Yield and Technical Efficiency of Maize Production in Busia County, Kenya

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YIELD AND TECHNICAL EFFICIENCY OF MAIZE PRODUCTION IN BUSIA COUNTY, KENYA

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DECLARATION

Declaration by the Candidate

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DEDICATION

This work is dedicated to my late parents Nicodemus and Dorothy, my dear wife Nelly and our children.

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ABSTRACT

This study sought to analyze the levels of the yield and the technical efficiency of maize production among small-scale farmers in Busia County, where the production of the food crop is well below its full potential to the extent that the County experiences food insecurity. The apparent inefficiency in maize production in the face of existing food insecurity is a serious cause for concern that led to this study being carried out. The stochastic frontier production function approach was used to determine the level of technical efficiency. The study which was carried out in Busia County, adopted a cross sectional survey research design, investigating a sample to determine the effect of a number of variables on the yield of maize, and on the technical efficiency of maize production. The study targeted the population of small-scale maize farmers in the County with farm sizes of fewer than three acres under maize cultivation. From these, a sample of 322 farms was drawn using a multi stage sampling procedure. Data was collected on farm inputs, farmer specific characteristics and maize yields using a semi structured questionnaire and computed using the Frontier 4.1 computer programme. Hypotheses that there was no statistical relationship between selected farm inputs and maize yields and, that there was no statistical relationship between selected farmer specific characteristics and technical efficiency, were tested. Results showed a 53 percent overall mean technical efficiency. Use of tractors for land preparation and use of certified seed were seen to positively influence the level of maize output. More years of education and higher off-farm incomes were found to be associated with higher levels of technical efficiency. The study recommends that in order to improve yields and the technical efficiency in maize production in the county, efforts be made to make farm machines and certified seed affordable and accessible to the small-scale farmers; that school attendance be encouraged, and that alternative sources of income to farming be sought.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

OPERATIONAL DEFINITION OF TERMS

ACDI VOCA: a private, international development, nonprofit organization based in Washington, DC, United States; formed to provide expertise and support to cooperative enterprises and volunteer assistance in developing countries (ACDIVOCA, 2013).

Certified Seed: seed that has been produced to standards set down by Government in a quality assurance scheme. Certified seed is grown and processed to meet a number of physical quality standards for example high germination, purity of clean seed relative to chaff, dirt among others., and a minimum of other crop and weed seeds (Australia, 2011).

Hired Labour: casual farm labourers who have no contract, engaged on a daily basis. They are employed year after year during the high season and are laid off again during periods of low production (Wilshaw, 2013).

Inorganic/chemical fertilizer: fertilizers that exclude carbon-containing materials except urea, as distinct from organic fertilizers that are plant or animal derived matter. Inorganic fertilizers are sometimes called chemical fertilizers since various chemical treatments are required for their manufacture (Jones, 2012).

Off-farm/Non-farm Income: income raised from an off the farm income generating activity distinct from income raised through the sale of farm output (Kibaara, 2005).

Small-scale maize farmer: farmers with fewer than three acres of land under maize cultivation (Woolverton, 2012).

Technical Efficiency: the technical efficiency of a given firm (at a given time period) is the ratio of its mean production (conditional on its level of factor inputs and firm effects) to the corresponding mean production if the firm utilized its levels of inputs most efficiently (Battese and Coelli, 1992)

Western Region: an area of 8436 Km^2 in western Kenya, which comprises of the following zones: Busia, Teso, Bungoma, Kakamega, Lugari, Vihiga and Mt. Elgon (Ali-Olubandwa *et al.*, 2011).

Yield: maize output level in terms of the number of 90kg bags produced per acre (Kamau *et al*., 2014).

ABBREVIATIONS AND ACRONYMS

ACDI	Agricultural Cooperative Development International
ACDIVOCA	Agricultural Cooperative Development International and Volunteers in Overseas Cooperative Assistance
AFAP	African Fertilizer and Agribusiness Partnership
ERA	Economic Review of Agriculture

F.E.W.S. NET	Famine Early Warning System Network
FAO	Food and Agriculture Organization
GOK	Government of Kenya
IFDC	International Fertilizer Development Centre
KARI	Kenya Agricultural Research Institute
KCBS	Kenya Central Bureau of Statistics
KFSSG	Kenya Food Security Steering Group
Kg	Kilogrammes
KIPPRA	Kenya Institute for Public Policy Research and Analysis
KMDP	Kenya Maize Development Programme
Ksh	Kenya Shillings
MOA	Ministry of Agriculture
NMG	Nation Media Group
REFSO	Rural Energy and Food Security Organization
VOCA	Volunteers in Overseas Cooperative Assistance
WEMA	Water Efficient Maize for Africa
WFP	World Food Programme

CHAPTER 1:

INTRODUCTION

1.1 Overview

This chapter discusses the background of the research and the problem statement. It also outlines the specific objectives of the study, the research hypotheses, significance and scope of the study.

1.2 Background to the Study

Increasing farm productivity is important in reducing poverty and food insecurity in rural agrarian societies (Ariga *et al.*, 2008). Fundamental to food security in Kenya, is the production of maize, which has a very low price elasticity of demand in the country and is grown on most farms (Wambugu and Muthamia, 2009). It is the Country's principal staple food. In fact, each year the average Kenyan consumes 98 kilograms of maize (ACDIVOCA, 2013).

Most of this maize is produced by the small scale maize farmer in Kenya (Olwande, 2012). However, inefficient production in the maize subsector contributes to maize deficits. Cross-border importation from Uganda and Tanzania as shown on table 1.1 (MOA, 2013) fills such deficits. Inefficiency on small holder maize farms in Kenya ranges from 7.2% to 98.3%, with a mean of 49%. This implies that there is scope of increasing maize production by 51% through adopting technologies and techniques used by the best maize farmers. Over 36% of maize farmers operate below the mean technical efficiency level; only 30% are at least 60% technically efficient (Olwande, 2012).

Table 1.1: Kenya's Main Maize Inflow Points (2013)

Border Point	Maize Inflow-90 Kg bags

Isebania	500
Namanga	1,520
Lunga Lunga	5,630
Suam	7,105
Malaba	9,055
Lwakhakha	13,920
Busia	307,364
TOTALS	345,094

Source: MOA-Republic of Kenya, 2013

Rational government policies have been put in place and various non-governmental organizations have intervened to try to alter the economic contribution of the subsector and make it a key element in accelerating growth and reducing poverty (WEMA, 2010; MOA, 2013). However, poor inputs have resulted in low yields for small-scale farmers (ACDIVOCA, 2013).

The small-scale maize farmer cultivates maize on a farm of typically three acres or less (Woolverton, 2012). He is located rurally and is usually to be considered financially poor. He produces a relatively small amount of maize and relies on his harvest both for his own consumption and as a cash crop. In general small-scale farmers depend on rain fed agriculture. Since they do not have access to irrigation systems because of their high costs, they are severely affected when dry spells occur and generally lose all or a large part of their harvest (Skjöldevald, 2012).

A report prepared by the Agriculture Livestock Sector Working Group of the Kenya Food Security Steering Group (KFSSG), jointly with the Food Agriculture Organization of the United Nations (FAO), WFP, FEWS NET and Ministries of Agriculture, Livestock Development and Fisheries Development of Kenya (KFSSG, 2012), showed unfavourable trends for the western Kenya region as far as maize production was concerned. Among the regions studied in this report namely: North Rift, South Rift, Nyanza, Central, and Western, only the western region showed a precarious and declining trend in maize production. According to the report, this trend had left 50% of the region's resident's food insecure.

The report indicated that the hardest hit area in the region was Busia County. Other records confirm that in the western Kenya region, Busia County has had the lowest maize yields in recent years. Between 2001 and 2006, Busia County produced a yearly average of 7 (90 kg) bags per acre (Ali-Olubandwa *et al.*, 2011) compared to the western region's annual average of 12.5 (90 kg) bags per acre (KFSSG, 2012) and the annual national average of 7.3 (90 kg) bags per acre (MOA, 2013) in the same period. Between 2007 and 2011, the County produced a yearly average of 13.2 (90 kg) bags per acre (ERA, 2012) compared to the western region's annual average output of 22.7 bags (ERA, 2012), and the national annual average of 18.5 (90 kg) bags per acre (Kang'ethe, 2011). On-farm trials indicate that potentially, the western Kenya region can produce 25 (90 kg) bags of maize per acre; while nationally, 27.7 (90 kg) bags per acre can be achieved when proper farming techniques are applied (Odendo *et al*., 2002). Table 1.2 shows how Busia County has lagged behind the nation and the other Counties in the western Kenya region in terms of actual maize production. It also shows the potential output of the regions.

Table 1.2: Maize Yields (90 Kg bags)

YEAR	2001-2006		2007-2011	
OUTPUT	Potential Output	Actual Output	Potentia l Output	Actual Output
National Output	27.7	7.3	27.7	18.5
Western Region: Overall	25	12.5	25	22.7
Western Region: Lugari / Kakamega	25	18	25	24.9
Western Region: Mt Elgon / Vihiga	25	15	25	16.5
Western Region: Bungoma	25	10	25	27.5
Western Region: Busia	25	7	25	13.2

Source: Odendo *et al.*, 2002; Ali-Olubandwa, 2011; Kang'ethe, 2011; ERA, 2012; KFSSG, 2012; MOA, 2013

Busia County, occupies 1,261.3 km^2 divided into seven administrative regions: Amagoro, Budalangi, Butula, Funyula, Matayos, Nambale, and Busia Township (KFSSG, 2012). The County has four main economic activities and is divided into these livelihood zones a shown in figure 1.1. Cash crop farming is done on about 30% of the farms Amagoro and 55% of the farms in Nambale where sugarcane is planted for sale. In Funyula and Budalangi, cultivation of rice for sale accounts for about 20% of the economic activities in each division. Mixed farming of cash crops, food crops and animals accounts for about 80% of all economic activities in Butula and 90% of such activities in Matayos. Fishing takes up about 30% of the output in both Funyula and Budalangi. Fnally in Busia Township over 90% of the population is enged in employment and trade (FAO, 2011).

The United Nations World Food Programme identified Busia County as a food insecure region as early as 2005 (KFSSG, 2012) and the situation has not changed to date. In 2013, the County produced only three-quarters of its total cereal demand of 63,748 metric tons (KIPPRA, 2013). Like in the rest of the Country, maize is the principal cereal food for households in Busia County (Kilonzi, 2011).

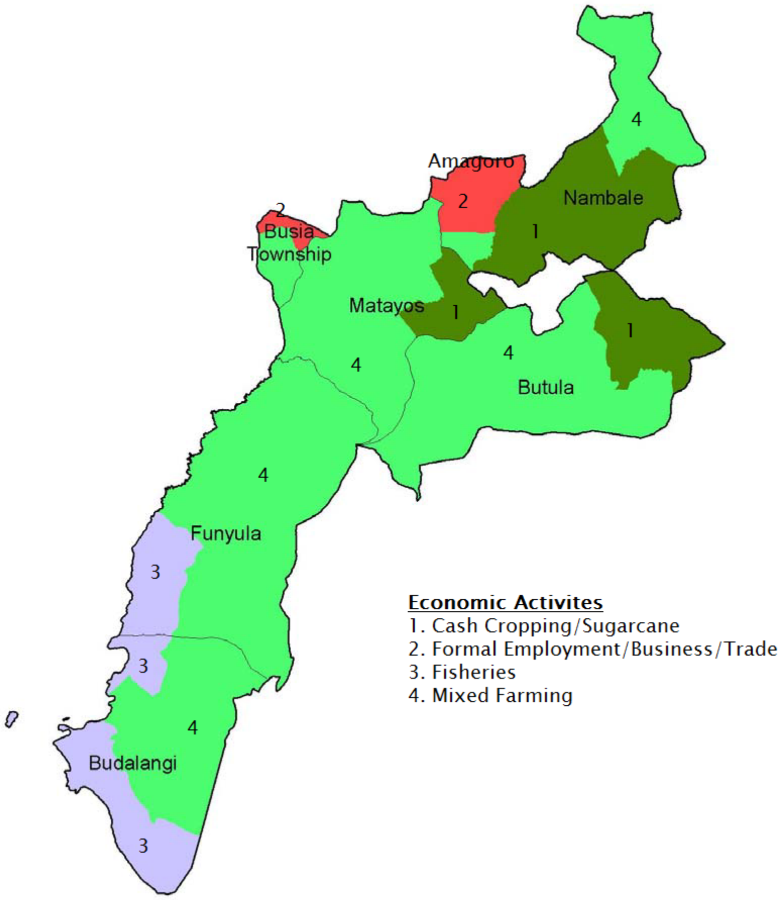


Figure 1.1: Research Area - Busia County

Source: FAO, 2011

There are enough resources in Busia County to be able to produce adequate yields of maize, yet maize yields in the County are well below the 25 (90) kg bag potential that can be produced in the western Kenya region. As a result, food insecurity is prevalent in the County. Busia County's food insecurity forces its residents to rely mainly on the importation of their staple food from outside the County - mainly from Uganda (KIPPRA, 2013) at constantly rising prices. The price of imported maize in Kenya has been constantly rising over the years from US$100 per ton between 2000 and 2006 to

US$240 per ton by August 2008 (Ariga *et al*., 2008) to US$650 per ton in 2011 (Bwire, 2014).

1.3 Statement of the Problem

Insufficient production of maize in Kenya, where the crop is the staple food is a documented fact (MOA, 2013). This is despite the fact that farmers in the County, with the help of the Government and non-governmental organisations engage all the available resources necessary to produce the maximum yields of maize (ACDIVOCA, 2013). Studies show that this condition is particularly pronounced in the western region of the country (KFSSG, 2012).

In the western Kenyan region, Busia County's maize yields lag behind both the yields of the region as well as those of the country as a whole in terms of both the actual output (Odendo *et al*., 2002; Ali-Olubandwa *et al*., 2011; Olwande, 2012), and the potential output (Kamau *et al*., 2014) leaving the County food insecure. This suggests that it is in Busia County that maize production is at its worst in the whole in the whole country.

Production below the full potential, points at technical inefficiency in production. This, in the face of existing food insecurity is a serious cause for concern and therefore, there was an urgent need for research on the factors that may have been responsible for influencing the level of technical inefficiency in the production of maize in Busia County.

1.4 Objective of the Study

This study sought to determine the factors of the yield and the level of technical efficiency in the production of maize by small-scale farmers in Busia County.

The specific objectives of the study were:

(i) To determine the relationship between various farm inputs and maize yields in Busia County,

(ii) To determine the relationship between farmer socioeconomic characteristics and maize production technical efficiency in Busia County.

1.5 Hypotheses

Ho_1: There is no statistically significant relationship between the various farm inputs and maize yields in Busia County,

Ho_2: There is no statistically significant relationship between the farmer socioeconomic characteristics and maize production technical efficiency in Busia County.

1.6 Significance of the Study

Studies on efficiency in maize production in Kenya have so far only been done on a national scale, on farms of all sizes. They include Kibaara and Kavoi, 2012; Ariga *et al*., 2008; Wambugu and Muthamia, 2009. This study concentrated on Busia County and targeted only small-scale farmers. It is of significance to farmers in the County as it indicates the technological shortfall from the frontier level of maize output given the existing technology. It is of importance to the Kenyan economy in terms of moving towards food sufficiency in the rural areas by determining the most significant factor inputs relevant to production of the staple food; as well as the most appropriate scale of production of maize for small-scale producers. Further, this research contributes to the pool of research findings gathered about technical efficiency in small-scale farm production.

1.7 Scope and Organization of the Study

The study covered small-scale maize farmers with holdings of less than three acres in Busia County. The respondents to this study were the heads of the farming households or senior members of the household charged with the day-to-day decision-making on the farm. Data was collected on the farm output of maize in terms of 90kg bags. The data included the use of the following farm inputs: the amounts of chemical or inorganic fertilizer that were applied, the amounts of certified seed planted, the hours of hired labour employed and the cost of machinery used. It also involved collection of data on farmer specific characteristics namely: his/her age, level of education, maize farming experience and off-farm income. These were used to assess the level of technical efficiency. The information collected related to the maize planting period for the year 2014. This study was carried out between November and December 2014

CHAPTER 2:

LITERATURE REVIEW

2.1 Introduction

This chapter establishes the theoretical basis of the study and it gives a review of literature on studies related to the current study by various researchers, scholars and authors. The research drew materials from several sources, which are closely related to the theme and objectives of the study. The chapter also gives the conceptual framework of the research.

2.2 Empirical Literature

Maize (*Zea mays*), is grown on most Kenyan farms in almost all agro-ecological zones (Odendo *et al*., 2002). Its production in the country is dominated by small-scale farming which contributes about 70% of its total output (Olwande, 2012). There is an increasing gap between production and consumption and an increasing frequency of supply shortages which shows the existence of stagnation in maize production and productivity in Kenya (Olwande, 2012). Part of the reason for this could be that Kenya having had a number of major food crops in the past, has over the years experienced a decline in food crop diversity especially of traditional varieties, leaving maize as the principal staple food of Kenya (Wambugu *et al*., 2009). Consequently, repetitive planting of the same crop in all regions - including those regions to which the crop is not best suited, has led to a decline in its production.

Apart from the fall in the variety of food crops planted in Kenya, a more serious problem is the encroachment of cash crops into food crop farms replacing maize production (KFSSG, 2012). In Busia County, tobacco and sugarcane, the main cash crops with a reliable market, have diverted the attention of the rural communities away from maize planting; being labor intensive and requiring constant attention at the expense of maize growing (REFSO, 2014). A study done by Kilonzi (2011) in Nambale division of Busia County found that there was competition between sugarcane and maize planting because there was little motivation for maize production, with most farmers going for the cultivation of the sugarcane in search for money (Kilonzi, 2011). Although mixed farming is widely practiced in Busia County, some regions in the County rely more on cash cropping as their principal economic activity than others.

In this study, small scale farming was analyzed using the production function, generally shown as Qx=f (K, L, L_d). That is, the required levels of inputs of labour L, capital K and land L_d for the output level X (Hardwick *et al*., 1999). In this study, the relationship between the farms inputs required to produce the observed levels of maize yield was considered. Literature points out common inputs in the production of maize, among them: soil fertility, the variety of seed planted, hired labour, cash cropping, credit availability, agricultural extension services and mechanization.

One major constraint to farm high maize output is the lack of finances. The results of a study in 2011 revealed that 37.9%, 36.6%, 20.3% and 38.9% of farmers from Bungoma, Lugari, Mt. Elgon and Busia counties respectively lacked finance for purchasing farm inputs (Ali-Olubandwa *et al*, 2011). With most small scale farmers being poor, and cost of farm inputs being high, credit financing would be the only way of finance maize farming (Peñalba *et al*, 2012). Agricultural credit ought to be extended for farmers to have access to production inputs, to plant alternative crops and adopt modern farm technologies (Peñalba *at al*, 2012). However, few microfinance institutions in Africa have so far shown interest in providing loans to support smallholder agricultural production, because they consider such lending to be too risky (Ndufa *et al*, 2005).

Interestingly though, a large majority of famers in western Kenya who lack finance to purchase farm inputs, being risk averse, are unwilling to acquire credit for various reasons; the main one being the fear of inability to pay back (Ali-Olubandwa *et al*, 2011).

Additionally, farmers in Busia have, in spite of the enormous chunk of land they own, proved not to heed the training information they frequently receive from agricultural extension officers (Abuje, 2012). Results of the study by Ali-Olubandwa *et al*, (2011) revealed that only 20.9% of the farmers in the western Kenya region adopted all the extension packages passed on to them by the extension staff. In Busia County, this percentage went down to 17.2% (Ali-Olubandwa *et al*, 2011)

In view of these facts, this study did not consider these variables, namely: cash cropping, credit availability and agricultural extension services even though they occur extensively in literature. Instead other commonly discussed farm inputs, namely: soil fertility, the variety of seed planted, hired labour person-hours and mechanization were studied.

2.3 Farm Inputs

Given the stagnation in maize production, efficiency needs to be improved through appropriate use of appropriate inputs (Olwande, 2012). Tijiana (2006) agrees with this stating that although increasing the resource base and investment in technology are important in raising agricultural output, more relevant for less developed countries due to the scarcity of resources and the lack of opportunities for new technology, are extension and education services on proper management of land and other inputs (Tijiani, 2006). In other words, given the scarcity of farm inputs, the only option for increasing farm output is to improve the efficiency and the productivity of the inputs.

2.3.1 Chemical Fertilizer

Land degradation remains an important global concern because of its adverse impacts on agricultural production, food security and the environment. Agricultural mismanagement of soil and water resources is seen in the form of deforestation, overgrazing and over-cutting, shifting cultivation, non-adoption of soil and water conservation practices, improper crop rotation, use of marginal land, as well as insufficient (Brinkman *et al.*, 2011). The Food and Agriculture Organization of the United Nations reported in 2011 that large areas of Sub-Saharan African soils are affected by fertility decline. Soils in most Sub-Sahara African countries have inherent low fertility and do not receive adequate nutrient replenishment (Brinkman *et al.*, 2011). Inspite of this, it has been estimated that the average fertilizer application in Sub-Saharan Africa is a mere 7 Kg per hectare (Muasya and Diallo, 2001) against a recommended 50 Kg per acre (Faidaseeds, 2014).

The situation is not different in Kenya where fertilizer use is also below the recommended rates among most of the small-scale farmers leading to reduced productivity per unit area (KFSSG, 2012). Fertile land in Kenya has in the recent past been on the decline due to genetic erosion brought about mainly by negative agricultural development policies, and land degradation (Wambugu and Muthamia, 2009). Apparently for Kenya, increased use of fertilizers is one of the most suitable ways by which households and nations can improve the productivity of arable land and increase food output (Ariga *et al*., 2008). This was confirmed by the positive statistically significant relationship between the input of fertilizer and yield in the country which was found by Kibaara and Kavoi, (2012).

In western Kenya region, according to Ariga (2008) only 13% of the maize farmers were using fertilizer on their farms by 2007 and they applied 12 kg per acre (Ariga *et al*., 2008). The situation had improved by 2013 where the proportion of the maize farmers in this region who were using fertilizer had risen to 44% (Karanja *et al.*, 2010). Reasons for low application of fertilizer include the high fertilizer prices and the poor design of government fertilizer subsidy programmes (Ariga *et al*., 2008). Mignouna *et al*., (2010) found that for this region, the relationship between the use of chemical fertilizer and maize yield was statistically significant but inverse; that is, -0.142 at 1% level of significance (Mignouna *et al*., 2010). The negative coefficient of fertilizer as an input implies that increase in quantity of this input would result in decreased output which does not conform to expectation.

For Busia County, the problem of low soil fertility is compounded by high population densities and small land holdings which force poor households in this area into a maize-focused cultivation with very little investment in soil fertility replenishment; the soils have become severely depleted and returns are low (Ndufa *et al*., 2005). This is a result of the fact that maize farmers in Busia do not heed the training information they frequently receive from agricultural experts about diversification to improve soil fertility (Abuje, 2012). Only 54.2% of the farmers had taken to using fertilizer for planting and 39% for top dressing their maize farms following advice from agricultural extension officers (Ali-Olubandwa *et al*., 2011). Then there is the problem of HIV/AIDS in the County. The disease increases the stress on soil fertility management by destroying local social structures, by taking away any modest capital and labour useful for soil fertility management that has been accumulated by the household (WFP, 2005).

2.3.2 Certified Seed

Non-adoption of productivity improving inputs is not evidenced by low fertilizer use only. It is also seen in the management of improved seed variety. Proper seed choice is important because seeds are developed and will perform best based on altitude, rainfall, type of soil and temperature and other climatic conditions (Australia, 2011). For example, the volatile climatic conditions, and in particular drought, make it difficult for the affected vulnerable smallholder maize farmers to cope and recover (WEMA, 2010).

To meet the needs of farmers in every climatic region, researchers have developed seed varieties that do well in those regions (Australia, 2011). Before adopting any new seed variety, it is important that farmers isolate a small portion of land, plant the variety and observe its characteristics (Sawe, 2014). However, many farmers in East and Southern Africa do not do this for lack of proper guidance and end up planting the wrong maize seed varieties, resulting in poor yields (KFSSG, 2012). Improper guidance comes in many ways; one of them is the opening of maize seed markets to private enterprise companies (Ali-Olubandwa *et al*., 2011). The seed companies are driven by a business approach that appeals to their clientele, which is to increase in the number of bags harvested per hectare. This has been pushed by efforts of various government policy papers that consider having food security as important in development of Kenya (ERA, 2012). In this regard, the seed companies have concentrated their efforts on high yielding varieties and have flooded the seed market with an ever increasing variety of seed, causing confusion for the farmer (Kang'ethe, 2011). These efforts have only been able to partially meet the goal of greater output.

A report by FAO indicates that farmers in the western Kenya region do not choose their maize seeds based on: high yield, early maturity, tolerance to weeds, low cost of seed, tolerance to diseases, and ability of a variety to perform reasonably without application of fertilizers and resistance to insect pests (Brinkman *et al.*, 2011). Most maize seed varieties in this region are manufactured or imported by thirty private enterprises located outside the region, mainly in Nairobi (Ali-Olubandwa *et al*., 2011). As a result nearly 80% of the farmers in western Kenya predominantly grow local maize varieties, whose seed they recycle for many seasons (Odendo *et al*., 2002). For example, in Bungoma County, only 30% of the maize farmers use recommended variety of seed for planting (Woolverton, 2012). In the western Kenya region too, availability of low quality seed in the market is another of the constraints to higher maize yields mentioned by Odendo *et al* (2002). Maize seeds are often adulterated or not true to type (Odendo *et al*., 2002).

Choice of suitable seed varieties is of great importance as most studies have shown. Omonona *et al.,* (2010) recorded the existence of a statistically significant relationship between the use of certified seed and yields of cowpea in Nigeria (Omonona *et al.,* 2010); and so too did Kibaara and Kavoi (2012) between the use of certified seed and maize yields in Kenya at 1% level of significance with a coefficient of 0.63 (Kibaara and Kavoi, 2012). According to the study by Mignouna *et al*., (2010) the relationship between the use of certified seed and maize yields in western Kenya was statistically significant at 1% level with a coefficient of -0.646 (Mignouna *et al.*, 2010).

2.3.3 Hired Labour

In traditional agriculture such as the one common in western Kenya, labour endowment whether hired or family is an important factor in determining farm yields. In the absence of sufficient family labour, the cost of hiring labour or opportunity cost of labour can greatly reduce production (Manyong, *et al*., 2007). Most hired labour is engaged at the peak of the season during second weeding and harvesting (Kibirige, 2008). The potential labour available in the western Kenya region based on the average number of adult equivalents during one agricultural year is 1,050 man days (Manyong, *et al*., 2007).

Studies in this region reveal the relationship between hired labour and maize yields not to be statistically significant. Kibirige (2008) found the relationship for maize yield in Masindi District Uganda not to be statistically significant with a coefficient of 0.10 (Kibirige, 2008). By comparison, the study by Kibaara and Kavoi (2012) revealed that the relationship between the use of hired labour and maize yields in Kenya was also not statistically significant, with a coefficient of 0.46 (Kibaara and Kavoi, 2012). The use of family labour in place of hired labour may be a possiple explanation for this state of affairs. However, for cowpea production in Nigeria, the same relationship was found to be significant at 1% level by Omonona *et al* (Omonona *et al*,., 2010).

2.3.4 Machinery

Machines are an important input in any form of production currently. The most obvious benefits of mechanization is their ability to reduce costs of production by replacing single operations with combined ones and using as less labour as possible (Havrland *et al*., 2006). Farm mechanization enhances the production and productivity of different crops due to timeliness of operations, better quality of operations and precision in the application of the inputs (Verma, 2008). Furthermore agricultural mechanization makes a significant contribution in enhancing cropping intensity. For example, irrigation and tractor use have direct bearing on the cropping intensity (Verma, 2008).

Before adopting a given type of technology or mechanization, technology assessment should be done according to budgets on the basis of those parameters considered as the main economic indicators such as market price of machines vis-à-vis that of the output. The main objective is to find out the best (most appropriate and profitable) technology on basis of the economic parameters (Havrland *et al*., 2006). Harvaland *et al.* (2006) put forth different types of farm technology. Of these, the most commonly used type in Kenya and in Busia County in maize farming is the classic mechanized technology where machines are mainly used for soil preparation and to a lesser extent for seeding operations. Here, Kibaara and Kavoi (2012) found the relationship between mechanization of maize farming in Kenya and yields to be statistically significant with a coefficient of 0.03744 (Kibaara and Kavoi, 2012).

2.4 Socio-Economic Characteristics

Literature gives some farmer socio-economic characteristics which influence technical efficiency, that is, the extent to which maximum output is achieved from given inputs (Black *et al*., 2013). According to Ball and Pounder (1996), technical efficiency in small-scale production was first analyzed by Schultz in 1964. Ball observed that Schultz's assertion that small-scale farmers in developing countries were poor due not due to inappropriately allocating the inputs to production but due to lack of inputs implied that small-scale farmers in developing countries were fully efficient and could not be helped through improvement in production methods (Ball and Pounder, 1996). However given the presence of variations in the characteristics of the producers, Schultz's assertion cannot hold.

These variations influence the producers' employment of inputs in terms of the nature, combination, quantity among others (Alene, 2007; Omonona *et al*., 2010); causing differences in technical efficiency. Several studies have exposed these differences. For example, in Kenya's maize production sector, Kibaara and Kavoi (2012), estimated overall mean technical efficiency at 49 percent with a range of between 8 to 98 percent. Such a range must occur because the variations in the characteristics of the producers inevitably create differences between observed and potential output for individual producers. In literature, the most common of these efficiency influencing characteristics are the farmer's off-farm income, his/her age, maize farming experience, as well as his/her level of education.

2.4.1 Farmer's Education Level

In a number of African countries, the relationship between the level of years of formal education of the farm head, and technical efficency of smallholder maize farmers shows mixed results. According Kibaara and Kavoi (2012), a higher level of education of the farm head lead to a higher technical efficiency in maize production in Kenya (Kibaara and Kavoi, 2012). Similarly in the study of cowpea production in Nigeria by Omonona *Et al*. (2010), the level of education was 56%, contributing 90% to efficiency in the production of cowpea (Omonona *et al.*, 2010). On the other hand Chirwa (2007) found that the relationship between the level or years of education of the farm head and technical efficency of smallholder maize farmers in Malawi was not statistically significant (Chirwa, 2007); same for Uganda, where also the relationship was not statistically significant for maize production in Masindi District (Kibirige, 2008).

In the Western Kenya region, Manyong (2007) found the average number of years of formal education attained by household heads to be 6.8 years (Manyong, *et al*., 2007).

He found the relationship between the years of formal education and maize production efficiency in this region to be negative (-0.128) and statistically significant. This meant that inefficiency decreases significantly with years of formal education.

2.4.2 Farmer's Maize Farming Experience

According to Omonona et *al*. (2010), the farming experience gathered over the years of practices had a negative relationship with the technical efficiency. In his study, the important factor was the number of years the farmer had been cultivating cowpea regardless of other crops. This experience was found to enhance the level of cowpea production in Nigeria. A year's increase in farming experience led to a better assessment of the complex decision-making, which is important for good farming, including efficient use of inputs (Omonona *et al.*, 2010).

In western Kenya, Manyong (2007) found that the relationship between age and technical inefficiency was non-linear. That is, young farmers tend to become more efficient as they gain experience, but after a certain age, their inefficiency begins to increase with age. However, the non-linear effect of age on technical inefficiency was not statistically significant.

2.4.3 Farmer's Age

It is not easy to predict what the relationship between the age of farmers and technical efficiency is likely to be. Younger farmers may be readier to accept instructions and changes that can improve efficiency than older farmers. However, it is possible that this may not happen, since compared to their older counterparts, younger farmers in Africa take farming less seriously preferring instead to look for urban jobs; in most cases they do not have ownership of the land they cultivate; and their funds for acquiring farm inputs are more limited.

Evidently, findings of this relationship from various studies are mixed. Kibaara and Kavoi (2012), found that the older age of the household heads did not lead to a higher technical efficiency in the production of maize in Kenya; the relationship was not statistically significant (Kibaara and Kavoi, 2012). The same was true for the findings of Tijiana (2006); with a relationship between the age of rice farmers in Ijesha Nigeria and technical efficiency being found not to be statistically significant (Tijiani, 2006). On the other hand, according to Omonona et *al*. (2010), the age of the farmers had a 93% input to the efficiency of cowpea production in Nigeria although it reduced to an average of 90%, with the increase in the age of the farmer.

2.4.4 Farmer's Non-farm Income

Off-farm or Non-farm Income refers to income raised from an off the farm income generating activity distinct from income raised through the sale of farm output (Kibaara, 2005). Such income is supposed to augment any on-farm income in ensuring the timely acquisition of farm inputs (Kibaara and Kavoi, 2012). It also allows the farming household ample opportunity to manage their farm without infringing on farming time to look for other means of livelihood. Sources of such non-farm income include transfer earnings from relatives employed in urban centres and from commercial activities carried out in the villages, for example running of kiosks. It would then be expected that higher off-farm income would lead to more efficient production.

A study in Nigeria by Tijiani conformed this expectation. It found that rice farming efficiency level bears a positive and statistically significant relatationship with off-farm income (Tijiani, 2006). On the contrary, Kibaara and Kavoi found that in Kenya's maize sector, farmers engaged in off-farm income earning activities tend to exhibit higher levels of inefficiency (Kibaara and Kavoi, 2012). They suggest that the reason for this is that farmers with higher non farm income engage in off-farm income earning activities. They reallocate time away from farm related activities essential for enhancing production efficiency, such as adoption of new technologies and gathering of technical information (Kibaara and Kavoi, 2012).

Besides the socio-economic farmer characteristics considered in the cited investigations, other studies carried out on the subject of technical efficiency of maize productivity dwelt on a few others such as family size, male versus female headship of the farm (Odendo et al., 2002) as well as subsistence mentality by farmers (Ali-Olubandwa et al., 2011). Ali-Olubandwa *et al*. (2011) on investigating the challenges facing small-scale maize farmers in the western region of Kenya in 2011 concluded that farmers in western Kenya region lacked awareness of improved agricultural practices and technical knowhow because the extension staff to farmer ratio was low. This negatively affected the farmers' efficiency. They further revealed that the region's farmers lacked finance for purchasing farm inputs due to poverty, but were risk averse and so did not acquire credit because they were afraid that they might be unable to pay back. The study put blame on late farm operations and lack of finance as the main factors that hindered maize production efficiency in the western Kenya region (Ali-Olubandwa *et al*., 2011).

The most important constraints found by Odendo *et al* (2002) in western Kenya were low soil fertility, low technical know-how and lack of financial resources to purchase inputs, especially fertilizers and seed. They ranked poor cash flow as a key constraint because they believed that alleviation of the constraint would lead to alleviation of many other constraints (Odendo *et al.*, 2002). Separately, Omonona found that farm size, farming experience and membership to a cooperative society are the major contributing factors to the efficient production of cowpea in Nigeria. He also established that a large family size exerted a positive effect on the efficient production of cowpea (Omonona et al., 2010).

2.5 Summary of Reviewed Studies

It became clear that there are common factors influencing maize production efficiency. In most cases reduced soil fertility is compounded by planting the wrong variety of seed and labour is used where machines would do better. Factors most often cited in relation to socioeconomic influences include the farmer's income from sources other than his/her farm, his/her age, his/her education level, his/her maize farming experience among others. The operation of all these factors in influencing maize yields and maize production efficiency has been explored on a national scale in Kenya and in other parts of the world. This study sought to find out the effect of the said factors in Busia County.

2.6 The Stochastic Frontier Analysis

This study made use of the Stochastic Frontier Analysis (SFA) to estimate the efficiency of maize production by small-scale farmers in Busia County. The stochastic frontier production function was proposed in 1977 and has since been used extensively in econometric modeling of production and estimation of efficiency (Battese and Coelli, 1992). It involves two random components, one associated with the presence of technical efficiency and the other being a traditional random error (Battese and Coelli, 1992).

The component associated with technical inefficiency of production is one-sided, and measures the extent to which the observed output deviates from potential output given a certain level of inputs and technology. Commonly, it is assumed that this component has an identical and independent half-normal distribution (Kibaara and Kavoi, 2012). The technical inefficiency component is assumed to be a vector of non-negative random variables δ_i, independently distributed and arising from the truncation at zero of the normal distribution with variance σ^2 and mean $E(\delta_i Z_i)$. Where, Z_i are coefficients that are determined. In other words the one sided component reflects technical inefficiency relative to the stochastic frontier and as such is greater than or equal to zero in value (Tijiani, 2006).

In this study, the term frontier in SFA was in reference to the maximum maize output for all levels of any set of factor inputs in the specified model for maize production. The estimated maximum potential maize output at the various levels of factor inputs was the frontier production curve. For any production unit whose output lies on the frontier, the technical inefficiency component is equal to zero and such a unit would be fully technically efficient. The technical inefficiency component is greater than zero for any output lying below the frontier (Kibaara and Kavoi, 2012). In other words, for farms that were less than fully efficient, observed output was lower than the frontier output. The inefficiency component for such farms was greater than zero. A negative relationship between the inefficiency component and maize output therefore denoted a decrease in inefficiency or an increase in efficiency (Kibaara, 2005). The term stochastic in SFA referred to the random component, which was separated from the inefficiency component of the error term as used in econometric models (Lawson *et al.*, 2004).

Many studies have explored the determinants of technical efficiency using the SFA. These include: Battese and Coelli (1992), Coelli *et al* (1998), Lawson *et al.*, 2004, Tijiani (2006), Kibaara and Kavoi (2012) among others.

In using the SFA it was assumed that farmers produced the maximum output from the available input factors. The approach therefore estimated a maximum maize output at the levels of a given set of factor inputs. The SFA method was used to compare the potential and observed maize output for an individual farm. The highest potential maize output for the farm was estimated from the factor inputs and farmer practices. This measure can be referred to as the maximal maize output on the frontier production curve (Lawson *et al.*, 2004). The observed output represents how efficient the individual farmer is in using the appropriate techniques and the available set of factor inputs. The farmer's specific socio economic factors may affect efficiency because they are related to his ability to manage the inputs. They formed the non-stochastic part of the error term in the econometric model.

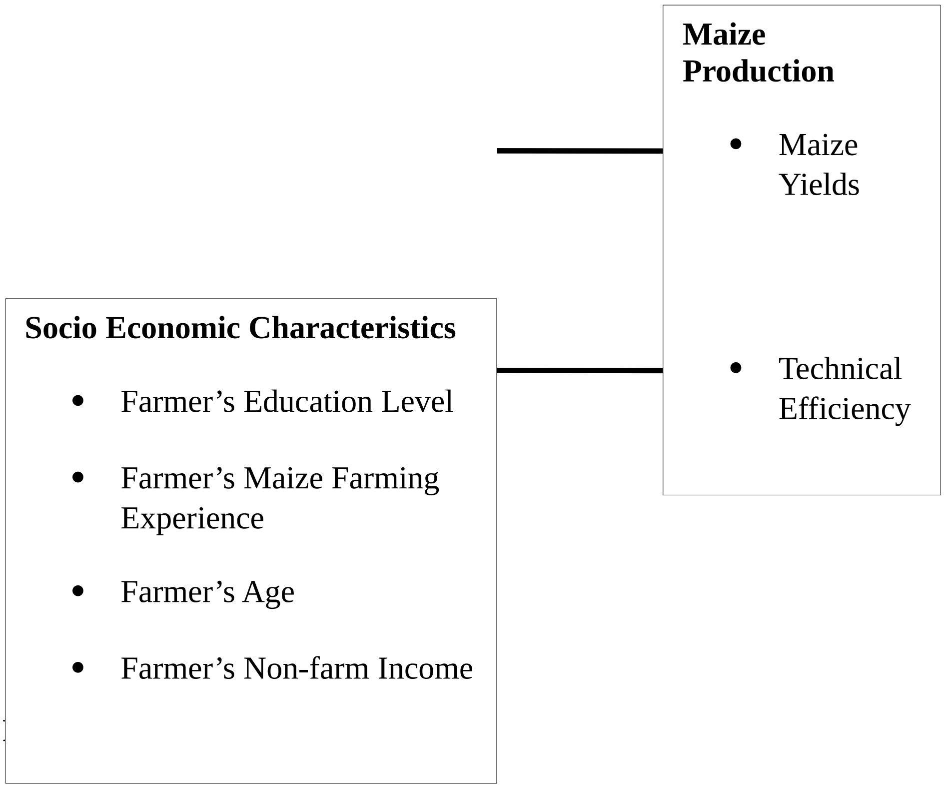
2.7 Conceptual Framework

This study assessed the extent of the effect of the following inputs on the yield of maize (in 90kg bags) by small-scale farmers in Busia County: the quantity of fertilizer applied, the quantity certified seed planted, the hours of hired labour employed, and the cost of machinery used. The farmers' specific socioeconomic factors were also examined to see the extent to which they influenced the level of technical efficiency of maize production in the County. These were the farmers': level of education, maize farming experience, off farm income and age. Diagrammatically, this was as shown in figure 2.1.

INDEPENDENT VARIABLES

- Quantity of Chemical Fertilizer used
- Quantity of Certified Seed used
- Hours of Hired Labour used
- Cost of Machinery used

DEPENDENT VARIABLES



Source: Author’s own Conceptualization, 2015

CHAPTER 3:

RESEARCH METHODOLOGY

3.1 Introduction

This chapter covers the research methodology and includes the theoretical framework, the study research design and the sampling design. It describes the data sources, data collection instrument and methods, as well as the data analysis procedure it also gives the assumptions for the study.

3.2 Research Design

This study used a survey research design, where the researcher tested the hypotheses of relationships between variables. A cross sectional research methodology was adopted to investigate a sample to determine the effect of a number of variables on the productivity of maize, and on the technical efficiency of maize production.

3.3 Target Population

Muyanga *et al*., describe small scale farmers as those cultivating farm sizes ranging between 0.5 hectares and 20 hectares (Muyanga *et al*., 2013); however, most of Kenya's maize is produced by farmers with fewer than three acres of land (Woolverton, 2012). This research therefore considered only farms of three acres and below for inclusion. The Kenya Bureau of Statistics put the population of such small-scale maize farmers in Busia County at 136,736 (Kenya Bureau of Statititics, 2013) and this number of farm households was the target population of this study. Household heads of these farming units charged with day-to-day decision-making in the farm were the respondents on behalf of their households.

3.4 Sampling Procedure and Sample Size

For this study, Busia County was the study area with the sampling frame being all the small-scale farmers with fewer than three acres of land under maize cultivation (Woolverton, 2012). This inquiry adopted a multi stage sampling procedure because of the large size of the area from which the sample was drawn. To take the sample conveniently, the County was divided into the seven administrative regions namely: Amagoro and Nambale Funyula and Budalangi (cash crop farming), Butula and Matayos (mixed farming), Funyula and Budalangi (fishing), and Busia Township (employment and trade) - Figure 1.1 (FAO, 2011). In consideration of the economic activities carried out in these divisions, Butula and Matayos sub-counties, (about 30% of the seven regions), were purposefully selected based on the fact that the economic activities in these two regions were predominantly mixed farming. Although Funyula and Budalangi are also dominated by mixed farming, the most common crops here are rice as acash crop in Budalangi and millet as afood crop in Funyula. From the selected two regions, the initial sample of 399 farms was drawn. The sample size of 399 was calculated using the formula 3.1 (Israel, 1992):

$$n = \frac{N}{\left[1 + N\left(e^2\right)\right]} \ldots 3.1$$

Where: n = sample size, N = population size and e = the accepted level of error. Given a population of 136,736 (Kenya Bureau of Statititics, 2013) and with ‘e’ at 0.05, the sample size for worked out at 399 farmers (Table 3.1).

Table 3.1: Calculation of Sample Size

Parameter	Notation	Result
Population	N	136736
	e	0.05
Sample size	N / 1+[N x $(e)^2$]	398.833

Source: Author, 2015

Of this initial sample size of 399, data was collected from 322. 77 respondents did not meet the inclusion criteria as far as farm size was concerned. Given the fact that the settlement patterns within the County are evenly distributed with minor concentrations in the urban centres (FAO, 2006), each of the sub-counties had about the same population in view of this, half of the sample respondents were taken from each of the two sub counties that had been selected.. This kind of design was also used by Ali-Olubandwa *et al*. in 2011 and by Deborah Masita in 2012.

3.5 Data Sources and Instruments

Primary data used in this study was collected using questionnaires and interviews with the heads of farms at their farms. A pre-tested questionnaire was administered by the researcher with the help of four enumerators. The enumerators were trained in advance on the handling of the research tool and briefed on the topic under study before being allowed to collect data. They were closely supervised by the researcher during data collection.

3.5.1 Instrument Validity and Reliability

The instruments were subjected to content validity through a pre-testing exercise for errors, vagueness or ambiguity in the questions. Questionnaires were given to twenty five farmers (6% of the sample size) from Bungoma County to complete. The data from the completed questionnaires were then checked and adjusted for relevance and correctness.

3.5.2 Data Collection Procedures

An introductory letter was sought from Moi University, School of Business and Economics to seek permission to carry out research. With the help of the enumerators, required data was collected through surveys using the structured questionnaires administered to the respondents. Any doubt that the respondents had on any questions were clarified on the spot during the interview. Data collection period took six weeks.

3.5.3 Data Analysis

Completed questionnaires were checked for accuracy before analysis. Data analyses were done using descriptive statistics and inferential statistics (multivariate regression analysis of the variables). A 5% level of significance was chosen for the analyses. Statistical analyses in this study were made with the help of computer software FRONTIER 4.1. Analyses were made for computation of certain indices or measures and for determining patterns of relationship that exist among the data groups.

3.6 Theoretical Framework

Efficiency is one of the most important considerations in the production process. It is measured by comparing the actually attained or realized value of the objective function against what is attainable at the frontier. Resource constraints make achievement of efficiency one of the important goals of the producer if he/she should wants to achieve growth (Alene, 2007). This is particularly true for places where the scarcity of resources is felt even more such as Africa and in particular Kenya. Analysis of efficiency in farm production is essential for formulation of appropriate policies aimed at food self-sufficiency in any community (ACDIVOCA, 2013); especially in places where food insecurity is known to exist like Busia County. Growth (more food) in production economics can be achieved through the introduction of more resources into the production process. However, where more resources are not forthcoming, the alternative is to improve on the efficiency of production. This underlines the importance of analysing technical efficiency in agricultural production with regard to making the availability of food adequate.

In microeconomic theory, economic efficiency is decomposed into technical and allocative efficiency (Alene, 2007). Technical efficiency is the ability to produce a given level of output with a minimum quantity of inputs under a particular type of technology. Allocative efficiency on the other hand, refers to the ability of using inputs in optimal proportions for given factor prices (Black *et al*., 2013). This study concentrated on technical efficiency, since the question as to whether or not the African small-scale farmer is economically rational and price responsive to make him allocatively efficient is not debatable (Alene, 2007). Instead, the answer to the question as to what factors explain why output on African farms is below what it can be is what should be sought after (KIPPRA, 2013).

The economic study of production aims at finding an optimum between outputs and inputs. The optimum is determined using several statistics such as productivity, technical efficiency and profitability (Metodi, 2014). This means that how efficiently production is carried out can be measured using any of these parameters. They are: the linear programming approach, the average factor productivity approach, the profit function methodology and the production function approach (Alene, 2007). Some of these have their shortcomings. The factor productivity approach investigates the influence of a single factor while disregarding the effect of a host of other factors, which also influence output. Similarly, a simple comparison of total factor productivity is not good enough since it ignores the fact that producers differ in their individual features and abilities. In farming, such features include non-farm income, subsistence needs, and input combining skills, among others which influence output. If profit methods were to be used, the assumption would be that all producers have maximization of profit as their principal objective. This is obviously not true going by economic theory. The only plausible measure of efficiency then is centered on the production function. The production function approach compares the actual production function to the potential or frontier function.

The frontier production function approach is the most widely used approach today because it is more closely related to the theoretical definition of a production function (Kibaara and Kavoi, 2012). The approach can be either deterministic or stochastic. Deterministic frontiers assume that all the deviations from the frontier are a result of the firm’s inefficiency, while stochastic frontiers assume that part of the deviation from the frontier is due to random events (reflecting measurement errors and statistical noise) and part is due to firm specific inefficiency (Chirwa, 2007).

In theory the producer is assumed to be rational. This means that he/she is assumed to want to maximize output from the least cost of inputs. In other words he/she is assumed to be technically efficient at his/her level of output. Technical efficiency is achieved when the producer cannot obtain a higher level of output from a certain amount of inputs given the existing technology (Hardwick *et al*., 1999). A cost minimizing producer (a rational producer) will spend a proportion of his total costs on each of his inputs (Black *et al*., 2013). He/she has to decide how much of each input to employ, how much labour, machinery, land and fertilizer; the objective being cost minimization (Metodi, 2014). This is not just an economic principle; it is of particular importance given the deeper scarcity of resources in poor countries (Tijiani, 2006). The producer must however keep in mind that varying combinations of the factors result in varying levels of output.

The combination of the factors hired depends on the substitutability of the factor inputs. Inputs may be perfect substitutes for each other; they may be completely unsubstitutable for each other and so must be combined in fixed proportions or they may also be smoothly but not perfectly substitutable for each other. In this case, the inputs can be substituted for each other although each unit of one input cannot give the same amount of output as each unit of a different output with which it is substituted. These three types of factor substitutability form the basis of production functions. The production function is a mathematical representation that shows the maximum quantity of output a firm can produce given the quantities of inputs that it might employ. It can generally be presented as $Q = f(L, K)$ (Carlton and Perloff, 2000); relating the maximum amount of output Q that can be produced and the inputs (L and K) required in making that output given a prevailing status of technology. Put in another way, the function gives for each set of inputs, the maximum amount of output of a product that can be produced (Hardwick *et al*., 1999).

The classification of the types of production functions is derived from this substitutability of factor inputs. According to Griffin *et al*., (1987) perfect substitutability between factors gives rise to the Constant Elasticity of Substitution (CES) type of function 3.2:

$$Y = A\,[\alpha K + (1-\alpha)\,L] \quad \ldots 3.2$$

Perfect factor unsubstitutabilty can be shown by the Leontief production function 3.3 (Griffin *et al.*, 1987):

$$Y = \min\,[\beta_1 X_1,\ \beta_2 X_2 \ldots \beta n X n] \text{ where } \beta_i > 0 \quad \ldots 3.3$$

The Cobb-Douglas production function 3.4 depicts the imperfectly substitutable type of factor input relationship (Mushunje, 2011):

$$Y = A\,L^{\alpha}\,K^{\beta} \quad \ldots 3.4$$

In all the equations above, Y is the output, α and β are constants between zero and one and A can be any positive number. X_is are factor inputs like labour (L) and capital (K).

Whatever the type of production function, the relationship depicted is that between factor inputs and output.

3.7 Specification of the Empirical Model

The regression model used was the Stochastic Frontier Analysis (SFA) based on the Cobb- Douglas production function 3.4.

Where (Bao Hong, 2008):

Y = total production (the yield of maize of all goods produced in a year)

L = labor input (the total number of person-hours worked in a year)

K = capital input (the monetary worth of all machinery, equipment, and buildings)

A = total factor productivity

α and β are the output elasticities of labor and capital, respectively. These values are constants determined by available technology (Bao Hong, 2008).

To make the model useful for ordinary least square estimation of the parameters or for regression analysis, it was linearised in its parameters. Consequently, constant returns to scale and a one to one substitutability between the factors were assumed.

Equation 3.4 was log-linearised to equation 3.5 (Bao Hong, 2008):

$$\ln Y = A + \alpha \ln L + \beta \ln K \qquad \ldots 3.5$$

The general form of the model was expressed as shown in equation 3.6 (Omonona *et al.* , 2010):

$$\ln Y_i = \beta_0 + \beta_i \ln X_i + (V_i - U_i) \qquad \ldots 3.6$$

Where:

Y_i was the production of the i^{th} farmer; it represented the dependent variable or maize output.

X_is represented the independent variables, which measured the inputs of the maize farm;

β was a vector of unknown parameters (Coelli, 2007).

V_i and U_i were the two elements which composed the error term. One error term V_i, represented the effect of statistical noise (such as weather, topography, measurement error, among others) or the effect of shock changes in the yield. V_i were random variables which were assumed to be normally distributed and independent of the U_i, that is, $N(0,\sigma V^2)$. The other error term U_i, was the efficiency indicator. It captured systematic influences that were unexplained by the production function and were attributed to the effect of technical inefficiency in production of maize. U_i were assumed to be positive, independent and normally distributed, that is, N(0,σU^2). U_i was a function of factors shown by equation 3.7 (Omonona *et al.*, 2010):

$$U_i = \delta_0 + \delta_i Z_i \qquad \ldots 3.7$$

Where:

Z_i was a column vector of hypothesized efficiency determinants and δ_o and δ_i were unknown parameters to be estimated (Coelli, 1996).

The general form of the model used was similar to the ones used in related studies by Tijiani (2006), Omonona *et al*. (2010), and Kibaara and Kavoi (2012) among others. The functional form of the stochastic frontier was therefore determined by the Cobb-Douglas function.

The empirical specification of the model was given by equation 3.8:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + (V_i - U_i)$$

$$\text{or} \quad \ln Y_i = \beta_0 + \sum_{i=1}^{4} \beta_i \ln X_i + (V_i - U_i) \qquad \ldots 3.8$$

and by equation 3.9

$$|u_i| = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4$$

$$\text{or} \quad U_i = \delta_0 + \sum_{i=1}^{4} \delta_i Z_i \qquad \ldots 3.9$$

The unknown variance parameter estimated in equation 3.8 is the variance associated with $\varepsilon_i = (V_i - U_i)$, that is, the composed error term. It was defined as in equation 3.10:

$$\sigma^2_\varepsilon = \sigma V^2 + \sigma U^2 \qquad \ldots 3.10$$

In functions 3.8 and 3.9, the measurements of the determination of inputs (X_i) and farmer characteristics (U_i) followed measurements used in related past studies like Tijiani (2006), Mignouna *et al*. (2010), and also Kibaara and Kavoi (2012).

Y_i= the production of the i^{th} farmer; it represented the dependent variable or maize output. The measurement for this variable was the yield of maize crop or the number of 90 Kg bags produced per acre planted;

X_1= the quantity of chemical or inorganic fertilizer used for cultivating the crop. It was measured by the number of kilogrammes of chemical fertilizer applied per acre.

X_2= the quantity of certified seed planted. It was measured by the number of kilogrammes of certified seed planted per acre.

X_3= the amount of hired labour used. This was measured by the number of person-hours employed per acre.

X_4 =Mechanization. This was the use of machines to plough the fields. It was measured by the expenditure on machinery used per acre in Kenya shillings.

Z_1 = the farmer's education level. This was measured in number of years of formal education achieved. It was categorized as follows: (a) no formal education, (b) 1 to 8 years of formal education or an average of 4.5 years, (c) 9 to 12 years of formal education or an average of 10.5 years, (d) 13 to 16 years of formal education or an average of 14.5 years.

Z_2 = the farmer's maize farming experience. This was measured by the number of years that the farmer had planted maize up to the time of the study.

Z_3= the farmer's age. This was measured as the number of years the farmer had lived since birth up to the time of the study.

Z_4= the farmer's non-farm income. This was defined as income received by the farmer from sources other than sale of farm produce in the year, and was measured in Kenya shillings.

3.7.1 The Ordinary Least Squares Estimation Procedure

Given functional and distributional assumptions, the maximum likelihood estimates of the parameters of the stochastic frontier production function in equations 3.8 and 3.9, that is β_0, β_i, δ_0 and δ_i as well as σU^2 and σV^2 were obtained using the FRONTIER 4.1 computer programme. Firstly, initial ordinary least squares (OLS) estimates were obtained for the parameters in the production model (equation 3.8). Secondly, a grid search for γ was made with the β parameters (Coelli, 1996). An estimated value of technical efficiency for each farm was then calculated using equation 3.11.

From the model specifications in functions 3.8 and 3.9, the estimated technical efficiency (TE) of each farmer was calculated as the observed maize yield divided by the potential maximum maize yield – Equation 3.11. It was used to measure their individual farm’s deviation from the frontier production curve (Lawson *et al*., 2004). Mathematically illustrated as:

$$TE = \frac{Actual \vee observed\ output}{Potential\ output}\ x\ 100$$

$$\beta_i \ln X_i + \left[V_i - ¿\, U_i\right]$$

$$\ln Y_i = \beta_0 + \sum_{i=1}^{4} ¿$$

$$¿$$

$$¿$$

$$TE = ¿$$

Or as per Lawson, *et al.*, (2004) and Tijiani, (2006),

TE = exp (-Ui) …3.11

If U_i did not exist in function 3.8, then the stochastic frontier production function would reduce to the traditional production function – indicating attainment of maximum efficiency. U_i therefore showed the average level of technical inefficiency and σU^2 showed the dispersion of the inefficiency level across observational units. V_i on the other hand could be obtained from its conditional expectation given the observed value (V_i - U_i) (Tijiani, 2006).

Fourthly, the producers were divided into three groups as per their level of technical efficiency namely: high efficiency farmers (technical efficiency of above 80%), medium efficiency farmers (technical efficiency of between 21% and 79%) and the low efficiency farmers (technical efficiency of below 20%). The inputs and socioeconomic characteristics were then analysed according to these levels of efficiency. Tests for the statistical significance of the parameters in the models, and the correlation coefficients were computed.

3.7.2 Assumptions of Ordinary Least Squares Estimation

In the ordinary least squares (OLS) estimation procedure, the error variance is assumed to be constant, otherwise heteroscedasticity is said to exist. The consequences of heteroscedasticity are that the estimated coefficients are unbiased but inefficient (Gujarati, 2004). Heteroscedasticity is common in cross-sectional data set such as the one used in this study, and so the Breusch Pagan test was used test whether or not heteroscedasticity was present in the data.

Another assumption of the OLS procedure that was tested was the presence of multicollinearity in the data set. The term multicollinearity means the existence of a linear relationship among some or all explanatory variables of a regression model which questions their usefulness as predictors of the dependent variable (Gujarati, 2004). To test for multicollinearity, the normal linear regression analysis was run including the variance inflation factor (VIF) diagnostic test. If the VIF value for any of the independent variables was to be greater than 3, then it would mean that some of the variables in the model were correlated.

Finally, in function 3.8, it was assumed that the efficiency indicator $U_{i,}$ which captured systematic influences that are unexplained by the production function and are attributed to the effect of technical inefficiency in production of maize, was a non-negative normal distribution N (0, σ^2). A kernel density function was plotted in order to confirm this assumption.

3.7.3 Overall Fit of the Regression Model

To evaluate the explanatory power of the regression production function 3.8, the analysis of variance (ANOVA) was tested. Gamma (γ), defined by equation 3.12 (Coelli, 2007) was also used to measure the goodness of fit and correctness of the U_i distribution assumption as given in the inefficiency function 3.9. Gamma measured the explanatory power of the inefficiency parameter in the error term:

$$Gamma,(\gamma)=\frac{\sigma U^2}{\sigma \varepsilon^2} \vee \gamma=\frac{\sigma U^2}{(\sigma U^2+\sigma V^2)} \ldots 3.12$$

The defined γ was expected to have a value between 0 and 1, as described by Coelli *et al* (Coelli *et al*., 1998). If inefficiency existed among farms, the estimated variance parameter γ was expected to be different from 0. However, if the parameter was 0, then the error term was expected to express the traditional random variation that is not under the control of the farmer (Lawson *et al*., 2004). Similarly, lambda (λ¿ given in equation 3.13 (Coelli, 2007), was used to determine which of the two between the U_i and V_i was the more significant component of the error term.

$$Lambda(\lambda)=\frac{variance\,of\,U_i}{variance\,of\,V_i} \ldots 3.13$$

The larger the λ would be, the greater an indication that the one sided error term U_i dominated the symmetric error V_i, such that variation in actual maize yield would then be explained more by differences in farmer’s practices rather than by the statistical white noise.

3.8 Assumptions of the Study

To effectively assess the effects of the inputs on production, it was assumed that all the factor inputs as well as the socio-economic characteristics had been taken into consideration even though questions could be raised as to whether all the inputs were actually accounted for (Wambui, 2005). It was also assumed that the producers had an identical production function.

CHAPTER 4:

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter discusses the results of the estimation of the Stochastic Frontier Model. A one step process was used to estimate the production function and technical efficiency using the maximum Likelihood method (Coelli, 2007). Individual farm level technical efficiencies were also estimated. The chapter presents hypotheses testing results.

4.2 Response Rate

Of the 399 targeted respondents in the sample, data was successfully collected from 322 (81%). A number of the farmers did not meet the inclusion criteria of planting maize on less than three acres and some did not consent to answering the questionnaire. The enquiry covered the farmers' inputs, their output/yield and their socio-economic characteristics over the 2014 maize planting year.

4.3 Yield

A summary of the relationships, as found by this study, between the yield and the factor inputs is given in table 4.1. The output per acre in 90 Kg bags ranged from a highest 45.00 (90 Kg) bags to a lowest 0.3 (90 Kg) bags among the farmers that responded. The mean output was 7.9 (90 Kg) bags per acre. The mean output for the County was close to that of seven bags per acre found earlier by Ali-Olubandwa *et al* (Ali-Olubandwa *et al.*, 2011). It meant that the level of maize productivity had not changed by much in the County since 2011 and was still comparatively low.

On average, per acre, farmers used 6.7 Kg of certified seeds and 29.8 Kg of chemical fertilizer. They hired on average 50.7 person-hours and spend Ksh 2,260.9 on mechanization.

Table 4.1: Production Data

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Yield (90 Kg bags/acre)	322	.30	45.00	7.885	6.080
Labour (Person-hours/acre)	322	.00	1250.00	50.663	101.197
Mechanization (Ksh/acre)	322	.00	22000.00	2260.879	2943.408
Certified Seed (Kg/acre)	322	.00	50.00	6.725	6.017
Chemical Fertilizer (Kg/acre)	322	.00	150.00	29.752	25.785

Source: Data Analysis Results, 2015

For analysis, the farmers were classified into three groups as per their level of technical efficiency namely: high efficiency farmers (technical efficiency of above 80%), medium efficiency farmers (technical efficiency of between 21% and 79%) and the low efficiency farmers (technical efficiency of below 20%). Figure 4.1 shows that the following combination of inputs was used by the most efficient farmers: 25.2 Kg of fertilizer, 6.6 Kg of certified seed, and 27.9 person-hours. They spend Ksh 994.3 average on tractor hire for land preparation. The medium efficiency producers' inputs on every acre were: 31.6 Kg of fertilizer, 6.7 Kg of seed, 53.1 person-hours and Ksh 2343.0 on tractor hire. The least efficient farms applied 20.5 Kg of fertilizer per acre, 7.09 Kg of seed, and 42.5 person-hours and spent Ksh 2096.2 to hire tractors. Appendix 3 details the average level of inputs used across various levels of technical efficiency.

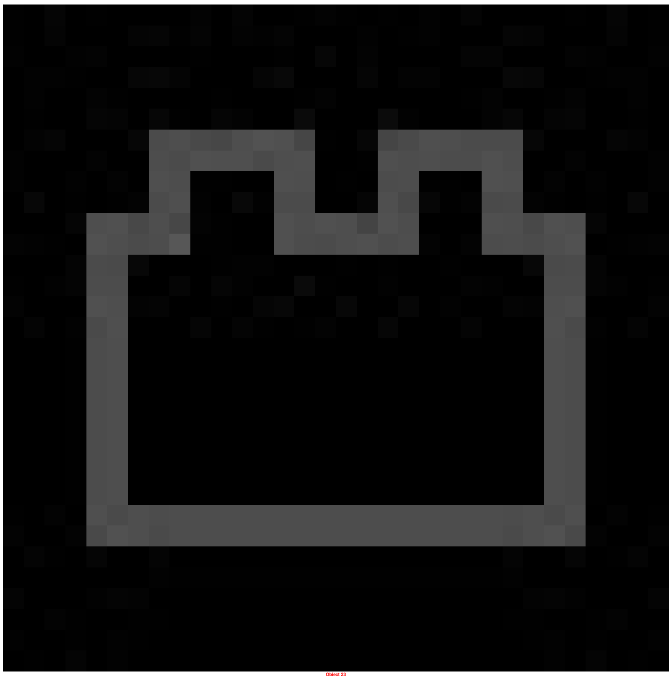


Figure 4.1: Inputs and Technical Efficiency

Source: Data Analysis Results, 2015

4.4 Farm Inputs and Yields

The total acreage put under maize production by the 322 farmers who responded to the questionnaire was 946.55 acres. Of these, about 20% was hired, the rest was owned by the farmers themselves. This worked out to an average of 2.94 acres per farmer. Figure 4.2 shows both the actual output as well as the potential output. The high efficiency producers had an average yield of 23 bags of maize per acre. Medium efficiency producers produced 8.38 bags of maize per acre on average, while the low efficiency ones produced 1.56 bags of maize per acre on average. In terms of efficiency, the most efficient producers had the potential to increase yields by 17%, medium efficiency farmers were doing 45% below their best while the least efficient could do better by about 85%.

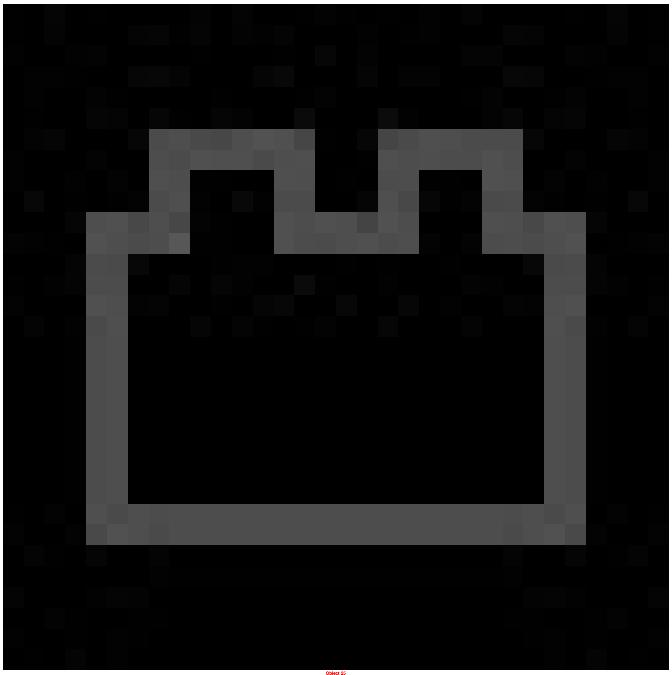


Figure 4.2: Average Maize Yields

Source: Data Analysis Results, 2015

Following is the analysis of the elasticity of yield for each factor input as given by the regression model.

4.4.1 Fertilizer Input

As shown in table 4.1, chemical fertilizer input per acre ranged from 150 Kg to 0.0 kg; with an average of 29.8 Kg per acre. The minimum fertilizer input of 0.0 kg per acre meant that some farmers did not use chemical fertilizers on their farms. Such farmers, as found out in this study, used organic fertilizer. Only a few farms did not use any fertilizer at all. The effect of the use of organic fertilizer on yields was assumed to be constant in this study seeing as most farmers used this readily available form of fertilizer in more or less the same amounts.

Out of the 322 firms that responded, 76% or 245 farmers were found to use chemical fertilizer in differing amounts. More farmers used chemical fertilizer compared to 2011 when only 54% such small-scale farmers had been found to be using such fertilizer in the County (Ali-Olubandwa *et al.*, 2011). Figure 4.1 reveals that in this study, the medium level technically efficient farmers were the heaviest users of chemical fertilizer, applying 31.6 kg per acre. However, the amount of chemical fertilizer applied by all the efficiency classes of farmers was still well below the recommended rate of 50 Kg per acre (Faidaseeds, 2014). This was possibly due to financial constraints given the high chemical fertilizer prices. This was consistent with the earlier report by FAO that fertilizer input in Africa in general was lower than it ought to be (Brinkman *et al.*, 2011).

From the stochastic production model, the relationship between the use of chemical fertilizer and yield was not statistically significant (p=0.207). This finding agreed with that made by Mignouna *et al*, (2010) in that they too found that greater use of chemical fertilizer did not significantly boost yields (Mignouna *et al*, 2010). A possible explanation for this unexpected condition could be that Busia County farmers may be using the wrong type of chemical fertilizer on their farms. It could be possible that the maize farmers use fertilizer meant for sugar cane (Busia's main cash crop) on their maize farms with inappropriate results given the difference in the nutritional requirements of the two crops. On the contrary Omonona *et al* (2010) on the efficiency of cowpea farmers in Nigeria found that greater use of chemical fertilizer did significantly boost yields (Omonona *et al.*, 2010).

Even though not statistically significant, the relationship between the use of chemical fertilizer and yield was positive. Increasing the use of fertilizer by 1kg would lead to improved maize productivity by 0.079 (90kg) bags, or 7 kilogrammes as shown on Table 4.3.

4.4.2 Seed Input

From this study, about 80% of the 322 responding firms planted certified seed. This showed a big improvement from 2011 when Ali-Olubandwa *et al* had found that only 32% of similar farmers used certified seed in the western Kenya region. The highest amount of certified seed input per acre was 50 kg while some farmers recycled their own crops as seed, planting 0.0 Kg of certified seed. It could be that such farmers do not know the benefit that they could gain from planting certified seed in terms of increased output. Figure 4.1 indicates that all the farmers planted about the same amount of certified seed regardless of their level of technical efficiency. However, this study found that the average quantity of seed planted was 6.7 Kg per acre and this also fell short of the recommended rate of 10 kilograms per acre (Faidaseeds, 2014).

At 1% level of significance, a positive and statistically significant relationship was found between the use of certified seed and maize yield ($p<0.001$). This conforms to *a priori* expectation. It means that the more kilogrammes of certified seed that was planted by the small-scale farmers in Busia County, the higher the level of maize yields they would get. Maize yields were found to be elastic only to certified seed among all the inputs studied as seen on Table 4.3. Specifically, a 1kg increase in the certified seed planted would boost maize yields by 0.203 (90kg) bags, equivalent to 18.27 kilogrammes of maize. This was consistent with the findings for farmers in the whole Country as per the study by Kibaara and Kavoi (Kibaara and Kavoi, 2012). However for the western Kenya region as a whole, the findings of Mignouna *et al*, (2010) differ. For them, a negative and statistically significant relationship was found between the use of certified seed and maize yield (Mignouna *et al*, 2010).

4.4.3 Labour Input

During the survey it was discovered that labour was readily available in the County and was relatively cheap. Farmhands were hired mainly to prepare the land for planting and to do the weeding and the harvesting of maize. In preparing the land for planting, farmhands cleared the land of thickets; they also tilled and ploughed the land. They transported the farm inputs like fertilizer, seed as well as the maize harvest. They worked for between seven to eight hours a day at a cost of Ksh 35 per hour on average. About 267 farms used hired labour. This represented 83% of the 322 firms. The average number of person-hours of hired labour employed by a firm was 50.7 hours per acre in the year. The highest of these was 1,250 person-hours per acre in the year, while some farmers did not hire labour at all, relying instead on family labour to do the entire cultivation – Table 4.1.

A negative statistically significant relationship between hired labour hours and maize yields was found to exist (p=0.027) at 5% level of significance. Table 4.3 shows that an additional hour of hired labour used reduced maize yield in Busia County by 0.001 (90kg) bags or 0.09 kilogrammes, unlike in the case of maize production in the whole of

Kenya (Kibaara and Kavoi, 2012), cowpea production in Nigeria (Omonona *et al.*, 2010) and maize production in Masindi District Uganda (Kibirige, 2008). In all the cases the relationship between hired labour hours and maize yields was positive. The possible reasons for this result could lie in the inappropriate employment of the hired workers in Busia County for example mothers being asked to weed the maize crop accompanied by their unweaned children, a common practice in the region or even in their assignment to duties not best suited to their ability on the farm.

4.4.4 Machinery Input

The only type of machinery found to have been used were tractors for preparing the land for planting. No machines were used during the planting, weeding or harvesting of maize. Most small-scale farmers in Busia County did not own tractors but hired them from the County Government or from other private owners. Tractors were made available across the County by the Busia County government for the farmers to hire for ploughing in the year 2014 (Buluma, 2014). The number of farms that used machines to prepare their land for planting was 151 out of the 322 or 47% of the respondents. The farmers spent an average of 2,260.9 Kenyan shillings per acre to hire machinery for the production of maize in the year. Some did not hire any machinery and so spent Ksh 0.0, while the highest expenditure on machinery was Ksh 22,000 per acre.

At 5% level of significance, there was found a positive and significant relationship between the use of machines and yields (p=0.022). This agreed with the findings of Kibaara and Kavoi (2012) for the whole Country (Kibaara and Kavoi, 2012). Yields would increase by 0.018 (90kg) bags of maize or 1.62 kilogrammes, with an additional investment of 1ksh on machinery in farming – Table 4.3.

Going by the average total inputs used, the high technical producers used fewer inputs than the low and medium technical farms as summarized in figure 4.3. Efficiency was negatively correlated to the amount of inputs used.

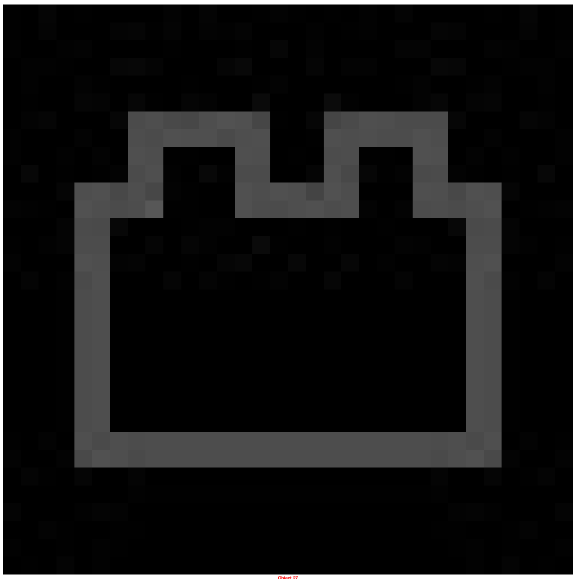


Figure 4.3: Technical Efficiency (TE) and Average Inputs

Source: Data Analysis Results, 2015

4.5 Estimated Potential Yield

Appendix 3 shows the potential yield of each farm which was arrived at using equation 4.1 ; this ranged between 0.3 bags and 45 bags per acre.

$$Potential\ yield = \frac{actual\ yield}{Technical\ Efficiency} \ldots 4.1$$

Source: Kibaara and Kavoi, 2012

The estimated potential yield averaged 14.68439 bags. This means that the small-scale farmers of Busia County had the ability to increase their yields to about 15 (90 Kg) bags from the computed 7.9 (90 Kg) bags. This would mean a possible increase of yields by 7.1 (90 Kg) bags per acre. Each farm's estimated potential yield was its frontier production function based on the inputs studied and the existing level of technology. The difference in actual yield from this frontier yield indicated the individual farm's shortfall from its potential output and therefore its level of technical inefficiency. Such difference was assumed to have been influenced by the specific farmer's socio economic characteristics.

4.6 The Socio-Economic Characteristics and Technical Efficiency

As stated above, the TE of the i^{th} farm was calculated using equation 4.2 (Tijiani, 2006):

$$TE_i = \exp(-U_i) \times 100 \text{ (i.e. as a percentage)} \quad \ldots 4.2$$

The mean technical efficiency scores were 53% and ranged between 5.1 and 90.5%. This compares well with the mean for the whole country of 49% found by Olwande (Olwande, 2012), but is lower than the western region's average of 63% found by Manyong *et al* (Manyong *et al.*, 2007). It is possible to increase maize output in Busia County by 47% from the current level of technology and input use. From the level of technical efficiency for each firm shown in appendix 3, about 50% of maize farmers operated below the mean technical efficiency level; only 33.5% were at least 60% technically efficient. These statistics are more or less the same as those found earlier in

2012 for the whole Country by Olwande (2012) who established that smallholder technical efficiency in Kenya ranged from 7.2% to 98.3%, with over 36% of maize farmers operating below the mean technical efficiency level Countrywide then, and only 30%, at least 60% technically efficient (Olwande, 2012).

Four farmer socio-economic characteristics were regressed for efficiency. They targeted the firm's head or main economic decision maker: his/her level of education, experience in maize farming, income from sources other than the farm and his/her age. On average, firm heads reported an age of 38.3 years, 11.1 years of farming experience, a non-farm income of Ksh 34,553.4, and 6.7 years of schooling as shown in table 4.2.

Table 4.2: Socio-Economic Characteristics

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Income (Ksh)	322	.00	400,000.00	34,553.427	66,244.727
Experience (years)	322	.00	40.00	11.0699	9.57121
Education (years)	322	.00	14.50	6.6537	4.87176
Age (years)	322	18.00	70.00	38.2578	12.19106

Source: Data Analysis Results, 2015

4.6.1 Farmer's Education Level

21% of the respondents had not received any formal education; 40% had attained up to 4.5 years of formal education; 25% had attained up to 10.5 years of formal education; and that 14% had attained at least 14.5 years of formal education. The distribution found by the study is shown in figure 4.4. The mean years of schooling for the entire sample were 6.7 years.

The study showed that at 1% level of significance there was negative and statistically significant relationship between years of formal education and efficiency ($p<0.001$). This meant that farmers with more years of education were more efficient since for the efficiency model. Since a negative relationship between the independent variable and the dependent variable implied a reduction in inefficiency or an increase in efficiency (Kibaara, 2005), due to an additional year of formal education gained, technical inefficiency would decrease output relative to the frontier function or the maximum possible output, given the existing level of technology and the inputs made.

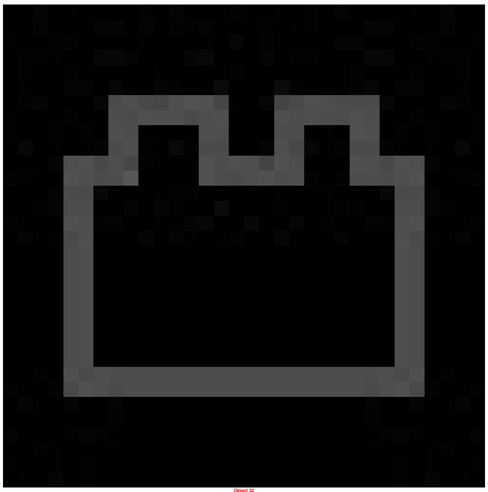


Figure 4.4: Distribution of Education Level Attainment

Source: Data Analysis Results, 2015

4.6.2 Farmer's Experience

As far as maize farming experience is concerned, some of the 322 firm heads had never engaged in maize planting before the year under study. The farmers possessed an average maize planting experience of 11.1 years, 40 years being the most experienced. Farming experience did not bear a statistically significant relationship with efficiency (p>0.05). This finding did not agree with those of Omonona *et al.*, 2010, that production experience gathered over years of practice significantly enhanced the level of technical efficiency. Farmers with more experience were not necessarily more efficient. This implied that a one-year increase in maize farming experience did not significantly influence farming decisions towards making more efficient use of the inputs.

As seen on table 4.3, the positive coefficient of the experience variable implies that an additional increase in maize farming experience by one year, increased inefficiency (or reduced efficiency) from the maximum possible output, given the existing level of technology and the inputs made. This could be the result of the repetitive nature of production methods and hence the need for adoption of new techniques.

4.6.3 Farmer's Age

An average age of 38.3 years was recorded for the farm heads. The oldest respondent was a 70 year old while the youngest was an 18 year old. The relationship between the age and technical efficiency was found to be negative as seen on table 4.3, such that an increase in the farmers age, decreased inefficiency (or increased efficiency) from the maximum possible output, given the existing level of technology and the inputs made. However, the relationship was not statistically significant and as a result, older farmers were not technically more efficient.

This could be attributed to the fact that older farmers are unwilling to adopt change in their farming methods that could raise their maize yields. They are less willing to execute the advice they get form extension services. Another possibility is that the older farmers did not put much emphasis on maize farming since they generally have alternative sources of income unlike young farmers who in most instances rely on the maize they plant to a greater extent for their upkeep.

4.6.4 Farmer's Non-farm Income

The income made by the farm heads off the farm was Ksh 34,553.4 on average, with 77(24%) reporting that they did not receive any such income in the past year. Those who had received such incomes got between Ksh 500 and Ksh 400,000 in the year. At 1% level of significance farmers with more off farm income were found to be more efficient, in other words, additional off farm income reduced technical inefficiency – Table 4.3. Higher off farm income was also significantly related with efficiency ($p<0.001$). Most probably, such income helped in the timely acquisition of necessary inputs like fertilizer and machinery. As such, low off farm income was an impediment to maize production in the County. One way in which this could have been overcome would have been through the acquisition of loans. However Ali-Olubandwa *et al*, (2011) had found that farmers in the western Kenya region did not take loans for farming for fear of paying large interest on the loans and for fear of having their land repossessed due to default on loan repayment.

4.7 Model Estimation

Table 4.3 summarises the estimated model. In the table, the negative sign on the variables for the number of years in school, off-farm income and age indicate that increases in the unit measurements of these variables reduced technical inefficiency (or increased technical efficiency) only farming experience decreased technical efficiency. However, of the four farmer characteristics studied, education and off-farm income were found to be statistically significant.

Table 4.3: Stochastic Frontier and Efficiency Models

Output Model			
Variable	parameter	coefficient	standard-error
Constant	β_0	2.089	0.193
Ln labour	β_1	-0.001**	0.029
Ln mechanization	β_2	0.018**	0.011
Ln seed	β_3	0.203***	0.056
Ln fertilizer	β_4	0.079	0.030
Efficiency Model			
Variable	Parameter	Coefficient	Standard-error
Constant	δ_0	1.347	0.126
Income	δ_1	-0.073***	0.027
Experience	δ_2	0.141	0.145
Education	δ_3	-0.206***	0.110
Age	δ_4	-0.078	0.390
Variance Parameters:			
Gamma (ϒ)			0.846
Mean technical efficiency			0.468
Sigma-squared (δ^2)			0.968
Log likelihood function			-353.746

** Significant at 5% level of significance

*** Significant at 1% level of significance

Source: Data Analysis Results, 2015

A positive relationship was found to exist between the yield and the use of chemical fertilizer, between the yield and the use of certified seed and between the yield and the use of tractors. This meant that a unit increase in these inputs led to an increase in maize yield. A similar relationship was also found to exist at the national level by Kibaara and Kavoi between the use of certified seed and yield, and between the use of tractors and yield (Kibaara and Kavoi, 2012) and also between the use of fertilizers and yield. In the western Kenya region, the relationship between the use of chemical fertilizers and yield and between the use of certified seed and yield was found to be negative by Mignouna *et al*. (Mignouna *et al*., 2010). The use of hired labour was negatively correlated with yield in Busia County as per this study.

The use of machines, hired labour and the amount of certified seed planted were the statistically significant inputs in the production of maize in the County while fertilizer was not a statistically significant input. More hours of hired labour reduced the yield of maize unlike the other three factors whose emphasized input lead to an increase in the level of output.

The estimated model was represented by the function shown by equation 4.3.

$$\text{Output/Yield} = 2.0894440 - 0.0014898\text{Ln}X_1 + 0.0184989\text{Ln}X_2 + 0.2027262\text{Ln}X_3 + 0.079305463\text{Ln}X_4 + (V_i - 1.3470742 - 0.072784014Z_1 + 0.14124526Z_2 - 0.20553269Z_3 - 0.078080307Z_4) \quad \ldots 4.3$$

Source: Data Analysis Results, 2015

4.7.1 Analysis of Variance Test Results

The results of the test for the explanatory power of the production regression equation (Table 4.4) showed that the ANOVA (Analysis of Variance) was significant. This implied that the independent variables in the production model significantly explained the variation in the yield.

Table 4.4: Analysis of Variance

	Sum of Squares	Degrees of freedom	Mean Square	F	Sig.
Regression	61.57	4	15.393	25.603	0.000
Residual	190.579	317	0.601		
Total	252.149	321			

a. Dependent Variable: Lnyield

b. Predictors: (Constant), Lnfertilizer, Lnlabour, Lnmachinery, Lnseed

Source: Data Analysis Results, 2015

Gamma, (γ) was used to measure the level of the inefficiency in the variance parameter. For the study model, γ was estimated as shown in equation 4.4.

$$Gamma, (\gamma) = \frac{\sigma u^2}{(\sigma u^2 + \sigma v^2)} = 0.85 (Table\ 4.3) \ldots 4.4$$

Source: Data Analysis Results, 2015

The gamma estimate of 0.85 was high meaning that much of the variation in the composite error term was due to the inefficiency component: or that 85 percent of the random variation in maize production in Busia County was due to inefficiency.

The estimate of lambda (λ) - the ratio of variance of U_i (σU_i^2) over variance of V_i (σV_i^2) was found to be as in equation 4.5:

$$Lambda(\lambda) = \frac{\sigma U_i^2}{\sigma V_i^2} = 2.3395965 \ldots 4.5$$

Source: Data Analysis Results, 2015

This was large and significantly different from zero, indicating a good fit and correctness of the specified distribution assumption. The large λ was an indication that the one sided error term U_i dominated the symmetric error V_i, so variation in actual maize yield was explained more by differences in farmer's practice - U_i, rather than random variability - V_i.

4.7.2 Test Results of the OLS Assumptions

The Breusch Pagan test was used to test for heteroscedasticity. Table 4.5 below shows the results.

Table 4.5: Breusch-Pagan / Cook-Weisberg Test for Heteroscedasticity

	Coefficient	Std. Err.	t	P>|t|	[95% Conf. Interval]	
lnlabour	-0.10514	0.07392	-1.42	0.157	-0.2514	0.04116
lnmachinery	-0.15713	0.101918	-1.54	0.126	-0.3588	0.04457
lnseed	0.356312	0.132357	2.69	0.008	0.09436	0.61826
lnfertility	0.256398	0.1053641	2.43	0.016	0.04787	0.46493
Constant	2.045425	0.9761017	2.1	0.038	0.113599	3.97725

Number of obs = 130;

F (4,125) = 4.68;

Prob > F = 0.0015;

R-squared = 0.1302;

Adj R-squared = 0.1024;

Root MSE = .72266

H_o: Constant variance Variables: fitted values of lnyield

$chi^2(1)$ = 0.06

Prob > chi^2 = 0.8080

Source: Data Analysis Results, 2015

The chi-square value was (0.06, p=0.8080). Since the Chi-square statistic was not significant ($p>0.05$), and the standard error for all the variables was less than 3, it was concluded that heteroscedasticity did not exist. This meant that for the values collected the error term variance did not depend on any of the independent variables. In effect, the yields of each of the individual farmers varied uniformly from the expected mean yield represented by theoretical regression line, validating the hypothesis testing as well as the analysis of variance (ANOVA) results.

A kernel density function was plotted and it showed a generally normal distribution of the U_i as shown in figure 4.5. This supported the normality in the distribution of the U_i - the efficiency indicator.

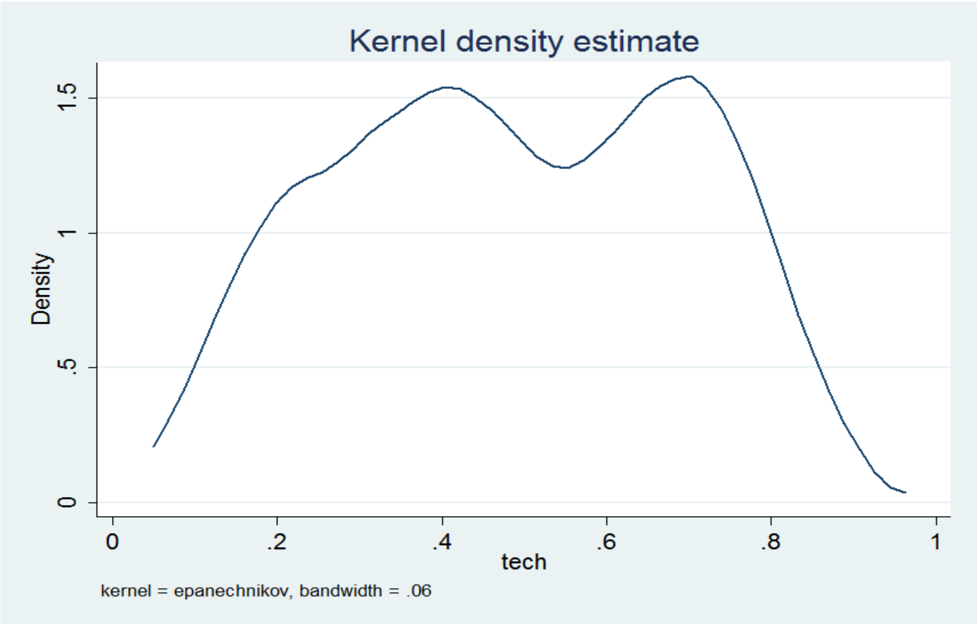


Figure 4.5: Kernel Density Estimate for "U_i"

Source: Data Analysis Results, 2015

The normal linear regression analyses run for the multicollinearity test showed that the variance inflation factor (VIF) was less than three as is seen on table 4.6. This meant that multicollinearity was not detected in the data and so it was okay to have all the independent variables used in the same model.

Table 4.6: Collinearity Regression Coefficients

	Un-standardized Coefficients		Standard-ized Coefficients			Collinearity Statistics	
	β	SE	β	t	Sig.	Tolerance	VIF
(Constant)	0.891	0.104		8.589	0		
Lnlabour	0.02	0.031	0.038	0.662	0.508	0.733	1.364
Lnmachinery	0.018	0.013	0.082	1.395	0.164	0.683	1.464
Lnseed	0.249	0.058	0.26	4.293	0	0.651	1.535
Lnfertilizer	0.126	0.033	0.232	3.765	0	0.626	1.598

a. Dependent Variable: Lnyield

Source: Data Analysis Results, 2015

CHAPTER 5:
SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

5.1 Introduction

This chapter gives an overview of the findings made in the study. It outlines the results of the hypotheses tests and gives policy implications of the study.

5.2 Summary

This study set out to provide estimates of technical efficiency of maize production in Busia County and to explain variations in technical efficiency among small scale farmers. A stochastic frontier model checked for heteroscedasticity and for a zero covariance between independent variables and the error term was used to generate technical efficiency estimates. Overall mean technical inefficiency was estimated at 47 percent. This meant that there was a 47 percent scope for increasing maize production through better use of the inputs. The levels of efficiency however varied greatly from 90.5% to 5.1% percent among the maize producers in the County.

Results showed that more years of formal education and higher off-farm income were associated with a higher technical efficiency; while greater age and farming experience did not improve efficiency. Similarly, the use of machinery and the planting of certified seed had a positive effect on the level of maize output. While the use of more hired labour hours and the greater use of fertilizer did not improve maize output.

5.3 Conclusions

Chemical fertilizer was found not to have a statistically significant relationship with the level of maize yields in Busia County leading to the failure to reject the null hypothesis. However, there was found to be a statistically significant relationship between the level of maize yields and the use of each of the following inputs: the use of certified seed, the cost of machinery used and the use of hired labour. As a result the null hypotheses were rejected with regard to each of these factors. Of the four factor inputs studied, more hours of hired labour and the use of more chemical fertilizer did not lead to higher output.

According to this study, the years of education and off-farm income bore a statistically significant relationship to technical efficiency of small scale maize production in Busia County. This led to the rejection of the null hypotheses in as far as these two efficiency factors were concerned. On the other hand the null hypotheses failed to be rejected with regard to the level of maize farming experience and the farmer’s age. This was because the famer’s age and his/her experience at maize farming were found not to have a statistically significant relationship to efficiency. The farmer’s years of education and off-farm income were significant contributors to technical efficiency of maize production in the County unlike his/her experience at maize farming and his/her age.

5.4 Policy Implications

Increased use of some farm inputs will help improve maize production, the main food item in Busia County. In this regard then, efforts could be made by the County Government to mechanise land preparation either through availing tractors for hire, or through direct purchasing. Subsidizing the hiring or purchasing of machines and starting loaning schemes at low interest rates are some methods that could help. To allay the fear of paying large interests on loans, advice needs to be given to the farmers about prudent financing of their farming activities. While most farmers are aware about the recommended levels of fertilizer and seed to use, they do not live up to these recommendations mainly because they cannot afford the said inputs. There is need for the Government to make seed and fertilizer more affordable. Facilitation of credit through setting up more microfinance loaning schemes would be a good way of financing such farm inputs. Collateral for loans to farmers could be tied to farm output for lack of alternative sources of security.

The study found that education has a positive impact on the technical efficiency in maize production. Steps need to be taken by the stakeholders to ensure that all children attend school because this will generate more efficient production. Higher non-farming income bolsters efficiency in farming. Ways should be found to increase earnings for residents in ways other than just farming. The commercial service sector could be activated to boost employment and incomes. Availing information on investment opportunities particularly in transportation and distribution of output could encourage investment that could earn farmers extra income. Such incomes may also be channeled into farming for example through the strengthening of farming cooperatives. Overall then it appears that solutions center around making funds accessible to the small-scale farmers in the County.

It is essential for the County Government to make policies that ensure that certified seed and farm machines are accessible and affordable to small-scale farmers in all parts of the County for improved maize production. This will ensure that the residents become self sufficient in matters of food provision.

5.5 Suggestions for Further Research

There are a number of directions in which this study can be extended. In the course of this study, it was found that many households also engaged in cultivation of sugar cane for sale. At the same time, the study only focused on the technical efficiency of maize production by small-scale farms of under 3 acres. In carrying out other studies, these additional variables could also be considered. Namely: the effects of cash cropping (sugar cane) and analysis of allocative efficiency of maize farming on farms of larger scales; to give more information on the efficiency of food production in the County.

REFERENCES

Abuje, J. (2012, July 20). Food insecurity rises in Busia County. 12-23. Nairobi: N.M.G.

ACDIVOCA. (2013). *Kenya – Kenya Maize Development Program.* Nairobi. Retrieved from www.acdivoca.org/site/ID/kenyaKMDP

AFAP. (2012, June). *Kenya Fertilizer Assesment.* Muscle Shoals: IFDC.

Alene, A. (2007). *Production Efficiency: Concepts, Approaches to Measurement, and Empirical Applications.* Pretoria, South Africa: Universitiet van Pretoria.

Ali-Olubandwa, A. M., Kathuri, N. J., & Odero-Wanga, D. (2011, October 23). *Challenges Facing Small Scale Maize Farmers in Western Province of Kenya in the Agricultural Reform Era.* Nairobi: Sciencedomain International.

Ariga, J., Jayne, T., Kibaara, B., & Nyoro, J. (2008). *Trends and Patterns in Fertilizer Use by Smallholder Farmers in Kenya, 1997-2007.* Nairobi: Tegemeo Institute.

Australia, R. S. (2011, November 15). Seed Services Australia. Perth, South Australia, Australia. Retrieved December 17, 2014, from http://solutions.pir.sa.gov.au

Ball, R., & Pounder, L. (1996, July). *"Efficient but Poor" Revisited* (Vol. 44). Chcago: The University of Chicago Press. Retrieved from www.jstor.org/stable/1154350

Bao Hong, T. (2008). *Cobb-Douglas Production Function.* New York: Jamador.

Battese, G., & Coelli, T. (1992). *Frotier Production Functions, Technical Effficiency and Panel Data: With Application to Paddy Farmers in India.* Boston: Kluwer Academic Publishers.

Black, J., Hashimzade, N., & Myles, G. (2013). *A Dictionary of Economics.* Oxford, United Kingdom: Oxford University Press.

Brinkman, R., Koohafkan, P., & Dudal, R. a. (2011). *Soil Fertility Management in Support of Food Security in Sub-Saharan Africa.* Rome: FAO.

Buluma, B. (2014, February 27). Local Farm Inputs. Nairobi: NMG. Retrieved June 12, 2014, from Standard Digital News: www.thenairobian.net

Bwire, F. (2014, June 28). Food Security: Busia Agriculture Officers' Report. Nairobi: NMG. Retrieved June 28, 2014

Carlton, W. D., & Perloff, M. (2000). *Economics.* Harlow: Pearson Education Publishers.

Chirwa, E. W. (2007). *Sources of Technical Efficiency among Smallholder Maize Farmers in Southern Malawi.* University of Malawi, Department of Economics. Nairobi: African Economic Research Consortium.

Coelli. (2007). *A Guide to frontier Version 4.1: A Computer Programme for Stochastic Frontier Production and Cost Function Estimation.* Armidale: The University of New England.

Coelli, T. (1996). *A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation.* Armidale: University of New England.

Coelli, T., Rao, D., & Battese, G. (1998). *An Introduction to Efficiency and Productivity Analysis.* Boston: Kluwer Academic Publishers.

ERA. (2012). *Economic Review of Agriculture.* Nairobi: Government printer.

Faidaseeds. (2014). *Maize Seed Variety.* Nakuru: Government Printers.

FAO. (2006). *Food Security District Profile-Busia District, Western Province.* Nairobi: Government printer.

Griffin, R. C., Montgomery, J. M., & Edward, R. M. (1987, December 2). *Selecting a Functional Form in Production Function Analysis.* Chicago: Western Agricultural Economics Association.

Gujarati, n. D. (2004). *Basic Econometrics.* Connecticut: The McGraw-Hill Companies.

Hardwick, P., Langmead, J., & Khan, B. (1999). *An Introduction to Modern Economics.* Edinburg, England: Pearson Education Limited.

Havrland, B., Kavka, M., & Růžička, M. (2006). *Influence of Factors on the Maize-Grain Mechanized Technology Net Margin.* Prague: Czech University of Agriculture.

Israel, G. D. (1992). *Determining Sample Size.* Florida: University of Florida.

Jones, B. J. (2012). *Inorganic Chemical Fertilizers and their Properties.* New York: CRC Press.

Kamau, D., Ayuo, A., & Kabete, P. (2014). *An Analysis of Credit Use and Expenditure on Agricultural Production - The Case of Maize Farming in Uasin Gishu County of Kenya.* Nairobi: Journal of Economics and Sustainable Development.

Kamau, M., Karin, F., Olunga, M., Onyango, K., & Makau, J. (2013). *Food Situation Assessment: October 2013.* Egerton University. Nairobi: Tegemeo Institute.

Kang'ethe, E. (2011, September). *Situation Analysis: Improving Food Safety in the Maize Value Chain in Kenya.* Nairobi: University of Nairobi.

Karanja, D. D., Jayne, T., & Strasberg, P. (2010). *Maize Productivity and impact of Market Liberalization in Kenya.* Nairobi: Tegemeo Institute.

KCBS. (2013). *Kenya Facts and Figures.* Nairobi: GOK.

KFSSG. (2012). *Crop, Livestock and Fisheries High Rainfall Areas Assessment.* Nairobi: F.E.W.S NET.

Kibaara, B., & Kavoi, M. (2012). *Application of Stochastic Frontier Approach Model to Assess the Technical Efficiency in Kenya's Maize Production.* Nairobi: Tegemeo Institute.

Kibaara, W. B. (2005). *Technical Efficiency in Kenya's Maize Production: An Application of the Stochastic Frontier Approach.* Colorado: Colorado State University.

Kibirige, D. (2008). *Analysis of the Impact of the Agricultural Productivity Enhancement Program on the Technical and Allocative Efficiency of Maize Farmers in Masindi District.* Kampala: University of Makerere.

Kilonzi, S. (2011, October). *Maize Production and Its Implication on Food Security for Small Scale Farmers in Bukhayo, West-Busia, Kenya.* Wageningen: Van Hall Larenstein University.

KIPPRA. (2013). *Creating an Enabling Environment for Stimulating Investment for Competitive and Sustainable Counties.* Nairobi: GOK.

Kothari, C. (2004). *Research Methodology.* New Delhi: New Age International Publishers Ltd.

Lawson, L., Bruun, J., Coelli, T., Agger, J., & Lund, M. (2004). *Relationships of Efficiency to Reproductive Disorders in Danish Milk Production; A Stochastic Frontier Analysis.* Copenhagen: American Dairy Science Association.

Manyong, V., Alene, A., Olanrewaju, A., Ayedun, B., Rweyendela, V., Wesonga, A., . . . Bokanga, M. (2007). *Baseline Study of Striga Control using IR Maize in Western Kenya.* Nairobi: International Institute of Tropical Agriculture.

Masita, D. K. (2012). *Determinants of household food security in rural areas of Kenya: a case of Busia County, Kenya.* Nairobi: University of Nairobi.

Metodi, U. (2014, July 21). *Theories of Production*. Retrieved August 6, 2014, from www.uiah.fi/projects/metodi/121.htm

Mignouna, D., Mutabazi, K., Senkondo, E., & and Manyong, V. (2010). *Adoption of a New Maize and Production Efficiency in Western Kenya.* Cape Town: International Institute of Tropical Agriculture (IITA).

MOA. (2013). *Food Security Situation as at 31st March 2013.* Nairobi: Government Printer.

Muasya, W. N., & Diallo, A. (2001). Development of Early and Extra-early Drought and Low Nitrogen Resistant Varieties Using Exotic and Local Germplasm for the Dry Mid Altitude Ecology. *Seventh Eastern and Southern Africa Reagional Maize Conference* (pp. 253-259). Nairobi: GOK.

Mushunje, A. (2011, June 18). *Farm Efficiency and Land Reform in Zimbambwe.* Retrieved July 5, 2014,

from www.ufh.netd.ac.za/bitstream/10353/98/6/Mushunje/thesis/ch5.pdf

Muyanga, M., Sitko, S., Jayne, T., & Hichaambwa, M. (2013). *Medium Scale Farmer Growth Trajectories in Africa: Implications for Broad-Based Growth and Poverty Reduction.* Nairobi: Tegemeo Institute.

Ndufa, J., Cadisch, G., Poulton, C., Noordin, Q., & Vanlauwe, B. (2005). *Integrated Soil Fertility Management and Poverty Traps in Western Kenya.* Nairobi: Kenya Forestry Research Institute.

Odendo, M., De Groote, H., Odongo, O., & Patrick, O. (2002). *Participatory Rural Appraisal of Farmers' Criteria for Selection of Maize Varieties and Constraints to Maize Production in Moist-Midaltitude Zone of Western Kenya - A case study of Butere-Mumias, Busia and Homa Bay Districts.* Nairobi: KARI.

Olwande, J. (2012). Small Holder Maize Production Efficiency in Kenya. *Regional Workshop on an Integrated Policy Approach to Commercializing Smallholder Maize Production.* Nairobi: Tegemeo Institute.

Omonona, B., Egbetokun, O., & Akanbi, A. (2010, March 1). *Farmers Resource – Use and Technical Efficiency in Cowpea Production in Nigeria.* Ibadan: Institute of Agricultural Research and Training,Obafemi Awolowo University.

Peñalba, L. M., Paunlagui, M. M., & Elazegui, D. D. (2012). *The Role of the Informal Credit System in the Agricultural Innovation Promotion Chain.* Philippines: University of the Philippines Los Baños.

Sawe, K. (2014, February14). *What to do when selecting maize seed.* Retrieved June 14, 2014, from The Organic Farmer: www.theorganicfarmer.org

Skjöldevald, M. (2012). *Small scale farmers' access to and participation in markets-The case of the P4P program in Western Kenya.* Uppsatser Fran Kulturgeografiska Intitutionen, Department of Human Geography. Stockholm: Stockholm University.

Tijiani, A. (2006, June). *Analysis of the technical efficiency of rice farms in Ijesha Land of Osun State, Nigeria.* Lagos: Agrecon.

Verma, S. (2008). *Impact of Agricultural Mechanization on Production, Productivity, Cropping Intensity Income Generation and Employment of Labour.* Punjab: Punjab Agricultural University.

Wambugu, P., & Muthamia, Z. (2009). *The State of Plant Genetic Resources for Food and Agriculture in Kenya.* Kenya Agricultural Research Institute, National Genebank of Kenya. Nairobi: FAO.

Wambui, B. K. (2005). *Technical Efficiency in Kenya's Maize production: An Appilcation of the Stochastic Frontier Approach.* Department of Agricultural and Resource Economics. Fort Collins: Colorado State University.

WEMA. (2010). *Reducing Maize Insecurity in Kenya - the WEMA Project.* Nairobi: The African Agricultural Technology Foundation.

WFP. (2005). *An Impact Study:"Nutrition & Care of People Affected by HIV/AIDS" Busia District, Kenya.* Nairobi: United Nations WFP (Kenya Office).

Wilshaw, R. (2013). *Exploring the Links Between International Business and Poverty Reduction: Bouquets and beans from Kenya.* Nairobi: Oxfam.

Woolverton, A. (2012, June 6). *Towards a Commercial Model:*

The Kenya Maize Farmer's Perspective. Nairobi. Retrieved from andrea.woolverton@fao.org