estimates. This underscored the need for the inclusion of ecological (environmental) variables in the estimation of both the production function and the accompanying inefficiency model, failing which such models may suffer from omitted variables bias (Okike *et al*., 2004).

4.4 Equality of Means

A t-test was employed to further analyze the differences in the mean technical efficiencies of male and female maize producers and those who are land owners and tenants to ascertain whether there is a significant difference between the mean technical efficiencies obtained. The null hypotheses state that the mean technical efficiency of:

a. male farmers is the same for female farmers
b. farmers who are land owners is the same for farmers who are tenants

The results of the t-test are presented in Table 4.5. Assuming an equal variance for both male and female farmers, the difference between technical efficiencies for male and female farmers is -0.980 and is significant at 1%, meaning that there is a statistical difference between the mean technical efficiency of male and female farmers. The hypothesis that there is no significant difference between the mean technical efficiencies for male and female farmers is rejected in favour of the alternative hypothesis that there is significant difference between the mean technical efficiencies for male and female farmers.

Again, assuming an equal variance for land owner and tenants, the difference between technical efficiencies for tenants and owners is -0.081 and is significant at 1%, meaning that there is statistical difference between the mean technical efficiency of land owners and tenants. The hypothesis that there is no significant difference between the mean technical efficiencies for land owners and tenants is rejected in favour of the alternative hypothesis that there is significant difference between the mean technical efficiencies for land owners and tenants.

Table 4.5: t-test for Equality of Means

		N	Mean	t	Sign (2-tailed)	Mean difference
Land tenancy	Owner	216	0.615	-3.793	0.000***	-0.081
	tenant	234	0.696	-3.766	0.000***	-0.081
Gender	Male	355	0.636	-3.760	0.000***	-0.980
	Female	95	0.734	-4.453	0.000***	-0.980

Source: Survey data, 2010. *** represent 1% level of significance.

4.5 Analysis of Maize Producer' Constraints

From table 4.6 the most pressing problem faced by maize producers differs in the different agro ecological zones. The Kendall's Coefficient of Concordance (W) indicates that there were 58.2%, 48.2% and 68% agreement among rankings by maize producers in the forest, transitional and savannah respectively and these are significant at one percent. Therefore it can be concluded that there is a reasonable degree of agreement among the respondents in the ranking of constraints to maize production in the three agro ecological zones. The low levels of agreement may be due to the heterogeneous nature of the farmers.

The null hypothesis that there is no agreement among rankings by farmers is rejected in favour of the alternative hypothesis that there is an agreement among rankings of farmers. High input price is the most pressing problem in the forest zone with a mean rank of 3.02. In the transitional zone inadequate capital constitute the highest ranked problem with a mean rank of 3.90. Irregularity of rainfall is also ranked high in the savannah zone by maize producers.

Table 4.6: Ranks of constraints faced by maize producers

Constraints	Forest		Transitional		Savannah	
	Mean rank	Rank	Mean rank	Rank	Mean rank	Rank
Irregularity of rainfall	7.61	9	5.09	4	2.91	1
Poor soil fertility	8.18	11	5.94	5	7.73	7
Soil erosion	10.08	12	9.60	11	9.83	11
Seasonal flooding	12.09	13	12.34	13	4.51	5
Temperature	7.79	10	10.52	12	4.45	4
Pest incidence	6.98	6	7.46	9	8.96	9
Disease incidence	6.74	5	8.50	10	10.08	12
Cost of labour	4.04	3	4.04	2	3.61	3
Inadequate harvesting and drying facilities	6.99	7	6.65	8	9.02	10
Lack of extension services	6.71	4	6.27	6	8.88	8
Land tenure insecurity	7.58	8	6.33	7	12.00	13
Inadequate capital	3.19	2	3.90	1	5.99	6
High input price	3.04	1	4.35	3	3.03	2
N	151		151		151	
Kendall's W	0.582		0.482		0.680	
Chi-square	1054.021		875.961		1.231E3	
Degree of freedom (df)	12		12		12	
Asymptotic significance	0.000***		0.000***		0.000***	

Source: Survey Data, 2010. *** represent 1% level of significance.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

This chapter presents a summary of the main findings, conclusion drawn and recommendations emanating from the study. The limitations of the study are discussed and finally suggestions are made for future research

5.1 Summary

This study sought to assess the technical efficiency of maize producers in three agro ecological zones of Ghana. The study tested the hypothesis that the technical efficiency of maize producers varied according to agro ecological (environmental) conditions, socio economic and institutional factors. To test the hypothesis, a sample of 453 maize producers was selected covering the three main agro-ecological zones of Ghana. A translog stochastic frontier production function technique was used to examine the differences in the production efficiency of maize producers, identify inefficiency effects and characterise the producers according to their efficiency scores. Results across the three agro ecological zones with and without the inclusion of environmental variables show that the overall mean technical efficiency is estimated at 64.1% and 64.2% respectively. This indicates the omission of environmental variables leads to bias estimates of technical efficiency.

The results also reveal that environmental production conditions significantly affect parameters of the production function and the technical inefficiency model. The analysis of technical efficiency scores revealed that technical efficiency ranges from 17.1%-94.1%, 10.0%-96.0% and 12.2%-91.8% in the forest, transitional and savannah zone respectively. The results also showed a significant variation in the mean technical efficiencies of maize producers in the three agro ecological zones. High input price, inadequate capital and irregularity of rainfall are the most pressing problems facing maize producers in the forest, transitional and savannah zones respectively.

5.2 Conclusions

The mean technical efficiency of 64.1% of maize producers across the three agro ecological of Ghana means that farmers are not operating on the production frontier (100% efficient), suggesting that substantial potential exist for increasing maize production with the current technology and resources available to farmers. The study reveals that extension, mono cropping, gender, age, land ownership and access to credit positively influence technical efficiency.

From the point of view of the methodology, the results show the need to include environmental and socio economic variables not only in production function but also in the accompanying inefficiency model, failing such models may suffer from omitted variables bias since the environmental production variables would have been ignored. Moreover, because environmental production conditions are rarely symmetrically distributed, the omission also generally leads to upward bias in estimated inefficiency and bias estimates of the correlates of the estimated technical inefficiency as well. This may cause analyst to draw false inferences, with undesirable consequences for the design and effects of the policies informed by such inferences.

5.3 Recommendations

Quantitative analysis of agricultural production systems has increasingly become the basis of agricultural policies in many countries. Quantitative analysis are of different types and includes attempts to measure economies of scale, producers' responsiveness to product and input price changes and relative efficiency of resource use. Given the empirical findings, the proposed recommendations are;

1. Development of new varieties of crops suitable to the three different agro ecological zones is essential as they face different challenges.

2. The Ministry of Food and Agriculture should intensify its extension services programme by training and deploying qualified extension agents. The agents, in turn, should intensify farmer education about input use.

3. The findings on the relationship between technical efficiency and access to credit suggest that improving farmer' access to credit will improve efficiency. In particular streamlining the acquisition of credit among farmers will help improve efficiency.

Even though, these challenges are not so easy to address due to the changing production environment particularly the climate, a boost in maize production in Ghana will help ensure food security.

5.4 Limitations of the Study

1. The study considers only a single crop and single period to estimate technical efficiency across the three agro ecological zones of Ghana, however in practice decisions are made on the basis of whole cropping pattern and crop rotation.
2. In Ghana, most farmers have lower educational level and many do not keep records of the inputs and outputs. This study suffers from the weakness associated with survey interviews when data accuracy depended heavily on the respondent's ability to recall past information and to answer survey questions accurately.

5.5 Suggestions for Future Research

On the basis of the present study, the following suggestions can be made for possible future research. Agro ecological disparity is an interesting topic to explore further with approaches such as spatial economics. Further research can also take into account the possibility of conducting a multi crop and multi period study while taking into account environmental variables of production.

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APPENDICES

APPENDIX A: Questionnaire

TECHNICAL EFFICIENCY OF MAIZE PRODUCERS IN THREE AGRO-ECOLOGICAL ZONES OF GHANA

Respondent I D #...............

Date………………………

Questionnaire for Maize Producers

a) Agro-ecological zone………………………
b) District…………………………………….
c) Community/ Village……………………….

A. PERSONAL& HOUSEHOLD CHARACTERISTICS

1. Gender of respondent

1=Male	[ ]
0=Female	[ ]

2. Age of respondent……………………years

3. Marital status

1=Married	[ ]
2=Single	[ ]

4. Are you a native of the community

1=Yes	[ ]
2=No	[ ]

5. Religion

1=None	[ ]

2=Christian [ ]

3=Muslim [ ]

4=Traditionalist [ ]

5=Others (Specify)……………………………………..

6. Ethnicity

1=Ashanti [ ]

2=Fante [ ]

3=Northerner [ ]

4=Ewe [ ]

5=Bono [ ]

6=Others (Specify)……………………………………..

7. (i) What is your total household size?...............................

(ii) Number of children…………………………

(iii) Children with age >18 years………………………

(iv) Children with age<18 years……………………….

8. What is your highest level of education?

1=None [ ]

2=Primary [ ]

3=JHS/Middle [ ]

4=SHS/Technical [ ]

5=Tertiary [ ]

6= Others (Specify)……………………………………..

9. (i) Do you belong to any farmer based organisation?

1=Yes [ ]

0=No [ ]

(ii) If yes, do you receive any of the following assistance from the farmer based organisation? Tick the appropriate box.

Assistance	Yes	No
Technical assistance/ training		
Access to inputs		
Machinery services		
Equipments		
Credit in kind		
Credit in cash		
Storage		
Marketing services		
Transportation of inputs and/ products		

B. FARM CHARACTERISTICS

10. What was your total farm size?...............................acres

11. What is the distance between your farm and your homestead?…………….km

12. How far was your farm to the nearest market?.................................km

13. (i) Are you a tenant or landowner?..

    (ii) If tenant, what type of contract have you entered with landowner?

    1=Sharecropping (abunu) [ ]

    2=Sharecropping (abusa) [ ]

    3=Fixed rent [ ]

    4=Borrowed [ ]

    5=Gift [ ]

    6=Others (Specify)……………………………………..

14. (i) Did you practice any anti-pest and disease control measure?

1=Yes [ ]

0=No [ ]

(ii) If yes, mention…………………………………………….

15. (i) Did you practice the slash and burn method of land preparation?

1=Yes [ ]

0=No [ ]

(ii) If yes, why………………………………………………

16. (i) Did you grow only maize on a farm plot (mono cropping)?

1=Yes [ ]

0=No [ ]

(ii) If yes, why………………………………………………….

(iii) If No, what crops do you grow apart from maize?

1=Cassava [ ]

2=Plantain [ ]

3=Cocoyam [ ]

4=Vegetables [ ]

5=Others (Specify)……………………………………..

17. What farming system do you practice?

1=Mono cropping [ ]

2=Mixed cropping [ ]

3=Mixed farming [ ]

4=Others (Specify)……………………………………..

18. How long have been a maize producer?.......................................years

C. FARM INPUTS

19. (i) Did you use improved maize variety?

1=Yes [ ]

0=No [ ]

(ii) If yes, why…………………………………………………………..

20.(i)What quantity of maize seeds did you plant per acre?...........kg/bowl/rubber

(ii) What is the unit cost of maize seeds per kg/bowl/rubber? GH₵………….

21. (i) Did you use tractor in land preparation during 2009 crop season?

1=Yes [ ]

0=No [ ]

(ii) If yes, what was the unit cost of the tractor usage per acre? GH₵…………..

22. (i) Did you use chemical fertiliser during production?

1=Yes [ ]

0=No [ ]

(ii) If yes, which type…………………………

(iii) If yes, how many kg of chemical fertiliser per acre? ....bag(s)

(iv) What is the cost of fertiliser per bag? GH₵………………..

23. (i) What was the major source of labour for your maize production activities?

1=Family [ ]

2=Hired [ ]

3=Others (Specify)……………………………………..

(ii) Indicate the type, gender involved and number of labour used and rate paid (man-days) for the major and minor seasons of production.

Males

Farm Operation	Major Season		Minor Season		Cost of hired	Unit of hire
	Family Labour	Hired labour	Family labour	Hired Labour		

	No. Of males	Days worked	No. Of males	Days worked	No Of males	Days worked	No. Of males	Days worked	labour (GH ₵)	d pay
Land preparation										
Planting										
Weeding										
Fertiliser application										
Applying chemicals like herbicides										
Harvesting/ bagging										
Total										

Unit codes: 1= per day; 2= per acre; 3= others (specify)……………………………….

Females

Farm Operation	Major Season				Minor Season				Cost of hired labour (GH ₵)	Unit of hired pay
	Family Labour		Hired labour		Family labour		Hired Labour			
	No. Of females	Days worked	No. Of females	Days worked	No. Of females	Days worked	No. Of females	Days worked		
Land preparation										
Planting										
Weeding										
Fertiliser application										
Applying chemicals like herbicides										
Harvesti										

ng/ Bagging										
Total										

Unit codes: 1= per day; 2= per acre; 3= others (specify)……………………………….

D. INVESTMENTS IN LAND IMPROVEMENTS

24. (i) Do you practice any erosion control measure?

1=Yes [ ]

0=No [ ]

(ii) If yes, mention………………………………………………….

25. (i) Did you practice any soil fertility management options on your farm?

1=Yes [ ]

0=No [ ]

(ii) If yes, what did you use to improve soil fertility in your farm?

1=Animal droppings [ ]

2=Crop residue [ ]

3=Compost [ ]

4=Fallow [ ]

5=Others (Specify)…………………………………………

26. (i) Did you use herbicides in controlling weeds?

1=Yes [ ]

0=No [ ]

(ii) If yes, how many litres/bottles of herbicides per acre?.........litres/bottles

(iii) What is the unit cost of litre/bottle of herbicides? GH₵………………

E. TECHNICAL SERVICES & ACCESS TO CREDIT

27. (i) Did you have access to extension service for the 2009 crop season ?

1=Yes [ ]

0=No [ ]

(ii) If yes, how often (number of extension contacts per year)?

1=Once [ ]

2=Twice [ ]

3=Thrice [ ]

4=More than 3 times [ ]

28. (i) Did you have access to credit for the 2009 crop season?

1=Yes [ ]

0=No [ ]

(ii) If yes, provide the information below

Source of Credit	Amount received (GH₵)	Mode of Payment
Formal/bank		
Money lenders		
Friends		
Family/relatives		
Others (Specify)……..		

F. INCOME FROM MAIZE PRODUCTION

29. (i) What is the quantity of maize output for the 2009 crop season?............... mini/ maxi bags.

(ii) What was the price per mini/maxi bag? GH₵………………..

(iii) Provide the following information about the usage of maize.

Maize Utilization	Quantity (mini/maxi bags)
Sold	
Consumed	
Stored	
Others (Specify)	

G. NON-FARM ACTIVITIES

30. What is your major occupation?

1=Farming [ ]

2=Trading [ ]

3=Salary worker [ ]

4=Artisan [ ]

5=Others (Specify)………………………

31. (i) Did you engage in an off-farm employment activity?

1=Yes [ ]

0=No [ ]

(ii) If yes, provide the information below

Off-farm Work	Income (GH₵)

(iii) Approximately what was your total household farm income from various sources last year?

Livestock

Livestock	Number. Sold	Unit Price (GH₵)	Total value(GH₵)
Cattle			
Pigs			
Sheep			
Goats			
Guinea fowls			
Chicken			
Others (Specify)….			

Crops

Crops	Number. Sold	Unit Price (GH₵)	Total value(GH₵)
Cocoa			
Cassava			
Yam			
Plantain			
Vegetables			

Beans			
Cocoyam			
Others (Specify)….			

H. CONSTRAINTS/PROBLEMS AND COPING STRATEGIES

32. What are the constraints you faced in maize production? Please rank these problems by ticking the appropriate box.

Constraints/ problems	Rank					Coping strategies
	Very high	High	Low	Very low	None	
Abiotic constraints						
Rainfall						
Soil fertility						
Soil erosion						
Seasonal flooding						
Temperature						
Biotic constraints						
Pest						
Disease						
Input constraints						

Cost of labour						
Input price						
Lack of harvesting and drying facilities						
Institutional constraints						
Extension agents						
Insecure land tenure						
Lack of capital						
Others (specify)						

APPENDIX B: Technical Efficiency of Maize Farmers in the Forest Zone

Farmer No.	TE	Farmer No.	TE	Farmer No.	TE	Farmer No.	TE
1	0.502	41	0.853	81	0.740	121	0.896
2	0.879	42	0.848	82	0.877	122	0.908
3	0.794	43	0.876	83	0.884	123	0.875
4	0.828	44	0.889	84	0.811	124	0.661
5	0.769	45	0.847	85	0.850	125	0.895
6	0.720	46	0.681	86	0.849	126	0.941
7	0.629	47	0.893	87	0.827	127	0.915
8	0.856	48	0.714	88	0.904	128	0.875
9	0.866	49	0.754	89	0.750	129	0.863
10	0.829	50	0.710	90	0.838	130	0.597
11	0.844	51	0.871	91	0.733	131	0.649
12	0.874	52	0.838	92	0.888	132	0.895
13	0.892	53	0.876	93	0.922	133	0.930
14	0.869	54	0.829	94	0.769	134	0.746
15	0.846	55	0.861	95	0.890	135	0.895
16	0.797	56	0.883	96	0.897	136	0.841
17	0.905	57	0.778	97	0.913	137	0.902
18	0.538	58	0.921	98	0.872	138	0.734
19	0.696	59	0.860	99	0.813	139	0.850
20	0.802	60	0.759	100	0.812	140	0.887
21	0.763	61	0.846	101	0.904	141	0.345
22	0.510	62	0.869	102	0.603	142	0.786
23	0.891	63	0.920	103	0.934	143	0.871

24	0.723	64	0.882	104	0.737	144	0.773
25	0.616	65	0.907	105	0.776	145	0.757
26	0.883	66	0.890	106	0.610	146	0.883
27	0.695	67	0.747	107	0.498	147	0.566
28	0.611	68	0.938	108	0.791	148	0.896
29	0.876	69	0.882	109	0.917	149	0.446
30	0.867	70	0.825	110	0.815	150	0.823
31	0.669	71	0.882	111	0.856	151	0.919
32	0.778	72	0.630	112	0.823		
33	0.915	73	0.679	113	0.768		
34	0.843	74	0.841	114	0.708		
35	0.614	75	0.881	115	0.511		
36	0.888	76	0.848	116	0.738		
37	0.894	77	0.856	117	0.827		
38	0.425	78	0.929	118	0.780		
39	0.749	79	0.907	119	0.173		
40	0.693	80	0.815	120	0.769		

APPENDIX C: Technical Efficiency of Maize Farmers in the Transitional Zone

Farmer No.	TE	Farmer No.	TE	Farmer No.	TE	Farmer No.	TE
1	0.471	41	0.662	81	0.800	121	0.569
2	0.901	42	0.306	82	0.583	122	0.619
3	0.843	43	0.256	83	0.724	123	0.699
4	0.744	44	0.100	84	0.655	124	0.755
5	0.801	45	0.780	85	0.367	125	0.705
6	0.720	46	0.830	86	0.528	126	0.240
7	0.810	47	0.845	87	0.714	127	0.389
8	0.819	48	0.840	88	0.825	128	0.673
9	0.500	49	0.935	89	0.692	129	0.495
10	0.317	50	0.841	90	0.612	130	0.864
11	0.782	51	0.809	91	0.895	131	0.861
12	0.304	52	0.694	92	0.814	132	0.695
13	0.377	53	0.358	93	0.552	133	0.864
14	0.586	54	0.227	94	0.655	134	0.854
15	0.762	55	0.666	95	0.960	135	0.661
16	0.140	56	0.837	96	0.288	136	0.898
17	0.259	57	0.716	97	0.659	137	0.358
18	0.631	58	0.559	98	0.814	138	0.535
19	0.439	59	0.745	99	0.526	139	0.325
20	0.652	60	0.871	100	0.454	140	0.453
21	0.770	61	0.254	101	0.475	141	0.510
22	0.311	62	0.483	102	0.494	142	0.689
23	0.669	63	0.251	103	0.705	143	0.580

24	0.225	64	0.343	104	0.724	144	0.464
25	0.577	65	0.784	105	0.293	145	0.841
26	0.123	66	0.800	106	0.327	146	0.781
27	0.637	67	0.856	107	0.755	147	0.308
28	0.591	68	0.887	108	0.509	148	0.183
29	0.652	69	0.765	109	0.873	149	0.649
30	0.874	70	0.450	110	0.864	150	0.865
31	0.875	71	0.375	111	0.709	151	0.342
32	0.710	72	0.415	112	0.789		
33	0.884	73	0.407	113	0.358		
34	0.613	74	0.797	114	0.543		
35	0.402	75	0.153	115	0.595		
36	0.316	76	0.803	116	0.386		
37	0.863	77	0.584	117	0.693		
38	0.534	78	0.810	118	0.545		
39	0.316	79	0.710	119	0.246		
40	0.868	80	0.441	120	0.838		

APPENDIX D: Technical Efficiency of Maize Farmers in the Savannah Zone

Farmer No.	TE	Farmer No.	TE	Farmer No.	TE	Farmer No.	TE
1	0.343	41	0.811	81	0.659	121	0.734
2	0.472	42	0.737	82	0.372	122	0.459
3	0.327	43	0.800	83	0.520	123	0.796
4	0.424	44	0.325	84	0.219	124	0.789
5	0.328	45	0.886	85	0.234	125	0.783
6	0.417	46	0.826	86	0.466	126	0.157
7	0.430	47	0.789	87	0.441	127	0.263
8	0.716	48	0.739	88	0.562	128	0.473
9	0.364	49	0.681	89	0.326	129	0.605
10	0.348	50	0.716	90	0.538	130	0.555
11	0.464	51	0.412	91	0.549	131	0.373
12	0.753	52	0.387	92	0.554	132	0.918
13	0.154	53	0.519	93	0.122	133	0.308
14	0.229	54	0.386	94	0.721	134	0.630
15	0.742	55	0.494	95	0.808	135	0.681
16	0.725	56	0.758	96	0.390	136	0.433
17	0.498	57	0.345	97	0.191	137	0.247
18	0.225	58	0.234	98	0.708	138	0.252
19	0.391	59	0.749	99	0.409	139	0.351
20	0.303	60	0.716	100	0.365	140	0.206
21	0.240	61	0.749	101	0.797	141	0.336
22	0.151	62	0.685	102	0.831	142	0.384
23	0.521	63	0.745	103	0.644	143	0.875

24	0.457	64	0.280	104	0.756	144	0.789
25	0.218	65	0.456	105	0.717	145	0.423
26	0.536	66	0.817	106	0.747	146	0.482
27	0.290	67	0.718	107	0.786	147	0.876
28	0.311	68	0.248	108	0.791	148	0.227
29	0.371	69	0.327	109	0.779	149	0.210
30	0.403	70	0.685	110	0.786	150	0.245
31	0.544	71	0.328	111	0.834	151	0.249
32	0.364	72	0.642	112	0.696		
33	0.299	73	0.252	113	0.759		
34	0.211	74	0.332	114	0.836		
35	0.180	75	0.710	115	0.663		
36	0.357	76	0.740	116	0.733		
37	0.289	77	0.684	117	0.819		
38	0.732	78	0.717	118	0.730		
39	0.788	79	0.387	119	0.536		
40	0.803	80	0.373	120	0.564		

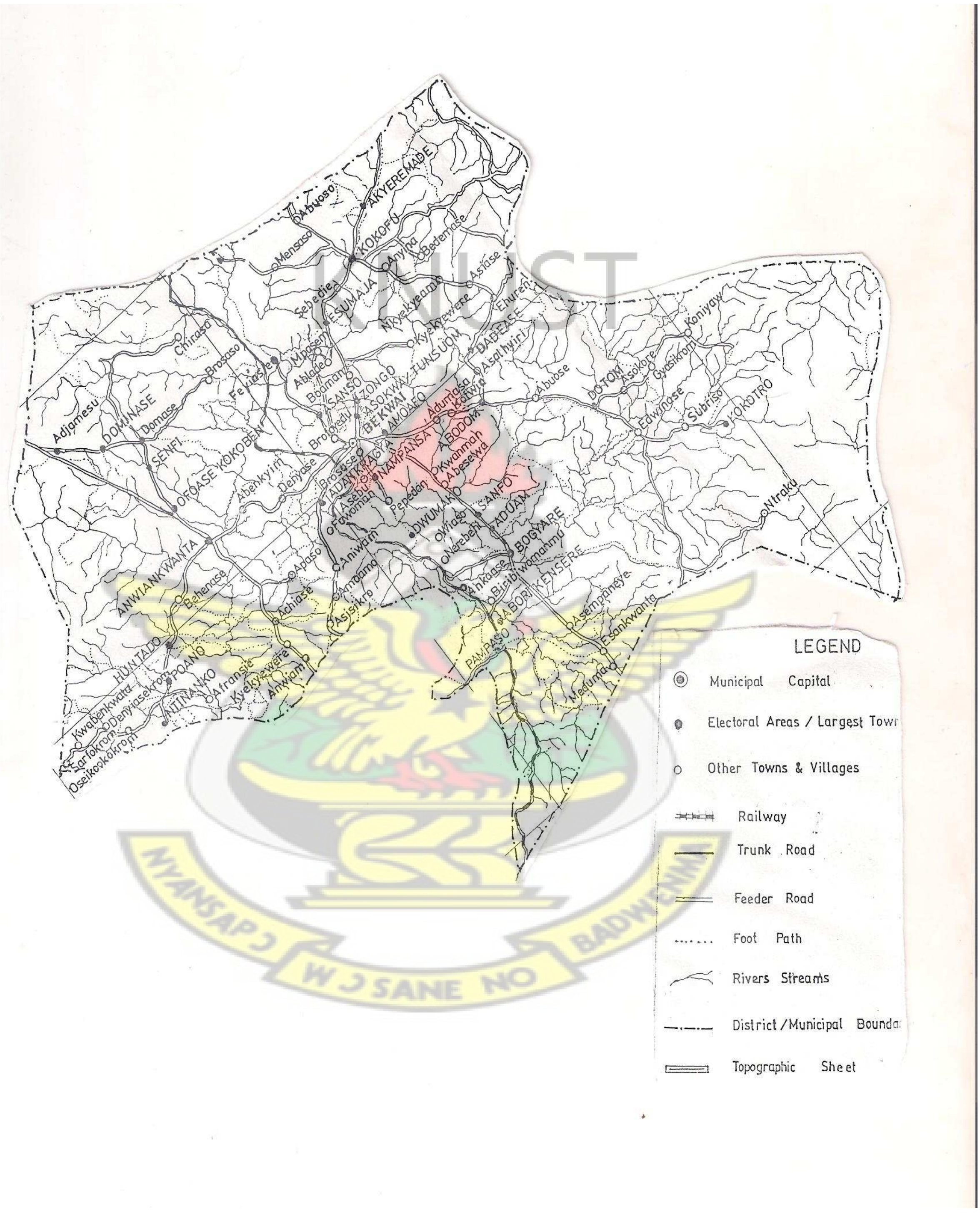
APPENDIX E: Descriptive statistics for the variables used in the study for the different agro ecological zones

Variable	Forest Zone				Transitional Zone				Savannah Zone			
	Mean	Sd	Min	Max	Mean	Sd	Min	Max	Mean	Sd	Min	Max
Yield	2569.30	849.06	450	4800	1554.47	1508.93	150	1800	170.54	86.12	5.33	480
Labour	724.41	401.44	176.25	2945.83	436.03	497.60	22	4249	33.16	27.83	0.6	196.4
Seed	3.70	0.48	2	4.8	3.27	0.71	0.4	4.4	2.37	0.48	1.2	3.6
Farm size	1.00	0.53	0.2	4	2.24	1.81	0.4	10	11.77	7.61	2.5	40
Chemical fertilizer	4.64	8.47	0	20	28.28	11.59	0	60	19.54	14.39	0	40
Gender	0.63	0.48	0	1	0.75	0.44	0	1	0.99	0.08	0	1
Age	46	10.17	25	65	41.86	10.96	20	66	44.67	10.87	22	75
Household size	7.30	2.44	1	15	6.40	3.27	1	15	14.03	8.04	3	40
Education	8.69	2.41	6	16	6.75	4.66	0	16	2.58	3.65	0	12
Land ownership	0.68	0.47	0	1	0.57	0.50	0	1	0.30	0.46	0	1
Mono cropping	0.36	0.52	0	1	0.54	0.50	0	1	0.40	0.49	0	1

Hybrid seed	0.95	0.21	0	1	0.17	0.37	0	1	0.23	0.43	0	1
Extension	0.81	0.39	0	1	0.16	0.37	0	1	0.41	0.49	0	1
Credit	0.62	0.49	0	1	0.17	0.37	0	1	0.09	0.29	0	1
Off-farm work	0.22	0.41	0	1	0.26	0.44	0	1	0.06	0.25	0	1

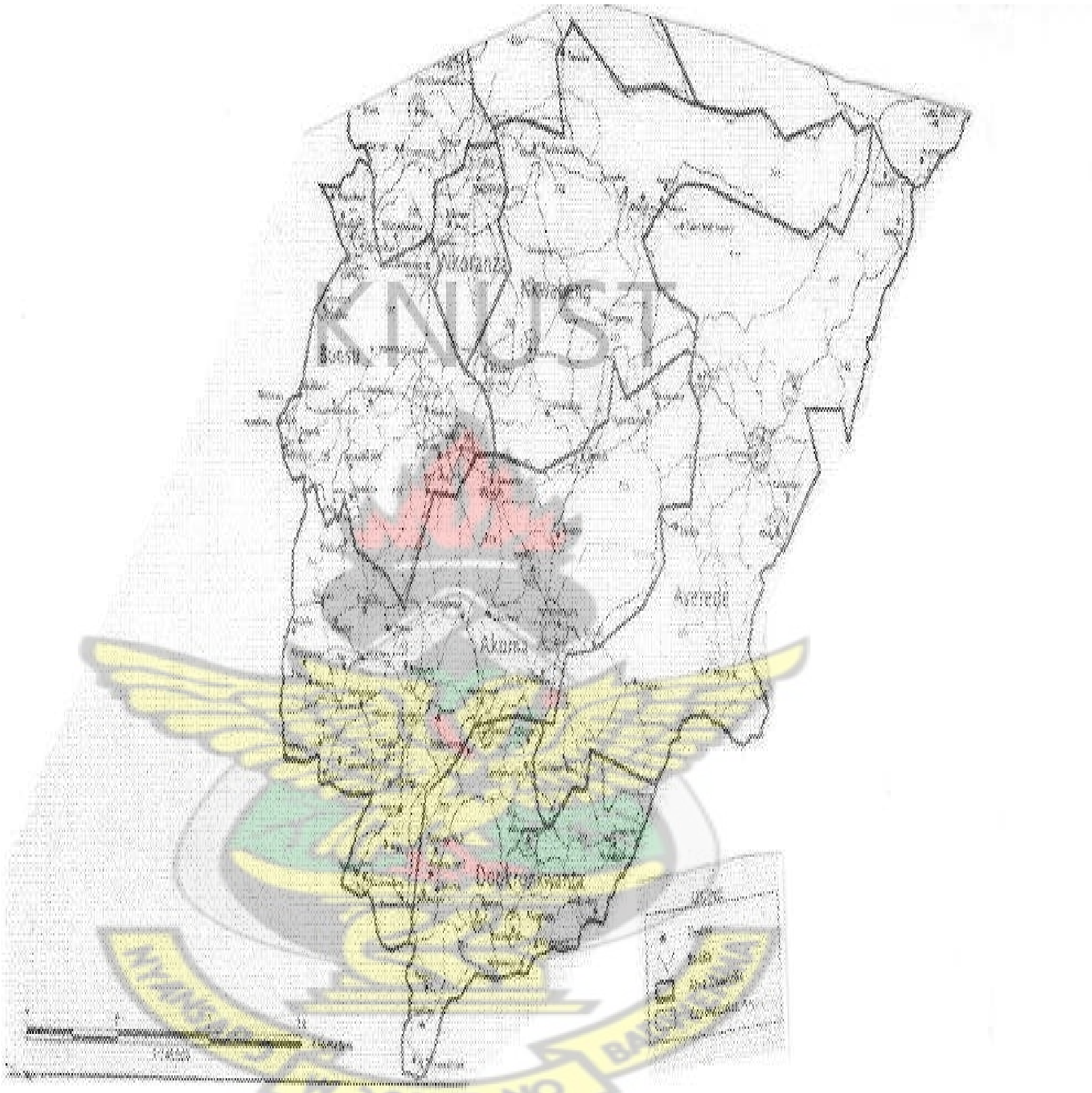
Source: Survey Data, 2010

APPENDIX F: A Map of Bekwai Municipal



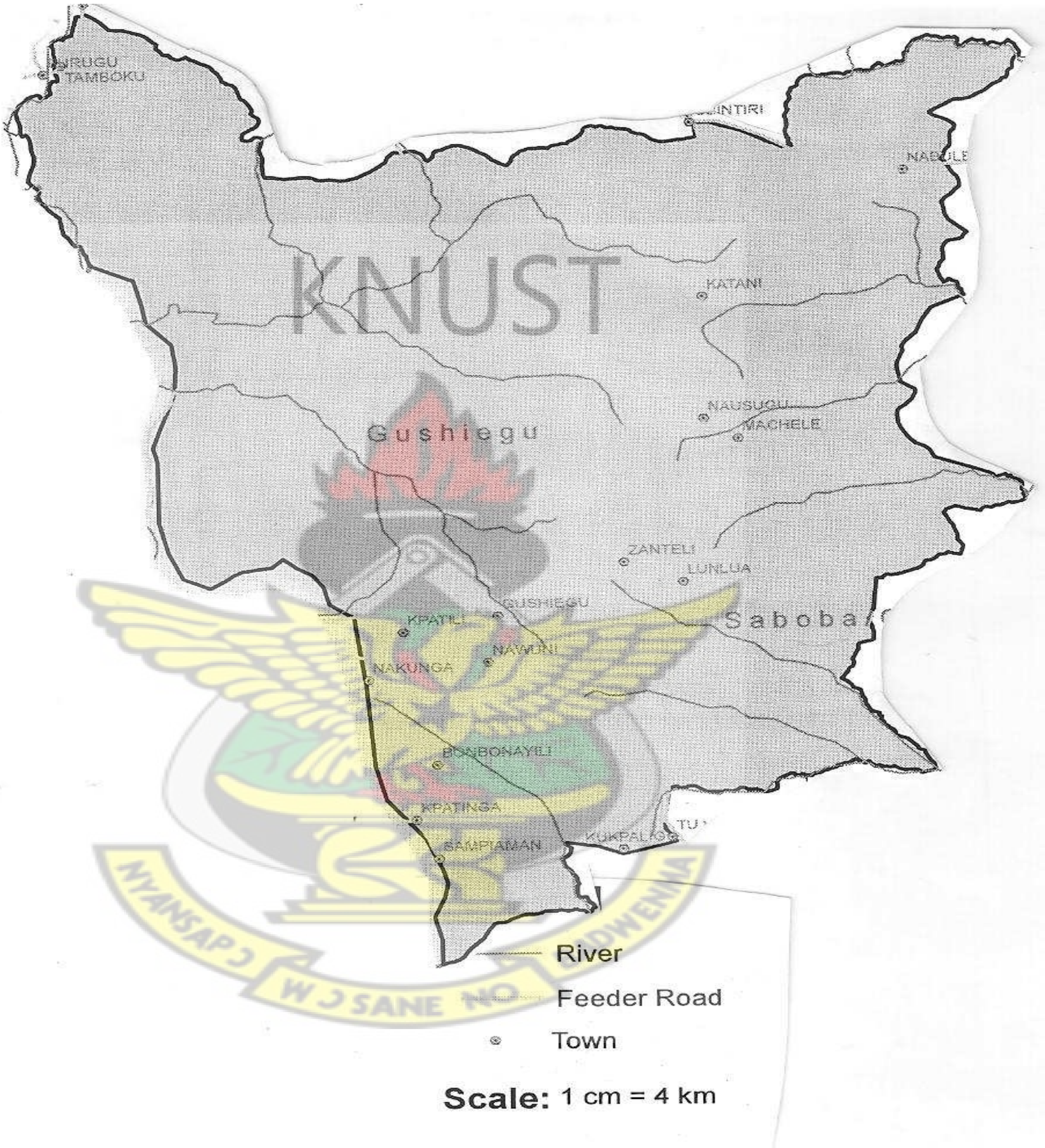
Source: Town and Country Planning, Bekwai

APPENDIX G: A Map of Nkoranza South District



Source: Town and Country Planning, Nkoranza South District

APPENDIX H: A Map of Gushiegu District



Source: Town and Country Planning, Gushiegu District