FACTORS AFFECTING FARM-LEVEL EFFICIENCY IN IRRIGATION SCHEMES: A CASE OF TURKANA SOUTH SUB-COUNTY

BY

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DECLARATION

This research thesis is my original work and has not been presented for a ward of degree in any other University.

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ABSTRACT

Irrigation is one of the long-term strategies towards enhancing productivity in agriculture. It offers an opportunity towards the achievement of the food security and poverty reduction. However, the potential of these irrigation schemes has remained unexploited. Kenya has a potential of 1.3 million hectares for irrigation. However, currently, only 114,600 hectares of irrigation have been achieved. Turkana South Sub-County has 714 hectares of irrigation against a potential for expansion of 8040 hectares.

Irrigation schemes productivity in Turkana South Sub-county has been very low that is, maize yield levels being eight to ten bags per acre against a potential of 20-25 bags. Food insecurity is very high with farm and non-farm households depending on relief food despite the existence of these irrigation schemes. The causes of low productivity and the current levels of farmers' efficiency in the irrigation schemes have not been studied. The research therefore, aimed at evaluating the technical, allocative and economic efficiency at farm level. It also aimed at characterizing irrigation scheme farm production and to identify the factors that explain the variation in farm level efficiency. To achieve these objectives, stochastic frontier model and descriptive statistics were used. Data was collected from a sample of 183 farmers drawn from two irrigation schemes namely Katilu and Koputiro irrigation schemes in Katilu and Kainuk Divisions respectively using multistage sampling technique. The findings of the research indicate that the average efficiency levels of the irrigation scheme farmers, that is, technical efficiency (TE), allocative efficiency (AE) and economic efficiency (EE) were 45.30, 67.23 and 30.46 percent respectively. The socio-economic and technical factors that significantly explained the variation in technical and allocative efficiency levels were Age, gender, level of education, access to credit, farm size, income, status of irrigation scheme infrastructure and number of extension visits.

The study recommended improvement of irrigation scheme infrastructure through rehabilitation, enacting of policies to improve rural financing to ease credit accessibility by the farmers, supporting table banking groups, improvement and support of extension service delivery, adult education, farmer trainings and consideration of the youth in allocation of land in the irrigation schemes.

DEDICATION

Special dedication to my loving wife Lilian Simiyu, my daughter and son Blessings and Ryan. To my mother Grace Ipala. To my aunts and uncles: Margaret Asangire, Joselyne Iyale Jackyline Amadiro, Jafred Erukan and Boaz Ijakaa. Further dedication to my late grandmother Melisa Omuse and the late uncle Naaman Were. They all made this possible. God bless you. To the late grandmother and uncle, rest in eternal peace.

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LIST OF ACRONYMS

AE	Allocative Efficiency
AERC	African Economic Research Consortium
APP	Average Physical Product
CBS	Central Bureau of Statistics
CIDP	County Integrated Development Plan
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DRS	Decreasing Returns to Scale
EE	Economic Efficiency
FOC	First Order Conditions
GDP	Gross Domestic Product
GoK	Government of Kenya
Ha	Hectare
HELB	Higher Education Loans Board
HH	Household head
IPTRID	International Programme for Technology and Research in Irrigation and Drainage
IRS	Increasing Returns to Scale
Kg	Kilogram
KIHBS	Kenya Integrated Household Budget Survey
Ksh	Kenya shilling
Ln	Natural logarithm

LR	Likelihood Ratio
Max	Maximum
Min	Minimum
MLE	Maximum Likelihood Estimation
MPP	Marginal Physical Product
MVP	Marginal Value Product
NIB	National Irrigation Board
No	Number
RTS	Returns to Scale
SFA	Stochastic Frontier Analysis
Std	Standard
Std Dev	Standard deviation
TCG	Turkana County Government
TE	Technical Efficiency
TPP	Total Physical Product
TVC	Total Variable Costs
TVP	Total Value Product

CHAPTER 1.

INTRODUCTION

1.1 Background

It is increasingly recognized that the world concern on access to adequate and nutritional food for a growing population has prompted the emergence of strategies in seeking for ways of increasing agricultural productivity and food production in order to cope up with the increasing demand for food. One among many is seeking for ways of increasing agricultural productivity through irrigated systems, especially under smallholder-managed irrigation schemes that mainly produce food products for direct consumption or trading in the rural spot markets (Karina and Wambua 2011).

The projected population increase in Sub-Saharan Africa raises concern to most African governments and policy makers. The population is projected to increase from 800 million people (year 2010) to 1.2 billion in year 2025 and nearly to two billion in year 2050 (Tukufu and Kevin, 2012). This shows that there will be larger demand for food with the increasing population in Sub-Saharan Africa and therefore ways of increasing agricultural productivity have to be sought so that food production keeps pace with the increasing population. Irrigation therefore, is one of the long-term strategies towards enhancing productivity in agriculture (Ackello-Ogutu et al., 2012).

Irrigated agriculture offers an opportunity for achieving food security and poverty reduction. It further plays an important role in changing smallholder agriculture from subsistence to commercially focused agriculture (GoK, 2010).Despite of the cultivated land under irrigated agriculture accounting for only 17 percent, irrigation provides 40 percent of the food produced in the world (IPTRID, 1999). Irrigated agriculture can bring a variety of benefits to individual farmers and households. These include: increased income from farming due to increased intensity of cropping, increased yields, reduced out-migration and increased return migration, lowering of food prices and improved nutrition throughout the year, reduced poverty levels among other benefits (IPTRID, 1999). During the World food summit held in 1996, it was estimated that 60 percent of the additional food required to sustain the world in the future must come from irrigated agriculture. Improvement of existing irrigation schemes was emphasized for the increase in food production to be achieved (IPTRID, 1999).

The area under irrigation in Africa is currently estimated to be slightly more than 13 million hectares (Liangzhi et al., 2011). This accounts for six percent of the total hectares cultivated (Liangzhi et al., 2011). The six percent is lower as compared to Asia, which is 37 percent and 14 percent for Latin America (Liangzhi et al., 2011). Five countries in Africa that is, South Africa, Egypt, Sudan, Madagascar and Morocco have more than one million hectares of irrigated area and account for over two thirds of the existing irrigated area in Africa (Liangzhi et al., 2011).

According to the Kenya Agriculture Sector Development Strategy paper (2010-2020), of the total area under cultivation in Kenya, irrigated area accounts for only 1.7 percent. However, it contributes 3 percent to Gross Domestic Product (GDP) and provides 18 percent of the value of all agricultural produce (GoK, 2010). This shows its potential in increasing production and productivity in agriculture. The irrigation potential of Kenya is estimated at 1.3 million hectares (GoK, 2010). Currently 114,600 hectares of irrigation have been developed of which smallholder schemes account for 49,000 hectares (43 percent), private schemes 45,000 hectares (39 percent) and public (National) Schemes account for 20,600 hectares (18 percent). The undeveloped area of over 424,400 hectares of irrigation calls for increased focus to unleash this potential (GoK, 2010).

Less than 20 percent of land mass in Kenya has medium to high agricultural potential and supports about 75 percent of the population. The remaining 80 percent lies in the arid and semi- arid lands where sustainable rain fed crop production is limited by water deficits – an indication that the potential for rain fed agriculture is low which by itself, cannot meet the challenge of achieving food security (GoK, 2010). These areas host about 10 million people and have lowest development indicators and highest incidence of poverty. The areas also experience frequent drought and food insecurity. Most of the people in these areas fall below the National poverty line with poverty levels in Turkana, Marsabit, Mandera and Wajir above 90 percent (Anderson et al., 2009; KIHBS, 2005/2006).

Irrigation can help improve agricultural production by up to 300 percent and create jobs at the rate of up to 15 persons per acre directly and indirectly (GoK, 2010). Reliability in the supply of raw materials for the agro-based industries could also be assured through irrigation. Furthermore, irrigation can help improve National security through creation of opportunities in agriculture in which the youth can be economically engaged while reducing rural urban migration (GoK, 2010). Over the years, empirical experience has shown that irrigation increases yield of most crops by between 100 and 400 percent (Karina and Wambua, 2011; GoK, 2011). Although 20 percent of the land is suitable for rain fed agriculture in Kenya, there is a potential to increase the available land by 10 percent through irrigation (Karina and Wambua, 2011). This however remains unexploited due to technological constraints, inadequate capital among the farming communities and lack of capacity for user managed irrigation schemes.

1.1.1 Overview of Irrigated agriculture in Turkana

Irrigated agriculture in Turkana County is practiced along two river basins that is, River Turkwel and River Kerio basins. Turkwel river basin crosses three Sub-Counties namely Turkana South, Loima and Turkana Central. Along this river basin, there are 24 irrigation schemes utilizing water for agriculture production. These include: Juluk, Kabulokor, Kaitese, Kalemunyang, Kangalita, Kapelibok, Kaputir, Katilu, Konoo, Koputiro, Lokipetot, Lomokomol, Loyapat, Nadoto, Nakamane, Nakwamoru, Nanyee, Naoros, Naotin, Napak, Napeikar, Nawoyawoi, Simailele and Turkwel. For Kerio river basin, it crosses Turkana East Sub-County and has four irrigation schemes located along it, namely Elelea, Lokubae, Morulem and Nakurio. This therefore, brings the total number of irrigation schemes in the County to 28 (Enviroplan, 2013).

The total acreage of irrigated agriculture in the County is estimated at 2,458 Ha,[1] (TCG, 2013). Major crops grown include Maize, sorghum, green grams and cowpeas. Other crops include watermelons, bananas and kales. In order to feed its population of close to 1,000,000 people, Turkana County requires 70,300 metric tonnes of maize per annum whereas the quantity produced is 18,000 metric tonnes. Cereals productivity in those irrigation schemes is eight, 90 Kg bags per acre (TCG, 2016).

1.1.2 The Study Area-Turkana South Sub-County

Turkana South Sub-County is one of the Sub-Counties in Turkana County with a population of 135,913 people (2009 population census). It is one of the least developed Sub-Counties in Kenya with poverty levels being 96 percent (The Kenya Integrated Household Budget survey 2005/2006 report). The Sub-County is characterized by underdeveloped infrastructure with

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[1] 1 Ha=2.471 acres

roads being in poor state and some areas inaccessible. Some parts of the Sub-County do not have communication network.

Administratively, it is divided into three divisions, namely; Lokichar, Kainuk and Katilu. It is characterized by semi-arid to arid environment with a temperature range of between 24 degrees Celsius to 38 degrees Celsius and with a mean of 30 degrees Celsius. Two rainfall seasons are experienced in the Sub-County. The long rains are normally received between March and July and short rains between October and November. The rainfall received ranges between 120mm-500mm per annum (GoK, 2008; Enviroplan, 2013). This rainfall is erratic in distribution and unreliable thus not adequate to support rain-fed farming. Droughts are also more common in the Sub-County which have negative impacts on pasture and water availability for the livestock thus affecting pastoralism. Table 1.1 below shows the mean monthly and annual rainfall for the period indicated.

Table 1.1: Mean monthly and annual rainfall of Turkana County (1991-2011)

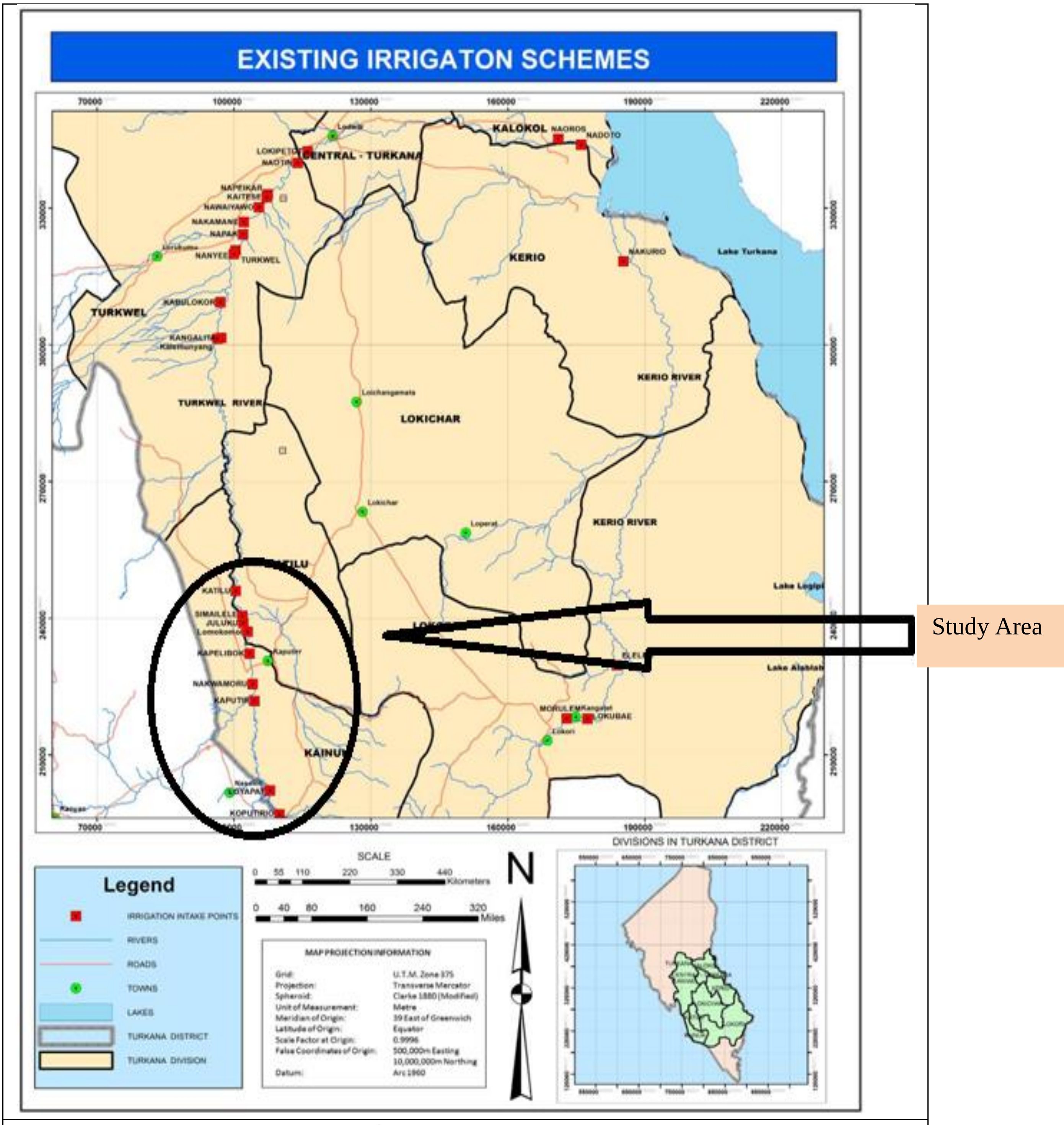
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Year**
Mean Rainfall (mm)	9.7	3.4	30.7	32.3	22.9	5.7	10.5	10.4	11.1	13.8	26.3	11.2	16
StdDev	18.1	6.5	29.6	32.3	32.2	14.1	14.2	15.9	29.8	17.6	47.1	25.3	18.1

Source: Enviroplan, 2013

The major activities in the Sub-County are pastoralism and agro-pastoralism. Agro-pastoralism is mainly found in Kainuk and Katilu divisions . There are two main permanent rivers found in the Sub-County. These are: River Turkwel and River Malimalite both having their source in the Southern highlands and flowing through Kainuk and Katilu divisions. These rivers are the most important in the Sub-County as they are the source of water for both irrigation schemes and livestock. The other rivers are seasonal. Along these two rivers, there are nine irrigation schemes, which are either conventional or non-conventional. Irrigated agriculture is mainly carried out in Kainuk and Katilu divisions with Lokichar division having no permanent river. Katilu irrigation scheme is the largest with approximately 1200 acres under irrigation. The agro-pastoralists mainly depend on these irrigation schemes for food production. The total achieved acreage under irrigation by year 2013 in the Sub-County was 714 hectares. However, there exists a potential for expansion of 8040 hectares (Enviroplan, 2013).

Most people in the Sub-County depend on relief food from the government and other charitable organizations for survival due to high food deficits. Traditionally, pastoralism was the main source of livelihood. However, due to droughts that have become common as a result of the effects of climate change, many pastoralists have lost their livestock, and therefore rendered poor. Moreover, insecurity due to frequent cattle raids has also led most of the people to lose their livestock and even lives and therefore escalating the poverty levels and high levels of dependency. These combined factors have led to increased levels of poverty in the Sub-County thus making most of the people depend on relief food.

Of recent, oil has been discovered in several parts of Lokichar division in the Sub-County. However, it is not known whether the oil will bring a curse or blessing to the residents as seen in some other oil producing countries in Africa for example Nigeria. The study area was selected on the basis of the high poverty levels and the number of irrigation schemes in the Sub-County as compared to other Sub-Counties in Turkana County. Majority of the irrigation schemes are located in Turkana South.



Source: Enviroplan Consultants Prefeasibility Study Report, 2013

Figure 1.1: Existing Irrigation Schemes in Turkana County

Source: Enviroplan Consultants Prefeasibility study report, 2013

1.2 Statement of the problem

Although 20 percent of the land in Kenya is suitable for rain-fed agriculture, there is a potential to increase the available land by 10 percent through irrigation. However, this remains unexploited (Karina and Wambua, 2011). There has also been inadequate research in the area of irrigated agriculture in Kenya (GoK, 2011). Irrigation scheme farm-level production in Turkana South Sub-County has been very low that is, eight to ten bags per acre of maize against a potential of 20-25 bags. The cultivated acreage in the schemes is also less than the designed capacities that is, 714 hectares against 1404.4 hectares (Enviroplan, 2013). Moreover, food and nutritional insecurity is high with food poverty being 81 percent (Alex et al., 2012). Most farm and non-farm households depend on relief food despite the existence of these irrigation schemes, which have the potential of food production. Productivity in terms of output per unit area under irrigation is expected to be high and people depending on the irrigation schemes to be food secure.

The causes of low productivity levels in the irrigation schemes in the Sub-County are not well understood. Further, the efficiency levels of the farmers in these irrigation schemes have not been studied. Generation of this information is important in deriving practical policy recommendations for enhanced production of food and food security. It is also crucial that the factors affecting farm production efficiency in the irrigation schemes are identified to guide policy intervention. This study will evaluate farm-level efficiency (with respect to maize enterprise) and the factors affecting it in the irrigation schemes.

1.3 Purpose and objectives of the study

The purpose of this study was to characterize farm production, evaluate farmers' efficiency levels and identify factors affecting the efficiency of farmers in the irrigation schemes of Turkana South Sub-County.

Specific objectives

The specific objectives of the study include:

1. To characterize the maize farmers in the irrigation schemes
2. To compare technical, allocative and economic efficiency among socio-economic groups of maize farmers in the irrigation schemes
3. To determine the factors affecting technical and allocative efficiency among maize farmers in the irrigation schemes

1.4 Hypotheses of the study

1. Irrigation scheme maize farmers are technically and allocatively efficient
2. Socio-economic and technical factors have no significant contribution in explaining the variation in farm-level technical and allocative efficiency in irrigation schemes

1.5 Justification of the study

As the Government and other stakeholders venture into the implementation of irrigation projects in the Sub-County to achieve food security goal, knowledge on the current levels of efficiency and the causes of low farm productivity in the irrigation schemes is important. If this is overlooked, the new irrigation schemes to be established will still be affected and therefore put them in danger of collapse or underutilization. Non-Governmental Organizations and the government are investing a lot of resources in the Sub-County in the fight against hunger and poverty. Irrigation is one of the areas that a lot of investment is being put and therefore, it is crucial that the factors affecting farm-level production efficiency in these irrigation schemes are identified so that appropriate policies are put in place to achieve the intended goal of food security and reduction of poverty.

The findings of this study will give insights into the current efficiency levels of the farmers and the possible factors affecting it. This will be useful in understanding the existing potential to increase productivity, improve competitiveness of farms and better capacity utilization. This information will also be useful to the Government that is, both National and County Government of Turkana, Non-Governmental Organizations, the farmers and other stakeholders undertaking or intending to undertake investment in irrigation projects in the Sub-County in their policy or decision-making.

1.6 Organization of the thesis

The thesis is made up of five chapters. This chapter covers the introduction, the statement of the problem, purpose and objectives, hypotheses and justification. The next chapter reviews the literature. Chapter three gives the outline of the methodology used to achieve the study objectives. In chapter four, the results of the study are discussed in four sections. The first section gives the descriptive statistics for maize farmers in the irrigation schemes with a focus on the important characteristics that aid in understanding the drivers of efficiency in maize production. The second section presents results on technical efficiency and factors determining it. The third section assesses the status of allocative efficiency and factors determining it in the irrigation schemes. The fourth section presents the results of economic efficiency analysis. The last chapter summarizes key findings from the study and gives recommendation for policy and other suggested areas for further research in future. References supporting the study are attached at the end of the thesis. An appendix has also been attached and contains the field survey questionnaire used during data collection and the correlation matrix of socio-economic and technical factors

CHAPTER 2.

LITERATURE REVIEW

This chapter reviews the literature on efficiency. It begins with a review of the concepts of efficiency and measurement methods followed by empirical efficiency studies review. In the last section, the socioeconomic and technical factors that affect efficiency are reviewed.

2.1 The concept of efficiency and measurement methods

The efficiency in use of resources is important in agriculture for developing countries. Given the level and quality of the inputs available, farmers prudent utilization of the inputs is an important determinant of the quantity of output they are able to produce (Lenis Saweda et al., 2011). Efficiency studies have been based on a paper by Farrell (1957) who proposed that the efficiency of a firm comprises of two components: technical efficiency and allocative efficiency. The combination of the two measures of efficiency provides a measure of total economic efficiency (Coelli et al., 2005).

Technical efficiency reflects the ability of a firm to obtain maximal output from a given set of inputs whereas allocative efficiency reflects the ability of a firm to use inputs in optimal proportions, given their respective prices and the production technology (Coelli et al., 2005). A technically efficient firm operates on the production frontier. A firm has to choose its input combinations in a cost-minimizing manner (Coelli et al., 2005). For allocative efficiency to hold, farmers must equate their marginal returns with true factor prices. Thus technical inefficiency reflects deviations from the frontier isoquant, that is by how much actual output missed the maximum possible output, given a production technology, while allocative inefficiency reflects deviations from the minimum input cost ratios that is, it measures by how much actual total cost exceeded the minimum total cost of production, given input prices and technology (Bravo-Ureta and Pinheiro, 1997; Mutoko, 2008; Lenis Saweda et al., 2011). Economic efficiency as defined by Farrell (1957) refers to the capacity of a firm to produce a pre-determined quantity of output at minimum cost for a given level of technology (Farrel, 1957; Lenis Saweda et al., 2011). It is derived from the product of the technical and allocative efficiencies.

2.1.1 Input-Oriented measures

The input oriented technical efficiency measure addresses the question: "By how much can input quantities be proportionally reduced without changing the output quantities produced?" Farrell illustrated his ideas using a simple example involving firms, which use two inputs (X_1 and X_2) to produce a single output (Y) under the assumptions of constant returns to scale. Figure 2.1 adapted from Farrell, 1957 is used to show the unit isoquant of a fully efficient firm represented by SS' that can allow measurement of technical and allocative efficiencies (Coelli, 1996). If a given firm uses quantities of inputs, defined by point P, to produce a unit of output, the technical inefficiency of that firm could be represented by the distance QP, which is the amount by which all inputs could be proportionally reduced, without a reduction in output (Coelli, 1996). This is usually expressed in percentage terms by the ratio QP/OP, which represents the percentage by which all inputs could be reduced. The technical efficiency (TE) of a firm is measured by the ratio:

$$TE_I = OQ/OP, \qquad (2.1)$$

This is equal to one minus QP/OP (Coelli, 1996). It will take a value between zero and one, and hence provides an indicator of the degree of technical inefficiency of a firm. A value of one indicates the firm is fully technically efficient. For example, the point Q is technically efficient because it lies on the efficient isoquant (Coelli, 1996).

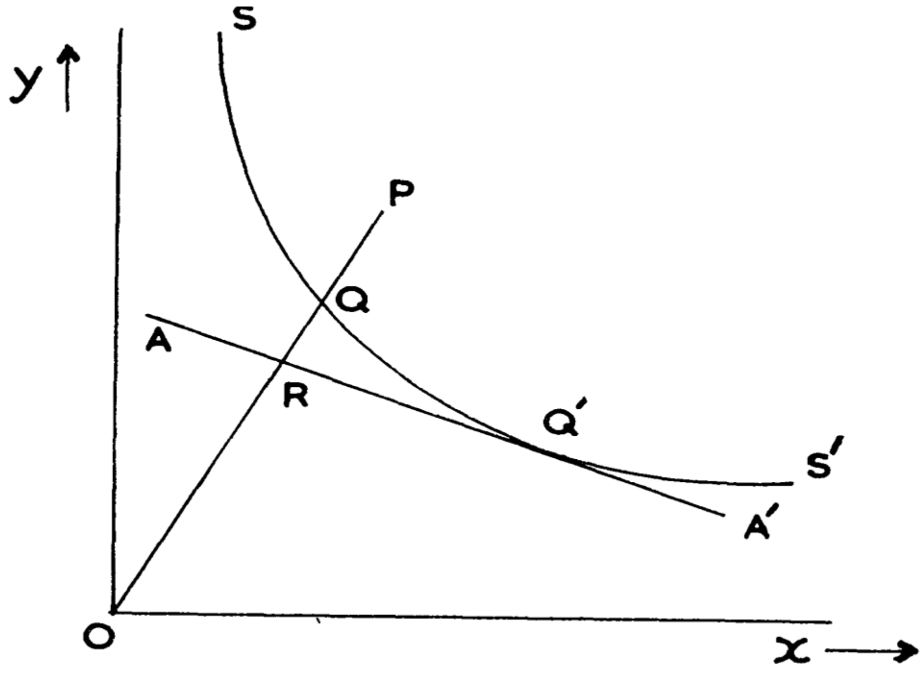


Figure 2.1: Technical and allocative efficiencies

Source: Farrell 1957

If the input price ratio, represented by the line AA' in figure 2.1 is also known, allocative efficiency may also be calculated. The allocative efficiency (AE) of the firm operating at P is defined by the ratio:

$AE_I = OR/OQ$ (2.2)

The distance RQ represents reduction in production costs that would occur if production were to occur at the allocatively (and technically) efficient point Q' instead of at the technically efficient but allocatively inefficient point, Q (Coelli, 1996). The total economic efficiency (EE) is defined by the ratio

$EE_I = OR/OP$ (2.3)

Where, the distance RP can also be interpreted in terms of a cost reduction. The product of technical and allocative efficiency provides the overall economic efficiency (Coelli, 1996)

$TE_I X AE_I = (OQ/OP X OR/OQ) = (OR/OP) = EE_I$ (2.4)

There are two methods of efficiency analysis. These are Data Envelopment Analysis (DEA)-non-parametric method and stochastic frontier model (SFA) developed by Aigner et al., (1977). DEA involves the use of linear programming methods to construct a non-parametric piecewise surface (or frontier) over the data so as to be able to calculate efficiencies relative to the frontier. The stochastic frontier model is explained in the methodology section.

2.2 Irrigation efficiency

With the increasing water scarcity and competition, for it across water using sectors, there is need for water saving and its efficient use (Cai et al., 2001). Improvement in the physical efficiency of water use is related to water conservation through increasing the fraction of water beneficially used over water applied. Economic efficiency seeks the highest economic value of water use through both physical and managerial measures. Both physical and economic efficiency of irrigation water use is crucial in irrigation schemes (Cai et al., 2001) Minimization of water loss through wastage in the farms and along the canals is important to achieve the desired efficiencies in irrigation. However, this study will be limited to the evaluation of technical, allocative and economic efficiency of farm-level production in the irrigation schemes and will not look at the physical and economic efficiency of irrigation water use.

2.3 Empirical efficiency studies review

Abid and Nawaz (1998), measured technical efficiency of farms in irrigated areas of Pakistan’s Punjab. The authors employed the stochastic frontier model specified as the Translog variable cost frontier. The study examined the cost behavior of 387 farms in five districts. The causes of technical inefficiency were identified by focusing on attributes of farms and farm operators, irrigation mechanism, loans and farm size. The study used whole farm data, which included all crop and non-crop outputs and all measurable inputs used on farm. Tobit regression model was specified to evaluate the sources of measured efficiencies. The explanatory variables used in the Tobit regression were farmers' level of education (education taken as proxy for managerial ability and efficiency in decision making), age, access or location of farm from irrigation facility, access to institutional credit, area operated and size of land holding and geographic location.

The study found out that the farms' cost efficiency varied from 29 percent to 95 percent with a mean technical efficiency of 76 percent. This implied that costs of an average farmer were raised by 24 percent due to technical inefficiencies. Other findings of the study included: years of formal schooling had a significant positive influence on farm technical efficiency, which indicated that farms managed by farmers that are more educated were relatively more cost efficient. Age of the farmers had no significant influence on technical efficiency of the farms in any of the models. This suggested that on average older farmers were equally efficient in their use of resources as their younger counterparts. Farm size was negatively associated with technical efficiency in the findings of the study implying that farmers with small farms were more efficient as compared to those with large farms. The study recommended the promotion of policies geared towards investment in education of rural households and canal irrigation management so that to improve the technical efficiency of farms.

However, data collected by the authors did not permit them to reach a clear conclusion on the role of institutional loans (credit) in farm efficiency. The study concluded that since long-term loans take a longer period to increase technical efficiency, their effect on efficiency might be unknowable. Moreover, if the loans are misemployed by their users, then the key policy change should be to eliminate existing distortions. This was explored more by the current study. In addition, the current study explored more on the effect of status of irrigation infrastructure, access to extension services and household size on the efficiency in irrigation schemes. Abid and Nawaz (1998) employed a double stage approach in the estimation of the stochastic frontier. This is often criticized by literature because it introduces bias (use of TE estimates from one equation as a dependent variable in the subsequent regression violates the assumption that the technical efficiency term (u) is independently and identically distributed normal random variable) and thus leads to inconsistent estimates of inefficiency effects.

Md.Abdul and White (2002), carried a study on the determinants of technical inefficiency of farms in Bangladesh. The study was carried out for the rice farmers in two villages using two different irrigation infrastructures from each other (diesel pump and electricity). It sought to know the type of farm households that were relatively efficient and whether barriers to efficiency were due to environmental degradation, weak irrigation infrastructure or the socioeconomic characteristics of the farm households. The authors used stochastic frontier production model represented by specifying the translog stochastic frontier. Data was collected from a sample of 150 farms in the two villages with the farm households additionally representing different degrees of environmental degradation.

The authors found out that output elasticity with respect to land was the highest followed by irrigation. This showed that land as an input had major influence on output. The study also found that the farmers were engaged in production on a non-optimal scale of operation, as the returns to scale was 0.888, implying decreasing returns to scale. The coefficients of the age and education of the farmers were positively related to technical inefficiency. The finding by the authors study on the relationship between age and technical inefficiency contradicts the finding by Abid and Nawaz (1998) which stated that age had no significant effect on technical efficiency and therefore, this study will explore more on the relationship between this variable and the technical efficiency of irrigation farmers in Turkana South Sub-county.

Land fragmentation was found to have negative effect on inefficiency. This showed that large farm sizes had lower levels of technical inefficiencies as compared to small farm sizes, which contradict the finding by Abid and Nawaz (1998). With regard to irrigation infrastructure, technical inefficiencies in agricultural production were found to increase in irrigation schemes operated by diesel pumps as compared to the ones using electricity. The study recommended policies leading to electrification in the rural area for irrigation and reduction of land degradation so that to reduce inefficiencies in production thus improving farmers' welfare in Bangladesh.

The current study will adopt the stochastic frontier model in evaluating the effect of technical and socio-economic factors of the farm households on technical efficiency. However, it will mainly deal with irrigation scheme farmers using canal (gravity) fed irrigation as opposed to diesel and electrified irrigation used in the reviewed study. In addition to the factors studied by the reviewed study, the current study included evaluation of the effect of status of irrigation scheme infrastructure (canal, intake and other scheme structures) on technical and allocative efficiency. The current study further assessed the effects of income of the farmer, education of the farmer, gender, extension service, status of irrigation infrastructure and soil salinity on irrigation scheme farm level efficiency in Turkana South Sub-County-Kenyan case.

Amaza et al., (2006) studied on the determinants of food crop production and technical efficiency in the Guinea savannas of Borno State, Nigeria. Data was collected from a sample of 1086 farmers. The authors used a stochastic frontier production function using maximum likelihood estimation (MLE) technique in the analysis. The MLE results showed that the coefficients of farm size, fertilizer and hired labor on output were positive and significant at (P=0.01). The mean technical efficiency of the farmers in the study area was found to be 0.68. Farmers' age, education, extension, credit and crop diversification were found to be significant factors that accounted for the observed variation in efficiency among the farmers.

The study recommended improved farmer education, access to credit, access to improved extension services and less crop diversification in order to improve the technical efficiency in food production. The current study adds to the study conducted by Amaza et al., (2006) by including the analysis of allocative efficiency and overall economic efficiency of farmers. More variables for example gender and household size were considered in the analysis of factors influencing efficiency.

Mutoko, (2008) analyzed economic efficiency in maize production for small-scale farmers in Northwestern Kenya. The study sought to establish the factors determining technical, allocative and economic efficiency in maize production. Stochastic production and cost frontier models within production theoretical framework were applied in analyzing cross-sectional data from 373 small-scale maize farmers stratified by agro-ecological zones and soil fertility management choices in Lugari and Transzoia districts. The findings of the study indicated that maize farmers were only 49 percent economically efficient. On average, the smallholder maize farmers were 64 percent technically efficient and 75 percent allocatively efficient. Further findings by Mutoko's study indicated that education, off-farm income, family size, extension contacts, credit and market access and soil fertility management were significant factors influencing economic efficiency in smallholder maize production. Technical efficiency decreased with the number of years in farming (farming experience). This was attributed to reduced physical strength of the older farmers to execute or supervise major agronomic practices. In addition, younger farmers are more market oriented, eager to experiment with new production techniques unlike the older ones who are likely to continue with their traditional practices and focus mainly on satisfying subsistence food requirements. Technical efficiency was found to increase with an additional year spent in formal schooling. Farmers who made more contacts with extension agents were found to be more technically efficient. Policy interventions inform of price stabilization for both maize grains and inorganic fertilizers, increased extension coverage, improvement in rural roads and provision of agricultural credit to relax liquidity constraints among maize farmers were recommended by the study.

Kagwe, (2010) analyzed land tenure’s effect on technical efficiency in smallholder crop production using data from 22 districts in Kenya mainly from the main agro-ecological zones. The socio-economic factors considered for analysis in the study included: gender of the household head, education level, farm size and credit. The author used a stochastic frontier function to estimate technical efficiency and its determining factors.

The findings of the study indicated that land owned with title deeds had the highest technical efficiency level while rented land had the lowest efficiency level. Persons with larger parcels of land were more technically efficient in crop production than those with smaller land sizes. In addition, parcels of land owned by persons with no education had lower technical efficiency level than those parcels from households headed by persons with higher levels of education. Furthermore, households that accessed credit had higher technical efficiencies than those that did not. The study recommended land titling to be extended to all regions in the country as this will increase tenure security, which would lead to increased technical efficiency. Provision of farmers with affordable credit was also recommended in order to ensure that they acquire the required farm inputs in the recommended proportions thus increasing their technical efficiency. The current study differs from Kagwe's in that it mainly focuses on irrigation scheme farmers in one Sub-County. It also includes additional variables in the analysis of efficiency. However, it adopted the stochastic frontier function in the analysis of technical efficiency as done by Kagwe.

Makombe et al., (2011) comparatively analyzed technical efficiency of rain-fed and smallholder irrigation in Ethiopia. The authors employed stochastic frontier model of the translog production functional form in estimating the technical inefficiency of farms for the different production systems. Among the production, systems included in the analysis are purely rain-fed production, farmers practicing rain-fed crop production but with access to irrigation, traditional irrigation and modern irrigation. A sample of 753 farming households was selected through simple random sampling technique with representation from all the four production systems.

The study considered five inputs for analysis in the translog production function. These are: total area planted (hectares), Labor (man- days), fertilizer used (kilograms), total number of irrigations (number of times crop irrigated) during the year and oxen days needed for land preparation. The gross value of output was taken as the dependent variable in the production function. A chi-square test of association was used to examine the impact of socio-economic variables on technical inefficiencies. The socio-economic variables analyzed included; age, gender, education of the household, cropped area and extension. The authors also analyzed the relationship between the production constraints encountered by the farmers and technical inefficiency using chi-square test.

The results of the study showed that modern irrigation schemes technical inefficiencies varied from seven to 21 percent with an average of 12 percent. For the traditional irrigation schemes, the technical inefficiencies varied between one percent and seven percent with an average of four percent. Therefore, traditional irrigation schemes had lower inefficiencies as compared to modern irrigation schemes. The authors also found out that most of the variables were non-significant, showing lack of relationship between the variables used and the estimated technical inefficiencies.

For households doing rain-fed farming but with no access to irrigation, age was found to be significant. Younger households aged 40 years and below had a mean technical inefficiency of 20 percent whereas older households had a mean technical inefficiency of eight percent. Therefore, older households had lower technical inefficiencies as compared to younger households. However, for modern irrigation schemes sample, the results on technical inefficiencies were opposite. Young households aged below 40 years had lower inefficiency of 10 percent on average as compared to older households who had an average of 14 percent. Gender was significant for modern irrigation schemes. Male-headed households had lower technical inefficiency levels of 12 percent on average as compared to female-headed households who had a mean technical inefficiency of 20 percent.

In the modern irrigation schemes, results were counterintuitive in that farmers visited by extension agents exhibited higher levels of inefficiencies in comparison to those not visited.

This current study explored more on this finding. Further findings of the study indicated that the production constraints assessed were significantly related with levels of inefficiency in the rain-fed production system of farmers without access to irrigation in comparison with the rain-fed producers with access to irrigation. Upgrading of the existing traditional irrigation systems to modern schemes was recommended by the study.

The current study specifically dealt with irrigation scheme farming households and therefore did not incorporate the rain-fed farmers, as rain-fed farming is limited in the Sub-County due to unreliable rainfall pattern. However, the current study used the stochastic frontier production function in analyzing the technical efficiency among the irrigation scheme farmers as used in the reviewed study.

Kibaara and Kavoi, (2012) assessed the technical efficiency in maize production for smallholder farmers in Kenya using a stochastic frontier model. Cross-sectional household data for the period 2003 and 2004 main cropping season was used. It was found that the technical efficiency index of the smallholder farms ranged from eight to 98 percent. The inefficiency model variables which included tractor use in land preparation, use of certified seed, years of schooling of household head, age and access to credit had negative signs, an indication that they decreased technical inefficiency. Further, households headed by males were found to have decreased levels of technical inefficiency. On the other hand, farmers engaged in off-farm income earning activities were found to exhibit higher levels of technical inefficiency. This was attributed to reallocation of time away from farm related activities. However, when the off-farm income variable was interacted with education, the resulting sign was negative an indication that educated farmers engaging in off-farm income earning activities exhibit higher levels of technical efficiency in the production of maize. This is explained by the fact that these farmers can make timely decisions in the allocation of resources in maize production and are not constrained financially. The study recommended improvement in the availability and affordability of hybrid seeds, tractor services and agricultural credit in order to increase technical efficiency in maize production. The current study adds to Kibaara and Kavoi study by including allocative efficiency in computing the overall economic efficiency.

2.4 Factors affecting efficiency: Rationale and expected signs

From the empirical studies reviewed for the different authors, various factors (socio-economic and technical) are hypothesized to influence efficiency in farm production. The expected influence of these factors on farm efficiency is discussed below.

2.4.1Socio-economic Factors

2.4.1.1 Age of the farmer:

Studies of factors influencing farmer efficiency levels by Md.Abdul and White (2002); Ajibefun and Daramola, (2003); Amaza et al., (2006); Makombe et al., (2011); Kibaara and Kavoi (2012) indicate that older farmers are relatively less efficient in farming than the younger farmers are. In other words, technical inefficiencies increased with age. Younger farmers are hypothesized to be more flexible, progressive and tend to adopt innovative technologies than older farmers. Therefore, in this study, this variable was anticipated to have a negative effect on technical and allocative efficiencies that is, efficiency decreases with age.

2.4.1.2 Gender of the household head (Main decision maker)

Studies on efficiency by Makombe et al. (2011); Kibaara and Kavoi (2012), Omondi and Shikuku, (2013) indicate that households headed by males had lower technical inefficiency levels as compared to households headed by females. The explanation behind this is that generally women have less access to agricultural resources for example land ownership, credit and extension services thus resulting into inefficiency in their operation. In this study, male-headed households are hypothesized to have lower inefficiency levels as compared to the households headed by females. This is because; men have fewer responsibilities and have better access to information and services as compared to women. Further women have more responsibilities to perform and therefore the time devoted to farming activities is expected to be less. Therefore, higher levels of technical and allocative efficiency are expected from farms managed by males in comparison to those managed by women.

2.4.1.3 Education level of the farmer (Highest level of education):

This variable is taken as a proxy for managerial skills (ability) and efficiency in decision-making. Abid and Nawaz, (1998); Ajibefun and Daramola, (2003); Amaza et al., (2006); Mutoko, (2008) and Kibaara and Kavoi, (2012) in their efficiency studies found out that years of formal schooling had a positive influence on efficiency. The findings of these studies indicate that technical efficiency increased with years of formal schooling. Farmers who had attained higher levels of education had higher efficiency levels as compared to farmers with lower levels of schooling. Ajibefun and Daramola in their study found that a percentage increase in the mean level of education would lead to arise in the mean level of technical and allocative efficiency. Educated farmers are able to make and implement informed and timely farming decisions. Moreover, educated farmers readily adopt the use of improved technology in farming, for example application of fertilizers in crop farming thus producing close to the frontier. Therefore, in this study, this variable is expected to positively influence the level of technical and allocative efficiency. In other words, technical and allocative inefficiencies are expected to decrease with an increase in educational level.

2.4.1.4 Access to credit

Studies conducted by Amaza et al., (2006); Kagwe, (2010); Kibaara and Kavoi, 2012 indicate that access to credit decreased levels of technical inefficiency. This implies that farmers with greater access to credit tend to be more efficient in their crop production. Farmers' access to credit enables them to procure inputs necessary to improve farm productivity. In addition, credit availability eases constraints of production facilitating farmers to get inputs in a timely basis and hence it was expected to increase farmers' efficiency.

2.4.1.5 Farm size

Studies that have considered this variable in the analysis of efficiency have had varying results on its effect on technical efficiency of the farmers. For example, Abid and Nawaz (1998) found that farm size was negatively correlated with technical efficiency in that farmers with small farm sizes were more efficient as compared to those with bigger farms. A study by Mignouna et al., (2010) on maize production efficiency in western Kenya found that farm size variable was negatively significant in explaining farmers' inefficiency. This indicated that every unit increase in land leads to a decrease in technical inefficiency. Kagwe (2010) findings indicate that farmers with larger parcels of land had higher levels of technical efficiency as compared to farmers with smaller parcels. Therefore, in this study, it is anticipated that farmers with larger farm size (acreage) in the irrigation scheme are expected to be more efficient.

2.4.1.6 Household size

Studies on the effect of this variable on efficiency have varied findings. For example, Nambiro et al. (2010) studied the technical efficiency and its relationship with agricultural information services among maize producers in Kakamega, Kenya. Household size being one of the variables analyzed was found to be negatively associated with technical efficiency. The larger the household size, the lower the technical efficiency. The negative association was attributed to reallocation of income, which would have been used to purchase essential inputs in maize production for example fertilizer, to other activities like purchase of food to meet household consumption needs.

However, a study by Mignouna et al., (2010), found that household size variable was negative and significant in the inefficiency model. The variable was found to reduce technical inefficiency. This implied that consistent availability of labor helps decrease inefficiency by mitigating the shortage of labor. A lager household size assures labor availability for farm operations to be completed in time and ensures availability of a broad variety of family workforce. The current study adopts Mignouna et al., 2010 and expects household size to be positively related with technical and allocative efficiency.

2.4.1.7 Income (Farm and off-farm)

Kibaara and Kavoi, (2012) found that farmers engaged in off-farm income earning activities exhibited higher levels of inefficiency. This was attributed to reallocation of time away from farm related activities. However, when this variable was interacted with education variable, the resulting coefficient in the inefficiency model was negative, indicating that educated farmers engaging in off-farm income earning activities exhibit higher levels of technical efficiency in maize production. Such farmers can easily procure the required inputs in maize production since they are not financially constrained. A study by Omondi and Shikuku, (2013) on the technical efficiency of rice farmers in Ahero found that, as the income levels of the farmers increased, their technical efficiency also increased. Farmers with lower levels of income had lower technical efficiencies as compared to those with higher levels of income.

This current study therefore expected this variable to positively influence efficiency. Farmers with more income are expected to be more efficient as they are able to obtain the needed inputs in the production process than those with lower levels of income.

2.4.2 Technical factors

2.4.2.1 Access to extension services

Studies by Amaza et al., (2006) and Mutoko, (2008) found out that extension services were positively related with technical and allocative efficiency. Farmers with more extension contacts were more technically efficient. This finding indicates that extension information is valuable in enabling farmers to apply modern productive farming techniques more effectively. Moreover, access to extension services enables farmers to get information on new technologies and knowledge on how to improve their production. Therefore, access to extension services is hypothesized to positively influence the technical and allocative efficiency of the farmers (decrease in technical and allocative inefficiency) in the irrigation schemes.

2.4.2.2 Status of irrigation infrastructure:

From the reviewed literature on efficiency, the influence of this factor on technical and allocative efficiency of farmers in irrigation schemes has not been studied. However, the current study incorporated it in trying to establish its effect on the technical and allocative efficiency. Good irrigation scheme infrastructure ensures steady and adequate flow of water to farms and thus increasing farmer efficiency. On the other hand, poor irrigation scheme infrastructure increases the levels of inefficiencies. Therefore, good irrigation scheme infrastructure was hypothesized to increase technical and allocative efficiency.

2.4.2.3 Soil salinity

Studies investigating the effect of this factor on farmer efficiency are also scanty. This study will explore more on the effect of this variable on irrigation schemes farmer efficiency that is technical and allocative. The factor is expected to negatively affect farm efficiency and productivity. Farmers whose plots are located in saline soils are expected to realize lower yields thus being technically and allocatively inefficient.

CHAPTER 3

METHODOLOGY

This chapter provides the conceptual and theoretical framework that guides this study to achieve the stated objectives. It has four sections with the first section providing the conceptual framework that summarizes the key variables in the study. The second section provides the theoretical framework on which the study is based on. The third section gives the empirical model specification whereas the last section gives the sampling design, sample size determination, data collection and analytical procedures followed.

3.1 Analytical framework

3.1.1 Conceptual Framework

Figure 3.1 shows the conceptual framework of factors hypothesized to affect farm-level efficiency in irrigation schemes and their links to the overall economic efficiency levels among the farm households in the irrigation schemes in Turkana South Sub-County. The factors are divided into two that is socio-economic and technical as indicated in the diagram. The outcome of these factors can lead to either inefficient effects that is, low yields realized by the farmer and high costs incurred in the production or efficient effects that is, high yields per acre and low costs.

Other intervening factors that may affect farmer efficiency level are also included. These are irrigation scheme management factors (scheme maintenance) and input prices. A poorly maintained irrigation scheme is likely to have poor water delivery system to the fields thus affecting farmers' output levels and subsequently efficiency. Prices of farm inputs can also have an effect on the utilization of farm inputs. For example, if inputs like fertilizer and seeds are priced highly, some farmers may not be able to afford and therefore this will directly affect their output levels and consequently efficiency in production.

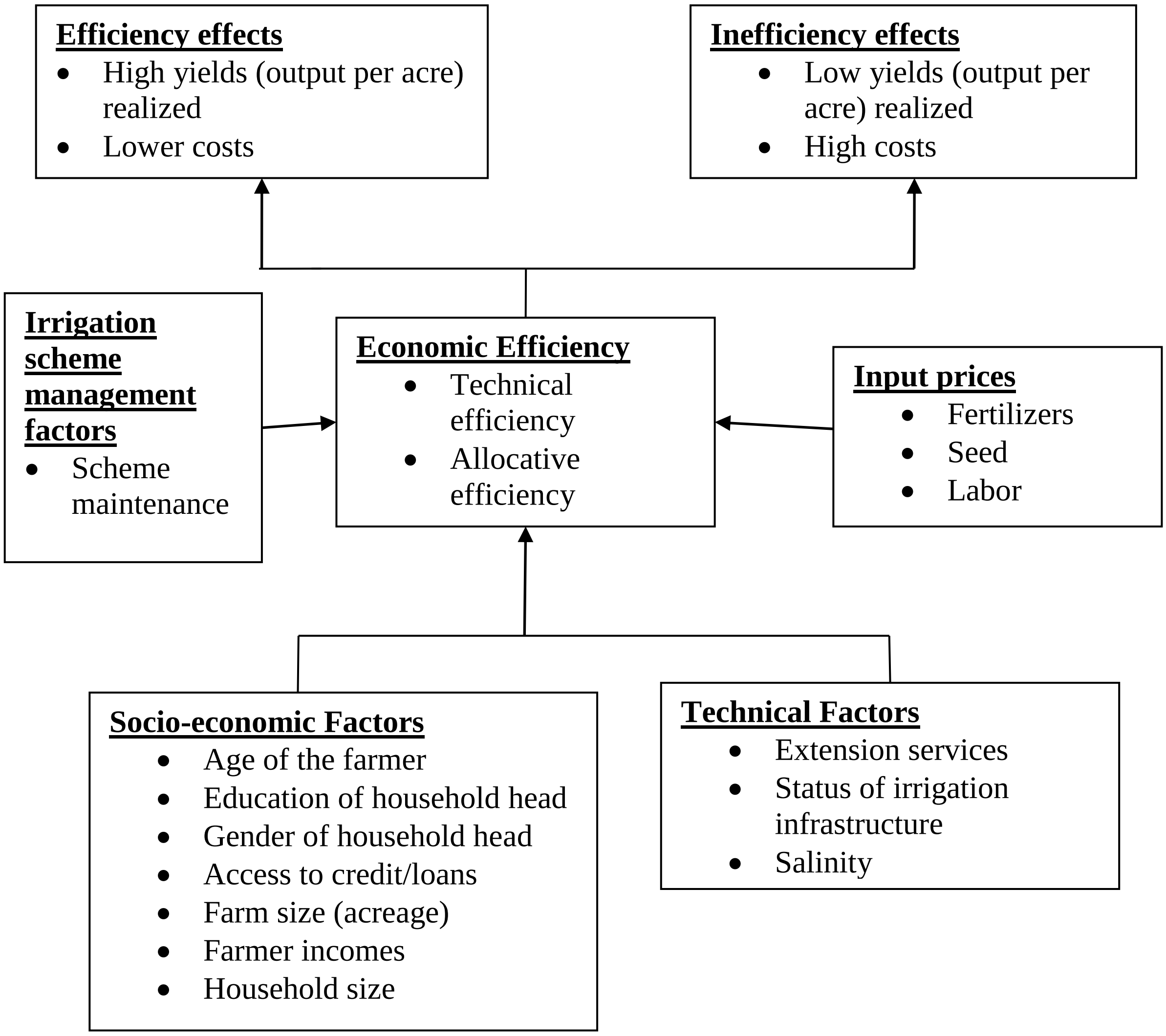


Figure 3.1: Conceptual framework of factors affecting irrigation scheme farm-level efficiency

Source: Author’s, 2014

3.1.2Theoretical Framework: Review of Producer theory

This study is based on the theory of the firm (Producer theory). Irrigation scheme farming households are considered as producing units (firms) aiming at obtaining maximum farm output at minimal costs in order to raise profits. The producer is assumed to be motivated by the objective of maximizing profits.

A firm is a decision-making unit, which through the process of production converts inputs into outputs. Production refers to the process of transforming inputs into outputs using a given level of technology. The technology of the firm can be described by the production function. The classical production function describes the technical relationship that transforms inputs (resources) into outputs (commodities), (Debertin, 2012). Assuming only a single output is produced from various inputs, a production function can be specified as: $Q_i = f(X_i; \beta) + \varepsilon$ where Q_i is the output (total physical product-TPP) of the i^{th}farm, X_i is a vector of inputs used in the farm while the β_s are the parameters to be estimated. ε is the error term that is assumed to capture statistical noise in the model. ($f(.)$) is the functional form used, for example the Cobb-Douglas specification. The area below the production function represents the set of feasible production plans or the production possibility set. The inputs that were considered in this study are; Labor, Seed, Fertilizer and irrigation water.

The marginal physical product (MPP) refers to the change in output associated with an incremental change in the use of an input. The incremental change in the use of an input is usually taken to be one unit. Thus, MPP is the change in output associated with a one-unit increase in the input (Debertin, 2012). For example, the marginal physical product of labor is given by equation 3.1 below.

$$MPP_L = \frac{\partial Q}{\partial L} \tag{3.1}$$

Equation 3.1 is derived from the first derivative of the production function. Diminishing marginal productivity of an input arises when further increase in the use of the input results to lower productivity. By taking the second derivative of equation 3.1, the result will be less than zero as indicated in equation 3.2 thus showing diminishing marginal productivity of the labour input used in production.

$$\frac{\partial MPP_L}{\partial L} < 0 \tag{3.2}$$

Average physical product (APP) is defined as the ratio of output to input. It represents the average amount of output per unit of input used (Debertin, 2012). APP is dependent on the level of other inputs used in production. For example, the APP of labor is given by:

$$\mathrm{APP_L} = \frac{\mathrm{Q}}{L} = \frac{\mathrm{f(Labor, Seed, Fertilizer, Irrigation\ water)}}{\mathrm{Labor}} \tag{3.3}$$

The concept of returns to scale (RTS) is also very useful in the production theory. The RTS measures the responsiveness of output when all inputs are increased in the same proportion in the long run (Coelli et al., 2005; Debertin, 2012). Returns to scale can either be: Constant, decreasing or increasing returns to scale abbreviated as CRS, DRS and IRS respectively. A function homogenous of degree one is said to have constant returns to scale or neither economies or diseconomies of scale. A function homogenous of degree greater than one is said to have increasing returns to scale or economies of scale whereas a function homogenous of degree less than one is said to have decreasing returns to scale or diseconomies of scale (Debertin, 2012). RTS is also referred as elasticity of production and is obtained by the ratio of MPP to APP (Debertin, 2012) i.e.

$$\mathrm{RTS} = \frac{\mathrm{MPP}}{\mathrm{APP}} \tag{3.4}$$

In addition to the above theoretical concepts of production theory, the value of the TPP (TVP) can also be derived by multiplying total physical product by the price of the output that is $(TPP * PRICE\ OF\ OUTPUT)$. Given the price of output say as P_q, its value of marginal product that is MVP can be obtained by multiplying MPP by P_q . From these concepts of a production function, a profit function can also be derived as follows: Profit (π) =TVP-TVC where TVC is the total variable costs of inputs used in the production. Applying the first order conditions (FOC) to this profit function, we obtain a change in profit with respect to change in input. For example, labour (L)

$$\partial\pi/\partial L = \text{MVP-MVC} = 0 \qquad (3.5)$$

Therefore, at profit maximization, the marginal value of product equals marginal value of costs and unit price of the input that is, MVP=MVC=w and in this case, for labor. Determination of whether the inputs are used at optimum levels is derived by equating MVP to unit factor price.

3.2 Empirical model specifications

Studies on efficiency measurement begin with Farrell (1957) who drew upon the work of Debreu (1951) and Koopmans (1951) to define simple measure of firm efficiency, which could account for multiple inputs. There are two principal methods of estimating frontier production functions, these are: non-parametric Data Envelopment Analysis (DEA), which was developed by Charneset al., (1978), and parametric (econometric) Stochastic Frontier Analysis (SFA) developed independently by Aigner et al., (1977).

DEA is a non-parametric mathematical programming approach to frontier estimation. It is a deterministic approach for measuring efficiency and assumes that any deviations from optimal output levels are due to inefficiency and not errors. It uses the extreme point (or corner point) approach in comparing each producer with only the “best” (or most efficient) producers. Efficient producers form an envelope over other inefficient producers. However, DEA approach has the following limitations that made it not adopted by this study. These limitations are: It does not capture the stochastic nature of the production function for example due to external shocks or measurement error, since it is a non-parametric technique hypothesis cannot be tested on technical efficiency estimates, requires weights on inputs and outputs which are arbitrarily assigned, DEA estimates have greater variability-either overestimates or underestimates efficiency, its estimates are sensitive to returns to scale assumed-whether IRS,DRS or CRS and finally it entails computational complexities.

3.2.1 Descriptive statistics

To achieve the first objective, descriptive statistics were used to analyze the data that was collected. Measures of dispersion and central tendency for example percentage, frequency, mean, range and standard deviation were used.

3.2.2 Efficiency estimation models

In order to achieve the second and third objectives, stochastic production and cost frontier functions were used in deriving the technical, allocative and economic efficiencies.

3.2.2.1 Stochastic frontier production function

The above function as proposed by Aigner et al., (1977) was used to estimate technical efficiency of farms in the irrigation schemes that were sampled. The stochastic frontier was preferred to DEA in this study because it takes into account the existence of random statistical noise and the unobserved randomness in firm decision-making behavior unlike the DEA model. Irrigation scheme farmers are vulnerable to external shocks or influences like weather and crop diseases. Further, SFA produces efficiency estimates of individual producers. Using these estimates, one can identify those producers who require intervention. Lastly, since efficiency scores vary across producers, they can be related to producer characteristics, which can be used to identify the source of inefficiency. The general stochastic frontier model is specified in equation 3.6, as shown below.

$$Y_i = f(X_i; \beta) + \varepsilon_i \quad i = 1,2 \ldots \ldots \ldots \ldots . . N \qquad (3.6)$$

Where:

Y_i = The output of the ith firm,

$f(X_i; \beta) =$ A suitable functional form such as Cobb-Douglas or translog production function

X_i = A vector of physical inputs

β = A vector of unknown production function parameters to be estimated

$\boldsymbol{\varepsilon_i}$ = A composite error term made up of two components that is, $\varepsilon_i = v_i - u_i$.

The error term v_i represents the effects of statistical noise (which includes errors of measurement, unobserved factors beyond the control of the farmer for example weather effects like rainfall failure, and omitted variables in the production function). It is assumed to be independently and identically distributed (iid) as a normal random variable with mean zero and variance sigma squared i.e. $V_i \sim iid\ N(0, \delta_V^2)$, (Aigner et al., 1977). The u_i represents non-negative random variables accounting for the technical inefficiency in production and are often assumed to be independently and identically distributed half-normal i.e. $u_i \sim iid\ |N(0, \delta_u^2)|$.

Based on the assumption that μ_i and v_i are independent of the parameters of the production frontier, the frontier specified in equation 3.6 was estimated using Maximum Likelihood Estimation (MLE) method. Farm specific Technical efficiency was obtained using the relationship given in equation 3.7.

$$TE = \frac{Y_i}{\mathrm{Y}^*} = \frac{\exp(X_i;\beta + V_i - u_i)}{\exp(X_i;\beta + V_i)} = \exp(-u_i) \qquad (3.7)$$

Equation (3.7) is the ratio of the observed output (Y_i) to the corresponding frontier output (Y^*) given the available technology (Coelli et al., 2005). Technical efficiency takes values within the interval of zero and one, where one indicates a fully efficient farm.

Technical inefficiency=1-TE (3.8)

Since maize is the main crop grown in most of the irrigation schemes in the Sub-County, the output of maize obtained by a farmer in his or her farm was used as the dependent variable. The inputs used by the farmers that were considered for analysis are: labor, fertilizer, seed and irrigation water (represented by the frequency of irrigation during the season).

There are various functional forms, which can be used in efficiency estimation. The mostly commonly used forms are translog and Cobb-Douglas. The translog production function is more flexible functional form, takes account of the interaction between variables, and allows for non-linearity in parameters (Nyagaka, 2009). However, the translog production function specification suffers from the problems of multicollinearity among the explanatory variables as a result of the squaring and interaction of terms of the inputs used (Nyagaka, 2009; Omondi and Shikuku, 2013). For this reason, a Cobb-Douglas functional form was used in model specification despite its limitation of restricting production elasticities to be constant.

The Cobb-Douglas functional form satisfies the requirement of being self-dual in deriving the cost frontier to be used in the estimation of allocative and economic efficiency. It has been widely used in farm efficiency analysis for both developed and developing countries (Bravo-Ureta and Pinheiro, 1997). Some empirical studies that have used the functional form in the estimation of farmer efficiency are Bravo-Ureta and Pinheiro, 1997; Ogundari et al., 2006; Mutoko, 2008; Nyagaka, 2009; Omondi and Shikuku, 2013.

In order to identify the sources of differential technical efficiency observed among farmers, the following variables were analyzed: Age, gender, education, credit access, farm size, income, status of irrigation infrastructure, household size, number of extension visits and salinity. A stochastic Cobb-Douglas production frontier function specified in equation 3.9was used in estimating farmers' technical efficiency in the irrigation schemes.

$$\ln \mathrm{y_i} = \beta_0 + \sum_{\mathrm{i}=1}^{4} \beta_\mathrm{i} \ln \mathrm{X_i} + \varepsilon_\mathrm{i} \tag{3.9}$$

Where: $\varepsilon_\mathrm{i} = \mathrm{v_i} - \mathrm{u_i}$(3.10)

ln = Natural logs

y_i = Maize output (90kg bags) per acre obtained by the farmer in 2013 main[2]cropping season.

X_i= The physical inputs used in the production of maize in the irrigation schemes where, X_1 =Labour (Man-days/Acre);X_2 = Fertilizer (Kg/Acre);X_3=Seed planted (Kg/Acre);X_4= Irrigation water(frequency of irrigation during the season that is, number of times the irrigation scheme farmer irrigated his or her maize crop from planting to maturity)

β_i = Unknown input coefficients (parameters) to be estimated.

v_i = Random errors associated with measurement or omission of the effects of input variables in the production function .The random errors are assumed to be independently and identically distributed that is, $v_i \sim iid\ N(0, \delta_V^2)$random variables.

u_i = Non-negative random variables associated with the technical inefficiency of production of the individual farmer and is assumed to

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[2] Main cropping season refers to the first cropping season during year 2013. It is sometimes referred as the long rains season which usually occurs between March and July

be independently and identically distributed half normal that is,

$u_i \sim iid\ |N(0, \delta_u^2)|$.

In evaluating the factors influencing technical efficiency among the irrigation scheme farmers, the technical inefficiency score (u_i) in the Cobb-Douglas stochastic frontier equation 3.9 was specified as follows (equation 3.11):

$$\mathrm{u_i} = \delta_0 + \sum_{\mathrm{k}=1}^{10} \delta_\mathrm{k}\, \mathrm{Z_i} = \delta_1 \mathrm{Z}_1 + \delta_2 \mathrm{Z}_2 + \delta_3 \mathrm{Z}_3 + \delta_4 \mathrm{Z}_4 + \delta_5 \mathrm{Z}_5 \ldots\ldots\ldots\ldots \delta_{10} \mathrm{Z}_{10} \qquad (3.11)$$

Where:

$\mathrm{u_i}$ = Inefficiency score

δ_k = Unknown parameters of the technical inefficiency, for specific variables to be estimated

Z_i = Variables in the technical inefficiency model postulated to have an effect on technical efficiency levels of the farming households in the irrigation schemes as listed in table 3.1.

The signs of the coefficients in the inefficiency model 3.11 are interpreted as follows: Positive sign implies that the variable (factor) *increases* the technical inefficiencies (*decreases* in technical efficiency). Similarly, negative sign implies that the factor (variable) *decreases* technical inefficiencies (*increase* technical efficiency). Table 3.1 presents the expected signs of the variables included in the technical inefficiency model.

Table 3.1: Variables included in the technical inefficiency model

Variable	Notation of variable	Parameter	Expected sign
Age of household head	Z_1	δ_1	+
Gender of household head	Z_2	δ_2	-
Education level of the farmer	Z_3	δ_3	-
Access to Credit	Z_4	δ_4	-
Farm size (Acreage farmed)	Z_5	δ_5	-
Income	Z_6	δ_6	-
Status of irrigation infrastructure	Z_7	δ_7	-
Household size	Z_8	δ_8	-
Number of extension visits	Z_9	δ_9	-
Soil Salinity	Z_{10}	δ_{10}	+

Table 3.2 gives the description of the variables included in the inefficiency model that explain the differences in efficiency measures.

Table 3.2: Description of socio-economic and technical variables

Variable	Description
Age of household head	Age of household head in number of years
Gender of household head	Dummy variable with value 1 if household head is male and 0 if female
Educational level of the farmer	Highest level of education attained by the farmer with value 0 if No formal education; 1 if attained Primary level; 2 if attained Secondary level of education; 3 if attained Middle level college and 4 if attained University level of education
Access to credit	Dummy variable with value 1 if household received credit and 0 otherwise
Farm size	The total acreage planted with maize crop measured in acres in the 2013 season 1
Income	The estimated total income of the farmer during the first season of the 2013 cropping year
Status of irrigation infrastructure [3]	Farmer perception of the irrigation scheme infrastructure with value 1 if very bad; 2 if bad ; 3 if fair and 4 if good
Household size	Total number of members of the household (family, relatives and workers)
Number of extension visits	Total number of times a farmer was visited by extension service providers during the first season of the year 2013
Soil Salinity	Dummy variable with value 1 if salinity is reported and 0 if no soil salinity

Equation 3.9 and 3.11 were the first to be estimated together. The equation gave the coefficients of the inputs and various socio-economic and technical factors that were hypothesized to have an effect on the technical efficiency levels among the irrigation scheme

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[3] Irrigation scheme infrastructure includes intake, canals (primary, secondary and tertiary), check boxes that control flow of water in the schemes, diversion boxes and cut-off drain

farmers. Estimation of the equation also gave parameter estimates of total variance represented by sigma-squared (σ^2) and gamma (γ). The gamma was used to test for the presence of technical inefficiency. The coefficient of gamma gives the proportion of total variation that is explained by technical inefficiencies ($\gamma = \sigma_u^2/\sigma_v^2 + \sigma_u^2$) . In the absence of technical inefficiencies that is $\mu = 0$, the value of gamma will be zero and therefore farmers are assumed to be fully technically efficient. If the value of gamma is >0 then it means inefficiencies are present. The total variance represented by sigma squared, $\sigma^2 = \sigma_v^2 + \sigma_u^2$ gives the overall variation in maize yields due to all other factors excluded in the specification and the estimated inefficiency, (Mutoko, 2008).

3.2.2.2 Stochastic frontier cost function

The stochastic cost frontier function was used to estimate allocative efficiency levels of the farmers in the irrigation schemes. The error term components in a stochastic cost frontier have both positive signs because inefficiencies are assumed to always increase costs (Ogundari and Ojo, 2006). According to Bravo-Ureta and Pinheiro (1997), the production frontier function in equation 3.9 is assumed to be self-dual. The general form of the dual cost frontier is specified in equation 3.12 below.

$$\ln C_i = h(P_i, Y_i; \alpha) + \varepsilon_i \qquad \varepsilon_i = v_i + u_i \tag{3.12}$$

Where:

C_i = The total production costs

H = a suitable functional form such as Cobb-Douglas and translog

P_i = a vector of input prices

Y_i = maize output produced

α = a vector of parameters to be estimated.

u_i = One sided error term assumed to be half-normal and measures how much the actual production costs exceeded the minimum efficient cost bounded by the cost frontier.

Allocative inefficiency score of an individual farm for this study is defined in terms of the ratio of observed cost that is the actual total production cost, to the corresponding minimum cost given the available technology. The minimum cost represents the frontier total production cost or least production cost level. The allocative inefficiency takes values greater than one. The stochastic frontier cost function that was estimated for allocative efficiency is as shown in equation 3.13 below. This function is specified as Cobb-Douglas Stochastic frontier cost function as it is self-dual to the stochastic frontier production function specified in equation 3.9.

$$\mathrm{lnC_i} = \alpha_0 + \alpha_1 \mathrm{lnP_1} + \alpha_2 \mathrm{lnP_2} + \alpha_3 \mathrm{lnP_3} + \alpha_4 \mathrm{lnP_4} + \alpha_5 \ln \mathrm{Y} + (\mathrm{v_i} + \mathrm{u_i}) \quad (3.13)$$

Where:

C_i = Total variable costs incurred by the maize farmer in the irrigation scheme

α_0 = Intercept representing fixed costs in maize production

$\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$ = Parameters to be estimated for the prices of Labour, fertilizer, seed, irrigation water and yield respectively

P_1, P_2, P_3, P_4 = Prices of the inputs; Labour, fertilizer, seed and Irrigation water respectively

Y_i = Maize yield in 90kg bags per acre obtained by the farmer

v_i = It is an error term representing random disturbance costs beyond the control of the farmer. It is assumed to be identically and normally distributed with mean zero and constant variance as, $\mathrm{v_i} \sim iid\ N(0, \delta_V^2)$.

u_i = It is a one sided error term used to represent cost inefficiency. It is independent of v_i. It is assumed to be independently and identically distributed half normal that is, $u_i \sim iid\ |N(0, \delta_u^2)|$.

$\mathrm{u_i} = 0$ for a firm whose costs lay on the frontier, $u_i > 0$ for a firm whose cost is above the frontier (Ogundari et l., 2006).

The allocative inefficiency model was estimated using equation 3.14 below.

$$\mathrm{u_i} = \delta_0 + \sum_{k=1}^{10} \delta_k \mathrm{Z_i} = \delta_1 \mathrm{Z_1} + \delta_2 \mathrm{Z_2} + \delta_3 \mathrm{Z_3} + \delta_4 \mathrm{Z_4} + \delta_5 \mathrm{Z_5} \ldots\ldots\ldots\ldots \delta_{10} \mathrm{Z_{10}} \qquad (3.14)$$

The description of the variables in equation 3.14 above is as defined in table 3.2.

Equations 3.13 and 3.14 were the second to be estimated jointly using the Maximum Likelihood Estimation framework in Frontier 4.1 software, which generated coefficients of prices and coefficients of the various socio-economic and technical factors hypothesized to influence allocative efficiency of the maize farmers in the irrigation schemes. In addition, the estimation of equation 3.13 was used to generate parameters for variances, that is sigma-squared (δ^2) and gamma (γ). The gamma parameter was used to test for the presence of allocative inefficiencies in the use of limited financial resources among maize farmers in the irrigation schemes. The signs of the coefficients in the inefficiency model equation 3.14 are interpreted as follows: Positive sign implies that the variable (factor) *increases* the allocative inefficiencies (decrease in allocative efficiency) whereas negative sign implies that the factor (variable) *decreases* allocative inefficiencies (increase allocative efficiency). These signs are as indicated in table 3.1.

3.2.2.3 Estimation of Economic Efficiency

In deriving economic efficiency for the maize farmers in the irrigation schemes, the technical and allocative efficiency scores estimated in equations 3.9 and 3.13 were multiplied. The economic efficiency takes the values between zero and one. According to Farrell (1957) and Bravo-Ureta and Pinheiro (1977), EE is the product of TE and AE. Therefore; EE=TE*AE. Table 3.3 gives a description of variables used in equation 3.9 (stochastic frontier production function) and equation 3.13 (stochastic frontier cost function).

Table 3.3: Description of variables used in the Stochastic Frontier production and Cost functions models for Technical and Allocative Efficiency estimation

Variable name	Description
Dependent variable in equation 3.9 (stochastic frontier production function)	
Maize yield	Ln of maize yield in 90 kg bags/acre
Explanatory variables (Inputs used in maize production)	
Labour	Ln of total labor used in operations in the farm ranging from land preparation to harvesting (Man-days per acre)
Fertilizer	Ln of total kilograms of fertilizer applied in the maize field (Kg/Acre)
Seed	Ln of total kilograms of maize seed planted in the farm (Kg/acre)
Water	Ln of total number of times (frequency) the maize crop was irrigated during the first season of 2013
Dependent variable in equation 3.13 (Stochastic frontier cost function)	
Total variable costs	Ln of total costs incurred by the farmer in hiring of labor, buying seed, fertilizer and paying for irrigation water
Explanatory variables	
Labor wage rate	Ln of labor wage rate (Ksh/Man-day)
Price of fertilizer	Ln of average price of fertilizers (Ksh/Kg)
Price of maize seed	Ln of price of seed (Ksh/Kg)
Price of Irrigation water	Ln of price of water (Ksh/cropping season)
Maize yield	Ln of maize yield (90kg bags/acre)

3.3 Estimation procedure

The empirical model equations 3.9[4] and 3.11[5], were jointly estimated using maximum likelihood estimation (MLE) procedure in FRONTIER 4.1 (Coelli, 2006). Similarly,

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[4] Stochastic frontier production function for the estimation of technical efficiency

[5] Equation for the technical inefficiency model

equations 3.13[6] and 3.14[7]were also jointly estimated using the same procedure. This study adopted a single-step MLE procedure in the estimation of technical and allocative efficiency with their determinants using FRONTIER 4.1 software (Battese and Coelli, 1995). A two-step MLE process was not used since it introduces bias (for example, use of technical efficiency estimates from one equation as dependent variable in the subsequent regression violates the assumption that μ_i is independently and identically distributed normal random variable) and therefore leads to inconsistent parameter estimates of inefficiency effects. The two-stage process also does not give estimates, which are as efficient as those obtained using a single step (Coelli, 1996).

3.4 Testing for existence of inefficiencies

In each of the equations to be estimated that is 3.9 and 3.13, the underlying null and the alternative hypotheses are that the irrigation scheme farmers are fully efficient, $H_0: \gamma = 0$and that the explanatory variables have no effect on the observed inefficiencies;

$H_0: \delta_0 = \delta_1 = \delta_2 = \delta_3 \ldots \delta_{10} = 0$

The alternative hypotheses:

$H_1: \gamma > 0$ (Farmer not fully efficient and therefore inefficiencies exist)

$H_1: \delta_0 \neq \delta_1 \neq \delta_2 \neq \delta_3 \neq \cdots \delta_{10} \neq 0$ (Explanatory variables have significant coefficients)

Following Battese and Coelli (1995), the hypotheses were tested using the significance of the gamma parameter and generalized Likelihood Ratio (LR). The LR is shown in equation 3.15.

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[6] Stochastic frontier cost function for the estimation of allocative efficiency

[7] Equation for the allocative inefficiency model

$$LR = -2\{\log[L(H_0)] - \log[L(H_1)]\} \qquad (3.15)$$

Where:

LR=Likelihood Ratio

$L(H_0)$ =Value of the likelihood function under the null hypothesis of complete efficiency,

$H_0: \gamma = 0$

$L(H_1)$ =Value of likelihood function under the alternative hypothesis of presence of inefficiency, $H_1: \gamma > 0$. The test statistic has approximately a chi-square distribution with degrees of freedom equal to the difference between the number of parameters involved in the null and alternative hypotheses.

3.5 Sampling design

Multistage sampling technique was used in this study. In the first stage, a list of all the nine irrigation schemes was obtained from the Sub-County Agriculture office. From the nine irrigation schemes, two irrigation schemes were randomly selected for the study using simple random sampling technique. The selected schemes were Katilu and Koputiro irrigation schemes in Katilu and Kainuk Divisions respectively. In the second stage, a list of all the farmers in the two irrigation schemes for all the blocks was obtained from the irrigation scheme water user association officials. This list formed sampling frame from which the irrigation scheme farmers were sampled. The names of farmers in each block were arranged chronologically. Koputiro irrigation scheme had four blocks; 1, 2, 3 and 4 whereas Katilu irrigation scheme had 19 blocks; B1, B2, B4, B6, C1, D1, D3, G1, G3, G5, J1, J3, J5, K1, K3, L1, L2, L3, and L4. Finally, farmers from each block were randomly selected systematically with each block assigned a proportionate size of sample.

3.5.1 Sample size determination

Since the population of the irrigation scheme farmers was known for the two irrigation schemes, the study used the formula by Yamane (1967:886) in determining the sample size. The sample size determination formula is as indicated in equation 3.16 below:

$$n = \frac{N}{1 + N(e)^2} \qquad (3.16)$$

Where:

n = Sample size of irrigation scheme farmers for the study

N = Total Population of maize farmers in the two sampled irrigation schemes

e =Level of precision

The proportionate number of respondents per scheme was obtained using the formula

$$n_i = \frac{Total\ number\ of\ farmers\ in\ scheme\ i}{Total\ population(N)} * n \qquad (3.17)$$

Where

n_i = Proportional sample size for irrigation scheme i

n =Total sample size for the two irrigation schemes

The total number of farmers in the two irrigation schemes was 885 with Katilu irrigation scheme having 708 and Koputiro 177. From the sample size determination formula in equation 3.16, taking a precision level of ±7 percent at 95 percent confidence interval, the sample size was166 respondents. This was adjusted to 183in order to take care of respondents who could not be contacted or were not available during interview. The 183-sample size was distributed proportionately between the two schemes using the formula given in equation 3.17. Katilu had 147 respondents and Koputiro 36. The sample size for each scheme was further distributed proportionately according to the farmer population in each block in the irrigation scheme as shown in table 3.4 and table 3.5 respectively:

Table 3.4: Sample size distribution in Koputiro Irrigation scheme

Block	Farmer population	Proportional sample size
1	47	10
2	45	9
3	27	5
4	58	12
TOTAL	177	36

Source: Field survey data, 2014

Table 3.5: Sample size distribution in Katilu irrigation schemes

Block	Farmer population	Proportional sample size
B1	51	11
B2	65	14
B4	52	11
B6	28	6
C1	59	12
D1	46	9
D3	39	8
G1	48	10
G3	34	7
G5	27	5
J1	27	6
J3	32	7
J5	21	4
K1	4	1
K3	6	1
L1	41	8
L2	43	9
L3	42	9
L4	43	9
TOTAL	708	147

Source: Field survey data, 2014

From the field survey, it was found that farmers in block C1in Katilu irrigation scheme had not planted any maize crop during the season considered for the survey. Therefore, the proportion of sample size allocated to that block was proportionately distributed to other blocks within the scheme thereby maintaining the total sample size for Katilu irrigation scheme at 147 farmers.

3.6 Data collection procedure

A household questionnaire was used to collect primary data from the irrigation scheme farmers. This data was collected in the months of June and July 2014. The data collected was mainly with reference to season one of the 2013 cropping year. Secondary data on prices of inputs was also obtained from the National Irrigation Board field office located in Katilu irrigation scheme. Six enumerators were selected and trained for the data collection. The enumerators came from within Kainuk and Katilu divisions. These enumerators were trained during the pre-test exercise. The training covered objectives of the study and the expected input of the enumerators during data collection. It also involved taking the enumerators through every question that was contained in the questionnaire and discussions held on how to approach each question when gathering field data for accuracy.

During the pre-test of the field survey questionnaire, a total of six irrigation scheme maize farmers were sampled from Katilu and Koputiro irrigation schemes and the draft questionnaire pre-tested. Thereafter, the team met and discussed on the pre-tested questionnaire. Adjustments were made in some of the questions that were contained in the semi-structured questionnaire. The out-put of the pre-test exercise led to the development of the final questionnaire that was finally administered to the 183 sampled farmers during the main survey. This questionnaire is as attached in appendix 2.

The data collected was cross-sectional and included socio-demographic information (Age, gender, level of education, household size, income among others), maize production data (physical inputs used in maize production and other marketing aspects), status of irrigation infrastructure and the production constraints experienced by the irrigation scheme farmers. This information was considered essential in the estimation of efficiency levels of the farmers in the irrigation schemes and in determination of the factors that influence the technical and allocative efficiency of the farmers.

3.7 Challenges During data collection

Firstly, the high level of illiteracy amongst the irrigation scheme farmers was a challenge during data collection. This necessitated a lot of translation of the questions in the questionnaire into Ng'iturkana (local language). However, this was overcome through the use of enumerators from the same region who knew the language very well. Secondly, farmers had not kept farm records on maize production and therefore, we relied on the information they could remember about their production activities for the season under consideration for the study. Lastly, the area was prone to cases of insecurity due to cattle rustling and highway banditry and therefore this necessitated hiring of security personnel during the exercise. The harsh climatic condition also limited the time taken per day to interview farmers. Interviewing of the farmers could not go past 2.00pm.

3.8 Data analysis

The data collected was analyzed using Statistical Package for Social Scientists (SPSS), STATA and FRONTIER 4.1 computer software. SPSS and STATA were used to analyze the descriptive statistics of the irrigation scheme farmers. FRONTIER 4.1 was used to estimate the efficiency levels of the farmers.

3.9 Testing for the problems of estimation

3.9.1 Heteroscedasticity

Heteroscedasticity is a violation of one the basic assumptions of ordinary least squares (OLS) in which the error variance is not constant (Kibaara, 2005). It is a more common problem with cross-sectional data sets. There is the tendency of the disturbance term to vary with some or all the explanatory variables. This tendency violates the constant variance assumption of the disturbance term (homoscedasticity). Heteroscedasticity renders the estimated betas inefficient and thus invalid for use in making predictions about the dependent variable (Zuma, 2001). Given that the data used in this study was cross-sectional, presence of heteroscedasticity was tested using the Breusch-Pagan test by use of the command hettest in STATA. The results obtained showed that probability of Chi-square value was 0.689 at 5 percent level of significance. Since this value was greater than 0.05 at 5 percent level of significance, it was concluded that heteroscedasticity was absent in the data and therefore failed to reject the null hypothesis of constant variance.

3.9.2 Multicollinearity

Multicollinearity is the existence of a ‘perfect’ or exact linear relationship among some or all explanatory variables (Gujarati, 2005). Estimation in the presence of multicollinearity has some practical consequences. OLS estimators have large variances and covariance making precise estimation difficult. The confidence intervals also tend to be much wider leading to the acceptance of the zero null hypotheses that the true population coefficient is zero more readily. Furthermore, the t-ratios of one or more coefficients tend to be statistically insignificant (Gujarati, 2005). Two tests were conducted to ascertain the presence of multicollinearity in the data. These tests included; Variance Inflation Factors (VIF) and pair-wise correlation of regressors. These were used as some of the indicators of detecting multicollinearity. According to Gujarati 2005, if VIF of a variable exceeds 10, then that variable is said to be highly collinear and therefore indicating that there is serious multicollinearity problem. Further, pair-wise correlations of greater than 0.5 are said to be highly collinear. The results of these tests are as indicated in table 3.6 and table3.7 respectively.

Table 3.6: Variance Inflation Factors of variables in the Cobb-Douglas production function

Variable	**VIF**	**1/VIF**
Labour	1.14	0.877854
Fertilizer	1.13	0.887981
Seed	1.10	0.906148
Frequency of irrigation	1.05	0.956638
Mean VIF	1.10	

Source: Field survey data, 2014

Table 3.7: Correlation matrix of variables in the Cobb-Douglas production function

	Labour	Fertilizer	Seed	Frequency of irrigation
Labour	1			
Fertilizer	-0.3030	1		
Seed	0.1220	-0.0649	1	
Frequency of Irrigation	-0.2156	0.2041	-0.1910	1

Source: Field survey data, 2014

From the results in table 3.6, all the VIF's were less than 10. Results from table 3.7 indicate that the pair-wise correlation coefficients among the variables were all less than 0.5. Therefore, from these results, it was concluded that there was no multicollinearity in the data. A correlation test was also done for the socio-economic and technical factors to ascertain whether they are correlated. The results showed that the factors considered for analysis were not correlated as they had correlation coefficients less than 0.5. This is indicated by the results attached in appendix1.

3.9.3 Assumption of zero covariance between the error term and the explanatory variables

In ordinary least squares, it is assumed that the error term μ_i and the explanatory variables do not co-vary. This ensures that the separate influences of the error term and the explanatory variables on the endogenous variable are independent. This independence is critical in the estimation of stochastic production and cost frontiers as they are based on the distribution of the error term for two reasons: First, the variables describing the inputs in the stochastic frontier function need to be independent from the socio-economic and technical variables explaining inefficiency effects. Secondly, the stochastic frontier functions and the equation explaining inefficiency have to be estimated simultaneously. If the independence condition is not satisfied, the parameter estimates from both functions will be biased (Kibaara, 2005; Mutoko, 2008).

In establishing this independence, each explanatory variable in the inefficiency model was regressed against the variables in the main model in equation 3.9that is Labor, Fertilizer, Seed and Irrigation water (frequency of irrigation). The strength of dependence is indicated by the coefficient of multiple determination, R^2 (Gujarati, 2005). R^2 values greater than 0.5

indicated high dependence (Gujarati, 2005; Mutoko, 2008). The result of this analysis is as indicated in the table 3.8.

Table 3.8: Coefficients of multiple determination obtained from zero covariance test

Dependent variable	R-squared value
Age	0.014
Gender	0.021
Highest level of Education	0.008
Access to credit	0.033
Farm size	0.087
Income	0.037
Status of irrigation infrastructure	0.469
Household size	0.046
Extension visits	0.087
Soil Salinity	0.014

Source: Field survey data, 2014

From the above table 3.8, there was no evidence that the error term and the main model variables co-vary since all the coefficients of multiple determination,R^2 were less than 0.5.

CHAPTER `4

RESULTS AND DISCUSSIONS

This chapter is organized as follows; the first section gives description of important characteristics of irrigation scheme farmers and their production information. The second section presents the estimates of technical and allocative efficiency while the third section gives detailed effects of the factors explaining the observed inefficiency among the maize farmers in the irrigation schemes. The fourth section concludes with the estimation and discussion of economic efficiency.

4.1 Characteristics of irrigation scheme farmers in Turkana South Sub-County

4.1.1 Socio-economic and technical characteristics of irrigation scheme farmers

Table 4.1: Socio-economic and technical characteristics of irrigation scheme farmers

Variable	Mean	Std.Dev	Min	Max
Age of household head (years)	54.37	13.98	25	90
Household size (No. of persons)	7.68	3.36	1	16
Farm size (acres)	0.68	0.27	0.5	1.5
Income Season 1 (Ksh)	35,345.98	25,028.11	7,200	127,600
Extension worker visits (Number)	6.80	6.32	0	25
Dummy variable for Gender (1=Male;0=Otherwise)	0.48	0.50	0	1
Dummy variable for Access to credit(1=Accessed credit;0=otherwise)	0.1	0.31	0	1
Dummy variable for Salinity (1= reported; 0=otherwise)	0.58	0.49	0	1

Source: Author’s survey, 2014

Table 4.1 shows the summary statistics of the socio-economic and technical characteristics of the irrigation scheme farmers. The average age of the sampled farmers was 54 years, with the youngest farmer being 25 years and the oldest 90 years. This average age is slightly above the national average age of Kenyan farmers of 53 years (Ogada et al., 2014). Women farmers in the irrigation schemes were slightly more than the male farmers, constituting 52 percent as compared to male farmers who were 48 percent. The average household size in the study area was eight members, which was above the national average of 5 (KIHBS, 2005/2006). Farm sizes ranged between 0.5 to 1.5 acres with an average of 0.7 acres as compared to the national average of 1.7 acres (KIHBS, 2005/2006). This shows that farming in the irrigations schemes is at small scale.

The average income of the irrigation scheme farmers during the first season of the year 2013 was Ksh 35,345.98. This income was obtained from various sources including trading, Equity bank funding for the aged and vulnerable, remittances, salaried employment among other sources as shown in figure 4.1. Sale of maize accounted for only 3 percent of the average household income an indication that most of the maize produced in the irrigation schemes is mainly used for subsistence.

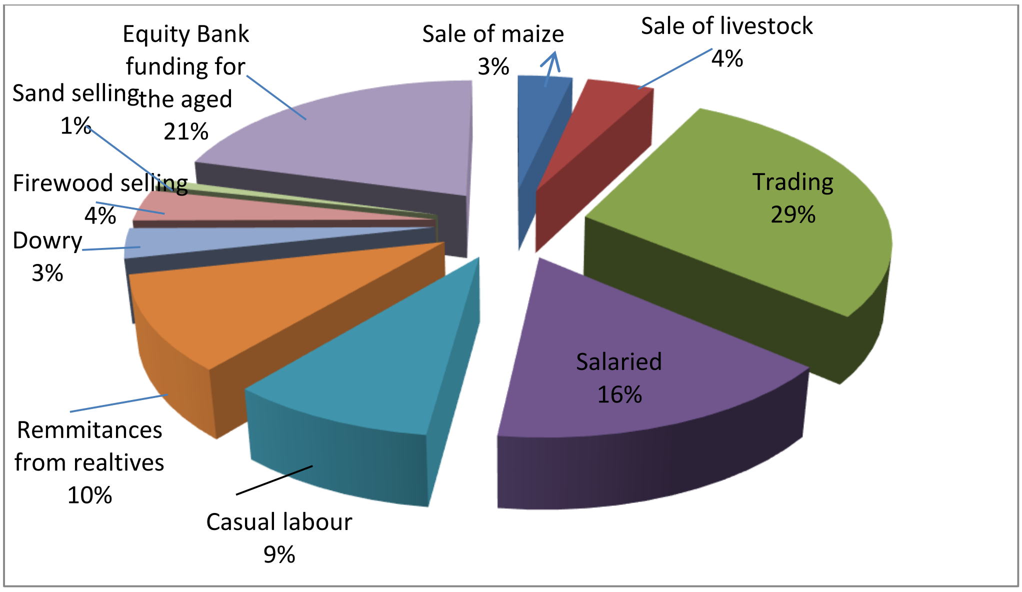

Figure 4.1: Percent sources of household income

Source: Author’s survey, 2014

On average, each farmer had received seven visits by the extension service providers. The main extension service providers were the Ministry of Agriculture and the National Irrigation Board extension staff. It was found that extension service provision in the irrigation schemes is mainly supply driven.

With regard to access to credit by the farmers during the first season of the year 2013, only 10 percent of the sampled farmers accessed credit from the bank and self-help group’s table banking. Majority of the farmers (90 percent) had not accessed credit. Among those who accessed credit, women constituted 31.6 percent while the men were 68.4 percent. This implies that more men than women have access to credit in the study area.

Approximately 58 percent of the sampled households reported problems of soil salinity in their farms during the first season.

Table 4.2 presents farmer characteristics with respect to educational level of the household head. The results show that majority of the household heads (73.8 percent) in the irrigation schemes had no formal education. Only 26.2 percent had attained at least primary level of education. Education plays a critical role in improving the capacity of the farmers in making farming decisions. With the majority of the household heads in the irrigation schemes having no formal education, their ability in making critical farming decisions may be limited thus negatively affecting their efficiency in maize production.

Table 4.2: Education level of household head

Characteristic	Number of farmers	Percent of farmers
Education level of the household head:		
No formal education	135	73.8
Primary	37	20.2
Secondary	7	3.8
Middle-Level college	3	1.6
University	1	0.5

Source: Author's survey, 2014

A further analysis of the education attainment by the male and female-headed households in the study area showed that more men than women attained primary, secondary and middle level college education. Women headed households that do not have any formal education in the irrigation schemes constituted a bigger proportion that is 58.5 percent as compared to the male-headed households. This is as shown in table 4.3

Table 4.3: Education attainment by gender of household head

Level of education	Percent of Male HH	Percent of female HH
No formal Education	41.5	58.5
Primary	67.6	32.4
Secondary	57.1	42.9
Middle-Level college	66.7	33.3
University	100	0

Source: Author's survey, 2014

Majority of the sampled household heads (83.3 percent) in Koputiro irrigation scheme as shown in table 4.4perceived their irrigation scheme infrastructure to be between very bad to bad states. This shows that the status of infrastructure in the mentioned scheme is in poor state. In comparison to Katilu irrigation scheme, majority of the farmers (74.1 percent) perceived their irrigation scheme infrastructure as being in good state. This is attributed to the rehabilitation of the Katilu irrigation scheme infrastructure by National Irrigation Board (NIB).

Table 4.4: Farmer perception of status of irrigation scheme infrastructure

Characteristic		No. of farmers	Percent of farmers
Farmer perception of irrigation scheme infrastructure			
Koputiro irrigation:	Very bad	14	38.9
	Bad	16	44.4
	Fair	6	16.7
	Good	0	0
Katilu irrigation:	Very bad	0	0
	Bad	16	4.1
	Fair	32	21.8
	Good	109	74.1

Source: Author's survey, 2014

The distribution of farmers' age in the irrigation schemes (Table 4.5) shows that majority of the farmers are the ageing with those aged 55 years and above accounting for 53.55 percent. A smaller percentage of the youth that is 7.65 percent are participating in irrigated agriculture in the Sub-County. This is likely to pose a challenge to the future of irrigated agriculture and food security achievement in the Sub-County as aged farmers have reduced physical strength.

Table 4.5: Frequency distribution of farmers' age in the irrigation schemes

Characteristic of HH	Number of HH	Percentage of total HH
Age of Household head(Years)		
25-34	14	7.65
35-44	36	19.67
45-54	35	19.13
55 and above	98	53.55

Source: Author's survey, 2014

4.1.2 Inputs, costs and output of maize production in the irrigation schemes

From table 4.6, farmers planted maize on an average of 0.7 acres of land in the irrigation schemes in the 2013 cropping season. The acreage ranged between 0.5 acres to 1.5 acres. This implies that maize production in the irrigation schemes is in small scale. The average maize output realized by the farmers per acre was five bags[8].This was below the estimated national average maize yield of 20 bags per hectare equivalence of eight bags per acre (Kibaara and Kavoi, 2012).

The average maize yield realized by the farmers in the irrigation schemes was achieved through the use of on average, 76.34 kilograms of fertilizer, Six kilograms of seed, 104 man-days of labor and irrigating the maize crop 15 times during the season. On average, irrigation water costs less, which is Ksh 60.16 per season as compared to the cost of fertilizer and maize seed, which cost Ksh 70.11 and Ksh 149.23 per kilogram respectively. The total costs of all operations in maize production in the irrigation schemes averaged at Ksh 25,926.29 per acre

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[8] A bag of maize weighed 90 kilograms.

Table 4.6: Summary statistics of inputs, costs and output of maize production

Description	Mean	Std Dev.	Min	Max
Area under maize (Acres)	0.68	0.27	0.5	1.5
Total Labor (Man-days/Acre)	103.73	45.89	28	278
Total Fertilizer applied (Kg/Acre)	76.34	38.76	0	100
Total maize Seed planted (Kg/Acre)	5.88	1.40	3	8
Frequency of irrigation[9]	14.83	4.67	6	24
Total maize output (90Kg bags/Acre)	4.75	3.16	0.56	16
Labour wage rate (Ksh/Man-day)	92.75	74.35	3.08	515.85
Price of Fertilizer[10] (Ksh/Kg)	70.11	1.81	60	80
Price of maize seed (Ksh/Kg)	149.23	8.35	50	160
Price of irrigation water[11](Ksh/Season)	60.16	20.04	50	100
Production costs (Ksh/Acre)	25,926.29	7691.48	6200	39,299.92

Source: Field survey data, 2014

4.2 TECHNICAL EFFICIENCY ESTIMATION

4.2.1 Results of technical efficiency estimation using Cobb-Douglas stochastic frontier Production function

The Cobb-Douglas stochastic frontier production function stated in equation 3.9 was used in technical efficiency levels estimation for the farmers. The likelihood ratio (LR) statistic was used in this study to establish whether the stochastic frontier production function best represents the data as compared to ordinary least squares (OLS) production function. The

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[9] Frequency of irrigation is the number of times the maize crop was irrigated during the first season.

[10] Price of fertilizer is the average price per kilogram of the total quantity of fertilizer used that is both planting and topdressing. It was calculated as total cost spent on fertilizers divided by the total quantity of fertilizer used during planting and top dressing

[11] The price of irrigation water is the water cost per season

results showed that the calculated value of the LR= 118.267 was significant since the critical chi-square value for 11 degrees of freedom at 1 percent level was 24.73. This is an indication that the frontier production function fits the data better than the OLS production function.

In testing the first hypothesis of this study that is irrigation scheme farmers are technically efficient, the null hypothesis of absence of technical inefficiency effects that is; $H_0: \gamma = 0$, was tested against the alternative hypothesis;$H_1: \gamma > 0$, that is technical inefficiency effects are present. For the test of the inefficiency effects in the model, gamma parameter was used. The gamma parameter tests whether the observed variations in efficiency are simply random or systematic. This parameter ranges between zero and one. A value of zero indicates that inefficiency effects are not present and vice versa.

The results of the analysis indicated that gamma (γ) which had a coefficient of 0.367 was significantly different from zero at one percent level of significance and therefore the null hypothesis of complete efficiency (absence of inefficiency effects) was rejected. The significant gamma indicated that there was a significant difference in the technical efficiency levels among the irrigation scheme farmers due to technical inefficiency effects. Therefore, these farmers were not technically efficient. The value of gamma (0.367) implies that 36.7 percent of random variation in maize production in the irrigation schemes is explained by inefficiency. These results are indicated in table 4.7.

Table 4.7: Production function parameter estimates-Cobb-Douglas stochastic frontier model

Variable	Parameter	Coefficient	Std Error	t-ratio
Cobb-Douglas production frontier function				
Dependent variable : Ln Output/Acre (yield)				
Constant	β_0	1.843***	0.632	2.917
Labour	β_1	-0.055	0.104	-0.532
Fertilizer	β_2	-0.014	0.026	-0.557
Seed	β_3	0.294**	0.147	1.999
Frequency of irrigation	β_4	0.072	0.130	0.555
Inefficiency model				
Dependent variable : Technical inefficiency score				
Constant	δ_0	0.941**	0.435	2.163
Age	δ_1	0.009**	0.004	2.385
Gender of household head	δ_2	0.029	0.082	0.347
Education level of household head	δ_3	0.106	0.073	1.450
Access to credit	δ_4	-0.390**	0.198	-1.967
Farm size	δ_5	0.564***	0.172	3.283
Income	δ_6	-0.000	0.000	-1.604
Status of irrigation infrastructure	δ_7	-0.142**	0.060	-2.370
Household size	δ_8	-0.002	0.014	-0.164
Number of extension visits	δ_9	-0.053***	0.011	-4.722
Salinity	δ_{10}	0.066	0.085	0.777
Sigma-squared	$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.211***	0.026	8.061
Gamma	γ	0.367***	0.091	4.041
LR Test of the one sided error	LR[12]	118.267		
Mean technical efficiency		45.30 %		
Statistical significance levels: **5%;***1%				

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[12] Likelihood Ratio

From table 4.7, the estimated Cobb-Douglas stochastic frontier production function had four inputs namely: Labour, fertilizer, seed and irrigation water. The elasticity of output per acre with respect to maize seed as an input in the production function was the highest and significant at 5 percent level of significance. The negative signs observed for the coefficients of labor and fertilizer indicate that the input use is at maximum level and more use of the input beyond the current levels will lead to a fall in yields. The positive and significant coefficient of variable seed as shown indicates that it is the most limiting input in maize production in the irrigation schemes and any further unit increase in the use of the input will lead to 0.29 percent increase in output. The results from analysis indicate that these farmers were using on average six kilograms of seed per acre against the recommended 10 kilograms. It was also found that the irrigation scheme farmers in Turkana South are operating on decreasing returns to scale of 0.297[13].

The results of technical efficiency estimation further show that the farmers on the average achieved 45.30 percent technical efficiency. This implies that in the short-run, there exists a scope for increasing maize output in the irrigation schemes by 54.7 percent on average. This suggests that 54.7 percent of maize yield is lost due to technical inefficiencies and other factors outside the control of the farmer, for example environmental factors. The estimated potential yield [14]on average in the irrigation schemes is 10.58 bags per acre that is (100/45.29.*4.79)=10.58 bags. However, this potential could go up to 19.75 bags per acre among the most efficient farmers;(100/81 *16) = 19.75 bags.

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[13] The returns to scale value of 0.297 was found by adding the elasticities of labor, fertilizer, seed and irrigation water that is (-0.055+-0.0143+0.2936+0.0724)=0.297

[14] Potential yield is calculated as $\{Potential\ yield = (100/TE) * Actual\ yield\}$ Kibaara, 2005.

4.2.2 Determinants of technical efficiency among irrigation scheme farmers in Turkana South

To test whether the socio-economic and technical factors had a significant contribution in explaining the variation in farm-level technical efficiency using equation 3.11[15], the likelihood ratio (LR) test was used. The null hypothesis stated that socio-economic and technical factors do not have a significant contribution in explaining the technical inefficiencies ($H_0\colon \delta_0 = \delta_1 = \delta_2 = \delta_3 \ldots\ldots\ldots.\delta_{10} = 0$). This was tested against the alternative hypothesis $H_1 : \delta_0 \neq \delta_1 \neq \delta_2 \neq \delta_3 \neq \cdots \delta_{10} \neq 0$ using LR test. The calculated LR value was 118.267 (Table 4.7). Since the critical chi-square value for 11 degrees of freedom at 1percent level of significance was 24.73 and is less than the calculated LR value, the null hypothesis$H_0\colon \delta_0 = \delta_1 = \delta_2 = \delta_3 \ldots\ldots\ldots.\delta_{10} = 0$ was rejected leading to the conclusion that there exist technical inefficiency explained jointly by the explanatory socio-economic and technical factors specified.

Technical inefficiency score was used as the dependent variable. The signs of the coefficients in the inefficiency model equation 3.11 are interpreted as explained in the methodology. Positive sign implies that the variable (factor) increases the technical inefficiencies whereas negative sign implies that the factor (variable) decreases technical inefficiencies. The results of the coefficients obtained from analysis are as indicated in the Table 4.7. The results show that the coefficients of age, access to credit, farm size, status of irrigation infrastructure and number of extension visits were significantly different from zero. The signs of the coefficients of age, access to credit, income, status of irrigation infrastructure, household size, number of extension visits and soil salinity were as expected. However, the sign of the coefficient of farm size was not as expected.

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[15] $\mu_i = \delta_0 + \sum_{k=1}^{10} \delta_k Z_i = \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \cdots + \delta_{10} Z_{10}$ (Inefficiency model equation)

Age has positive and significant effect on maize production inefficiency at 5 percent level of significance implying that younger farmers were relatively more efficient than older farmers in the irrigation schemes. The increased technical inefficiencies with age is probably because older farmers have reduced physical strength to carry out most of the labor intensive activities in the irrigation schemes for example desilting of canals, ploughing, weeding, watering among other activities. This finding is therefore consistent with the study by Md. Abdul and White (2002), Ajibefun and Daramola, (2003), Amaza et al., (2006), Makombe et al., (2011) and Kibaara and Kavoi (2012).

The effect of access to credit is negative and significant at 5 percent level of significance indicating that farmers who accessed credit were 0.39 percent more technically efficient. The negative sign is as expected since credit accessibility enables farmers to procure the necessary inputs at optimal time. Amaza et al. (2006); Kagwe, (2010); Kibaara and Kavoi, (2012); Himayatullah and Imranulla, (2011) reported similar results.

Farm size had positive effect and was significant at 1 percent level of significance meaning farmers with large farm sizes were 0.56 percent more technically inefficient. This could be attributed to the low input use per acre. For example, the average kilograms of maize seed planted per acre was six kilograms against the recommended 10 kilograms per acre. Moreover, larger farm size requires higher capital for purchase of the required inputs. Since most farmers are poor, they are less able to afford optimal levels of inputs. These results agree with those of Abid and Nawaz, (1998) who found farm size as negatively correlated with technical efficiency. However, the findings of the study differ with the findings by Kagwe, (2010) who found that farmers with large parcels of land had higher levels of technical efficiency.

Appropriate irrigation scheme infrastructure ensures steady and adequate flow of water to farms. Status of irrigation infrastructure had negative effect significant at 5 percent level of significance implying that appropriate and good irrigation infrastructure [16]increases farmers' level of technical efficiency by 0.14 percent.

Finally, the coefficient of the number of visits by agricultural extension staff was negative and significant at 1 percent level of significance. This means that farmers who were visited by agricultural extension service providers had decreased technical inefficiencies. They were 0.05 percent more technically efficient. Extension enables farmers to obtain information on irrigation water management, crop spacing and good agricultural practices. These results agree with those of Mutoko, (2008) and Amaza et al., (2006).

4.3 ALLOCATIVE EFFICIENCY RESULTS

The allocative efficiency of the irrigation scheme farmers was estimated using the Cobb-Douglas Stochastic frontier cost function specified in equation 3.13[17]. First, the null hypothesis of absence of allocative inefficiencies that is, $H_0: \gamma = 0$ was tested against the alternative hypothesis $H_1: \gamma > 0$ using the gamma parameter. The results of analysis (Table 4.8) indicated that the coefficient of gamma parameter estimate was 0.348 and significant at 5 percent level. This implies that 34.8 percent of the variation in the allocative efficiency among the irrigation scheme farmers was due to allocative inefficiencies. Therefore, the null hypothesis of absence of allocative inefficiencies was rejected.

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[16] Irrigation infrastructure includes a functional intake, secondary canals, tertiary canals with check boxes to control water flow into the farms, diversion boxes and well maintained canals

[17] $lnC_i = \alpha_0 + \alpha_1 lnP_1 + \alpha_2 lnP_2 + \alpha_3 lnP_3 + \alpha_4 lnP_4 + \alpha_5 lnY + (v_i + u_i)$

From equation 3.14[18], the null hypothesis that socio-economic and technical factors have no significant effect on the allocative inefficiencies: $H_0\colon \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_5 \dots\dots..\delta_{10} = 0$ was tested against the alternative hypothesis $H_1\colon \delta_0 \neq \delta_1 \neq \delta_2 \neq \delta_3 \neq \cdots \delta_{10} \neq 0$ using the likelihood ratio test (LR). At 1 percent level of significance, the calculated LR value of 74.26 was higher than the critical chi-square value 24.725 at 11 degrees of freedom[19].Therefore, socio-economic and technical factors taken together have a significant effect in explaining the allocative inefficiencies among the irrigation scheme farmers.

The cost elasticities with respect to all input variables use in production (Table 4.8) are positive. A 1 percent increase in the cost of labor, fertilizer, seed and water will increase total cost of production by 0.18, 0.74, 0.13 and 0.02 percent respectively. A 1 percent increase in maize yields at the existing level of efficiency will increase total costs of production by 0.11 percent. The coefficient for wage rate is significant at 1 percent level of significance implying that any increase in the wage rate will significantly increase the total costs of production by 0.18 percent. The coefficients of fertilizer, seed and irrigation were not significant.

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[18] Allocative inefficiency model

[19] Degrees of freedom were equal to the total parameters in the inefficiency model that were restricted to zero.

Table 4.8: Maximum likelihood estimates of the parameters of the Cobb-Douglas Stochastic frontier cost function

Variable	**Parameter**	**Coefficient**	**Std Error**	**t-ratio**
Dependent variable: Ln of total variable costs				
Constant	α_0	4.969	3.983	1.248
Labor wage rate	α_1	0.175***	0.035	5.054
Price of fertilizer	α_2	0.744	0.881	0.845
Price of seed	α_3	0.127	0.243	0.521
Price of irrigation water	α_4	0.019	0.082	0.230
Output	α_5	0.106***	0.038	2.772
Inefficiency model				
Dependent variable: Allocative inefficiency score				
Constant (Intercept)	δ_0	0.961***	0.178	5.409
Age	δ_1	-0.001	0.002	-0.427
Gender of household head	δ_2	0.124**	0.052	2.364
Education level of household head	δ_3	-0.068*	0.041	-1.658
Access to credit	δ_4	-0.217***	0.079	-2.757
Farm size	δ_5	-0.891***	0.259	-3.442
Income	δ_6	0.000*	0.000	1.820
Status of irrigation infrastructure	δ_7	-0.022	0.026	-0.842
Household size	δ_8	0.006	0.007	0.884
Number of extension visits	δ_9	-0.008*	0.004	-1.705
Salinity	δ_{10}	0.016	0.053	0.303
Sigma-squared	$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.069***	0.008	8.820
Gamma	γ	0.348**	0.137	2.543
LR Test of the one sided error	LR	74.26		
Mean allocative efficiency		67.23%		

Statistical significance levels: *10%; **5%; ***1%.

The average allocative inefficiency score was 148.75 percent. This implied that inefficiency added total costs by 48.75 percent above the minimum total costs incurred by the most efficient farmer in the irrigation schemes. The 148.75 percent allocative inefficiency translated to allocative efficiency score of 67.23 percent[20]. The minimum and maximum allocative efficiency scores were 48.54 and 97.09 percent respectively. This implies that if the average farmer in the sample was to achieve allocative efficiency level of the most efficient counterpart in the irrigation schemes, the farmer could achieve a cost saving of 30.76 percent that is $(1 - 67.23/97.09) * 100 = 30.76$ percent. Similarly, if the most allocatively inefficient farmer in the sample were to achieve the allocative efficiency level of the most allocatively efficient farmer, the farmer could realize 50 percent cost saving. This is calculated as $(1 - 48.54/97.09) * 100 = 50.05$ percent.

4.3.1 Determinants of allocative efficiency among farmers in the irrigation schemes

Ten socio-economic and technical factors were analyzed and the results shown in table 4.8. From the likelihood ratio test, it was found that socio-economic and technical factors taken together have a significant effect in explaining allocative inefficiencies among the irrigation scheme farmers at 1 percent level of significance. The results of each factor's influence on allocative inefficiencies, is indicated in table 4.8.

The results of the MLE of allocative inefficiency model equation 3.14 indicated in table 4.8, show that age, highest level of education of the household head, access to credit, farm size, status of irrigation infrastructure and number of extension visits had negative signs implying that they improve the allocative efficiency. Other factors like gender, income, household size

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[20] Allocative efficiency score is calculated as $(\frac{100}{148.75}) * 100 = 67.23$. The value of 100 in the numerator is considered as the percentage base allocatively efficient level. The same formula was used in the computation of other allocative efficiency scores from the stochastic frontier cost function estimates of allocative inefficiency.

and salinity had positive signs implying that they increase allocative inefficiencies. The coefficient of gender[21] was found to be positive and significant at 5 percent level of significance. This implied that women are more allocatively efficient than men in the irrigation schemes. The implication is that female farmers make better decisions regarding input price differences and the quantities to be utilized on the farm.

The coefficient of education level of the household head was negative and significant at 10 percent level of significance. This implies that, as the level of education of the farmer increases, allocative inefficiencies decrease. Therefore, increase in the level of education of the irrigation scheme farmer, improves allocative efficiency by 0.07 percent. This direction of influence was as expected. Education sharpens the managerial capability of a farmer in making timely decisions. It also enables them make good use of information about production inputs, (Himayatullah and Imranulla, 2011). More educated farmers have also the ability to allocate inputs in a cost-minimizing manner. The findings of this study conform to the findings of a study by Ajibefun and Daramola, (2003); Himayatullah and Imranulla, (2011). However, the results of this study disagree with the findings of Mutoko, (2008) who found that allocative efficiency reduces with an extra year of formal schooling.

Access to credit had a negative coefficient, which was significant at 1 percent level of significance. This implies that farmer's access to credit increases their allocative efficiency. Therefore, in this study, credit accessibility improved farmers' allocative efficiency by 0.22 percent. Credit accessibility enables farmers to buy inputs in time especially when prices are not high (during periods of low demand for the inputs). It further enables a farmer to enhance efficiency by overcoming financial constraints, which may affect their ability to apply inputs

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[21] Gender was coded as 1=Male; 0=Female

and implement farm management decisions on time. Farmers who accessed credit may be in comparison to their counterparts, who never accessed credit, be more motivated to allocate resources efficiently in order to realize maximum returns so that they can repay the money borrowed (Obare, et al.,2010). This result agrees with the findings by Isah, H, et al., (2013) and Himayatullah and Imranulla, (2011).

The estimated coefficient of farm size was negative and significant at 1 percent level of significance. This implies that farmers who had larger farms were more allocatively efficient by 0.89 percent than those who had smaller farm sizes. This could be due to the fact that given limited resources and the level of poverty among the irrigation scheme farmers in the Sub-County; they tend to allocate the resources available efficiently with the increased farm sizes. However, as seen from the results of analysis of technical efficiency, increase in farm size is found to be associated with increased technical inefficiencies. Thus, the factor though increases allocative efficiency, it decreases technical inefficiency.

Income had positive effect on allocative inefficiency and was significant at 10 percent level of significance. This shows that increased levels of income leads to increased allocative inefficiencies (decrease in allocative efficiency). However, this was not as expected. The positive and significant coefficient of income could be attributed to the fact that those who had more income may have been involved in off-farm income earning activities. Therefore, they resorted to using hired labor in carrying out most of the activities in the irrigation schemes for example planting, weeding and watering among other activities thus resulting in overutilization of some inputs, which resulted in allocative inefficiencies.

Finally, the estimated coefficient for extension visits was negative and significant at 10 percent level of significance. This negative sign was as expected. This implies that increased number of extension visits improved the allocative efficiency of the irrigation scheme farmers by 0.008 percent. Farming households who have more contacts with extension service providers tend to be allocatively efficient. The extension workers disseminate useful information to the farmers for example input prices, optimal levels of input use per unit acreage and information on available technology. This improves the decision-making ability of the farmer thus improved allocative efficiency. Mutoko, (2008) and Nyagaka, (2009) reported similar results.

4.4 RESULTS OF ECONOMIC EFFICIECY

According to Farrel, (1957) economic efficiency is equal to the product of technical and allocative efficiency. It defines the ability of a firm to produce a pre-determined quantity of output at minimum cost for a given level of technology (Himayatullah and Imranulla, 2011). For this study, economic efficiency scores for the irrigation scheme farmers were derived from the product of estimated technical and allocative efficiency scores of equations 13[22] and 17[23] stated earlier. The results of economic efficiency estimates are as shown in table 4.9.

The average economic efficiency score of the irrigation scheme farmers was found to be 30.46 percent, which was lower as compared to the findings, by Mutoko, 2008 in which smallholder maize farmers in North Western Kenya were on average, 49 percent economically efficient. The minimum and maximum economic efficiency scores of the maize farmers in the irrigation schemes were 8.81 and 73.46 percent respectively. This implies that if the average farmer were to achieve economic efficiency level of the most economically

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[22] Equation 13 is the stochastic frontier production function

[23] Equation 17 is the Cobb-Douglas stochastic frontier cost function

efficient counterpart in the irrigation scheme, then the average farmer can have a 58.54 percent cost saving. This is calculated as $(1 - 30.46/73.46) * 100 = 58.54$ percent. This means that irrigation scheme farmers can reduce total production costs by 58.54 percent if they reduce input application levels to the technically efficient levels at minimum cost given the available technology. Similarly, if the most economically inefficient farmer is to achieve the economic efficiency level of the most economically efficient farmer, then the economically inefficient farmer will achieve 88.01[24]percent cost saving.

Table 4.9: Frequency Distribution of Technical, Allocative and Economic Efficiency of irrigation scheme farmers

Efficiency Score (%)	Technical Efficiency		Allocative Efficiency		Economic Efficiency	
	No[25]	Percent	No	percent	No	Percent
0-10	0	0	0	0	4	2.19
11-20	15	8.2	0	0	45	24.59
21-30	46	25.14	0	0	56	30.60
31-40	30	16.39	0	0	29	15.85
41-50	29	15.85	7	3.83	27	14.75
51-60	18	9.84	58	31.69	14	7.65
61-70	18	9.84	40	21.86	4	2.19
71-80	14	7.65	16	8.74	4	2.19
81-90	11	6.01	49	26.78	0	0
91-100	2	1.09	13	7.10	0	0
Total	183	100	183	100	183	100
Minimum (%)		12.30		48.54		8.81
Maximum (%)		92.00		97.09		73.46
Mean		45.30		67.23		30.46
Standard Dev		20.52		14.29		14.72

Source: Authors survey data, 2014

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[24] This is calculated as $(1 - 8.81/73.46) * 100 = 88.01$ percent.

[25] This is the number of irrigation scheme farmers

From the results in table 4.9, it can be concluded that the low level of economic efficiency was contributed more by the technical inefficiency. The technical inefficiency is attributed to the failure by the farmers to produce optimal levels of maize output.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

The growing world population has triggered the emergence of strategies in seeking for ways of increasing agricultural productivity and food production in order to cope up with the increasing demand for food. The projected increase in Sub-Saharan Africa population by the year 2025 raises concern to most African governments and policy makers. One of the strategies of increasing food production is through irrigation because rainfall has become increasingly unreliable due to the effects of climate change. Therefore, dependence on rain fed agriculture has become more challenging. Irrigation offers an opportunity for the achievement of food security and poverty reduction.

Even though irrigation in Kenya plays an important role in contributing to GDP, there still exists an enormous unexploited irrigation potential. The main focus of this study was irrigated agriculture in Turkana South Sub-County. The Sub-County is endowed with two permanent rivers that flow into Lake Turkana along which there are nine irrigation schemes falling in the Sub-County. In these irrigation schemes, maize is the major crop grown mainly for subsistence.

Despite the existence of the irrigation schemes some dating back to 1972, the Sub-County continues to experience periods of food shortages thus necessitating short-term interventions of relief food assistance, which is hardly a long-term solution to food insecurity. Furthermore, poverty levels are very high as per official statistics. The area has a very high potential for food production from the existing irrigation schemes. However, the output levels have been lower than expected. Similarly, cases of severe food insecurity in the Sub-County raise serious concerns.

Therefore, the objective of this study was to assess the technical, allocative and economic efficiency levels of the irrigation scheme farmers in Turkana South Sub-County and to determine the factors affecting their technical and allocative efficiency. To achieve these objectives, a representative sample of 183 farmers was taken from two irrigation schemes, namely Katilu and Koputiro located in Katilu and Kainuk Divisions respectively. The sampling frame was a list of all farmers in the two irrigation schemes whose names were arranged per block. Semi-structured questionnaire was used to collect data on the inputs and output levels of maize production by the farmers in the irrigation schemes including their socio-economic and technical characteristics.

The socio-economic and technical characteristics hypothesized to affect efficiency levels achieved by the farmers in irrigation schemes farm production were summarized using descriptive statistics. In order to estimate the actual efficiency levels and to identify the factors affecting it, a stochastic frontier production and cost functions were estimated.

5.2 CONCLUSIONS

5.2.1 Characteristics of irrigation scheme farmers

It was found that the average age, farm size, income, household size were 54.37 years, 0.68 acres, Ksh 35345.98 and 8 respectively, with the youngest and oldest farmer being 25 and 90 years old respectively. Analysis of age distribution revealed that 53.55 percent of the farmers in the irrigation schemes were 55 years and above whereas the youth were only 7.65 percent.

It can therefore be concluded that there is low youth participation in irrigated agriculture in the Sub-County.

From the results obtained for educational level of the irrigation scheme farmers, it can be concluded that majority of them have no formal education. This category was found to be 73.8 percent. Therefore, policies geared towards improving education of the farmers are very important in order enhance their capacity. The state of irrigation scheme infrastructure is also a key characteristic in irrigated agriculture. A larger proportion of Koputiro irrigation farmers (83.3 percent) perceived their scheme to be between very bad to bad states as compared to Katilu in which74.1 percent perceived their scheme to be in good state.

Access to credit among the irrigation scheme farmers is limited. Only 10 percent of the farmers had accessed credit. Majority of the farmers who constituted 90percent had not accessed credit an indication that credit accessibility is limited among the irrigation scheme farmers. With regard to gender, more than half (52 percent) of the farming households in the irrigation schemes are female headed.

Further, the results obtained showed that the average yield attained by the irrigation scheme farmers was approximately five bags per acre, which was below the estimated national average of eight bags per acre. This yield was achieved through the use of the following inputs on average per acre: 76.34 Kg of fertilizer, six Kg of seed and 104 man-days of labor. Seed as an input in production was found to be the limiting factor whereas labor and fertilizer were over utilized in the production. It can be concluded that input use in production in particular seed is not optimal.

5.2.2 Technical, Allocative and Economic Efficiency

The results of the study showed that, the average technical, allocative and economic efficiency levels of the irrigation scheme farmers were 45.30, 67.23 and 30.46 percent respectively. This shows that the irrigation scheme farmers were not technically, allocatively and economically efficient. There were scopes for the farmers to increase farm output, save costs of production and improve on economic efficiency. Farmers had a scope of increasing farm output by approximately 54.7 percent. On average, the estimated potential yield of an average farmer was 10.58 bags per acre. However, among the most efficient farmers, the potential yield can go up to 19.75 bags per acre. This indicates that there is potential to increase production in the irrigation schemes.

Similarly, the cost saving of an average farmer was estimated at 30.76 percent whereas for the most allocatively inefficient farmer 50.05 percent when compared to their most allocatively efficient counterpart. The low economic efficiency level was attributed to the fact that the farmers failed to achieve higher levels of technical efficiency. The socio-economic and technical factors that significantly determined the farmers' level of technical efficiency included age, access to credit, farm size, status of irrigation infrastructure and number of visits by extension service providers. Access to credit, status of irrigation infrastructure and extension visits are significant variables in reducing the technical inefficiency of the farmers. For allocative efficiency, education of the household head, access to credit and number of visits by extension service providers are important variables, which were found to significantly reduce the allocative inefficiency among the irrigation scheme farmers.

5.3 RECOMMENDATIONS

Based on the findings of this study, the following are recommended for policy intervention:

1) Given that good irrigation scheme infrastructure contributes to decreased technical and allocative inefficiencies, the study recommends rehabilitation of irrigation schemes which have dilapidated infrastructure for example Koputiro. This will enable steady flow of water into the farms thus contribute more in improving the efficiency levels of the farmers.

2) Policies to improve on rural financing should be adopted by the National government, County government and other stakeholders in order to improve on credit accessibility by the farmers. This could be through enacting laws that lower interest rates on money lent to the farmers. In addition, the lending institutions should create more awareness campaigns on credit availability to the irrigation scheme farmers. Furthermore, table-banking groups should also be encouraged and supported by the government and other stakeholders.

3) Improvement in extension service delivery to the farmers by the extension service providers. More farm visits, demonstrations and farmer trainings should be offered to the farmers by the extension service providers. Farmers tour to successful irrigation schemes are also recommended for them to learn more and improve on their production. Therefore, the National government, County government of Turkana and other stakeholders should support extension services in the Sub-County. Enough agricultural extension officers should be deployed in these irrigation schemes in order to serve the farmers.

4) Given the high number of farmers in those irrigation schemes who do not have formal education (approximated at 73.8 percent), strategies and policies should be put

in place to improve levels of education and literacy both in the short-term and long-term. It is suggested that in the short-term, adult education can be of great importance for the adult farmers. In addition, farmer trainings by the extension officers are recommended in educating these farmers on better ways of improving their production. Local visits to successful farmers within the County or to other areas with similar set up are also recommended for the farmers to learn more.

5) It is recommended that youth should be encouraged to actively participate in farming as the future of those irrigation schemes lies in the hands of the current youthful generation. This requires concerted effort in creating awareness among the youth that agriculture pays and the future of food security lies in irrigated agriculture. It's also recommended that whenever there is expansion of the existing irrigation schemes, the youth should also be considered in the allocation of land. Grants can also be advanced to youth groups participating in farming as an incentive for them to take up farming.

Suggested areas for future research

The study prompts the following areas for further research:

- With growing water scarcity, and increasing competition among water using sectors, the need for water saving and more efficient water use is important. However, this study was limited to the analysis of technical allocative and economic efficiency of farm level production in the irrigation schemes. Future studies can therefore look at the physical and economic use of the irrigation water.

- The scope of this research focused on maize enterprise mainly grown by the farmers in the irrigation schemes. However, farmers in the irrigation schemes grow other crops like sorghum and green grams. Therefore, future studies can focus on the analysis of efficiency of all the crops (maize, sorghum and green grams) grown by the farmers in the irrigation schemes. Further, given that the irrigation scheme farmers are agro-pastoralists, future studies can incorporate livestock enterprise in the analysis of efficiency.

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APPENDICES

APPENDIX 1: CORRELATION MATRIX OF SOCIO-ECONOMIC AND TECHNICAL FACTORS

	Age	Gender	Education	Access to credit	Farm size	Income	Status of irrigation infrastructure	Household size	Extension visits	Salinity
Age	1									
Gender	-0.0571	1								
Education	-0.3659	0.1372	1							
Access to credit	-0.1701	0.1423	0.0879	1						
Farm size	0.2521	0.0826	-0.1138	-0.1897	1					
Income	-0.1663	0.1547	0.3963	0.1165	-0.0006	1				
Status of irrigation infrastructure	-0.1168	0.1517	0.0554	-0.0559	0.2433	0.2587	1			
Household size	-0.0647	0.0377	0.0935	0.1603	-0.1392	0.1358	-0.0666	1		
Extension visits	-0.0931	0.1894	0.1009	0.1272	0.1466	0.2081	0.3397	0.0526	1	
Salinity	-0.0570	0.0029	-0.1041	0.1051	-0.0614	-0.1107	-0.1708	0.0823	-0.2181	1

Source: Author’s survey, 2014

APPENDIX 2: FIELD SURVEY QUESTIONNAIRE

UNIVERSITY OF NAIROBI

FIELD SURVEY QUESTIONNAIRE

TITLE: FACTORS AFFECTING FARM-LEVEL EFFICIENCY IN IRRIGATION SCHEMES: A CASE OF MAIZE PRODUCTION IN TURKANA SOUTH SUB-COUNTY

In this questionnaire, only households that are participating in irrigated farming will be eligible for interview. Only one person will be interviewed in the selected household. The study targets to interview household heads (main decision makers). In case the main decision maker is not available, the second in command should be interviewed to get information about the farm household. Respondents are kindly requested to give their honest response to every question.

Objective of the survey: The interviewer (enumerator) should explain this part to the respondent.

The purpose of this study is to obtain information on various aspects of irrigated agriculture in the sub-County with respect to maize enterprise. Therefore, your participation (respondent) in answering questions will be greatly appreciated. The information you will provide will be analyzed together with the information gathered from other irrigation scheme farmers. The information you will give will also be kept confidential.

SECTION A: IDENTIFICATION

1. Household code:…………………………………………………………………………….

2.Name of enumerator: ………………………………………………………………………

3. Name of Irrigation scheme: ………………………4) Date of interview……………………

5.Sub-County:……………………………………6)Division………………………………….

7.Location:………………………………… ….. 8) Sub Location……………………………

9. Village…………………………………………

SECTION B: SOCIO-DEMOGRAPHIC INFORMATION

10. Gender of respondent: Male …… Female……. (Please tick appropriate)

11. Age:…………………… years

12. Are you the household head?............... (1=Yes; 2=No)

13. Marital status :……………………..(1=Married; 2=Single; 3=Widow; 4=Widower)

14. Do you make farming decisions on land preparation, when to plant, purchase of seed and other inputs among other farming activities?................... (1=Yes; 2=No)

15. If No in question 14, who makes those decisions?........... (1=Husband; 2=Wife; 3=Other)

16. If No in question 12, what is your relationship with the household head? (Tick one option)

Spouse	
Son	
Daughter	
Relative	
Other(specify)	

17. Gender of Household head: Male……… Female…………………

18. Age of Household head: ……………………years

19. Marital status of household head :…………(1=Married; 2=Single; 3=Widow; 4=Widower)

20. Highest level of formal education completed by the household head: (*Please tick the appropriate and indicate the total years spent in school*)

	Level of education	**Tick appropriately**	**Total Number of years of schooling**
a)	Not gone to school (No formal education)		
b)	Primary		
c)	Secondary		
d)	Middle level college		
e)	University degree		

21. When did you start maize production under irrigation? ………… (Total years of experience………….years)

22. How many members were residing with you last year (2013) including relatives and workers if any?

Total membership:…………………………….

a) Male adult………b)Female adult……c)Male children…d) Female children………. e) other relatives and workers……………………………

NB: Adult means above 18 years and child means any household member below 18 years of age

23. Enumerator to fill the following table with regard to composition of household members (Household profile).*This question seeks to ascertain the human capital endowment of a household. Different persons in a household may have different skills and capabilities which can contribute to the implementation of farming activities e.g. labor, technical information etc.*

Household member No.	Gender 1=Male 0=Female	Age (years)	Relationship with Household head 1=Spouse 2=Son 3=Daughter 4=Relative 5=Other(specify)	Educational level 0=No formal education 1=Primary 2=Secondary 3=Middle level college 4=University	Participation in farming 0=Did not participate 1=Full time 2=part time
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

24. Apart from crop farming, what other income earning activities do you do? (*Enumerator to tick all that apply).*

Livestock farmer	
Teacher	
Business person	
Any other	

SECTION C: MAIZE PRODUCTION AND MARKETING IN THE IRRIGATION SCHEMES

Land

25. What was the area you planted with maize crop in the irrigation scheme last year 2013 (*including acres owned and hired*) for the first season?

	SEASON 1
Acres owned	
Acres hired	
TOTAL	

26. How many plots was this farm size?.........…………plots

27. What was the cost of hiring land in the irrigation scheme? Ksh………………..per acre per season

Farm inputs

28. Did you use any farm inputs (fertilizer, manure, seed etc) last year in the production of maize crop?....................... (1=Yes; 2=No)

29. If yes in question 28, which inputs did you use and what were the quantities utilized in each of the plots?

Plot No	**Plot area (Acres)**	**Seed**		**Planting Fertilizer**			**Topdressing fertilizer**			**Manure**	
		Qty (Kgs)	Price (Ksh/Kg)	Type 0=No fertilizer used 1=DAP 2=NPK 3=Other	Qty (Kg)	Price (Ksh/kg)	Type 0=No fertilizer used 1=CAN 2=UREA 3=Other	Qty (Kg)	Price (Ksh/kg)	Qty (Tons)	Price (Price/Ton)
1											
2											
3											

Labour

30. Please give information regarding your labour input supply in maize production in the irrigation scheme during the main cropping season.

Plot No.	Plot area (Acres)	Activity	Male family labor			Female family labor			Male Hired labor			Female hired labor			Wage rate Ksh/day	Tractor hours	Tractor Cost (Ksh)
			No of men	Hrs/ day	Days	No of women	Hrs/ day	Days	No of men	Hrs/day	Days	No of women	Hrs/ day	Days			
1		1stploughing															
		2ndploughing															
		Ridging															
		Planting															
		Weeding															
		Fertilizer/manure application															
		Watering															
		Other															
2		1stploughing															
		2ndploughing															
		Ridging															
		Planting															
		Weeding															
		Fertilizer/manure application															
		Watering															
		Other															
3		1stploughing															
		2ndploughing															
		Ridging															
		Planting															
		Weeding															
		Fertilizer/manure application															

		Watering															
		Other															

Irrigation water application

31. We would now like to ask you questions concerning how you irrigate your land. (Enumerator to use *the codes indicated below this table*)

PLOT NO.	**Frequency of irrigation season 1**			**Total number of times crop irrigated**
	1st month after planting	2nd month after planting	3rd month after planting	
1				
2				
3				

CODES

Code	**Frequency of irrigation water application**
0	No water application
1	Once a day
2	Twice a day
3	Once a week
4	Twice a week
5	Three times a week
6	Once after two weeks

32. Did you pay any water fees for the irrigation water used?................ (1=Yes; 2=No)

33. If yes, how much per season? Ksh………………………………………..

34. Which type of maize seed did you plant last year during the main cropping season? (*Please indicate the code*)

Plot No.	**Season**	**Type of seed planted** **1=Certified maize seed** **0=Local maize seed**
1	1	
2	1	
3	1	

35. What was the quantity of maize produce you harvested in your farm last year in the first season? *(Please fill the table below. The output to be recorded in 90kg bags*)

Plot No.	**Output (90kg bags)**
1	
2	
3	
TOTAL(BAGS)	

36. Did you sell any of the harvested produce?........... (1=Yes; 2=No)

37. If yes what was the quantity sold (*Enumerator to record the quantity sold in 90kg bags*)………………..bags

38. What was the average selling price of maize per 90 kg bag during the first season? Ksh………………

39. Apart from maize, are there any other crops you planted in your farm?............ (1=Yes; 2=No)

40. If yes, which crops did you plant?

Sorghum	
Kales	
Green grams	
Cowpeas	
Other (Specify)	

SECTION D: INCOME

41. What were your sources of income last year?

Income source	**Tick the appropriate income sources for Household**
Sale of maize crop	
Sale of livestock and livestock products	
Trading/Business(state type)	
Salaried employment	
Casual labor(state type)	
Remittances(income from relatives, friends etc)	
Dowry	
Other(Specify)	

A) Livestock and Livestock products

i) Livestock sold

Type of livestock	No. Sold	Price (Ksh)	Total (Ksh)
Goat			
Sheep			
Camel			
Poultry			
Other			

ii) Livestock product sold

Type of livestock product	Quantity sold	Price (Ksh) per unit	Total (Ksh)
Milk	…………litres		
Hides and skins			
Eggs			
Other			

B) Trading/Business

i) Type of business operated…………………………………..

ii) For how long did you operate the business last year?............................days

iii) What was the approximate amount earned from the business in a day? Ksh……………..

C) Salaried employment

i) State type……………………………………..ii) What was the approximate amount earned a month? Ksh………………………..

D) Casual labor

i) What is the approximate number of days you engaged in casual labor last year?................days

ii) How much were you paid per day worked? Ksh……………………………

E) Remittances from relatives, friends

i) How often do you receive remittances?...................................

ii) What was the approximate amount you received from remittances? Ksh…………………

F) Dowry

i) What was the form of dowry you received?................................. (Cows, shoats, camels, money)

ii) Number received: Cows…………Shoats…………Camels…………

iii) Amount of money received if dowry payment was in form of cash: Ksh…………………..

42. What was the approximate amount of income earned from the above sources for the whole year?

Income source	**Approximate amount (Ksh)**
Sale of maize crop	
Sale of livestock and livestock products	
Trading/Business	
Salaried employment	
Casual labor	
Remittances(income from relatives, friends etc)	
Dowry	
Other(Specify)	
TOTAL (KSH)	

SECTION E: ACCESS TO CREDIT

43. Did you have access to any formal or informal credit last year?.................. (1=yes; 0=No)

44. If yes, what was the source of credit? (*Please tick all that are applicable)*

Source of credit	Bank	Self-help group	Neighbour	Family member	NGO	Cooperative Society	Other(Specify)

45. Was the money borrowed used in maize production?.................. (1=Yes; 2=No)

46. Did any of the household members apply for credit or loan last year from the above mentioned sources?......................... (1=Yes; 2=No)

47. Was it used in maize production activities?.......................... (1=Yes; 2=No)

SECTION F: DISTANCE TO INPUT AND OUTPUT MARKETS

48. How much does it cost to travel to the nearest input markets? Ksh............................

49. What is the distance to the nearest seed and fertilizer stockist or market?..................... (Km)

50. What is the distance to the nearest maize market?.. (Km)

SECTION G: ACCESS TO EXTENSION SERVICES

51. Did any extension worker visit you last year to offer extension services or advice on maize production? ………. .(1=Yes; 0=No)

52. If yes, how many times did the extension worker visit you?......................times

53. If extension worker did not visit you, did you visit any extension service provider for advice?......... (1=Yes; 0=No)

54. If yes in question 53, whom did you contact and what type of information were you seeking?

Extension service provider 1=GOK(MOA,NIB) 2=NGO 3=Other(specify)	Extension message/Subject of visit

55. How many times did you contact the extension service providers?................times (visits)

55. What is the approximate distance in kilometers to the nearest extension service provider…………………….. (Km)

56. Did you receive any of the following services from any extension service provider(s)?

S/NO	**Extension service**	**Subject**	**Number**	**Service provider** 1=GoK(MOA) 2=NGO 3=Fellow farmer 4=Other
1	Farmer training			
2	Demonstrations			
3	Farmer excursion tours			
4	Other(specify)			

57. Who was the main extension service provider? (Please tick only one option)……………

1=GOK (MOA); 2=NGO; 3= Private company; 4=Other (specify)…………………….

SECTION H: NUMBER OF TIMES FIELD PLOUGHED

58. How many times did you plough your field before planting?....................times

SECTION I: SALINITY

59. Did you experience any soil salinity ("Amakat") in your farm?............. (1=Yes; 0=No)

60. Was there any water logging during that time? ………. (1=Yes; 0=No)

SECTION J: STATUS OF IRRIGATION INFRASTRURE

61. Was there adequate and uniform water flow for irrigation in your farm last year?.......... (1=Yes; 0=No)

62. What was the general state of irrigation scheme infrastructure last year?........... (1=Very bad; 2=Bad; 3=Fair; 4=Good) (*Indicate the rating using the codes provided*)

63. What was the state of the following irrigation scheme infrastructures in you scheme last year? (Use rating 1=Very bad; 2=Bad; 3=Fair; 4= Good)

Intake	Main canal	Secondary canal	Tertiary canal	Check boxes	Diversion boxes	Cut-off drain	Main drain

64. Do you normally make contributions towards scheme maintenance and management?.............. (1=Yes; 0=No)

65. If yes, how much did you contribute? Ksh………………………Per year.

SECTION K: IRRIGATION SCHEME PRODUCTION CONSTRAINTS

66. What constraints did you experience in maize production last year in your farm under the irrigation scheme? (*Tick all that are applicable*)

S/NO	**Production constraints**	
1	Crop pests and diseases	
2	Inadequate extension services	
3	Inadequate water for irrigation	
4	Degraded soil fertility	
5	Inaccessible input markets	
6	Poor maintenance of the irrigation scheme structures	
7	Siltation of canals	
8	Flooding in the irrigation scheme	
9	Weak irrigation scheme management	
10	Insecurity	
11	Inadequate farmer trainings	
12	Other(Specify)	

THANK YOU FOR YOUR PATIENCE, PARTICIPATION AND RESPONSES