TECHNICAL EFFICIENCY OF SUGARCANE MONOCULTURE AND SUGARCANE- SOYBEAN INTERGRATION AMONG SMALLHOLDER FARMERS IN AWENDO SUB-COUNTY, KENYA

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MAY, 2018

DECLARATION AND RECOMMENDATIONS

Declaration

This research thesis is wholly my original work and to the best of my knowledge has not been presented for the award of any degree course at any other University.

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DEDICATION

This thesis is dedicated to my parents Modicayo Orwa and Pamela Ouko, my siblings Oscar, Eunice and Derrick and my wife Cherine for their love, courage and sincere support.

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ABSTRACT

Sugarcane and soybean are emerging value chains in Awendo Sub-County of Kenya with the potential for alleviating the perpetual problems of food and nutrition insecurity, poverty and unemployment among the rural households. Agricultural extension officers have educated farmers on the economic benefits of sugarcane-soybean integration but the uptake and performance of this cropping system has not been evaluated. This study therefore aimed at contributing to increase in farmer's household income by improving the level of technical efficiency of sugarcane and soybean production among smallholder farmers in Kenya .The study was based on utility maximization theory and the production theory of the firm. A semi-structured questionnaire was used to collect cross-sectional data from smallholder sugarcane and soybean farmers administered by trained enumerators. A sample of 246 sugarcane and soybean farmers was obtained using multi-stage sampling method. The sample comprised of 154 sugarcane monoculture farmers and 92 sugarcane-soybean intercrop farmers. A logit model was used to assess the socio-economic characteristics influencing the choice of cropping systems among smallholder sugarcane farmers while a Cobb Douglas stochastic production frontier model was used to estimate technical efficiency of sugarcane and soybean production among smallholder farmers in Awendo Sub-County. A two- limit Tobit model was used to identify factors influencing technical efficiency and Stochastic Frontier Analysis was used to estimate the efficiency levels. Sugarcane farming experience, age of the farmer, acreage, marital status (divorce and widowed) and land ownership were the factors influencing the choice of sugarcane cropping system. Results have shown that sugarcane-soybean integrators were more efficient than sugarcane monoculture farmers and the variable land under sugarcane production was the single most important variable in influencing farmers' efficiency. The mean technical efficiency of 62% and 64 % showed that the potential exist to increase output by 38% and 36% for non-integrators and integrators respectively with the present technology. This study recommends that sugarcane farmers be encouraged to allocate part of their land to production of soybean to enhance food security and improve household income. It further recommends that there is need for training sugarcane and soybean farmers on farm inputs optimum utilization by the extension agents in Awendo Sub-County, Kenya.

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ABBREVIATIONS AND ACRONYMS

CAADP: Comprehensive African Agricultural Development Program

CIDP: County Integrated Development Plan

DEA: Data Envelopment Analysis

DFA: Distribution Free Approach

ERS: Economic Recovery Strategy

FAO: Food Agricultural Organization

FDH: Free Disposal Hull

GDP: Gross Domestic Product

GoK: Government of Kenya

KESREF: Kenya Sugar Research Foundation

KNBS: Kenya National Bureau of Statistics

KSB: Kenya Sugar Board

MT: Metric Tonnes

NGO: Non- Governmental Organization

OLS: Ordinary Least Squares

PSRP: Poverty Reduction Strategy Paper

SFA: Stochastic Frontier Approach

SRA: Strategy to Revitalize Agriculture

SBI: Sugarcane Breeding Institute

SONY: South Nyanza Sugar Company

TFA: Thick Frontier Approach

TE: Technical Efficiency

TC: Tonnes of Sugarcane

TCH: Tonnes of Sugarcane per Hectare

CHAPTER ONE
INTRODUCTION

1.1 Background Information

Agriculture is the backbone of Kenya's economy. The contribution of the sector to the country's Gross Domestic Product (GDP) has been declining over the years from 40 percent in 1963, 33 percent in 1980s to 27 percent in 2014 (KNBS, 2015). The sector however remains dominant sector in the overall economy. The sector accounts for about 60 percent of the foreign exchange in Kenya and about 16 percent of the formal sector employment (KNBS, 2015) and also provides for self-employment. The Kenya's development policy for the medium term (2000 - 2030) continues to recognize agriculture as an important sector for the economy, with priority centred on food security initiatives and provision of employment opportunities (Okuro *et al*., 2000). For the agricultural sector to play this central role in the economy rapid growth in output and productivity are critical and the role of sugarcane and soybean in the subsector is important as well.

In Kenya, sugarcane is mostly grown in rural areas of western parts of the country, which also predominantly comprises of low income earners (KNBS, 2007). Historically, sugarcane has been one of the most important crops in the Kenyan economy alongside tea, coffee, horticulture and maize. According to KSB (2010), the sugar sub-sector contributes about 15% of the agricultural GDP. By far, the largest contribution of the sugarcane industry is its silent contribution to the rural economies in the sugar belts. Farm households and rural businesses depend on the injection of cash derived from the sugar sub-sector. The survival of small towns and market places is also dependent on the incomes from the same. Besides the socio-economic contributions, the industry also provides raw materials for other industries such as bagasse for power co-generation and molasses for a wide range of industrial products including ethanol (KSB, 2010).

Over the years, the total land brought under cane production has been increasing in the sugar belts. Commercial sugarcane farming has transformed more arable land, particularly in the former Western and Nyanza provinces into expansive monoculture landscapes than any other single plantation crop (GoK, 2006). The total area under cane production in Kenya as at March 2013 was 206,809 hectares and the estimated area and yields by 2014 was 224,925 hectares and 100 tonnes cane per hectare (tch), respectively (KSB, 2010).The increase in area under cane is due to high cane demand because of new mills and expanded capacity of most sugar factories. The sugarcane growing is comprised of both the smallholder farmers as well as the nucleus estates commissioned by the sugar factories. The smallholder farmers supply 92% of the sugar milled in the country and the rest is provided by the nucleus estates (KSB, 2010). The smallholder farmers comprise about 85% of the cane growers in the country (GoK, 2007).

Sugar production in Kenya has grown from 548,206 MT of sugar in 2009 to 639,741 MT in 2016. During the same period, the quantity of sugar consumed increased from 762,023 MT in 2009 to 972,599 MT in 2016 (KSB, 2017). The deficit in meeting domestic sugar consumption needs from imports has grown from 169, 761 MT in 2009 to 334,109 MT in 2016 (KSB, 2017).On the other hand, the country's average yields have continued to decline to a low of 58.9 tch in 2011 from the historical high of 137 tch in 1973 as compared to scientific potential of 100 tch (KESREF, 2011), this is in spite of improved sugarcane production technologies such as introduction of new cane varieties developed by KESREF. This average yield is very low compared to other COMESA countries like Egypt 126.4 tch, Zimbabwe 93 tch, Tanzania 85 tch and Malawi 113 tch (MAFAP, 2013).

Despite the immense potential of sugarcane production in Kenya, the farmers have always reported low yields. The poor performance puts at risk the livelihoods of over 250,000 small scale farmers who depend on the sector. Currently, Kenya is witnessing a massive challenge in meeting the ever growing demand for sugarcane products by achieving self-sufficiency in sugarcane production. This could be due to increase in small scale growers who have autonomy in their operations. This leads to adoption of diverse farm practices which contribute to low sugar cane yields. The un-sustained supply of sugarcane to the processing industries has led to a steep increase in the sugar price in the country. The cost of sugar production in Kenya is currently estimated at USD 870 per MT which is twice the cost of production in other COMESA competing countries. This is very high compared to Zimbabwe (USD 300), Malawi (USD 350), Swaziland (USD340), Sudan (USD 340), and Zambia (USD 400), (Kenya National Assembly, 2015).

In Awendo Sub-County, Kenya, approximately 60 percent of arable land is under cash crop, 30 percent under food crop and 10 percent is left fallow (CIDP, 2013). Sugarcane occupies 2,400 ha within the nucleus of SONY factory with over 18,000 ha under the out growers

(CIDP, 2013). Sugarcane is mainly grown under contract between farmers and South Nyanza (SONY) Sugar Company. SONY Sugar Company was incorporated by the Kenyan Government in 1976 and commissioned in 1979 with the objective of generating economic, social and financial gains for the local community and the country through the manufacture of mill white sugar for local consumption. (SONY Sugar Company, 2009). The SONY Sugar Company contributes 15% of the sugar produced in Kenya and is only second to Mumias Sugar Company that contributes 53% (GOK, 2007). The performance of the company therefore has a significant impact on the sugar industry in Kenya. Over the years, the company has experienced production shortfalls, with sugarcane delivery to the factory by contracted farmers declining from 603,646 tonnes of sugarcane (tc) in 1998/99 to 464,754tc in 2011/12 against a target of 651,600tc; while the non-contract farming has been on the rise from 45,133tc to 81,338tc over the same period (FAO, 2013).The continuous production shortfalls is likely to hurt the sugar industry in Kenya; since the country is already a net importer of sugar to meet the domestic consumption.

Table 1: Kenya Sugar Demand, Supply and Consumption Schedule

Figures in tonnes	Production	Consumption	Imports
2009	548,206	762,023	169,761
2010	523,652	772,731	258,578
2011	490,210	783,660	139,076
2012	493,937	794,844	238,589
2013	600,179	841,957	238,046
2014	592,668	860,084	192,121
2015	635,674	889,233	247,392
2016	639,741	972,599	334,109
Average annual growth rate	3%	3%	-7%

(Kenya Year Book of Sugar Statistics, 2017).

Kenya has been experiencing a steady rise in the domestic demand for sugar. The gap between sugar production and consumption has continued to increase making Kenya a net importer of sugar as shown on the Table 1.

1.1.1 Soybean Production in Kenya

Soybean is an important crop in the world. It has been the dominant oilseed produced since the 1960s (Smith and Huyser, 1987) and is used as human food, livestock feed, and for various industrial purposes (Myaka *et al*., 2005). While most other beans contain 20% protein, soybean contains 40% (Greenberg and Hartung, 1998). Soybean products are cholesterol free and high in calcium, phosphorus, and fibre and have one of the lowest levels of saturated fat among vegetable oils, all these explain the high demand for soybean products (Greenberg and Hartung, 1998).Soybean grows to a height of 60–120 cm, maturing in 3 to 6 months (depending on variety, climate, and location). The pod is hairy and contains two to three seeds. Soybean grows best if planted in pure stands (Chianu *et al.*, 2008). Biophysical conditions in many parts of Kenya favour the production of soybeans. Former Nyanza province accounts for 11% to 15% of Kenyan land area potentially suitable to soybean cultivation and Awendo sub-county falls within this agro-ecological zone (FAO, 2008). There are five soybean varieties that have been used in the country for a long time namely Nyala, Hill, Black Hawk, Gazelle and EAI 3600 (FAO, 2008).

Currently, about 6000 – 7000 MT a year of soybean is produced in Kenya against an annual local demand of 50,000 MT. Human consumption accounts for 10% to 15%, meaning that the deficit is met through imports (Mahasi *et al.*, 2010). Nationally, FAO (2008) data estimates an average yield of 800 kg per ha of soybean. Jagwe and Owuor (2004) estimated the cost of producing soybean in western Kenya to be about US$ 175 per metric ton. Data from FAO indicate that the cost of soybean production in the United States of America ranges from US$ 160 to US$ 170. This shows that soybean production in Kenya can be competitive in the global market and can further be improved upon if the cost of soybean production can be reduced through comprehensive research on efficiency, ecological, edaphic, and agronomic factors (Jagwe and Owuor, 2004).

1.1.2 Sugarcane–Soybean Integration

Soybean cultivation with other crops in the same piece of land often benefits the subsequent crop from the surplus nitrogen left in the soil after soybean has been harvested .Soybean improves soil fertility by adding nitrogen from the atmosphere (Sanginga *et al.*, 2003). Some varieties fix 44 to 103 kg N per ha annually (Sanginga *et al*., 2003). This nitrogen fixation capacity of soybean is an important benefit to agricultural production where the soils have become exhausted and where fertilizers are too expensive for many farmers. Mineral fertilizers are too expensive for the generally resource-poor farmers to afford quantities sufficient for sustainable agricultural intensification. Advantage must be taken of this nitrogen fixation ability of soybean. With the right variety, soybean yields could be over 3 tons per ha, (Chianu *et al*., 2009).

Soybean and sugarcane presents the farmers with the much needed alternative cash income source. In the Economic Recovery Strategy (ERS) for wealth and employment creation, the Kenyan government identified agriculture as an important vehicle for the realization of its employment creation and poverty reduction objectives. According to this strategy, the government's vision is to transform Kenya's agricultural sector into a profitable economy (GoK, 2004). This transformation calls for fundamental shift to market oriented production, diversification of agriculture such as sugarcane-soybean integration and adoption of greater use of appropriate farming practices. Soybean is one such crop that has the potential to make significant contributions to healthcare (GoK, 2002; Ohiokpehai and Osborne, 2003), income and livelihood security. In Awendo Sub-County soybean is one of the emerging crops that have been identified along with sugarcane and other major crops which will contribute to pillar for the economic growth and are therefore being promoted along the value chain (CIDP, 2013).

1.2 Statement of the Problem

Sugarcane is a major cash crop produced in the agro-ecological zones of Awendo Sub-County of Kenya either as a monoculture or intercrop system. Despite the increase in total land allocation brought under cane production by the smallholder farmers and improved production technologies developed by various research institutes such as Kenya Sugar Research Foundation (KESREF), there has been a steady decline in sugarcane yields over the past few years in Awendo Sub-County. This implies that increase in land size under cultivation and technological advances generated through research have not widely translated to increased sugarcane production.

On the other hand, other alternative crops with potential benefits such as soybeans have emerged and are being promoted by agricultural extension officers as one of the value chains in Awendo Sub-County. Soybean is regarded as both a subsistence and cash crop and can be intercropped with sugarcane. However, the uptake and performance of this cropping system and technical efficiency measures in Awendo Sub-County have not been evaluated. This research intended to address this knowledge gap by comparing the technical efficiency of sugarcane monoculture and sugarcane soybean intercrop among smallholder farmers in Awendo Sub-County.

1.3 Objectives of the Study

1.3.1 General Objective

To contribute to increase in farmer's household income by improving the level of technical efficiency of sugarcane and soybean production among smallholder farmers in Awendo Sub-County, Kenya.

1.3.2 Specific Objectives

1. To determine the socio-economic characteristics influencing the choice of sugarcane cropping system among smallholder farmers.
2. To determine the level of technical efficiency of sugarcane monoculture and sugarcane- soybean integration among smallholder farmers.
3. To determine farm and farmer characteristics affecting technical efficiency of sugarcane monoculture and sugarcane-soybean integration among smallholder farmers.

1.4 Research Questions

1. What are the socio-economic characteristics influencing the choice of sugarcane cropping system among smallholder farmers?
2. What are the levels of technical efficiency of sugarcane monoculture and sugarcane soybean integration among smallholder farmers?
3. What are the farm and farmer characteristics affecting technical efficiency of sugarcane monoculture and sugarcane- soybean integration among smallholder farmers?

1.5 Justification of the Study

The Strategy to Revitalize Agriculture(SRA) succeeded by Agricultural Sector Development Strategy(ASDS), Kenya Vision 2030,Compehensive African Agricultural Development Program (CAADP) and Alliance for Green Revolution in Africa (AGRA) have all emphasized the need to continually increase agricultural productivity in efforts to fight poverty. The Kenya vision 2030 has identified agriculture as one of the key sectors to deliver the 10 per cent annual economic growth rate envisaged under the economic pillar and sugarcane and soybean has been identified as some of the crops which will contribute to the pillar for economic growth (GoK, 2007). Agricultural production is an important revenue generating activity to the people of Awendo Sub-County and among the key value chains being promoted in Awendo Sub-County are sugarcane, coffee, soybeans, sweet potato, horticulture, sunflower, tea and cotton (CIDP, 2013). This study thus, would establish the technical efficiency level of sugarcane and soybean farmers, and identify the determinants of inefficiency in sugarcane and soybean farming. This would serve as baseline information to help both peasant and commercially oriented farmers to avoid practices that lead to inefficiency and better harness the opportunities farm specific characteristics present to achieve higher yields. Secondly, the outcome of this study would help policy makers in Kenya to determine which farm inputs and technical services to promote among sugarcane and soybean farmers to achieve increased production and reduce farmer inefficiency. Finally, the study would augment the body of knowledge available on sugarcane and soybean production especially in the area of technical efficiency in Awendo Sub-County of Kenya. The findings in this study are expected to serve as a baseline for other similar studies in Awendo Sub-County.

1.6 Scope and Limitation of the Study

The study was confined to Awendo Sub-County in Migori County of Kenya with the sample drawn from 246 smallholder sugarcane and soybean farmers. It only focused on 2014/2015 production season data. The study did not look at the overall economic efficiency as it relied on the assumption that smallholder sugarcane and soybean farmers are allocatively efficient hence only the technical efficiency level was examined therefore it focussed on production constraints of sugarcane monoculture farmers and farmers practising sugarcane- soybean integration with respect to their technical efficiency. This study relied on the farmers’ ability to recall past information in cases where the farmers did not keep records to answer the questions correctly; this posed a challenged but was overcome by probing the farmers further.

1.7 Operational Definition of Terms

Sugarcane monoculture: this the agricultural practice where a farmer grows sugarcane as a single crop season after season in the same land, in the absence of rotation with other crops.

Sugarcane-soybean integration: is a form of mixed farming in which a farmer grows sugarcane and soybean as an intercrop in his farm in such a manner that there is an interaction and complementarities between sugarcane and soybean in terms of inputs use.

Technical efficiency: this is the ability of the farmer to maximize output from a given level of input or from a given set of resources.

Household: Defined as an independent male or female farmer and his/her dependants who must have lived together for a period not less than six months. The members are answerable to one person as the head and share the same eating arrangement.

Smallholder farmers: These are defined in this study as farmers with at most 10 hectares of total arable land whether entirely used for sugarcane or not and a maximum of 1 ha of arable land used for soybean production.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview of Sugarcane Cropping Systems in Kenya

The agricultural sector in Kenya is constrained by a number of factors such as the high costs of inputs resulting in low application of fertilizer and certified seeds, which thereby affect agricultural productivity (GoK, 2007). Cropping systems are the yearly sequence and spatial arrangement of crops and fallow on a given area. The objective of any cropping system is efficient allocation of all resources, maintaining stability in production and obtaining higher net returns. Cropping systems are sustainable when they involve successful management of resources to satisfy changing human needs while maintaining and enhancing environmental and natural resource conservation (SBI, 2011).Sustainable crop mixtures promote efficient utilization of incident solar radiation, thus exploiting variations between component crops in rates canopy development, photosynthetic efficiencies and rooting depth (Amolo *et al.,* 2014).

Crop integration is a form of cropping system which occurs in many forms and allow more efficient use of resources than specialized systems and spreading of risks. According to Barlas *et al*. (2001), the key dimensions of the integration of alternative farm enterprises (AFEs) are technological dependence and dependence on markets of the two enterprises. Integration occurs where the components of the farm are interdependent (Savadogo, 2000). These integrated systems provided a greater variety of products to a farm household than a single enterprise can do. One of the most common rationales for crop integration is to reduce environmental (climate shocks), ecological (pest and diseases) and economic risk associated with uncertainty and variations of net (aggregate/farm) income Integration of crops serves as a means of maximizing the use of limited farm land, food security of farmers, higher yields are obtained, suppressing the germination of weed seeds and reducing the level of inorganic fertilizer requirement (Barlas *et al*., 2001). In Kenya sugarcane is either grown under monoculture cropping system or as an intercrop. Sugarcane monoculture is where the crop is continuously or successively grown for many years followed by a shorter duration of natural fallow period for land preparation in readiness for the next crop (Amolo *et al.,* 2014). Successive systems are unsuitable since they harbour deleterious fungi and nematodes which retard plant establishment and early growth leading to decline in sugarcane productivity

(Pankhurst *et al*., 2005). Fallow sugarcane cropping system are either natural fallows(farms left under natural vegetation after sugarcane crop) or improved legume fallows where farms are rotated with alternative crops such as grain legumes for 8-12 months. In addition, the fallow systems may also be farms newly introduced to sugarcane for the first time. Natural fallows are common in the sugarcane growing areas in Kenya but the period varies from a few weeks to months. According to Pankhurst *et al*. (2004), improved fallows have moderate to neutral soil pH, high sugarcane yields and few or absence of parasitic nematodes. Yield improvements of 20-30%were achieved when sugarcane monoculture was broken with soybean (Garside *et al*., 2005).

2.2 The Concept of Technical Efficiency

Technical efficiency measures the relative ability of the farmers to get the maximum possible output at a given level of input or set of inputs. Technically efficient farmers are those that operate on the production frontier which represents maximum output attainable from each input level. All feasible points below the frontier are technically inefficient points. According to the neo-classical definition of technical efficiency, a production process is technically efficient if and only if it yields the maximum possible output from a give level of technology and input set. The concept of efficiency can be explained more easily using input or output-oriented approaches. The input -oriented approach measure of efficiency addresses the question “by how much can input quantities be proportionally reduced without changing the output quantities produced?” The output-oriented approach measure of efficiency addresses the question “by how much can output be increased without increasing the amount of input use by utilizing the given inputs more efficiently?” (Coelli *et al*., 1998).

2.3 Measuring of Efficiency

There has been a growing demand in developing methodologies to be applied for measurement of efficiency. Early methodologies were deterministic frontier models which attribute all deviations from maximum possible output only to inefficiency. However, recent improvement on early methodologies has made it possible to separately account for factors beyond and within the control of decision makers such that only the latter that causes inefficiency. Developments in production frontier have been an attempt to measure productive efficiency.

Generally efficiency measurements involve a comparison of actual performance with optimal performance located on relevant frontier. Since the true frontier is unknown, an empirical approximation is required. The approximation is normally called a “best-practice” frontier. Approximation of the best practice frontier can be done using parametric or non- parametric techniques. Both techniques put emphasis on optimizing behaviour subject to constraints. Berger and Humphrey (1997) identifies at least four different types of approaches (data envelopment analysis, free disposal hull, stochastic frontier approach, and thick frontier approach) that have been employed for determining the best-practice frontier against which relative efficiency scores are measured. However, there is no agreement on which is the best method. The differences in these methods lies in the differences on the assumptions made on:

i. the functional form of the frontier, be it a parametric or a nonparametric functional form;
ii. whether a random error is included; and
iii. if there is random error, what probability distribution is assumed for the efficiency scores?

2.3.1 Non-parametric Approaches

Data Envelopment Analysis (DEA) is a Non-parametric technique. It builds a linear piece-wise function from empirical observations of inputs and outputs, without assuming any a priori functional relationship between the inputs and outputs. Efficiency measures are then calculated relative to this surface. Another non-parametric method of estimation is the Free Disposal Hull (FDH). It is a special case of the DEA model, because it includes only the DEA vertices and the free disposal hull points, interior to these vertices. Thus, the FDH usually generates larger estimates of average efficiency than the DEA. Both DEA and FDH approaches allow the variation of efficiency over time and do not impose any a priori functional form to the distribution of inefficiency scores. They do not suffer multicollinearity and heteroscedasticity but testing of hypothesis is not possible

2.3.2 Parametric Approaches

The Stochastic Frontier Approach (SFA), also referred to as the econometric frontier approach, specifies a functional form for the cost, profit, or production relationship among inputs, outputs, and environmental factors, and it allows for random errors. Another parametric approach is the Distribution-Free Approach (DFA), which also designates a functional form for the frontier, except that it assumes that the efficiency of each firm is stable over time, whereas the random error tends to average out to zero over time. Finally, the Thick Frontier Approach (TFA) specifies a functional form and it assumes that deviations from the predicted performance values from the highest and lowest performance quartiles of the observations (stratified by size class) represent random error, while deviations in predicted performance between the highest and lowest quartiles represent inefficiency (Berger and Humphrey, 1997). Parametric methods are susceptible to misspecification errors. The advantage is that it becomes possible to test hypotheses.

Based on the reviewed literature and weaknesses associated with non-parametric methods, parametric method (SFA) was used in this study. The choice was made on the basis of the variability of agricultural production which is attributed to climatic conditions, insect pests, and diseases, on one hand. On the other hand, data gathered from small scale farmers is usually inaccurate because they do not keep up to date records; accuracy depends on the farmer's recall capability. The stochastic frontiers method simultaneously took into account the random error and the inefficiency component in estimating a frontier function (Bravo-Ureta and Pinheiro, 1997). Non- parametric methods have drawbacks since it forces all outputs to a frontier yet sensitive to outliers if large, it distorts efficiency measurements (Ogundele *et al*., 2006).

2.4 Empirical Review of Literature on Technical Efficiency

2.4.1 Studies conducted using Stochastic Frontier Analysis

A study conducted by Wakili (2012) to estimate technical efficiency of sorghum production in Hong Local government area of Adamana State, Nigeria used SFA and found that the mean technical efficiency of sorghum was approximately 73%. According to this research, major factors found significant in explaining efficiency were education levels of the farmers, household size, contact with extension agents and experience in sorghum farming. It was concluded that estimation of efficiency was of vital importance since increased production is directly related to production efficiency.

In a study to determine technical efficiency among the bulrush millet producers in Bomet, Bureti and Kericho districts in Kenya, Ngeno et *al*. (2011) found that there existed technical inefficiency among the bulrush millet producers. Technical efficiency could be increased by 28 to 56% through better use of resources given the current state of technology. It was proposed that policy strategies aimed at improving technical efficiency in the short run should emphasize on effective and efficient use of the current technology transfer instruments, which enhance capacity of the farmers to efficient use of physical inputs. Though technical efficiency was determined, factors that influenced it were not identified. Identification of these factors would be important especially when making policy recommendations.

A study was conducted by Elibariki and Shuji (2008) to explain productivity variations among smallholder soybean farmers in Tanzania. Technical efficiency using SFA approach was estimated and the results showed that efficiency ranged from 0.011-0.910 with a mean of 0.606. Approximately 40% loss in output was due to technical inefficiency because the resources were not efficiently utilized. According to the findings of the study, farmers' ages and education, access to credit, family size and access to fertilizer influenced efficiency. It was recommended that government should improve provision of agricultural credit and extension services in order to improve technical efficiency. This recommendation called for renewed public support to revamp the agricultural extension systems, which have been neglected since mid-1990s.

Chirwa (2007) estimated technical efficiency of maize smallholder farmers in Southern Malawi and identified factors that explain variations in technical efficiency using SFA one stage simultaneous estimate approach. It was found that many households were technically inefficient with an average of 46.23% and a low of 8.12% technical efficiency. Use of maize hybrid and club membership increased efficiency. It was concluded from this study that there is need to promote adoption of hybrid seeds among smallholder maize farmers and enhance social capital through revival of farmer organizations or through creation of agricultural cooperatives. Chirwa focused on maize, which is input intensive, and also used one stage estimation approach, which has been argued by Banker, Chang and Cooper (1996) not being very effective in identifying factors influencing efficiency.

While estimating the level of technical efficiency of Arabica coffee producers in Cameroon, Nchare (2007) used a translog stochastic production frontier and maximum likelihood method in identifying and analysing variables affecting efficiency. Technical efficiency varied from 0.24-0.98 with an average of 0.90. Ten percent of the output was lost due to specific inefficiencies pertaining to farms. Education and access to credit were the main socio-economic variables that affected technical efficiency. It was recommended that government should increase farmer's capacity on education and access to credit to increase technical efficiency.

From the above literature is evident that SFA has gained considerable ground in agricultural economics. Most studies using parametric methods have focused on other agricultural crops but not sugarcane and soybean which are important crops in Sub-Saharan Africa. This study will add on to literature on technical efficiency of smallholder sugarcane and soybean production**.**

2.4.2 Determinants of Technical Efficiency

For the purposes of policy implications in efficiency analysis, it is not only the level of efficiency that is important, but also the identification of the factors that influence it. Several studies have measured technical efficiency and its determinants among different types of farmers and countries, which provide useful information for this study. However, efficiency in these studies is relative and tends to be specific to the farmers' groups and country under study.

A number of approaches have been used in the identification of factors influencing technical efficiency, which may vary to some extent with the methodology employed. The most commonly followed procedure in most of the approaches is what is usually referred to as the two-step procedure. In the first step, the efficiency or inefficiency score is estimated. Secondly, the estimated score is taken as a dependent variable and is then regressed against a number of other explanatory variables that are hypothesized to affect efficiency levels (Coelli *et al*., 2002). The various methods used in regression include OLS and Tobit regression models.

Empirical studies have attempted to investigate the relationship between technical efficiency and the various farm and farmer characteristics such as levels of education, age, gender of the household head, family size, access to credit, extension services and experience (Kibaara, 2005; Chavas *et al*., 2005; Yusuf and Malomo, 2007; Abu, 2011; Chimai, 2011; Chiona, 2011; Nyagaka *et al*., 2011 and Nyanjong' *et al*., 2012). Other factors identified include membership to agricultural groups, land ownership, value of household assets, use of fertilizers and methods of cultivation adopted (Chirwa, 2007; Kariuki *et al*., 2008; Chimai, 2011 and Nyagaka *et al*., 2011). While some of the factors identified in studies can provide a general idea of what affects efficiency, generalization may not be possible because each country and agricultural product has unique characteristics.

The literature reviewed in this study revealed that most of the studies failed to explain the implication of technical efficiency on production cost which constraints farmers. What would be the implication on production cost if farmers improved their TE? What if farmers reduced their input application? What about if they attained the TE of the most efficient farmer? This would be important in guiding a smallholder farmer on the effects on costs since they are resource constrained. Therefore, this study was undertaken to assess the technical efficiency of sugarcane monoculture and sugarcane-soybean integration among small holder farmers in Awendo Sub-County while paying attention to the identified gaps, above.

2.6 Theoretical Framework and Conceptual Framework

2.6.1 Theoretical Framework

This study was based on utility maximization theory and production theory of the firm.

2.6.1.1 Utility Maximization Theory

The decision to integrate sugarcane and soybean and to undertake sugarcane monoculture can be regarded as a binary choice. This is because of the binary nature of the dependent variable, that is to integrate or not. Therefore, the binary choice model is true if the following conditions hold true.

i. The households are faced with two alternative choices
ii. Any choice a household makes depends on its socio-economic characteristics

The binary choice model is based on the foundation of utility maximization theory, therefore the net expected utility that is accrued from integrating or not integrating sugarcane and soybean is estimated as follows in equation (1) and (2);

$$Eu_i A = f(X_i) + e_i \quad (1)$$

$$Eu_i N = f(W_i) + e_i \quad (2)$$

$Eu_i A$ is the expected net utility of household i from integrating sugarcane and soybean enterprises. A is a denotation of sugarcane-soybean integration. N denotes sugarcane monoculture. X_i and W_i are independent variables which denote farmer characteristics, physical and economic, influencing the decision and e_i is error term. The expected net utility from each of the decisions is then compared such that: $Eu_i A - Eu_i N > 0$ or $Eu_i A - Eu_i N < 0$. Y_i is then used as an indicator of whether household i integrate or not, so that $Y_i=1$ if they integrate and $Y_i=0$ if they do not integrate.

$$Y_i = 1 \text{ if } Eu_i A - Eu_i N > 0 \quad \text{……………………………………………………………..…..} (3)$$

$$Y_i = 0 \text{ if } Eu_i A - Eu_i N < 0 \quad \text{………………………………..…………………..……….} (4)$$

Equation (3) implies that the probability that the household *i* participates in sugarcane-soybean integration is given by the probability that the expected net utility derived from participation is greater than the expected net utility derived from non-participation. While the probability that the household *i* does not participate in integration is given by the probability that the expected net utility derived from participation is less than the net utility derived from non-participation as shown in equation (4).

2.6.1.2 Production Theory of the Firm

A firm is a decision making unit that is involved in production. Production involves transforming inputs into outputs and the objective of production is to create value through transformation. The firm seeks to obtain the maximum possible returns (outputs) from a given set of resources. The theory of the firm is built on the idea of rationally calculating optimizing agents using a production function. The production function is the backbone of the theory of the firm. It describes the current state of technology and how inputs can be transformed into outputs (Coelli *et al.*, 1998). A farmer's sugarcane or soybean production function can be expressed as

$$Y = f(x) \quad \text{……………………..……………………………………………………………} (5)$$

Where Y is the total sugarcane or soybeans output and x is n x1 vector of variables that includes the physical units used in the production process such as land, labour and capital. The production function assumes the properties of non-negativity, monotonicity, concavity and weak essentiality. The non-negativity assumption ensures that the function f(x) results only in zero positive outputs of sugarcane from production. Monotonicity implies that additional units of inputs used in the production do not decrease the total production and therefore the marginal products of inputs used in the production are expected to be non-negative. Weak essentiality implies that positive quantities of at least one of the inputs used, planting material, are necessary to produce any sugarcane. The weak essentiality assumption is valid because it is not possible to produce any sugarcane without any planting material. The concavity assumption restricts the output obtainable from a linear combination of inputs to be no less than the sum of the outputs obtainable from each input on its own.

The objective of the producer is to maximize profit either by increasing the quantity of Y produced or by reducing the cost of producing Y. The production function shows the maximum amount of the good that can be produced using alternative combinations of factors of production. Figure 2.1 below illustrates a simple illustration of Farrell's (1957) to measure productivity and efficiency which is an extension of works by Koopman *et al.* (1951) and Debreu (1951) were assumption of two input firm to produce an output. Assume a firm is using only land and labour to produce output (Y). Loci AA' is an isoquant representing different combinations of inputs that produce same amount of output. AA' is the maximum output a firm can produce from different combination of input. A firm producing along AA' is technically efficient since it is producing along the efficiency frontier. DD' is an isocost line, it represents different combinations of cost ratios that yields the same total cost. It is the minimum cost combination. A firm with an objective of maximising output produces at point Q', where the least cost combination of two inputs is tangential to the isoquant.

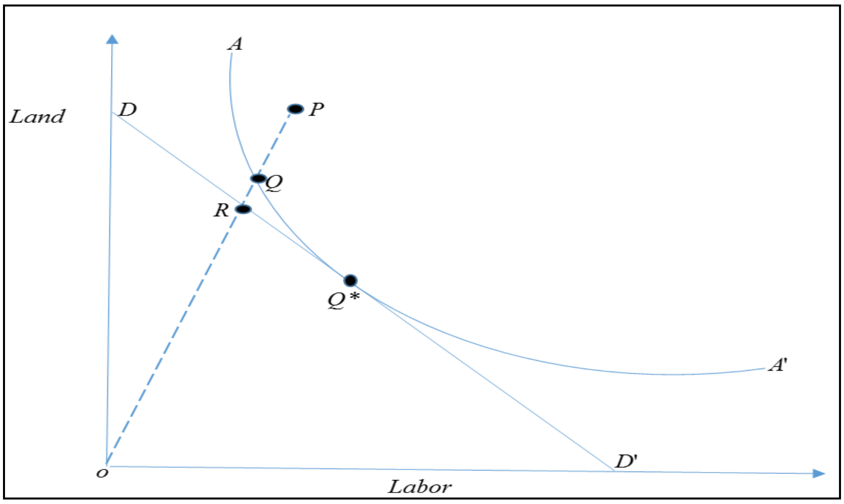

Figure 1: Input oriented decomposition function

2.6.2 Conceptual Framework

In this study, the production process was a function of several factors which were classified as; farm and farmer characteristics, institutional factors and technical factors. These factors determined the mix used to optimize on agricultural production. The decision making process is one of the household (farmer) characteristic that determine how the four questions in production are answered that is; what to produce, when to produce, how much to produce and for whom to produce, therefore decision making process at the household influence sugarcane and soybean production process taking into account the technical factors such as land size under production and farm labour and the various institutional factors. On the other hand, environmental and policy aspects (intervening variables) plays a big role in determining the efficiency of available resources for increased technical efficiency. The government policy such as minimum wage will influence the availability of labour for agricultural productivity. It also included the biophysical environment that is climatic factors such as amount of rainfall, drought and other environmental concerns that are exogenous to the farmers' day- to- day operations, since they influence technical efficiency at the household level. All these factors influence decision making process at the household level on whether to integrate sugarcane and soybean or not to integrate, which in turn will influence the technical efficiency levels and resulting output levels for improved household incomes and ultimately improved livelihoods. The conceptual framework is presented in Figure 2.

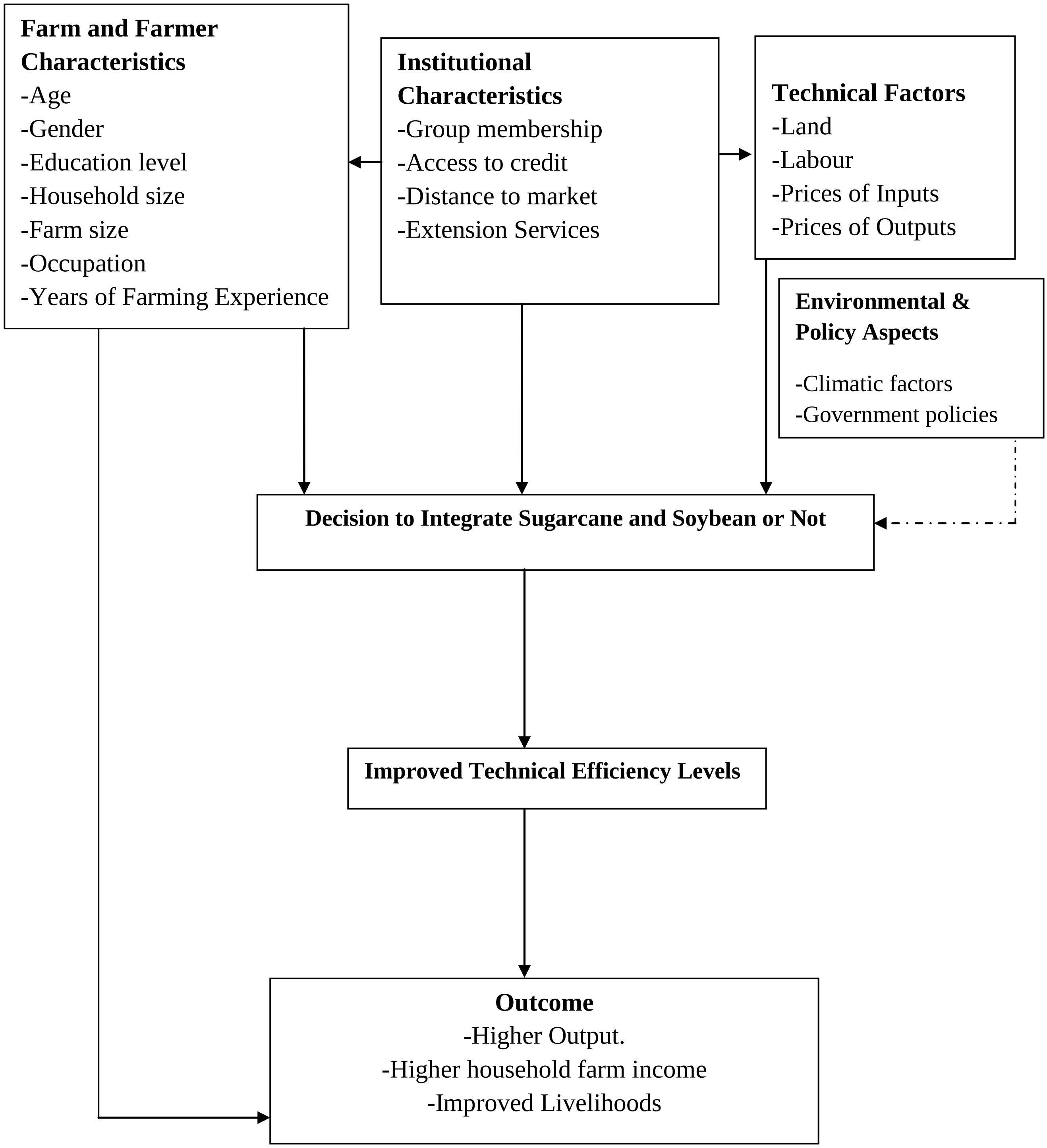

Figure 2: Interaction of Variables under Study
Source: Own Conceptualization

CHAPTER THREE
METHODOLOGY

3.1 Study Area

The study was conducted in Awendo Sub-County which is located in Migori County in South Western part of Kenya. The Sub-County consists of four wards namely, North Sakwa, South Sakwa, West Sakwa and Central Sakwa. The sub-county covers an area of 261.90 km^2 (KNBS, 2010). Figure 3.1 highlights the study area setting.

The Sub-County enjoys a bimodal rainfall pattern ranging from 700mm to 2,200mm (PRSP, 2004).The long rain commences in February/March and continues up to June while the short rain starts in July/August and ends in November. Temperatures range between 21^0 C and 35^0 C. The soil ranges from deep red clay loam soils to black cotton soil. Therefore, the climate and soils are suitable for the cultivation of sugarcane which is the main industrial crop. Other major crops include soybean, tobacco, and beans .The land tenure is mainly freehold and each landowner can be granted a freehold title deed in respect of their land parcels (CIDP, 2013).

According to the national census 2009, the population of the sub-county stands at 108,913 persons (KNBS, 2010). The main economic activities in the sub-county include agriculture, manufacturing and mining. Specifically, this study focussed on Awendo Sub-County in the South Nyanza Sugarcane belt where the SONY Sugar Company operates because of its significant contribution to the sugar industry in Kenya (CIDP, 2013).

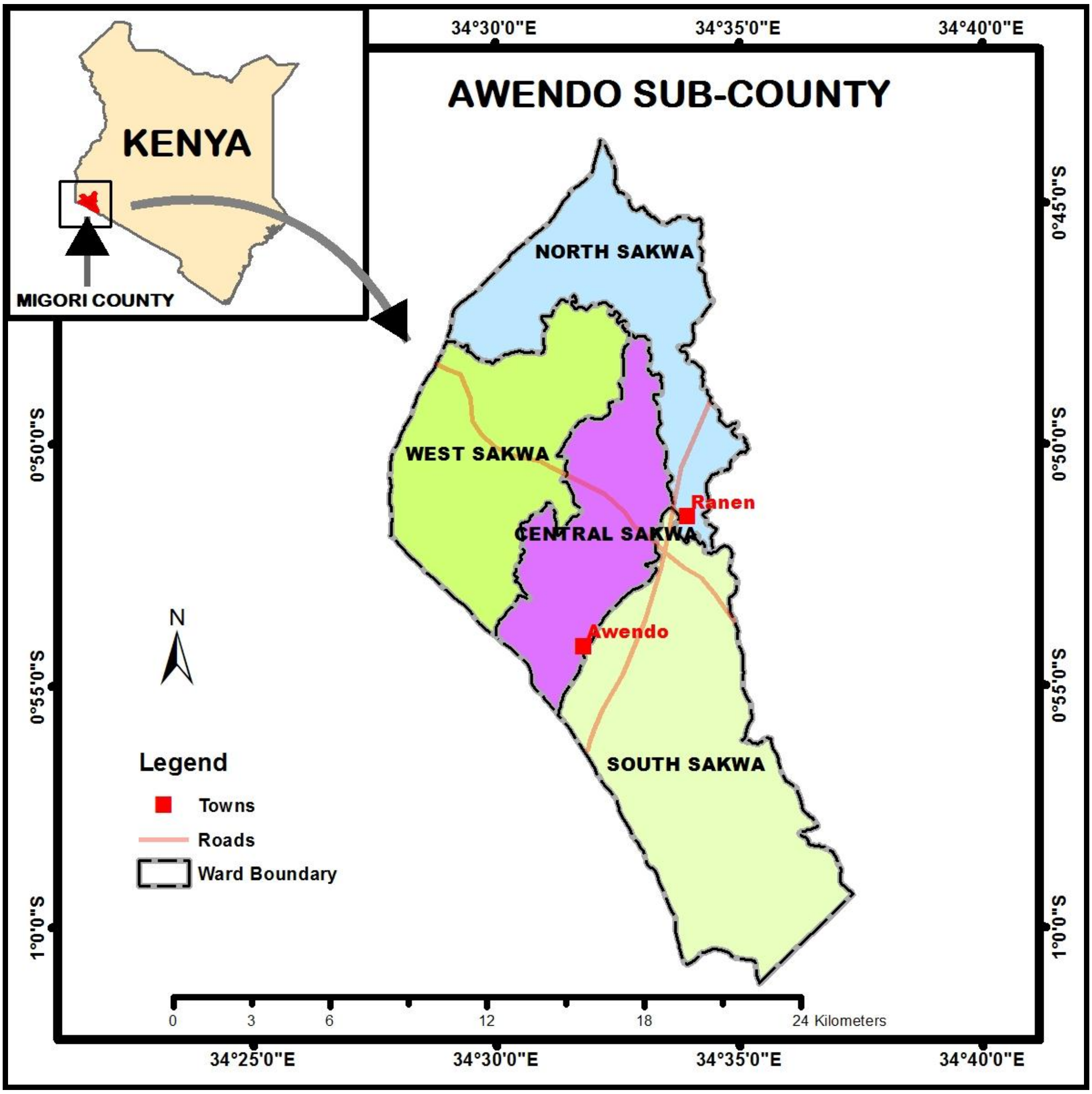

Figure 3: Map of the study area, Awendo Sub-county

Source: World Resource Institute. (2013)

3.2 Sampling Procedure

The population of interest constituted all farmers who practice sugarcane monoculture and sugarcane-soybean integration in Awendo Sub-County. A multistage sampling technique was used to get the study sample where the household was the sampling unit in this study. The first stage was the purposive selection of Awendo Sub-County, the region that harbours' higher potential for sugarcane and soybean production in the County (CIDP, 2013). All the four wards in the sub-county were included in study that is North Sakwa, South Sakwa, West Sakwa and Central Sakwa. Afterwards simple random sampling technique was used to select the respondents from all the wards proportionally according to size based on the list of sugarcane and soybean farmers given by the Sub-County Extension Officers at the ward headquarters in Awendo Sub-County.

3.3 Sample Size Determination

Determination of the sample size followed a proportionate to size sampling methodology as specified by Kothari (2004) and is calculated as:

$$n = \frac{Z^2 pq}{e^2} \quad \text{…………………………………………………………...….. (6)}$$

Where; n= required sample size

Z= confidence level at 95% (standard value of 1.96)

p= estimate of smallholder sugarcane farmers which is at 0.80. This was an assumption that 80% of household engages in sugarcane production in the study area.

q= this the weighting variable given by 1- P

e^2= margin of error at 5% (standard value of 0.05)

A sample size of 246 has therefore been determined by the following computation;

$$n = \frac{z^2 pq}{e^2} = \frac{1.96^2 \times 0.8 \times 0.2}{0.05^2} = 246 \quad \text{………………………………………………………….. (7)}$$

Using the 2009 Kenya National Bureau of Statistics (KNBS) data on the population of the 4 wards of interest (clusters) as reported by the Kenya Population and Housing Census, a proportionate to population size (PPS) of respondents for each ward was computed to arrive at 246 respondents interviewed proportionately. The probability of selection for each respondent in each of the selected wards was calculated as;

$$Probability = \frac{Ward\ Population}{Total\ Sub-County\ Population} \times 100\% \quad \text{.............................. (8)}$$

Table 2: Proportionate to population size per ward

Ward	Population	Cumulative sum	Prob (%)	Proportionate Respondents per Cluster (c)
North Sakwa	18,142	18,142	16.66	41
South Sakwa	36,200	54,342	33.24	82
Central Sakwa	27,561	81,903	25.31	62
West Sakwa	27,010	108,913	24.79	61
Total	**108,913**			**246**

Source: Kenya National Bureau of Statistics (2009)

3.4 Data Collection Procedure and Data Sources

Both primary and secondary data were used in this study. The study used cross sectional data on the inputs and outputs of sugarcane and soybean production and farm and farmer characteristics. The primary data was collected using semi-structured questionnaires administered by trained enumerators. The questionnaires were pretested before the actual data collection to ensure their validity. Primary data included all factors of production (land, labour, fertilizers, pesticides, herbicides) used in sugarcane and soybean production and their respective costs, as well as sugarcane and soybean yields, output sold, and sale prices. For farm and farmer characteristic variables, the data gathered comprised: the farmer's age, level of education, experience in sugarcane and soybean production, household size, services of agricultural extension agents, access to credit and use of chemical fertilizer on sugarcane and soybean production The data was collected for the period 2014/2015 production season. Secondary data was obtained from government publications, journals, unpublished thesis, research institutions such as MoA (located in the study area) and was used for literature review and boosting the study discussion.

Concerning labour input, data were collected for family and hired labour in terms of hours used in each activity in the production process. Calculations were made by choosing the man day as the base unit and weighting it according to the Food and Agriculture Organization (FAO) method. For women, working hours were multiplied by 0.75 and for children the coefficient is 0.5 (Nchare, 2007; Battese *et al*., 1992). Finally, working hours were converted to man-days by dividing actual working hours by eight. Therefore, labour input is expressed in man-days with each man-day equivalent to 8 hours of adult male labour.

3.5 Data Analysis

The study used descriptive statistics such as frequencies, means and standard deviations to analyse the farm and farmer characteristics of smallholder sugarcane and soybean farmers in the study area. The results were then be presented in form of tables from which inferences were drawn .The descriptive statistics were analysed using STATA version 12.0 computer program. The *t-test* and Chi-square tests were used to compare the selected household and farm characteristics between the two categories of farmers (integrators and non-integrator farmers).

To analyse the first objective on socio-economic characteristics of the farmers influencing the choice of the farming system, a Logit model was used. To analyse the second objective the Cobb-Douglas stochastic frontier production function was estimated from which the technical efficiency score of each farmer for each type of farming system was obtained. Lastly, the technical inefficiency effects were estimated using a two- limit Tobit model in order to achieve objective three.

3.6 Analytical Framework

Objective One: Socio-economic characteristics influencing the decision to integrate sugarcane and soybean or to undertake sugarcane monoculture.

The logit model is based on the logistic cumulative distribution and its results are thus not sensitive to the distribution sample attributes when estimated by maximum likelihood

(Mohammed and Ortmann, 2005). This study will assume a logistic distribution of the error term. Therefore, this study used a logit model to analyse objective one in that it provides the advantage of predicting the probability of a farmer integrating sugarcane and soybean or undertaking sugarcane monoculture. This is opposed to the probit model which assumes a normal distribution of the error term.

The dependent variable of the model represents a situation of whether a farmer is an integrator or a non-integrator of sugarcane and soybean crops. The variable was coded either as 1 for integration of sugarcane and soybean or 0 for non-integration (sugarcane monocropping). Since the dependent variable was of dichotomous nature, this suggests that either a binary logit model is appropriate. According to Aldrich and Nelson (1984) the Logit distribution function for the integration of sugarcane and soybean crops can be specified as:

$$P_i = \frac{1}{1+e^{-z_i}} \quad \text{.... (9)}$$

Where P_i: is the probability of event (success), Z_i: is a function of n- explanatory variables (X) and expressed as:

$$Z_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + ... + \beta_n X_{in} \quad \text{.. (10)}$$

Where:

0 is the intercept; 1, 2 and n are coefficients of the equation in the model. P_i can be written as:

$$P_i = \frac{e^z}{1+e^{-(\beta_0+\beta_1 X_{i1}+\beta_2 X_{i2}+...X_n\beta_{in})}} \quad \text{(11)}$$

This means that we cannot use the Ordinary Linear Square procedure to estimate the parameters. But this equation is intrinsically linear, which can be shown as follows. If P_i is the probability of event (success), then (1- P_i) the probability of event not occurring (failure) and can be written as:

$$1 - P_i = \frac{1}{1+e^{z_i}} \quad \text{(12)}$$

The ratio of the probability of event (success) to the probability of event not occurring (failure) can be written as:

$$\frac{P_i}{1-P_i} = \frac{1+e^z}{1+e^{-z}} = e^{z_i} \quad \text{(13)}$$

Where $\frac{P_i}{1-P_i}$ is simply the odds ratio event (success).

In this study this odds ratio is the ratio of the probability that the farmer will integrate sugarcane and soybean to the probability that he will not integrate. Finally taking natural log of equation 13 we get:

$$L_i = \ln \frac{p_i}{1-p_i} = Z_{i(0,1)} = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + ... + \beta_n X_{in} \quad \text{...(14)}$$

where L_i is log of the odds ratio (logit), which is linear not only in X, but also in the parameters. Thus, if the stochastic disturbance term is introduced, the logit model becomes

$$Z_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + ... + \beta_n X_{in} + \varepsilon \quad \text{..(15)}$$

Z_i is the weighted sum of household socio-economic characteristics (X_i). Table 3 shows a description of the logit model and their expected signs for sugarcane -soybean integration.

In this study, the above econometric model has been used to analyse the data. The model has been estimated using the iterative maximum likelihood estimation procedure. This estimation procedure yields unbiased, efficient and consistent parameter estimates (Aldrich and Nelson, 1984).

Table 3: Description of variables and expected signs in the logit model

Variable	Description	Expected Sign
Dependent variable		
Integration	If a farmer integrates sugarcane and soybean=1, 0= otherwise	
Independent variable		
Farming Experience	Farming experience of sugarcane farming in years	+
Household Head	If the respondent is a household head Yes=1,0=No	+
Credit access	If the farmer is able to access credit facilities Yes=1,0=No	+/-
Acreage	Total size of land in acreage a farmer has for sugarcane and soybean production	+
Age	The age of the farmer in years	+
Land ownership	If the farm owns land Yes=1,0=No	+/-
Marital status	Marital status of the farmer Single=1,0=otherwise	+
Occupation	Occupation of the farmer(Farming only=1,0=otherwise)	+

Objective Two: To determine the level of technical efficiency of sugarcane monoculture and sugarcane- soybean integration among smallholder farmers.

The Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) are the two principal methods to measure farm efficiency. As noted by Coelli *et al.* (1998), the SFA is considered more appropriate than DEA in agricultural applications, especially in developing countries, where the data are likely to be heavily influenced by the measurement errors and the effects of weather conditions, and diseases.

Thus, following Aigner *et al. (*1977) and Meeusen and van den Broeck (1977), the stochastic frontier production with two error terms can be modelled as:

$$Y_i = f(X_i, \beta)\exp(V_i - U_j) \ldots\ldots \quad (16)$$

Where Y_i is the production of the i^{th} farm (i=l, 2, 3 ......n); xi is a (l×k) vector of functions of input quantities applied by the i^{th} farm.; β is a (k×l) vector of unknown parameters to be estimated; V_{is} are random variables assumed to be independently and identically distributed *(N (0,* δ^2 *))* and independent of U_{is} and the U_{is} are non-negative random variables, associated with technical inefficiency in production also assumed to be independently and identically distributed.

The first error component *V* is intended to capture the effects of random shocks outside the farmer's control, measurement error and other statistical noise and the second error component *U* is intended to capture the effects of technical inefficiency. Following Battese and Coelli (1995), the technical inefficiency effects, U_i can be expressed as:

$$U_i = Z_i\delta + W_i \ldots\ldots \quad (17)$$

Where *W,* are random variables, defined by the normal distribution with zero mean and variance σ^2 *u.* Z_i is a vector of farm specific variables associated with technical inefficiency and δ is a (mxl) vector of unknown parameters to be estimated. The technical efficiency of the i^{th} sample farm denoted by *TE;* is given by:

$$TE_i = \exp(-U_i) = Y_i \big/ f(X_i\beta)\exp(V_i) = Y_i \big/ Y_i{}^* \ldots\ldots \quad (18)$$

Where Y_i^* =*f*(X_1 β,) *exp* (V_i) is the farm specific stochastic frontier. If Y_i is equal to Y_i^* then $TE_i = 1$, reflects 100% efficiency. The difference between Y_i, and Y_i^* *is* embedded in U_i.

If U_i=0, implying that production lies on the stochastic frontier, the farm obtains its maximum attainable output given its level of input. If $U_i<0$, production lies below the frontier-an indication of inefficiency.

The maximum likelihood estimates (MLE) of the parameters of the model are defined by equations (16) and (17) and the generation of farm-specific. The efficiencies are estimated using a predictor that is based on the conditional expectation of *exp (-U)* (Battese and Coelli, 1993; Coelli, 1994). In the process, the variance parameters $\sigma^2 u$, and $\sigma^2 v$, are expressed in terms of the parameterization:

$$\delta^2 = (\delta^2 u + \delta^2) \quad \text{.......(19)}$$

And

$$\gamma = \delta^2 u \big/ \delta^2 \quad \text{.......(20)}$$

The value of γ ranges from 0 to 1 with values close to 1 indicating that random component of the inefficiency effects makes a significant contribution to the analysis of the production system (Coelli and Battese, 1996). The Cobb-Douglas stochastic frontier production function was used to estimate the level of technical efficiency in a way consistent with the production theory in order to achieve objective two of the study.

$$Y_i = A X_{1ij}^{\beta i} X_{2ij}^{\beta 2i} X_{3ij}^{\beta 3i} X_{4ij}^{\beta 4i} X_{5ij}^{\beta 5i} e^{vi-ui} \quad \text{.......(21)}$$

The Cobb-Douglas specification provides an adequate representation of the production technology, if emphasis is placed on efficiency measurement and not on an analysis of the general structure of the underlying production technology (Taylor *et al.,* 1986). The Cobb-Douglas model is flexible and widely used in agricultural economics (Marinda, 2006). The stochastic production function for the sampled sugarcane and soybean farmers is specified as;

$$\ln Y = \beta_0 + \beta_1 \ln Area + \beta_2 \ln Cuttings + \beta_3 \ln Fertilizer + \beta_4 \ln Herbicides + \beta_5 \ln Labour + V_i - U_i \quad \text{.......(22)}$$

Where,

ln = Logarithm to base e (natural log)

β_0 = Constant or intercept

β_k ($\beta_1 - \beta_5$) = Unknown scalar parameters to be estimated

Y = Quantity of sugarcane in tonnes and soybean output in Kg

V_j = Stochastic error term

U_j = Technical inefficiency effect predicted by the model

In the Cobb-Douglas functional form the parameters to be estimated, β_k, represent the elasticity of output with respect to each i^{th} input, which is the percentage change in output from a 1% change in the i^{th} input.

Lambda (λ) that is *(σ2u / σ2)* was computed to assess goodness of fit and correctness of the specified normal/half-normal distribution assumption. It is also used to explain the disparities of sugarcane and soybean output among farmers. Marginal effects were also computed as {δ (lny/lnx)} at the mean of the independent variables values. Cost savings were also computed to explain the implication of technical efficiency improvement as shown in equation 23;

$$Cost\ \ savings\ \ \% \ \ = 1 - \frac{Mean\ \ Technical\ \ Efficiency}{TE\ \ of\ \ the\ \ most\ \ efficient\ \ farmer} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (23)$$

<u>Objective Three: To determine farm and farmer characteristics affecting technical efficiency of sugarcane monoculture and sugarcane-soybean integration among smallholder farmers.</u>

Since technical efficiency scores lies between 0 and 1, the Tobit model was used. This approach has been used widely in efficiency literature (Obare *et al.,* 2010). The estimation with OLS leads to biased parameters of the estimates hence it is not appropriate. The technical efficiency scores are continuous hence probit and logit models cannot be used in this case because they are only used when the dependent variable takes two values (Gujarati, 2006). Therefore, Tobit regression model offers the most preferred options.

The two-step procedure that is the most commonly used procedure was used in this study. In the first case, technical efficiency scores were estimated using the stochastic frontier model and secondly the technical efficiency scores obtained were then be regressed on farm and farmer characteristics variables to identify their influence on technical efficiency. Technical efficiency scores ranges between 0 and 1, hence the two-limit Tobit regression model was used. Following Coelli *et al*., (2002),

$$U_i^* = \beta_0 + \sum_{j=1}^{k} \beta_j Z_{ij} + \mu_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (24)$$

$$U_i^* = \begin{cases} 1 \ \ \text{if } U_i^* \geq 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (25) \\ 0 \ \ \text{if } U_i^* \leq 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (26) \end{cases}$$

Where i refer to the i^{th} farmer, U_i is the efficiency scores of the i^{th} farmer, U_i* is the latent efficiency, β_j are parameters that were estimated and u_i is the error that is independently and normally distributed with a mean zero and common variance. Z_{ij} are the farm and farmer characteristics variables. The farm and farmer characteristic regressed included gender, age, education, farming experience, occupation, value of assets, household size, extension services, group membership, and access to credit. The choice of these variables was intuitive although they have been found to have an effect on farm efficiency among smallholder farmers. Thus, the Tobit model used in this study is specified as:

$$\begin{aligned} U_i = {} & \beta_0 + \beta_1 gender + \beta_2 age + \beta_3 education + \beta_4 farming\,experience \\ & + \beta_5 occupation + \beta_6 credit + \beta_7 groupmembership + \beta_8 extension \\ & + \beta_9 FarmassetsV + \beta_{10} hhsize + \mu_i \end{aligned} \qquad \text{……...….. (27)}$$

The variables and the hypothesized relationships for the stochastic frontier production function and Tobit model were as shown in Table 4 and 5.

Table 4 : Variables used in stochastic frontier production function

Variables	Description	Hypothesized Sign
Production(Y)	The quantity of sugarcane and soybean produced during the 2014/15 season, expressed in tonnes	
Area	The size of land in hectares planted with sugarcane and soybean by a farmer in the period under investigation	+
Labour	The amount of hired and family labour used by the farmer, measured in man-days	+
Fertilizer	The amount of chemical fertilizer, measured in Kilograms(Kgs)	+/-
Herbicides	The quantity of herbicides and or pesticides used by the farmer, measured in litres	+/-
Seeds and Cane cuttings	Quantity of soybean seeds and sugarcane cuttings measured in Kilograms(Kgs)	+/-

Notes: The positive sign (+) means increase in the variable causes an increase in technical efficiency, while negative sign (-) means increase in the variable causes a decrease in technical efficiency.

Table 5: Two – Limit Tobit Regression Model Variables

Variables	Description	Measurement
Dependent Variable		
Technical Efficiency(u)	Technical inefficiency measures	Between 0 and 1
Independent Variables		
Age	Age of household head	Years
Gender	Gender of the household head	1=Male, 0= Female
Education	Level of schooling of the respondent	1=Primary,0=otherwise
Household size	Number of members of the farmer's household	Number
Experience	Number of years the farmer has been producing sugarcane	Years
Group membership	If the household head belongs to any group	1= Yes, 0=No
Extension service	Access to extension services	1=Yes , 0=No
Credit access	If the farmer received credit facilities,	1= Yes 0= No
Occupation	Occupation of the respondent	1=farming only ,0=Otherwise
Farm Assets	Value of farm assets the farmer owns	Kshs

CHAPTER FOUR
RESULTS AND DISCUSSIONS

This chapter presents results of the study findings. The first part, presents summary statistics of the variables used. Thereafter, results of logistic regression on choice of sugarcane cropping systems followed by the stochastic frontier function results and the distribution of technical efficiency levels of sugarcane and soybean farmers. Lastly the major determinants of technical efficiency in sugarcane and soybean production among the farmers (integrators and non-integrators) are presented. The estimate for all parameters were obtained using Statistical Analysis (STATA) software version 12.The discussion of results is presented while making a comparison of the findings with those of other studies.

4.1 Descriptive Results of Variables

4.1.1 Socio-Economic characteristics of Integrators and Non-Integrators

Table 6 presents characteristics of farmers practising sugarcane-soybean integration (integrators) and sugarcane monoculture (non-integrators) with respect to gender, marital status, education level, occupation, household head and sugarcane zone. A large proportion of the farmers were males constituting 65.4% while females were 34.6%.However, among the male farmers 41.0 % were integrators while 59.0% were non-integrators and among the females, 30.6% were integrators while 69.4% were non-integrators. Due to many socio-cultural values and norms males have freedom of mobility and participation in different meetings and consequently have greater access to information. This is an indication that men take up cash oriented enterprises and therefore, women take time in production of food crops. However, the chi square test reveals that this association was not significant.

The marital status revealed that 75.2% of the farmers were married, 9.3% single, 8.9 % divorced and 3.7% constituted other categories such as widowed, in relationship, among others. The divorce rate of 8.9 % implies that the farmers are composed of stable families. A stable family can concentrate more on production than an unstable one and this may influence productivity. Married farmers constituted 40.0% of the integrators and 60% of non-integrators, single farmers constituted 43.5% of integrators and 56.5% non-integrators, divorced farmers constituted 9.1% of integrators and 90.9% of non-integrators and among the other categories 55.6% were integrators and 44.4% non-integrators. Married households are able to make rational decisions because of different ideas in the family compared to single, divorced or separated households. The chi square results confirmed that the association between integrators and non-integrator farmers in terms of marital status was significant at 5% level.

On the education level, majority of the farmers (56.1%) had attained primary level education, with 32.1% secondary level,4.9% tertiary, 4.1% none and 2.8% university level. Out of the university level, 28.6% were integrators while 71.4% were non-integrators. The low percentage of farmers who had university education can be attributed to the fact that farmers with higher levels of education have a tendency of involving themselves in other off-farm activities as their education level increases. The influence of education levels in technology uptake is well documented. Mishra, (2010) found that farmers with higher education have better access to information and knowledge that are beneficial to farming operation. They also tend to possess higher analytical capability of the information and knowledge necessary to successfully implement new technology and realize expected results. Hence, higher education allows farmers to make efficient adoption decision and be the early adopters who can take advantage of new technology and benefit most from it.

The results indicated that 47.2% of the households were undertaking farming only as their occupation with 36.6% undertaking farming and off-farm business, 6.9% farming and salaried and another 9.3% undertaking farming and other activities. Out of the farmers who purely undertook farming as the sole source of income 37.1% were integrators while 62.9% were non-integrators. Involvement of the households in more than one job could be attributed to the need to subsidize income from employment, and to insulate the households from the shocks resulting from prevalent business cycles related to turbulent prices of sugarcane which is the main cash crop for the area, and also to shield the households from the risks facing agriculture which employs majority of the households either directly or indirectly.

In regard to household head, 85.0% of the farmers were household heads, while 15.0% were not. Out of the farmers who were household heads 37.3% were integrators while 62.7% were non-integrators. It was understood that non household heads face greater challenges in the agricultural production compared with their household head counterparts. This is due to the fact that non household heads in the rural Kenya who are especially women hold various tasks including collecting of fire wood from the field, fetching water from the far distance rivers, childrearing and household management.

Majority of the farmers (41.1%) fell in zone A of sugarcane farming classification according to transportation distance with 25.6% zone B, 21.5% zone C and 11.4% zone D. Out of zone D 39.3% were integrators and 60.7% non-integrators. Zone A comprised of farmers transporting sugarcane to SONY factory within a range of 0.1km to 5 km, Zone B ranges between 5.1km-13km while Zone C ranges between 13.1km to 20km and last Zone D ranges from 20.1 and beyond. Distance to the nearest market (SONY factory) and the frequency of contact that the farmer maintains with it is likely to influence uptake of sugarcane production. The closer they are to the nearest market, the more likely it is that the farmer will receive valuable information (Abadi, 1999; Roy *et. al*, 1999).

Table 6: Association of Household Characteristics by Farmer Type (Dummy Variables)

Variables		Integrators (%)	Non-Integrators (%)	Aggregate (%)	Chi-Square
Gender	Female	30.6	69.4	**34.6**	**2.57**
	Male	41.0	59.0	**65.4**	
Marital status	Married	40.0	60.0	**75.2**	**1.79****
	Single	43.5	56.5	**9.3**	
	Divorced	9.1	90.9	**8.9**	
	Others	55.6	44.4	**3.7**	
Education level	None	20.0	80.0	**4.1**	**11.29****
	Primary	38.4	61.6	**56.1**	
	Secondary	39.2	60.8	**32.1**	
	Tertiary	33.3	66.7	**4.9**	
	University	28.6	71.4	**2.8**	
Occupation	Farming only	37.1	62.9	**47.2**	**0.603**
	Farming and off-farm business	35.6	64.4	**36.6**	
	Farming and salaried	41.2	58.8	**6.9**	
	Farming and others	43.5	56.5	**9.3**	
Household Head	No	37.8	62.2	**15.0**	**0.004**
	Yes	37.3	53.3	**85.0**	
Sugarcane Zone	Zone A	38.6	61.4	**41.1**	**1.486**
	Zone B	39.7	60.3	**25.6**	
	Zone C	32.1	67.9	**21.5**	
	Zone D	39.3	60.7	**11.4**	

*, **, ***: significant at 10%, 5% and 1% level respectively

The mean differences of household characteristics by farmer type are presented in Table 7. The aggregated mean age was 42 years, while the mean age of integrators was 42 years and non-integrators 42 years. Age of the household head plays an imperative role in the uptake of new technologies. This may be attributed to the failure of the older farmers to embrace new ways of doing things and thus still continue the old ways (Langyintuo and Mulugetta, 2005). The farming households can therefore be regarded as young and may be considered to belong to economically active group.

The aggregate mean household size was 6 persons which is slightly above the national average of 5 members (KNBS, 2007). However, the mean household size of integrators and non-integrators farmers was 5 and 6 persons respectively. Household size has been linked to the availability of "own" farm labour in adoption studies. Amsalu and DeJan (2007) found that household size had a significant and positive effect among the determinants of adoption. The argument was that larger households have the capacity to relax the labour constraints required during the introduction of new technologies.

Non-integrator farmers had more years of sugarcane farming experience at 13 years while the integrator farmers had sugarcane farming experience of 12 years. The t-test results however revealed that the difference in years of experience was statistically significant at 10% between the two categories of farmers. However, non-integrators can be assumed rigid to new technologies. Integrators with less experience are able to give change a try. This result is in line with studies such as that of Kassie *et al*., (2013) in the adoption of improved wheat varieties.

Table 7: Mean Difference of Household Characteristics by Farmer Type (Continuous Variables)

Variable	Integrators n=92		Non Integrators n=154		Aggregate n=246		t-value
	Mean	**Std Dev.**	**Mean**	**Std Dev.**	**Mean**	**Std Dev.**	
Age	41.54	1.17	41.19	0.96	41.32	0.74	-0.221
Household size	4.97	0.27	5.20	0.21	5.11	0.17	0.682
Sugarcane farming experience (yrs.)	11.19	0.92	12.81	0.77	12.20	0.59	1.313*
Soybeans Farming Experience (yrs.)	3.22	0.15	0.00	0.00	1.20	0.12	-26.217*

*, **, ***: significant at 10%, 5% and 1% level respectively

Group membership positively and significantly contributes to the uptake of innovation and also information sharing and resource mobilization and higher market bargaining power (Shiferaw *et al.*, 2006). Overall, 55.1 % of the farmers were members of various groups while 44.9% were not as presented in Table 8, out of the farmers in group 38.5% were integrators while 61.5% were non-integrators. Group membership enables farmers to exchange ideas and learn about the benefits of various upcoming technologies. Group members also may easily organize and receive training on diverse agricultural technology issues that influence the choice of sugarcane-soybean integration. The benefits of group membership include access to credit, shared labour, joint input purchase, group marketing, and group training, lobbying for favourable agricultural policies and unity among member farmers (Owuor *et al.,* 2004).

Majority of the farmers (73.2%) did not have access to extension services. Only 26.8% of the farmers had access to extension services. Out of the farmers who had access to extension services 39.4% were integrators while 60.6 % were non-integrators. It is still evident that access to extension services is still low among the farmers. Extension services are important because it provides information, knowledge and skills that enable farmers to be aware and use the technology. Extension services play a central role of providing support for institutional mechanisms designed to support the dissemination and diffusion of knowledge among farmers and demonstration of gains from new technologies (Baidu-Forson, 1999).

Access to extension has been widely reported to positively influence adoption and continued use of agricultural technologies (Knowler and Bradshaw, 2007). Similarly, the frequency of visits by extension officers and development agents was found to significantly influence the decision to use new agricultural technology. The extension officers have a number of services they render to the community that includes advices on crop management, crop pest control, and availability of agricultural inputs. Extension services would inform and build the capacity of farmers, increasing their knowledge and reducing their uncertainty in decision-making.

Credit service is a prerequisite in the growth and development of farming enterprises just like any other entrepreneurial venture. Credit is necessary for enhanced expansion of business activities. Approximately, 76.3% of the farmers did not access credit facilities to enhance their farming; only 23.7% were able to access credit facilities. Out of the farmers who were able to access credit facilities 42.1% were integrators while 57.9% were non-integrators. It is apparent that access to credit is still low in general and lower among integrators than their non-integrators. Teklewold *et al.*, (2006) reported that farmers with better access to credit are significantly more likely to be adopters of the technology and that credit schemes tend to focus on their non-adopters counterparts. Farmers who have access to credit may overcome their financial constraints and therefore buy inputs. Farmers without cash and no access to credit will find it difficult to attain and adopt new technologies.

Table 8: Institutional Characteristic for Discrete Dummy Variables

Variable		**Integrators %**	**Non-Integrators %**	**Aggregate**	**Chi-Square**
Group Membership	Yes	38.5	61.5	55.1	0.120
	No	36.4	63.6	44.9	
Extension	Yes	39.4	60.6	26.8	0.153
	No	36.7	63.3	73.2	
Credit	Yes	42.1	57.9	23.7	0.600
	No	36.4	48.5	76.3	

*, **, ***: significant at10%, 5% and 1% level respectively

4.1.2 Summary Statistics of Input and Output Variables for the Sampled Farmers

A summary statistics of the variables which are defined in the production function empirical model are presented in Table 9. The mean land size under sugarcane production of the sampled farms was 2.688 hectares with a range of about 0.12 to 40.1 hectares. This implies that most of the farmers grew sugarcane in small-scale than on average the national sugarcane acreage ranges between 0.5 to 5 hectares (Lung'aho *et al.*, 2006).

The mean sugarcane yield obtained by farmers was approximately 168.782 tonnes per hectares with a standard deviation of 200.228. Sugarcane yields were highly variable, ranging from 9.88 tonnes per hectares to 1240 tonnes per hectares. These results suggest that there is considerable room for improving average sugarcane yields in Awendo Sub-County. In terms of soybean productivity, the results show that the maximum yield obtained by soybean farmers in Awendo Sub-County was 17,297 kg per hectares with the minimum of 247.1 kg per hectares. On average, the results show that soybean farmers obtained the yield 2,788.128 of kg per hectares, which is low compared to the potential level of between 3000 –3600 kg per ha (Mahasi *et al.*, 2010).

Fertilizer is another important variable and is one of the critical inputs in sugarcane production because of high nutrient requirements of the crop. Average fertilizer use in sugarcane was 273.599 kilograms per hectare. The average quantity falls below the recommended fertilizer quantity of 500 kilograms per hectare of Diammonium Phosphate (MoA, 2002).

The quantity of soybean seed is also an important variable, which might cause considerable variation in yield. The average quantity of soybean seeds planted in the study area by the farmers was 5.404 kilograms per hectare and this was found to vary from 2.47 to 14.83 kilograms per hectare.

Average labour use was for sugarcane farming was 10.057 man-days per hectare which varied widely from a minimum of 2 to a maximum of 35 man-days while the average labour use for soybean farming was 1.262 man-days per hectare which varied widely from a minimum of 1 to a maximum of 7 man-days per hectare.

Table 9: Overall summary of descriptive statistics for the input and output variables assessed (n=246)

Variables	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Land under Sugarcane(Ha)	246	2.688	3.424	0.12	40.4
Sugarcane Cuttings (Kgs/Ha)	246	16.212	14.318	1.24	135.91
Sugarcane Yield (Tonnes/Ha)	246	168.782	200.228	9.88	1240
Sugarcane Price (Ksh/Tonne)	246	2862.195	612.301	1200	4500
Soybeans Area planted (Ha)	92	0.368	0.183	0.2	1
Soybean seeds(Kgs/Ha)	92	5.404	2.609	2.47	14.83
Soybeans yield (Kgs/Ha)	92	2788.128	3144.659	247.10	17297
Price per unit soybean(Ksh/Kg)	92	91.264	12.050	70	125
Sugarcane Fertilizer (Kgs/Ha)	246	273.599	1925.621	2471	2965.2
Sugarcane Herbicides(Litres/Ha)	246	6.679	5.453	2.47	32.12
Sugarcane Labour (Man days/Ha)	246	10.057	7.102	2	35
Soybean Labour (Man days/Ha)	91	1.262	1.043	1	7

Note: Conversion rate, 1 acre=0.40 hectares; 1 tonne per acre= 2.471 tonnes per hectares

4.2 Factors Influencing Choice of Sugarcane Cropping Systems

Based on the results as shown in Table 10, six variables out of the thirteen variables were found to be statistically significant including sugarcane farming experience, age of the farmer, acreage, marital status (divorce and widowed) and land ownership. The rest of the variables like credit access, household head, marital status (married and others), and occupation of the farmer were insignificant.

Sugarcane farming experience was significant at 10 % significance level and negatively associated with the sugarcane- soybean integration. The sign is in contrast to what was hypothesized, and it shows that as experience of sugarcane farming increases, the probability to integrate sugarcane and soybean decreases. An increase in sugarcane farming experience by one year decreases the chances of integration by 0.008. A likely explanation is that due to acquired experience and accumulated knowledge stemming from a long period of observations and experimenting, some farmers may have perfected in sugarcane farming and combining this with the age factor, these farmers are likely to be more risk averse and are more reluctant to change to their cropping systems to sugarcane soybean integration. Another possible explanation is that there may be some past unpleasant experience with the performance of crops integration which may be a barrier to the adoption of sugarcane-soybean integration. These results confirm those of Bonabana-Wabbi (2002) where past experience with poor performance of cowpea intercrops was cited as a probable reason that discouraged increased practice of intercropping cowpeas with cereal crops as an IPM technology in Kumi District, Uganda.

The age of the farmer in years was significant at 10% significance level and positively associated with sugarcane soybean integration. The sign shows that as the age of the household increases, the probability to integrate increases. The positive impact of age on integration of sugarcane and soybean may be explained by the fact that with time, the older household heads may have gathered more resources and experience required for technology adoption than younger household heads. Similar results were reported by Nchinda *et al*. (2010) and Tassew and Oskam (2001).

Land ownership and land size were statistically significant at 10% and negatively influenced sugarcane soybean integration. The result would tell us the status of sugarcane cropping system among different sizes of land and land ownership. It implies that large farms decrease the chances of sugarcane-soybean integration. The result enhances the validity of an argument which states that farmers are efficient as they intensify farm technologies. This result is also in agreement with previous empirical findings such as (Abrhaley, 2006).

Divorced farmers and widowed farmers were also statistically significant at 5% and 1% respectively compared to their single farmer's counterparts. Most of the successful integrators opined that they had good understanding, support and encouragement from extension officers because of their marital status in terms of extension advice and link to agricultural credit facilities. This could have stimulated the widowed and divorced farmers to increase their participation in integration as a mean of income diversification. They could also easily concentrate on farming as a source of livelihood to take care of their children left behind. These results are in agreement with that reported by Sabo (2006) which showed significant relationship between marital status and participation in women in agriculture programme in Borno State, Nigeria.

Table 10: Socio-economic characteristics influencing the decision to integrate or not

Variable	dy/dx	Std. error	Z	P>|z|	X
Sugarcane Farming Experience	-0.0080	0.0044*	-1.83	0.067	12.1577
Age of the farmer	0.0057	0.0034*	1.66	0.097	41.3568
Land Size under production	-0.0112	0.006*	-1.88	0.061	6.68817
Credit Access	0.1181	0.08259	1.43	0.153	0.2365
Household Head	-0.0573	0.0971	-0.59	0.555	0.8465
Married _Marital status dummy	-0.0279	0.1207	-0.23	0.817	0.7552
Divorced _Marital status dummy	-0.2533	0.1227**	--2.06	0.039	0.0290
Widowed _Marital status dummy	0.3296	0.0727***	-4.53	0.000	0.9129
Other _Marital status dummy[1]	0.0985	0.2095	0.47	0.638	0.0373
Land Ownership	-0.1716	0.9535*	-1.80	0.072	0.8423
Farmer_ Occupation dummy	0.0324	0.0732	-0.44	0.658	0.3734
Farming & Salaried_ Occupation dummy	-0.0007	0.1340	-0.01	0.996	0.0664
Farming & Others_ Occupation dummy[2]	0.0849	0.1258	0.67	0.500	0.0913

*, **, ***: significant at 10%, 5% and 1% level respectively; [1] and [2] are dummies

4.3 Estimation of Technical Efficiency of Farmers

4.3.1 Stochastic Production Frontier Estimates

A generalized stochastic production frontier was estimated using the STATA software. The dependent variable of the estimated model was sugarcane output in the 2014/2015 production season and the independent variables include; land size under production, amount of fertilizer in kilogrammes, labour in man days and amount of sugarcane cuttings planted in kilograms. Technical efficiency scores were thus generated from this estimation.

Table 11 presents the results of the maximum likelihood (ML) estimates of Cobb-Douglas stochastic frontier production function. All the coefficients of the inputs in the production function were positive, with the exception of the coefficient of labour which was negative. The positive effects of inputs on the output were expected because more inputs used in rightful proportions increases production. The coefficients of land area under production, fertilizer, herbicides and sugarcane cuttings were positive implying that increase in the use of any of these factors, all things held constant, will increase the total production of sugarcane.

Results indicated the highest output elasticity for land size (0.532) followed by herbicides (0.051). Both variables were positively related to sugarcane productivity. The higher elasticity of herbicides and land size implied that their contribution to total factor productivity was dominant. A one percent increase in the use of land size and herbicides, *ceteris paribus,* leads to a 0.532 and 0.051 percent increase in sugarcane output, respectively. Land area had a strongly significant influence in sugarcane production at 1% level. The results suggests that the more farm land a farmer allocated to sugarcane farming, the higher the yields obtained, which presents similar findings as those reported by Goni *et al.* (2007). The authors argued that most smallholder farmers usually fail to maximize yields due to underutilization of farm land. This might be due to limited availability of other production factors or due to farmers' risk averseness coupled with rainfall fluctuations brought about by climate change. However, Ugwumba (2010) in Nigeria observed that land was underutilized mainly due to land tenure problems associated with land fragmentation.

Another important input in terms of its effect on the sugarcane production is the amount fertilizer followed by sugarcane cuttings. An addition of one percent of amount of fertilizer area and sugarcane cuttings increases output by 0.029 and 0.015 percent, respectively. This implies that increase in the amount of fertilizer use holding other inputs constant, will increase output. This agrees with the findings of Oladiebo and Fajuyigbe (2007), who asserted that fertilizer significantly increase output in upland rice cultivation in Osun State.

The sum of the partial elasticities (function coefficient) indicates the scale of production. A function coefficient of one indicates constant returns to scale. Similarly, a function coefficient less than one and greater than one indicates decreasing and increasing returns to scale respectively. The sum of the estimates for the coefficients in the estimated model was 0.583 which implies that on average, the production frontier exhibited decreasing returns to scale and that the farmers were operating on the rational part of the production process that is stage II of the production region. The implication of this result is that every proportionate increase to the production inputs would lead to less than proportionate addition to the sugarcane output for the farmers. In other words, if all the inputs are increased by 1%, output of sugarcane will increase on average by 0.583%.

The parameter sigma-squared lies between 0 and 1; with a value equal to 0 implying that technical inefficiency is not present and the ordinary least square estimation would be an adequate representation and a value close or equal to 1 implying that the frontier model is appropriate (Piesse and Thirtle, 2000). The value of the sigma square indicates the goodness of fit and correctness of the specified assumption of the composite error terms distribution. The value of the parameter lambda (λ) is 0.95 is statistically significant at the 1% level, which implies that 95% of variation in output is attributable to inefficiency. The log likelihood ratio was found to be 299.20 and was statistically significant at 1% level. This log likelihood ratio test indicates that inefficiency exists in the data set.

Table 11: Maximum likelihood estimates of the stochastic frontier production function results

Ln_yield	Coefficient	Std. Error	Z	P>z
Ln_ Land size	0.5317***	0.07134	7.45	0.000
Ln_ Amount of fertilizer	0.0286	0.02240	1.2s8	0.202
Ln_ Herbicides	0.0509	0.07932	0.64	0.521
Ln_ Labour	-0.040	0.0837	-0.48	0.631
Ln_ Sugarcane Cutting	0.0146	0.0533	0.28	0.783
_cons	3.399***	0.5375	6.32	0.000
/lnsig2v	-0.6913**	0.3098	-2.23	0.026
/lnsig2u	-0.7732	0.9279	-0.83	0.405
Sigma_v	0.7078	0.1096		
Sigma_u	0.6794	0.3152		
Sigma_Squared	0.9624	0.2913		
Lambda	0.9599	0.4185		
n = 246		Wald $chi^2(5)$	= 60.48	
Log likelihood = 299.20		Prob >chi^2	= 0.0000	

*, **, ***: significant at 10%, 5% and 1% level respectively

4.3.2 Technical Efficiency Levels of Integrators and Non-Integrator Farmers

Technical efficiency was obtained using the estimated parameters from the log linear Cobb Douglas stochastic production frontier. T.E. computed for each farmer later was disaggregated into the two farmer group that is integrators and non-integrator farmers. The results of the Stochastic Frontier Models showed that the mean technical efficiency of integrators and non-integrators were 0.64 and 0.62, respectively (Table 12). This shows that farmers practicing sugarcane-soybean integration and sugarcane monoculture were 64% and 62% technically efficient, respectively. The results mean that the farmers in both categories produced sugarcane below their respective frontier levels with non-integrators producing at a lower level than the integrators, although the two categories produced at above half of the frontier. The aggregate maximum, minimum and mean technical efficiencies for farmers were found to be 0.83, 0.22 and 0.63 respectively. This implies that, the farmer with the best practice had a technical efficiency of 0.83; farmer with the worst practice had a technical efficiency of 0.22 while in general, the farmers had an average technical efficiency of 0.63.The aggregate mean technical efficiency of 0.63 implies that on the average, they were able to obtain a little over 63% of optimal output from a given mix of production inputs and production technology. This indicates that there is a scope for increasing technical efficiency by 37 % in the short-run under the existing technology. Even though for the two types of cropping systems, integrators and non-integrators, none achieved a technical efficiency of 100%, which implied that improved efficiency in sugarcane production was still possible without any improvement in the resource base. But the integrators revealed the possibility for a more technically efficient and well sustainable sugarcane production.

For non-integrators technical efficiency level of its most efficient counterpart could realize a cost saving of 22 % (1- [62/80]). A similar calculation for the most technically inefficient farmer reveals cost saving of 72.5% (1-[22/80]. On the other hand for integrators the technical efficiency level of its most efficient farmer could realize cost saving of 22.89% (1- [64/83]. And a similar calculation for the most technically inefficient farmer reveals cost saving of 47% (1-[44/83]). These results indicate very high technical inefficiency exists among the small holder sugarcane producers in the study area. Hence there is great potential to enhance sugarcane and soybean productivity by improving technical efficiency of the farmers, resulting to improved income, with a resultant impact on poverty reduction and wealth creation in the study area.

4.3.3 ; Distribution of technical efficiency scores based on Cobb-Douglas specification

Table 12: Distribution of technical efficiency scores based on Cobb-Douglas specification

	Non-Integrators		Integrators		Aggregate	
TE score	**No of farmers**	**Percentage**	**No of farmers**	**Percentage**	**No of farmers**	**Percentage**
≤ 0.2	0	0	0	0	0	0
0.21-0.40	7	4.55	0	0	7	2.85
0.41-.60	50	32.47	30	32.61	80	32.52
0.61-0.80	96	62.34	59	64.13	155	63.01
0.81-1.00	1	0.65	3	3.26	4	1.63
Total	**154**	**100**	**92**	**100**	**246**	**100**
Mean	0.62		0.64		0.63	
Minimum	0.22		0.44		0.22	
Maximum	0.80		0.83		0.83	
Std. Dev.	0.1152		0.0884		0.1066	

It was observed that a sum of 35.37 % of the aggregate farmers had the lowest efficiency levels below 0.60; whereas the largest percentage (64.63%) of farmers had efficiency levels above 61%. Generally integrators had a majority of farmers (67.39%) having efficiency levels of 0.61 and above as compared to non-integrators (62.99%) who were in similar range of efficiency scores.

4.3.4 The t-test of Technical Efficiency for Integrator and Non- Integrator Farmers

The STATA software was used to test and compare technical efficiency levels of integrators and non-integrator farmers in Awendo Sub-County (Table 13). The variable tested was the technical efficiencies of the cropping systems with the two hypotheses Ho: $\mu_1 - \mu_2 = 0$ and Ha: $\mu_1 - \mu_2 > 0$. Where X_1 and X_2 are sample means for the sugarcane monoculture farmers (non-integrators) and sugarcane -soybean farmers (integrators) respectively.

Table 13: Variation of technical efficiencies among integrators and non-integrators

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
Non-Integrators	154	0.616	0 .009	0.115	0.598	0.634
Integrators	92	0.643	0.009	0.088	0.624	0.661
Combined	246	0.626	0.007	0.107	0.613	0.639
Diff		-0.0266	0.0140		-.054	.001

Diff = mean(X_1) - mean(X_2) **t = -1.9011**

Ho: diff = 0 degrees of freedom = 244

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0

Pr(T < t) = 0.0292 Pr(T > t) = 0.059 Pr(T > t) = 0.9708

Since the t calculated (0.059) is far beyond the critical value of *t* with *df* 244 for α equal to 0.10, therefore we fail reject the the null hypothesis at 5% level of significance but reject the null hypothesis that there was no significant difference in TE between sugarcane- soybean integrators and non-integrators at 10 % level of significance. Integrators had relatively higher technical efficiency than non-integrators. These results indicate the importance of improved resource use since the average productivity of integrators was higher than that of non-integrators.

With a mean technical efficiency of 63%, the technical efficiency of sugarcane and soybean farmers is not high, which is an indication of inefficiency in resource use by the smallholder sugarcane farmers. Wide variation in farmer specific efficiency levels is a common phenomenon in developing countries (Amaza and Ogundari, 2008). These results were in line with those of Ike and Inoni (2006), who found that the economic efficiencies of yam farmers in Nigeria differs substantially ranging from 0.07 to 0.85 with a mean economic efficiency of 0.41 and Ali *et al*. (2012) in their study among wheat and faba bean farmers in Sudan found that economic efficiency levels of the faba bean farmers in Dongola ranged from 0.15 to 0.92 with a mean economic efficiency of 0.57. The low technical efficiency is an indication of inefficiency in resource use by smallholder sugarcane and soybean farmers in Kenya. Also, there exists a wide gap between the efficiency of the most efficient farmers and that of the average farmer. Furthermore, the varying socioeconomic characteristics of the sampled farmers such as farming experience, educational level and age must have influenced farmers' ability to use available technology; a situation that must have contributed to the observed variation and the low level of technical efficiency amongst them.

4.4 Factors influencing technical efficiency among integrators and non-integrators

In order to make appropriate recommendations for relevant policy review and implementation, it is necessary to identify sources of variations in technical efficiencies among integrators and non-integrators. As it follows from SFA, the efficiency scores fall between 0 and 1, hence making the dependent variables (technical efficiency scores from SFA model) a limited dependent variable. In this regard, censored regression model (the Tobit model) was applied as the most appropriate analytical model.

Selected farm and farmer characteristics were regressed against the TE scores of each farmer using the Tobit model. The results describing the influence of the selected variables and their direction of influence on TE overall among the two categories of farmers (integrators and non-integrators) as presented in Table 14. The results from Tobit were then subjected to post estimation test using marginal effect analysis in order to estimate the trivial change from each factor that influence TE. Some of the variables that yielded positive and significant coefficients among integrators included age, secondary education level, university education level and household size. Sugarcane farming experience, farm asset value and occupation of the farmer (farming and others) yielded negative and significant coefficients among integrators. This implies that the variables which influenced technical efficiency positively meant that their increase respectively improved technical efficiency of sugarcane and soybean production while the variables that influenced technical efficiency negatively implied that their increase respectively decreased the technical efficiency of sugarcane and soybean production. On the other hand among the non-integrators only three variables were significant and positively influenced technical efficiency. According to the results indicated in Table 14, these variables included age, secondary education and extension service.

The differences in the two types of cropping systems occurred in variables such as university education which was positive and significant to technical efficiency among integrators while positive and not significant among non-integrators . Household size was positive to technical efficiency and significant at 1% level among integrators while among non-integrators though positive to technical efficiency was not significant at 5% level. Other variables that displayed differences were sugarcane farming experience, farm assets value and occupation (farming and off farm income which was negative and significant to technical efficiency among integrators except farm assets value which was positive and significant.

Table 14: Factors influencing technical efficiency among integrators and non-integrators

	Non-integrators		Integrators	
Technical Efficiency	**Coefficient**	**t-value**	**Coefficient**	**t-value**
Age	0.0019**	2.02	0.0019**	2.15
Gender	0.0063	0.33	0.0118	0.64
None_ Education dummy	-0.0006	-0.02	0.0402	0.73
Secondary_ Education dummy	0.0704*	3.03	0.0739*	4.14
Tertiary_ Education dummy	0.0041	0.09	0.0231	0.59
University_ Education dummy[1]	0.0400	0.76	0.0902**	1.67
Household size	0.0035	0.87	0.0108*	2.85
Sugarcane Farming Experience	-0.0003	-0.26	-0.0019**	-1.76
Credit Access	-0.0110	-0.45	-0.0027	-0.13
Extension	0.0849*	3.42	0.0040	0.22
Group	-0.201	-0.99	-0.0102	-0.54
Farm Asset Value	3.62e-07	0.66	1.34e-06**	2.63
Off farm_ Occupation dummy	0.3342	1.49	-0.0132	-0.71
Farming & salaried_ Occupation dummy	0.5748	1.30	-0.0274	-0.82
Farming & others_ Occupation dummy[2]	0.3224	0.84	-0.0701	-2.54
Constant	0.4707***	10.43	0.4956***	11.65
LR chi2(15) =	29.90		38.95	
Prob > chi^2 =	0.0123		0.0007	
Pseudo R^2 =	-0.2556		-0.2668	
Log likelihood =	73.4551		92.4675	

Note: *, **, ***: significant at 10%, 5% and 1% level respectively; [1] and [2] are dummies

The coefficient for age of a farmer was positive and significant at 5% level. The positive effect of this coefficient implies that as the sugarcane-soybean integrator farmers grow old by a year, holding other factors constant, the inefficiency in sugarcane and soybean production increases by 0.19%. This means that older farmers were less technically efficient in sugarcane-soybean integration than their younger counterparts. The finding is attributed to the fact that older sugarcane-soybean integrator farmers are relatively more reluctant to take up better technologies, instead they prefer to hold to the traditional farming methods thus become more technically inefficient compared to their younger counterparts. This is consistent with findings by Waluse (2012), Sarfraz and Bashir (2005) and Idiong (2007).

Farmers with secondary and university level of education were found to be more efficient and significant at 10% and 5 % respectively as compared to their primary level counterparts. Educated farmers are generally better placed to receive, interpret and respond to new information. These results are in agreement with the findings of Nyagaka *et al* (2011), Mussa *et al* (2011), Shehu *et al* (2010), Njeru (2010), Ajewole and Folayan (2008), Elibariki and Shuji (2008), Chirwa (2007), Idiong (2007) and Amaza *et al* (2006). All these studies have argued that high formal education level reduces inefficiency. More educated farmers tend to adopt and respond rapidly to the use of improved technologies which could positively influence the technical efficiency of sugarcane-soybean integration.

Experience in sugarcane-soybean integration was negative and significant at 5% level. This implies that as years pass with continuous sugarcane-soybean integration farming, farming experience tends to decrease farmers' capacity to do better, hence; they become more technically inefficient. These findings are in line with those of Ajewole and Folayan (2008) but contrary to those of Gul *et al* (2009) and Padilla-Fernandez and Nuthall (2009). Farmers with more years of farming experience are better placed to acquire knowledge and skills necessary for choosing appropriate new farm technologies over time.

The size of the household was positive and significant at 10% level in explaining the technical efficiency, implying that as the household size expanded, the technical efficiency of sugarcane-soybean integration increased. Wakili (2012), Shehu *et al* (2010), Ajewole, and Folayan (2008) found that household size was positive and significant in explaining technical efficiency. Larger household size increased the labour available, hence increase in the technical efficiency.

Farm assets value possessed by sugarcane-soybean integrators had the expected positive and was significant at 5%. According to Chimai (2011), assets are taken to indicate the household wealth status. In regard to smallholder sugarcane and soybean farmers, assets are expected to influence technical efficiency positively. This is because assets act as shock absorbers, especially when sold off in times of need.

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The first objective dealt with in this study was to determine the factors influencing the choice of sugarcane cropping system among smallholder farmers in Awendo Sub-County, Kenya. The variables that were found to be statistically significant included sugarcane farming experience, age of the farmer, acreage, marital status (divorce and widowed) and land ownership. The variable sugarcane farming experience was significant at 10 % significance level and negatively associated with the sugarcane- soybean integration. Little sugarcane farming experience has a negative implication on the effectiveness and innovations on integration activities. The age of the farmer in years was also significant at 10% significance level and positively associated with sugarcane soybean integration. The variable land ownership and land acreage were statistically significant at 10% and negatively influenced sugarcane-soybean integration. Divorced farmers and widowed farmers were also statistically significant at 5% and 1% respectively compared to their single farmers' counterparts.

Land under sugarcane production was the most single most important variable in influencing the farmers' level of efficiency. This implies that land was the most motivating factor in sugarcane farming in Awendo Sub-County since its function coefficient was positive. This was against the expectation of the study that farmers were not properly utilizing the land resource in production suggesting that other factors outside the estimated model could be the major cause of sugarcane productivity decline. The results also indicated that non-integrator farmers were less technically efficient as compared to integrator farmers. The mean technical efficiency of 62% and 64 % showed that the potential exist to increase output by 38% and 36% for non-integrators and integrators respectively with the present technology Therefore, non-integrator farmers had the highest scope in the improvement of their efficiency. It was also encouraging that at least half of the farmers had technical efficiency scores exceeding the 50% limit and could easily improve to the level of the most efficient farmers. Since the technical efficiency was found to differ among integrator farmers and non-integrators, the production of sugarcane and soybeans crops by the farmers can only be guaranteed in the short-run. The average non-integrator farmer could make a cost saving of 22% to the current production costs incurred through improved technical efficiency to that of the most efficient farmer while the average integrator farmer could realize a cost savings of 22.89%. This study has therefore concluded that there exist technical inefficiencies among sugarcane and soybean farmers in Awendo Sub-County, Kenya.

Finally, the Tobit regression model estimation revealed that age, secondary education level, university education level and household size had positive and significant coefficients among integrators while sugarcane farming experience, farm asset value and occupation of the farmer (farming and others) had negative and significant coefficients among integrators. Increase in number of years spend in sugarcane production negatively affects the level of technical efficiency, thus as the farmers grow old they lose energy needed in accomplishing hard tasks in farming. This may result into low participation in sugarcane-soybean integration and consequently low levels of technical efficiency and hence low agricultural productivity which may further result into low income levels for the participants in the sugarcane and soybean value chain both in rural and urban population. The differences in the two types of cropping systems occurred in variables such as university education which was positive and significant to technical efficiency among integrators while positive and not significant among non-integrators. Household size was positive to technical efficiency and significant at 1% level among integrators while among non-integrators though positive to technical efficiency was not significant at 5% level.

5.2 Recommendations

Based on the findings of the study, the following recommendations are made for policy implementation. It is envisaged that these recommendations would provide a framework for increasing the overall efficiencies of smallholder sugarcane and soybean farmers within the study area and other related areas. The following recommendations are provided based on the results of the study:

1. Stakeholders in agricultural sector need to design programs that attract more youth in agricultural production as a means of creating employment since age was found to be influencing choice of sugarcane cropping system. There is also the need for policies to address the limitation of farming experience, through targeted training programs that will enhance the knowledge gap of such farmers on better integration activities. The non-integrators should be sensitized on the benefits of integration in order to encourage them to adopt the integration technology in order to increase sugarcane and soybean production.

2. There is the need for farmers' to increase their use of land, fertilizer, herbicides and sugarcane cuttings since they were found to have an impact of the output. The study recommends that farm inputs should be made readily accessible to farmers and at subsidized prices through adequate supply and efficient distribution. The resource inputs used were as well not efficiently being utilized. Thus, there is need for training sugarcane and soybean farmers on farm inputs optimum utilization by the extension agents in order to increase the overall productivity. The farmers should also allocate part of their land to incorporate soybean production in order to increase the household food security and improve the household income.
3. Efforts should be made to improve farmers' education, since education was found to affect farmers' technical efficiency positively. This can be achieved through increased extension contact, non-formal education and farmer-based organizations (FBOs) that promote farmer education. Proper policies measure that strengthening the provision of education to farmers will lead to the increase of technical efficiency of farmers in long run. Importance of education comes on decision making and implementing informed and timely farming decisions.

5.3 Further Research

The main intention of the study was to contribute to increase in farmer's household income by improving the level of technical efficiency of sugarcane and soybean production among smallholder farmers in Awendo Sub-County, Kenya. However, there are several areas for further research.

1. While this study focused on measuring technical efficiency and finding the factors that influence technical inefficiency among farmers practising sugarcane monoculture(non-integrators) and sugarcane-soybean integrators in Awendo Sub- County, other studies can be done on allocative and economic efficiency in sugarcane and soybean farming not only in Awendo Sub- County but also in other parts of the Country. This will help to understand fully why sugarcane and soybean productivity has remained low over time yet there exists high potential for their production.
2. There is need to undertake more studies on sugarcane and soybean marketing and value chain development in the country. This will enhance the chances of exploiting the potential opportunities that sugarcane and soybean farming offers to the country.

Moreover, the strategy for improving agricultural productivity is through market-led approach.

3. This study considered only the stochastic production frontier approach. Given the developments in the statistical DEA models, an extension of this work using DEA models can add to the technical efficiency literature and also help to compare the findings with the ones for the stochastic frontier approach.

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APPENDICES

ANNEX 1: STRUCTURED HOUSEHOLD SURVEY QUESTIONNAIRE

This study is being undertaken to analyse technical efficiency of sugarcane monoculture and sugarcane- soybean integration among smallholder farmers in Awendo sub-county, Kenya. The purpose of administering this questionnaire is for academic research. The information provided will assist in formulation of policies and programs that will improve sugarcane and soybean production in the county. The information needed is for the 2014/2015 production season; your voluntary and confidential participation in this survey will be much appreciated. As a respondent, you are assured that all information provided will be secure and confidential.

SECTION I: GENERAL INFORMATION

Number of questionnaire …….……………………………………………………………..

Name of the farmer…………………………………………………………………………

Mobile No……………………………………………………………………………………

Enumerator…………………………………………………………………………………

Location of the farmer

Sub- County………………………………………………………….………………………

Location………………………………………………….……………………….………….

Village…………………………...…………………….…………………………………….

Date………………………………………...

NB: Do not leave any blank spaces. Use code 0 if the answer is No; and code -99 if not applicable and -88 if no response is given. Circle the appropriate responses.

SECTION II

A: FARMERS' HOUSEHOLD CHARACTERISTICS

QUESTIONS	**CODES**	**RESPONSE**
1. Gender of the respondent	*1=Male; 0=Female*	
2.Are you the household head	*1=Yes; 0=No*	
3. Age in years of the respondent	Actual number of years	**a)** **b)**
4. Marital status	*1=Married; 2=single;* *3=Divorced;* *4=Widowed5=others (specify)*	
5.Highest level of education	*1= None* *2=Primary level* *3=Secondary level* *4= Tertiary college level* *5=University level* *6=others(specify)*	
6. Number of years of schooling	Actual number of years	
7. How many people are currently living with you	*Females* *Males*	
8. What is your current occupation?	*1=farming; 2= off-farm business; 3=salaried* *4=others (specify); 99=not applicable*	
9.How many years have you been farming sugarcane	*Number of years*	
10. How many years have you been farming soybean	*Number of years*	

B: STRUCTURE OF LAND OWNERSHIP AND USE

	Tenure System in (ha)			
	Owned	Rented in	Rented out	Communal
Acres				

SECTION III: SUGARCANE AND SOYBEAN PRODUCTION ISSUES

A: LAND UTILIZATION

1. Did you have land which you did not use in growing sugarcane or soybean in the last production season? 1=Yes; 0=No.
2. If yes, what was the size of the unused land in ha: in 2013/14 production season?

3. If you did not cultivate all of the land you had access to in the previous season, give reasons

Reasons for non- use	1=Yes 0=No	Score the ranks between 1 lowest and 5 highest
1.Not enough seeds		
2.Not enough funds		
3. Not enough labour		
4.Left fallow land		
5.Not enough other inputs		
6.Others(specify)		

B: SUGARCANE AND SOYBEAN PRODUCTIVITY IN THE LAST PRODUCTION SEASON

a) Sugarcane productivity

Sugarcane cuttings type	Area planted (Acres)	Sugarcane cuttings (kg)	Source of seeds	Fertilizer applied 0=no 1=yes	Herbicides applied 0=no 1=yes	Yield or Production in tonnes	Price/ Unit

b) Soybean productivity

Soybean seeds variety	Area planted (Acres)	Soybean seeds (kg)	Source of seeds	Fertilizer applied 0=no 1=yes	Herbicides applied 0=no 1=yes	Yield or Production in Kgs	Price/ Unit

C: ACCESS TO INPUTS

1. How did you access and use the following inputs in the last production season?

Type of Inputs	1Common Source	Distance from house to source (km)	Average cost per unit	d) Unit	e)Quantity used	2Main constrai-nts to use of input	3Was this usage better or similar to 2013/14?
Soybean seeds							
Sugarcane cuttings							

Fertilizer							
Herbicides							
Others(specify)							

1Common source of inputs: 1=purchased from market; 2=purchased from stockiest; 3=purchased from other farmers; 4=received from government; 5=received from SONY sugar factory; 99=others (specify)…

2 Main constraints to access: 1=Too far from household, 2=Unsuitable packaging (large) 3=No knowledge of how to use 4=No transport, 99= others (specify)

Which farm assets do you own?

Asset[i]	Size or number	Date acquired/built	Source of income[ii]
Tractor			
Plough			
Disc harrow			
Irrigation pump			
Farm store			
Lorry			
Others(specify)			

[i]*code 1= tractor 2=plough 3= irrigation pump 4=lorry 5= others(specify)……….*

[ii]*code 1= equity 2=loan 3= others(specify)………………………*

D: LABOUR DISTRIBUTION

1. How did you use labour in the last production season?

Ploughing	Planting	Weeding	Fertilizer application	Herbicides /pesticides application	Harvesting	Post-harvest handling	Marketing

Codes 1=Husband only; 2=Wife only; 3=Husband mostly; 4=Wife mostly; 5=Husband and wife equally; 6=Children; 7=Hired labour; 8=Other (specify)……

2. a) How did you utilize outputs from your sugarcane farm in the last production season?(NB ; For quantities specify unit of measure and get the conversion factor)

[1]Purpose	Total quantity produced	Quantity consumed locally	Value added	Quantity sold	Quantity spoilt or wasted	Price per unit	[2]How do you market	Months when sugarcane is sold

b) How did you utilize outputs from your soybean farm in the last production season?(NB ; For quantities specify unit of measure and get the conversion factor)

[1]Purpose	Total quantity produced	Quantity consumed locally	Value added	Quantity sold	Quantity spoilt or wasted	Price per unit	[2]How do you market	Months when soybeanis sold

Codes

[1]Purpose:1= subsistence only 2= both for food and sale 3= commercial purposes only

[2]*Marketing : 1=individually/self 2= collectively through network or group 3= both self and group 4 others (specify*

E: SUGARCANE AND SOYBEAN MARKETING

1. Please provide information about sugarcane and soybeans sale in the last season

crop	Who do you sell mostly to?	Quantity sold(in Kgs & tonnes)	Mode of selling 1=cash 2=credit 3=both 4=(others)specify	Distance to market in Km	Transport means to market	Time of the year when prices are very high (specify)	Time of the year when prices are very low (specify)
Soybean							
Sugarcane							

Sales: 1= local farmers 2= SONY sugar company 3= others (specify)…………

Transport means: 1= self 2= group means 3= SONY sugar factory

F. GROUP MEMBERSHIP

1. Are you a member of any group? 1=Yes 0 = No
2. If yes state the type(s) of group and reason(s) for participating.

Type of group 1=SONY sugar contract scheme 2=women group 3= youth group 4= cooperative society 5= others(specify)	Reason for participation 1=share information 2= access farm inputs 3= access credit 4= marketing sugarcane 5=generate income 6= others(specify)

G: EXTENSION SERVICES

1. Did you have an extension contact in the last production season? 1=Yes 0= No

2. If yes, what information did you obtain that influenced your sugarcane production**?**

H: CREDIT ACCESS

1. Did any household member try to get credit loan in the last 12 months? 1 = Yes, 2 = 0

If yes, was the loan received? 1 = Yes, 2 = No

2. What were the sources of credit loan? (*Tick all that apply)*.

1. Bank 2 .Cooperative society 3. SONY sugar factory 4. Self -help group 5. Family 6. Neighbour 7. Other (specify)

3. Was the credit loan mainly used in (*Tick one option*):

1. Sugarcane production? 2. Other purposes, e.g., food, fees, medical bills?

I. FARM INCOME AND EXPENDITURE

1. What is your approximate total annual farm income for the household?

Source of farm income	**Quantity sold(in tonnes)**	**Price/unit**	**Totals**
Sugarcane production			
Livestock production			
Soybean production			
Other crops			

2. What are your other sources of income

Other income	**Amount(Ksh)**
Income from employment	
Transfers	
Pension	
Others(specify)	

3. What is your approximate total annual farm expenditure

Expenditure	**Number of units**	**Cost/unit**	**Totals**
Labour			
Sugarcane Cuttings			
Soybean seeds			

Fertilizer			
Chemicals(pesticides and herbicides)			
Transportation			
Others(specify)			

4. If your household income were to double, what would you do with the extra money?

Investment decision	Rank the 3 most important decisions

J.PROBLEMS ENCOUNTERED IN SUGARCANE AND SOYBEAN FARMING

1. Have you experienced any sugarcane and or soybean yield reduction in the last 1-2 years? 1=Yes; 2=No

   Sugarcane………………… Soybean……………………..

   If yes, give reasons

2. Have you experienced any sugarcane and or soybean yield reduction in the last 4-5 years ago? 1=Yes; 2=No

   Sugarcane………………… Soybean……………………..

   If yes, give reasons**.**

3. In general what are the main problems you encounter in sugarcane and or soybean production? Please rank them (1=highest 5=lowest) in the order of their importance, starting with the most important to you.

1. Decreasing soil fertility 3 .High cost of inputs
2. Lack of agricultural farm equipment 4 inadequate labour
5 Lack of credit for farm operations.

Thank You!

ANNEX 2: LOGISTIC REGRESSION RESULTS

```
Logistic regression                          Number of obs   =        241
                                             LR chi2(13)     =      26.22
                                             Prob > chi2     =     0.0159
Log likelihood = -146.64382                  Pseudo R2       =     0.0821
```

CropSystem	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ScFarmingexp	-.0348972	.0191222	-1.82	0.068	-.0723761	.0025817
Age	.0247859	.0149684	1.66	0.098	-.0045516	.0541233
Acreage	-.0492517	.0265075	-1.86	0.063	-.1012054	.0027021
Creditaccess	.5015255	.3430031	1.46	0.144	-.1707483	1.173799
HHhead	-.245315	.408019	-0.60	0.548	-1.045018	.5543875
married	-.1209925	.5194708	-0.23	0.816	-1.139136	.8971515
divorced	-1.529593	1.20959	-1.26	0.206	-3.900346	.8411598
widow	-2.178334	.9189592	-2.37	0.018	-3.979461	-.3772071
marother	.4124278	.8498117	0.49	0.627	-1.253173	2.078028
Landownership	-.7158647	.3890429	-1.84	0.066	-1.478375	.0466454
ocupoffarm	-.1426302	.3241429	-0.44	0.660	-.7779385	.4926782
ocupfasa	-.0032946	.5957365	-0.01	0.996	-1.170917	1.164328
ocupfaot	.3586571	.5172311	0.69	0.488	-.6550972	1.372411
_cons	.1548185	.7741674	0.20	0.841	-1.362522	1.672159

ANNEX 3: MARGINAL EFFECTS AFTER LOGIT

```
Marginal effects after logit
      y  = Pr(CropSystem) (predict)
         =  .35301645
```

variable	dy/dx	Std. Err.	z	P>|z|	[95%	C.I.]	X
ScFarm~p	-.0079704	.00436	-1.83	0.067	-.016508	.000568	12.1577
Age	.005661	.00342	1.66	0.097	-.001033	.012355	41.3568
Acreage	-.0112489	.006	-1.88	0.061	-.023006	.000509	6.68817
Credit~s*	.1180854	.08259	1.43	0.153	-.043794	.279965	.236515
HHhead*	-.0572932	.0971	-0.59	0.555	-.247596	.13301	.846473
married*	-.0278735	.1207	-0.23	0.817	-.264447	.2087	.755187
divorced*	-.2532511	.12272	-2.06	0.039	-.49377	-.012732	.029046
widow*	-.3295514	.07268	-4.53	0.000	-.472001	-.187102	.091286
marother*	.098487	.20948	0.47	0.638	-.31209	.509064	.037344
Landow~p*	-.1716124	.09535	-1.80	0.072	-.358488	.015263	.842324
ocupof~m*	-.0323914	.07324	-0.44	0.658	-.17594	.111157	.373444
ocupfasa*	-.0007522	.13595	-0.01	0.996	-.267208	.265704	.06639
ocupfaot*	.0849057	.1258	0.67	0.500	-.161662	.331474	.091286

(*) dy/dx is for discrete change of dummy variable from 0 to 1

ANNEX 4: STOCHASTIC PRODUCTION FRONTIER RESULTS

```
. frontier lnyield  lnarea lnfert lnherb lnlabour lncutting

Iteration 0:   log likelihood = -299.24893
Iteration 1:   log likelihood = -299.20337
Iteration 2:   log likelihood = -299.20336

Stoc. frontier normal/half-normal model          Number of obs   =        246
                                                 Wald chi2(5)    =      60.48
Log likelihood = -299.20336                      Prob > chi2     =     0.0000
```

lnyield	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnarea	.5316669	.0713438	7.45	0.000	.3918356	.6714982
lnfert	.028604	.0224022	1.28	0.202	-.0153035	.0725116
lnherb	.0509023	.0793189	0.64	0.521	-.1045599	.2063646
lnlabour	-.0402436	.0837556	-0.48	0.631	-.2044016	.1239143
lncutting	.0146692	.0533047	0.28	0.783	-.0898061	.1191444
_cons	3.398713	.5375305	6.32	0.000	2.345172	4.452253
/lnsig2v	-.6913159	.3097797	-2.23	0.026	-1.298473	-.0841589
/lnsig2u	-.7732061	.9279822	-0.83	0.405	-2.592018	1.045606
sigma_v	.7077545	.109624			.5224445	.9587936
sigma_u	.6793607	.3152173			.2736217	1.686749
sigma2	.9624474	.2913404			.3914308	1.533464
lambda	.9598818	.4185001			.1396367	1.780127

```
Likelihood-ratio test of sigma_u=0: chibar2(01) = 0.59   Prob>=chibar2 = 0.221
```

ANNEX 5: TOBIT MODEL REGRESSION RESULTS FOR TECHNICAL EFFICIENCY FOR NON-INTEGRATORS

```
-> CropSystem = Nonintegrator

Tobit regression                                  Number of obs   =        119
                                                  LR chi2(15)     =      29.90
                                                  Prob > chi2     =     0.0123
Log likelihood =  73.455145                       Pseudo R2       =    -0.2556
```

efficiency	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Age	.0019365	.0009569	2.02	0.046	.0000389	.0038341
Gender	.0063325	.0193777	0.33	0.744	-.0320942	.0447592
educnone	-.0005782	.0382071	-0.02	0.988	-.0763443	.0751879
educsec	.0703949	.0232443	3.03	0.003	.0243007	.1164891
eductert	.004146	.0445069	0.09	0.926	-.0841128	.0924049
educuni	.0399651	.0526282	0.76	0.449	-.0643985	.1443287
HHsize	.0035647	.0040997	0.87	0.387	-.0045651	.0116944
ScFarmingexp	-.0003094	.0012079	-0.26	0.798	-.0027046	.0020859
Creditaccess	-.0110445	.0246363	-0.45	0.655	-.0598991	.0378101
Extension	.084855	.0248014	3.42	0.001	.0356729	.1340372
Groupmember	-.0200681	.0202363	-0.99	0.324	-.0601974	.0200613
FarmAssetsV	3.62e-07	5.50e-07	0.66	0.512	-7.29e-07	1.45e-06
ocupoffarm	.0334188	.0224068	1.49	0.139	-.0110148	.0778524
ocupfasa	.0574821	.0442363	1.30	0.197	-.0302401	.1452043
ocupfaot	.0322478	.0382511	0.84	0.401	-.0436055	.1081011
_cons	.470697	.0451283	10.43	0.000	.3812058	.5601881
/sigma	.0961978	.0070636			.0821904	.1102052

```
Obs. summary:          19  left-censored observations at efficiency<=.5
                      100     uncensored observations
                        0 right-censored observations
```

ANNEX 6: TOBIT MODEL REGRESSION RESULTS FOR TECHNICAL EFFICIENCY FOR INTEGRATORS

```
-> CropSystem = Sugarcane-soybean integrator

Tobit regression                                  Number of obs   =         89
                                                  LR chi2(15)     =      38.95
                                                  Prob > chi2     =     0.0007
Log likelihood =   92.46754                       Pseudo R2       =    -0.2668
```

efficiency	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Age	.0018775	.0008742	2.15	0.035	.0001355	.0036194
Gender	.0118476	.0184115	0.64	0.522	-.0248381	.0485333
educnone	.0401802	.055243	0.73	0.469	-.0698939	.1502543
educsec	.0738616	.0178593	4.14	0.000	.0382762	.1094471
eductert	.0230833	.0392817	0.59	0.559	-.0551872	.1013538
educuni	.0901663	.0538861	1.67	0.098	-.0172041	.1975367
HHsize	.0107613	.0037695	2.85	0.006	.0032504	.0182722
ScFarmingexp	-.0019378	.0010989	-1.76	0.082	-.0041273	.0002517
Creditaccess	-.0026848	.0206533	-0.13	0.897	-.0438374	.0384678
Extension	.0039893	.0185314	0.22	0.830	-.0329354	.0409139
Groupmember	-.0101969	.0187516	-0.54	0.588	-.0475604	.0271666
FarmAssetsV	1.34e-06	5.11e-07	2.63	0.010	3.25e-07	2.36e-06
ocupoffarm	-.0131909	.0185593	-0.71	0.479	-.0501712	.0237894
ocupfasa	-.0273607	.0332536	-0.82	0.413	-.0936201	.0388986
ocupfaot	-.0700974	.0276142	-2.54	0.013	-.12512	-.0150748
_cons	.4955901	.0425504	11.65	0.000	.4108066	.5803736
/sigma	.0709744	.0056613			.0596941	.0822548

```
  Obs. summary:          7  left-censored observations at efficiency<=.5
                        82     uncensored observations
                         0 right-censored observations
```