ANALYSIS OF TECHNICAL EFFICIENCY OF SMALLHOLDER SORGHUM PRODUCERS IN MACHAKOS AND MAKINDU DISTRICTS IN KENYA

EVALINE CHEPNG’ETICH

(Dip Ag Ed; BSc Ag Ed, Egerton University)

Thesis submitted in partial fulfillment of the requirements for the Award of Masters of Science degree in Agribusiness Management and Trade in the school of Agriculture and Enterprise Development of Kenyatta University

OCTOBER 2013
DECLARATION

Student declaration
This thesis is my original work and has not been presented for a degree in any
other university or any other award
Evaline Chepng’etich Reg. No. A103/21864/2010
(Dip Ag Ed; BSc Ag Ed, Egerton University)

Sign ___________________________ Date ___________________________

Supervisors’ declaration
We confirm that the work reported in this thesis was carried out by the candidate
under our supervision and has been submitted with our approval as university
supervisors

Dr. Eric K. Bett (PhD)
Senior Lecturer
Department of Agribusiness Management and Trade
Kenyatta University

Sign ___________________________ Date ___________________________

Dr. Sospeter O. Nyamwaro (PhD)
Senior Principal Research Scientist
Division of Socio-Economics and Applied Statistics
Kenya Agricultural Research Institute (KARI)

Sign ___________________________ Date ___________________________
DEDICATION

I dedicate this work to my husband Kipyegon for his immeasurable support; to our sons Kiprotich and Kibet for their understanding when I did not give them enough attention during their early stages of life when they needed it most; to my parents Mr. and Mrs. Tonui for their selfless efforts and encouraging me to go on. Finally to my brothers Kiprutoh, Mainek, Kiplang’at, Cheruiyot, Kipkirui, my only sister Chelang’at and my sister-in-law Cherotich for trusting me.
ACKNOWLEDGEMENTS

I wish to acknowledge the staff of the Department of Agribusiness Management and Trade in the School of Agriculture and Enterprise Development, Kenyatta University for their support since I enrolled for my studies in the Department. My special thanks go to my supervisors Dr. Eric Kiprotich Bett of the Department of Agribusiness Management and Trade and Dr. Sospeter Onchoke Nyamwaro of Kenya Agricultural Research Institute (KARI) Muguga for their tireless effort in guiding and supporting me during the study and research period.

I also take this opportunity to convey my sincere thanks to Mr. Kwena Kizito of KARI – Katumani for giving me an opportunity to carry my research within their project, which was funded by the Association for Agricultural Research in Eastern and Central Africa (ASARECA). ASARECA is thus greatly appreciated for partially funding this research project.

I appreciate the support of my colleagues, especially Charles Karani, Nick Karuku and Lucy Wangui for sharing with me useful ideas during the entire period of study. I also thank all the enumerators, particularly Bill Musembi and
Silvester Mutua, and the guides Jeremiah Mbaluto, Philiph Kyengo and Agnes Mueni, who assisted me during field data collection.

Finally, special thanks to my parents for their support throughout my life. To my husband whom I am highly indebted for his financial and emotional support and encouragement throughout my studies. To the rest of my family and all whom, in one way or the other, contributed significantly to the success of this study, to all I say may God reward you abundantly. Above all, Glory and Honour to GOD, the ALMIGHTY for bestowing unto me His mercy, care, strength, health and guidance during the entire period of study and beyond.
Table of Contents

DECLARATION............................................................................................................ ii
DEDICATION............................................................................................................... iii
ACKNOWLEDGEMENTS.............................................................................................. iv
TABLE OF CONTENTS................................................................................................. vi
LIST OF TABLES ........................................................................................................... ix
LIST OF FIGURES ........................................................................................................ xi
ABBREVIATIONS AND ACRONYMS ........................................................................ xiii
ABSTRACT .................................................................................................................. xv

CHAPTER ONE

BACKGROUND

1.1. Introduction ........................................................................................................... 1
1.2. Sorghum Production in Kenya ............................................................................. 1
1.3. Sorghum Productivity.......................................................................................... 4
1.4. Variability in Sorghum Production....................................................................... 4
1.5. Problem statement .............................................................................................. 7
1.6. Objectives .......................................................................................................... 8
1.6.1 General objective ............................................................................................. 8
1.6.2 Specific objectives ............................................................................................ 8
1.7. Hypotheses ......................................................................................................... 9
1.8. Research Justification ......................................................................................... 9
1.9. Significance of the study ................................................................................................. 11
1.10. Scope of the Study ........................................................................................................ 11

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction ..................................................................................................................... 12
2.2 General Literature Review ............................................................................................. 12
2.3 Efficiency ........................................................................................................................ 14
2.3.1 Measures of efficiency ............................................................................................... 14
2.3.2 Parametric methods .................................................................................................. 16
2.3.3 Non-parametric methods .......................................................................................... 17
2.4 Empirical Literature on Technical Efficiency ................................................................. 19
2.4.1 Studies conducted using Stochastic Frontier Analysis ............................................. 19
2.4.2 Studies undertaken using Data Envelopment Analysis .......................................... 25
2.4.3 Summary of technical efficiency studies ................................................................. 29
2.5 Review of Factors Influencing Technical Efficiency ..................................................... 32
2.6 Theoretical and Empirical Models for the Study ......................................................... 34
2.7 Conceptual Framework .................................................................................................. 35

CHAPTER THREE
METHODOLOGY

3.1 Introduction ..................................................................................................................... 38
3.2 Study Site, Population, Sample Size and Sampling Procedure .................................... 38
3.3 Research Design ............................................................................................................. 42
3.4 Data Collection Procedure ........................................................................................... 43
3.5 Data Analysis ................................................................................................................. 44
CHAPTER FOUR

RESULTS

4.1 Introduction ............................................................................................................... 53
4.2 Descriptive Analysis Results ................................................................................... 54
  4.2.1 Farmer socio-economic characteristics/ profiles ............................................. 54
  4.2.2 Farm characteristics ......................................................................................... 59
  4.2.3 Economic activities ........................................................................................... 63
  4.2.4 Transport and communication ......................................................................... 65
  4.2.5 Access to agricultural credits and extension services ..................................... 66
  4.2.6 Constraints faced by sorghum farmers in the region ...................................... 66
  4.2.7 Suggestions on how to improve sorghum enterprise overall in both districts ................................................................................................................. 71
  4.2.8 Selected comparative characteristics of sorghum farmers in the two districts ................................................................................................................. 73
4.3 Econometric Analysis Results .................................................................................. 77
  4.3.1 Technical efficiency indices ............................................................................. 77
  4.3.2 Output and input slacks ................................................................................... 82
4.4 Factors Influencing Technical Efficiency ................................................................. 84
4.5 Marginal effect analysis ............................................................................................ 90
CHAPTER FIVE
DISCUSSION

5.1 Technical Efficiency ................................................................. 92
5.2 Farm and Farmer Characteristics that Influence Efficiency .............. 94
5.3 Constraints Faced by Smallholder Sorghum Farmers overall in both district ........................................................................ 102
5.4 Farmer Suggestions on How to Improve Sorghum Production in the study sites .................................................................. 104

CHAPTER SIX
CONCLUSIONS, RECOMMENDATIONS AND POLICY IMPLICATIONS

6.1 Introduction .................................................................................. 106
6.2 Conclusions .................................................................................. 107
6.3 Recommendations ........................................................................ 109
6.4 Policy Implications ...................................................................... 110
REFERENCES .................................................................................. 112

APPENDICES

APPENDIX 1: QUESTIONNAIRE .......................................................... 121
List of Tables

Table 1: Description of variables used in the DEA Model.................................50
Table 2: Description of variables used in the Tobit model and expected hypotheses...............................................................52
Table 3: Summary descriptive statistics of selected farmer characteristics in Machakos and Makindu districts..........................58
Table 4: Summary descriptive statistics of selected farm characteristics in Machakos and Makindu districts..........................60
Table 5: Summary statistics of variables used in the technical efficiency analysis ........................................................................78
Table 6: Frequency distributions of technical efficiency scores obtained with DEA model ..................................................................79
Table 7: Output and input slacks from DEA model in Machakos and Makindu districts ..............................................................83
Table 8: Tobit model results showing farm and farmer characteristics that influence technical efficiency .........................87
Table 9: Marginal effect results showing the change expected from a unit change in each variable ..................................................91
List of Figures

Figure 1: Conceptual Framework ................................................................. 37

Figure 2: Study site indicating the location of Machakos and Mukindu districts ........................................................................................................ 39

Figure 3: Gender of sampled household heads overall in both districts .................................................................................................................. 55

Figure 4: Level of education of the household heads overall in both districts ............................................................................................................. 56

Figure 5: Years of sorghum farming experience overall in both districts ..................................................................................................................... 57

Figure 6: Methods of land preparation overall in both districts ...................... 62

Figure 7: Occupation of household heads overall in both districts .................. 63

Figure 8: Source of income from livestock and other crops overall in both districts ........................................................................................................... 65

Figure 9: Constraints faced by sampled farmers from planting to maturity of the sorghum crop ............................................................................. 68

Figure 10: Prices (KES/kg) farmers received for their sorghum grains ................................................................................................................................. 70

Figure 11: Farmers’ preferred prices per kg of sorghum grain ............................ 71

Figure 12: Farmers’ suggestions on how to improve sorghum production in the study region ................................................................. 73
Figure 13: Sorghum farming experience in Machakos and Makindu districts

Figure 14: Membership of sampled HHs to farmer associations

Figure 15: Technical efficiency distributions per district
<table>
<thead>
<tr>
<th>Abbreviations and Acronyms</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASALs</td>
<td>Arid and semi-arid lands</td>
</tr>
<tr>
<td>CRS</td>
<td>Constant return to scale</td>
</tr>
<tr>
<td>DEA</td>
<td>Data envelopment analysis</td>
</tr>
<tr>
<td>DEAP</td>
<td>Data envelopment analysis program</td>
</tr>
<tr>
<td>DMUs</td>
<td>Decision making units</td>
</tr>
<tr>
<td>EABL</td>
<td>East Africa Breweries Limited</td>
</tr>
<tr>
<td>FDH</td>
<td>Free disposal hull</td>
</tr>
<tr>
<td>Ha</td>
<td>Hectares</td>
</tr>
<tr>
<td>HOPE</td>
<td>Harnessing Opportunity for Product Enhancement</td>
</tr>
<tr>
<td>HHs</td>
<td>Households</td>
</tr>
<tr>
<td>HHHs</td>
<td>HH heads</td>
</tr>
<tr>
<td>HYSVs</td>
<td>High yielding sorghum varieties</td>
</tr>
<tr>
<td>ICRISAT</td>
<td>International Crop Research Institute for Semi-Arid Tropics</td>
</tr>
<tr>
<td>IFAD</td>
<td>International Fund for Agricultural Development</td>
</tr>
<tr>
<td>INTSORMIL</td>
<td>International Sorghum and Millet Program</td>
</tr>
<tr>
<td>KARI</td>
<td>Kenya Agricultural Research Institute</td>
</tr>
<tr>
<td>KES</td>
<td>Kenya Shillings</td>
</tr>
</tbody>
</table>

xiii
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>kgs</td>
<td>Kilograms</td>
</tr>
<tr>
<td>LP</td>
<td>Linear Programming</td>
</tr>
<tr>
<td>MoA</td>
<td>Ministry of Agriculture</td>
</tr>
<tr>
<td>NGOs</td>
<td>Non-governmental organizations</td>
</tr>
<tr>
<td>OLS</td>
<td>Ordinary least square</td>
</tr>
<tr>
<td>SSA</td>
<td>Sub Saharan Africa</td>
</tr>
<tr>
<td>SFA</td>
<td>Stochastic frontier analysis</td>
</tr>
<tr>
<td>TE</td>
<td>Technical efficiency</td>
</tr>
<tr>
<td>TEI</td>
<td>Technical efficiency indices</td>
</tr>
<tr>
<td>VRS</td>
<td>Variable return to scale</td>
</tr>
</tbody>
</table>
ABSTRACT

Majority of the rural households in Kenya depend mainly on agriculture as a source of food and livelihoods. Agricultural productivity has been declining due to many factors including climate change. Declining agricultural productivity has in turn resulted in increased food insecurity in the country. Consequently, there is a renewed interest in promoting drought-tolerant crops such as sorghum, which are known to perform well in the arid and semi-arid lands of the developing world. Owing to its ability to thrive in drought prone and low input conditions, sorghum production has been widely promoted among smallholder farmers in the arid and semi-arid parts of Kenya. However, performance of sorghum production among the smallholder farmers has remained low. This study was carried out to determine the technical efficiency of sorghum production among smallholder farmers in Machakos and Makindu districts in Kenya. Multistage sampling technique was used to sample a total of 143 sorghum-farming households; 71 households in Makindu district and 72 in Machakos district as representative samples. A semi-structured questionnaire was administered to collect data and information on farm inputs and outputs; and on farm and farmer characteristics. Data Envelopment Analysis technique was used to estimate efficiency scores, while a Tobit regression analysis model was used to determine the influence of farm and farmer characteristics on the technical efficiency. Result highlights showed that the average technical efficiency achieved overall in both districts was 41%. This implies that technical efficiency in sorghum production in Machakos and Makindu districts is low and could be improved by 59% through better use of available resources given the prevailing state of technology. Research findings suggest that technical efficiency was positively influenced by various farm and farmer characteristics such as land sizes planted with sorghum and use of manure; and formal education of the household head, household size, years of sorghum farming experience, membership to farmer associations, hired labour, and production advice given to farmers. It is recommended that in order to reduce technical inefficiency farmers should be trained appropriately to improve their agronomic knowledge on sorghum production. Farmers are also encouraged to form and be active members of farmer associations. Policies and programmes that promote extension services should be emphasized in order to improve performance of sorghum production enterprise in Machakos and Makindu districts, Kenya.
CHAPTER ONE

BACKGROUND

1.1. Introduction

Grain sorghum, *Sorghum bicolor (L.) moench* is the fifth most important cereal crop grown in the world (U.S Grain Council, 2010). Probably because of its versatility and diversity, sorghum is mainly grown in the arid and semi-arid lands (ASALs) of Africa and Asia for rural food security (International Research Network, 2005). Sorghum is processed into a wide variety of attractive and nutritious traditional foods, such as semi-leavened bread, dumplings and fermented and non-fermented porridges. It is still largely a subsistence food crop, but it is increasingly forming part of the foundation of successful food and beverage industries after being proven the best alternative to barley for lager beer brewing (Taylor, 2010).

1.2. Sorghum Production in Kenya

In Kenya sorghum is a traditional crop, which is grown in many parts of the country especially in the arid and semi-arid regions of the country. It is grown mainly for subsistence use, but the crop lost favour with farmers when maize
became the preferred crop and staple food after its introduction by the white settlers. However, due to the desire to stabilize food security in the country there is now renewed interest in promoting drought-tolerant crops such as sorghum and pigeon pea, which are known to be well adapted to harsh environments (GoK, 2009).

A lot of research on sorghum breeding has been going on and there is substantial documentation about this within Sub-Saharan Africa (SSA). Stable, high-yielding sorghum varieties (HYSVs) have recently been developed (Olembo et al., 2010). Sorghum production has widely been promoted among smallholder farmers because of its ability to thrive well in arid and semi-arid regions and the low input requirements compared with most staple cereals like maize. In Kenya, for example, the initiatives to promote sorghum production are mostly concentrated in the ASALs. This promotion is done as a government strategy to enable the country meet household food security needs and increase rural income (Ochieng et al., 2011; GoK, 2009; Okuthe, 2008). These initiatives have great potential for growth and expansion of the crop and are expected to impact the livelihoods of many farmers through food security and income generation.
Eastern Kenya is characterized by increasingly frequent drought occurrences, sometimes extending for two to three years in a stretch. Over the last two decades, there have been repeated maize crop failures in many parts of eastern Kenya especially because of droughts (Nagarajan and Audi, 2007). Coupled with improved production technologies, improved sorghum varieties if grown in semi-arid areas like the eastern province, can survive and yield well in such unreliable climatic conditions (Karanja et al., 2009). To promote the crop, Kenya Agricultural Research Institute (KARI) has developed HYSVs with accompanying supporting production technologies for higher yields. In recognition of the role sorghum can play in food security especially in ASALs, the government through the Ministry of Agriculture (MoA) initiated projects such as the Eastern Province Horticulture and Traditional Food Crops project, an International Fund for Agricultural Development (IFAD)-funded project, and Orphan Crops project in these regions to promote the sorghum, among other crops. The main aim of these projects was to encourage farmers to adopt these improved varieties in order to improve food security and rural incomes.
1.3. **Sorghum Productivity**

Sorghum is among the most important cereals in the ASALs. Much research on the cultivars has been done successfully and in the past two decades, approximately 40 cultivars have been released. Cultivated area under sorghum has been increasing although the yields have continued to decline. According to Olembo *et al* (2010), efforts to improve the production and productivity of these crops have been employed by different governments by pooling of resources together. To increase the productivity of sorghum there is need to understand the efficiency of sorghum production because increase in productivity is directly related to production efficiency. It is therefore necessary to improve productivity of the farmers by enabling them reduce their technical inefficiencies.

1.4. **Variability in Sorghum Production**

The area under sorghum production has been increased from 122,368ha in 2005 to 173,172ha in 2009 while the national average yield per hectare declined from 1.2tons per hectare in 2005 to 0.5tons per hectare in 2009 (GoK, 2010). Several public efforts supplemented by Non-Governmental Organizations (NGOs) and
other stakeholders like International Sorghum and Millet (INTSORMIL) program and International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) have, for instance, provided interventions for Harnessing Opportunities for Productivity Enhancement (HOPE), targeted at improving productivity and marketing of sorghum. These interventions include breeding, distribution of improved HYSVs that are pest and disease tolerant and promotion of resource conserving management practices. Despite all these efforts, there has been variability in production between the expected potential yields and the actual yields. The expected potential yield for the Gadam sorghum variety is 2-2.5tons ha\(^{-1}\) while farmers however have only realized production of up to 1.2tons ha\(^{-1}\) so far (GoK, 2009; Karanja et al., 2009). In the year 2010 for instance, East Africa Breweries Limited (EABL), through the IFAD-funded projects and Orphan Crops projects, had anticipated to collect 12,000tons of sorghum from the farmers but they only delivered close to 1,000tons (Africa the Good News, 2011). This was very much lower than the anticipated production target for the EABL requirements.

Variability in production is a function of differences in scales of operation, production technologies, operating environment and operating efficiency (Fried et
al., 2008). Production increases depend mainly on the efficient use of available appropriate technologies but not necessarily on adoption rates of new technologies (Chiona, 2011). Therefore, improving efficiency in production allows farmers to increase their output (Chimai, 2011). Chimai (2011) also noted that for the smallholder farmers, variation in production due to differences in efficiency might be affected by various factors, which include regional and farm specific socio-economic factors.

To achieve higher productivity, technological innovations though necessary are not sufficient conditions alone but efficient use of old technologies are also necessary (Chiona, 2011). If farmers are not using existing technologies efficiently, then ways of improving efficiency will be more cost effective in short run than introducing other technologies (Ibid). Technical inefficiency may arise primarily due to managerial incompetence and therefore efficiency differences could be explained in the context of the management characteristics such as training, experience and motivation (Ahmed et al., 2005).
1.5. Problem statement

The future of sorghum enterprise is linked to the contributions of sorghum to food security, income growth and alleviation of poverty. This is more relevant in developing countries in the African continent than in developed nations. Scientific research on improved sorghum varieties and associated technologies has been carried out by many research institutions. The government of Kenya and NGOs has invested a lot of resources in promoting the adoption of these new improved varieties and technologies especially in the ASALs through dissemination of the research work and high yielding sorghum varieties seeds by agricultural extension officers. Despite all these efforts to improve sorghum production there still exists a significant yield gap between the farmers’ production levels and the expected yields. According to research conducted by KARI, yield potential for improved varieties for instance Gadam under prescribed agronomic conditions ranges between 2-2.5tons per hectare, however farmers are only able to achieve, on average, 1.2tons per hectare. EABL has been identified as a reliable buyer who can purchase the dry sorghum grains at a price almost double of what the farmers used to get from the local market. In the year 2010 EABL had anticipated to buy 12,000tons of grain sorghum for its beer industry, but it managed to purchase only
1,000 tons that was available. The investment in the new supportive technologies and the availability of market have not yielded much results as anticipated. This implies that the technological advances generated through research have not translated much to increased efficiency and improved production. This study therefore aims at determining the current levels of technical efficiency among the small holder sorghum producers and identify the farm and farmer characteristics that influence levels of technical efficiency. Though many studies in Kenya have been done on technical efficiency with reference to some crops, none of these studies have considered technical efficiency on sorghum. This study aims at filling this gap.

1.6. Objectives

1.6.1 General objective

The study sought to analyze sorghum production among smallholder farmers in Machakos and Makindu districts in Kenya.

1.6.2 Specific objectives

Specific objectives of this study were to:
1. Determine the levels of technical efficiency of sorghum production among smallholder farmers in Machakos and Makindu districts,

2. Identify farm and farmer characteristics affecting smallholder technical efficiency in sorghum production.

1.7. **Hypotheses**

   a) That there is no significantly high level of technical efficiency of sorghum production among smallholder farmers in Machakos and Makindu districts, Kenya,

   b) That farm and farmer characteristics are not statistically significant in explaining technical efficiency of sorghum production among the smallholder farmers.

1.8. **Research Justification**

Sorghum has a major potential in reducing the problem of food insecurity and improving the living standards of the people in ASALs. The government and NGOs have invested a lot of resources in promoting the growing of sorghum especially in ASALs through promoting adoption of the new improved varieties
and technologies and identifying of a critical market, the EABL. Despite deregulated production and marketing environment for sorghum crop, the attainment of improved efficiency remains a major problem among the majority of smallholder farmers. The difference in production from the research and the actual production could be attributed to many factors in which technical inefficiency being one of them. Measuring efficiency provides a way of quantifying and comparing the performance of each farmer and identifying factors that could explain any inefficiency in performance. Identification of these factors and their marginal effects can assist stakeholders in the improvement of productivity, to identify controllable and uncontrollable factors affecting efficiency that need to be taken into account in designing relevant interventions. The aim of this study is primarily to provide insights into technical efficiency of sorghum production in Machakos and Makindu districts in Kenya. This will help in identifying avenues for possible policy interventions towards improving sorghum production in ASALs especially in Kenya. Raising sorghum productivity will profoundly positively affect, either directly or indirectly, the household food security and income levels of the majority of people growing sorghum and those who live around them.
1.9. **Significance of the study**

The information generated from this study will help inform the government and NGOs on the policy change and formulation of new policies in order to enhance the performance of the sorghum sub-sector. This will assist the sorghum value chains actors and evaluators to identify the part of the chain that needs interventions, in order to maintain continuous flow of the sorghum products to the consumers. It will help farmers to improve production levels and performance of the sub-sector in general, The study will also motivate other researchers to build on the recommendations given after the completion of the research, hence continue to bridge the knowledge gap.

1.10. **Scope of the Study**

The study was limited to Makindu and Machakos districts of Makueni and Machakos Counties in the eastern Kenya respectively. The two districts were among the initial districts in which the projects to promote sorghum farming were initiated and undertaken. The study mainly focused on sorghum farmers particularly those who planted sorghum in the 2010-2011 cropping season.
CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter covers literature review in general and specific literature review on sorghum productivity, efficiency and its measures, as well as different approaches of measuring technical efficiency. Empirical literature on technical efficiency and the choice of the models to be used in the study are also reviewed.

2.2 General Literature Review

Productivity and efficiency are two different concepts except under the assumption of constant return to scale. According to Fried et al. (2008), productivity is a ratio of production output to what is required to produce it (inputs). The measure of productivity is defined as a total output per one unit of total input. This measure is easily calculated if the farmer uses a single input to produce a single output. However, when multiple inputs are used to produce several outputs, the output in the numerator and the inputs in the denominator have to be combined in some sensible economic fashion so that productivity remains the ratio of two scalars (Coelli et al., 2002). Productivity may vary
depending on scale of operation, operating environment, production technologies and operating efficiency. Efficiency on the other hand is the success with which a farm uses its resources to produce output.

Productivity is simply a measure of the efficiency of production. Agricultural productivity depends on how factors are efficiently used in the production process. Efficiency can be achieved by either minimizing the resources required for producing a given output, or maximizing output produced from given resources. Intensification of agricultural land and expansion of technology use therefore must be accompanied by resource use efficiency that enhances productivity of factors of production. According to Chimai (2011), improving productivity could increase income obtained from the limited pieces of land owned by farmers and could result in improved economic wellbeing of farmers. One way of reducing the cost of production in a farm is to increase farm output by increasing technical efficiency. In this regard, it is necessary to quantify current levels of technical efficiency among the farmers in order to estimate the losses in production attributed to inefficiency due to different socio-economic characteristics and management practices.
2.3 Efficiency

Efficiency is a commonly used term in economics. It is usually concerned with the relative performance of the various processes used in transforming given inputs into outputs. The first analyses of efficiency measures started way back with Farrell (1957) and have now become the most widely used concept in economics. According to Charnes et al (1978), efficiency is the degree to which the observed use of resources to produce outputs of a given quantity matches the optimal use of resources to produce output of a given quantity. It is measured by comparing the observed output against the feasible (frontier) output (Fried et al., 2008). The scarcity of resources is the major reason that makes improvements in efficiency so important to an economic agent or a society.

2.3.1 Measures of efficiency

Coelli et al (2002) noted that there are two major types of efficiency measures that are usually distinguished at the firm level in production economics. One is technical or production efficiency, which measures the firm’s success in producing maximum output in a given set of inputs (Talluri, 2000). The other is the allocative or price efficiency, which measures a firm success in choosing an optimal set of input with a given set of input prices (Charnes et al., 1978). Both
technical and allocative efficiency make up the economic efficiency. Efficiency measurement shows how firms operate on the outer bound of the production function.

Technical efficiency reflects the ability of a firm to maximize output from a given set of resource inputs. Either it can be an output or an input oriented, where the former occurs when the maximum amount of an output is produced from a given set of inputs. Input oriented on the other hand, occurs when minimum amount of inputs are required to produce a given level of output. Technical efficiency of an individual farm is defined in terms of the ratio of the observed output to the corresponding frontier output, conditioned on the level of input used by the farm (Farrell, 1957). It is a comparison between the observed and optimal values of its outputs and inputs.

In sorghum production, a technically efficient farmer maximizes output subject to input constraints by minimizing the amount of input necessary to produce a given output (Chimai, 2011). In a production frontier, a technically efficient farmer is always located on the frontier while the inefficient farmer at the anterior (Coelli et al., 2002). One way of reducing the cost of production in a farm is to increase farm output by increasing technical efficiency (Fried et al., 2008). In this regard,
it is necessary to quantify current levels of technical efficiency of farmers in order to estimate the losses in production attributed to inefficiency due to different socio-economic characteristics and management practices. Literature (Fried et al., 2008; Coelli et al., 2002; Charnes et al., 1978; Farrell, 1957) suggests several alternative approaches to measure technical efficiency. These approaches are normally grouped into non-parametric and parametric frontiers.

### 2.3.2 Parametric methods

Parametric methods involve econometric modeling of the production processes. There are priori assumptions made on the functional form of the production function and the distribution of the efficiency terms. The method consists of specifying and estimating a parametric production function representing the best available technology (Coelli et al., 2002). The use of the functional forms of the production function such as the Cobb-Douglas and the Translog models is common. Depending on the treatment of deviations of an observation from a frontier, the estimated frontier can be either deterministic or stochastic. Deterministic are regression based and attribute all deviations to inefficiency while stochastic assumes that part of the deviation from frontier is due to random
errors (Coelli et al., 2002). The most commonly used parametric method is the Stochastic Frontier Analysis (SFA).

2.3.3 Non-parametric methods

Non-parametric methods use mathematical programming methods to measure relative efficiency of units commonly known as decision-making units (DMUs). This approach has the advantage of not imposing a priori-parametric restriction on the underlying technology (Charnes et al., 1978). The most commonly used non-parametric methods are Data Envelopment Analysis (DEA) and the more general Free Disposal Hull (FDH). These methods take the production function as unknown.

Data Envelopment Analysis is a relatively new technique developed in operation research and management science over the last few decades (Coelli, 1996). It is used for measuring productive efficiency only on observed input output data of firms or DMUs and does not require any data on input prices. According to Coelli (1996), it is a mathematical programming approach used for considering optimum solution relative to individual units or firms rather than assuming that a solution applies to each DMU. The efficiency of an organization is calculated relative to
the group’s observed best practice. DEA models can be either output or input oriented. Farell (1957) in distinguishing the two types argues that input oriented addresses the question of ‘by how much can input quantities be proportionately reduced without changing the output quantities produced?’ On the other hand, the output oriented addresses the question of ‘by how much can output quantities be proportionately expanded without altering the input quantities used?’ However, the relative range of the efficiency scores remains the same whether input-oriented or output-oriented method is employed. The output-oriented models can be either constant returns-to-scale (CRS) or variable returns-to-scale (VRS).

Technical efficiency indices (TEIs) are the efficiency measures obtained from ratios of sums of weighted outputs to the sums of weighted inputs. In DEA, these efficiency indices are generated as radial measures based on Farrell’s (1957) concept. The radial measures can be radial contraction of inputs to the least level necessary for production of a specific level of output or expansion of outputs obtained from a given combination of inputs (Farrell, 1957). DEA constructs a piece-wise frontier enveloping most DMUs in the sample. In output orientation, the frontier is constructed based on the DMUs that are furthest from the origin. This is because the further they are the greater the ability to produce more from a
fixed set of inputs and are therefore on a higher production possibility frontier (Coelli, 1996). This measure of performance is relative in the sense that the efficiency of each DMU is evaluated against the most efficient DMU. It is measured by the ratio of the actual output to maximal potential output. A DMU can be rated as fully (100%) efficient on the basis of available evidence if and only if the performance of the other DMUs does not show that some of its inputs or outputs can be improved without worsening the others inputs or outputs (Coelli et al., 2002). The other DMUs with less than 100% technical efficiency score are rated as being inefficient.

2.4 Empirical Literature on Technical Efficiency

2.4.1 Studies conducted using Stochastic Frontier Analysis

Various efficiency studies have been conducted using Stochastic Frontier Analysis (SFA) method. For example, while estimating technical efficiency in Kenya’s maize production using SFA, Kibaara (2005) found that most farmers were technically inefficient with 70% of them operating in less than 0.60 efficiency score. This study found that technical efficiency is positively
influenced by hybrid and tractor use, presence of male-headed households, age of the farmer, access to credit and the number of years in formal schooling. It was recommended from this study that the extension service program be targeted to women who handle 80% of work yet they are only allocated 5% of the resources through extension by the Ministry of Agriculture (Kibaara, 2005).

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

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

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

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

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

In their study analyzing the effect of land tenure on technical efficiency in smallholder crop production in Kenya, Kariuki et al (2008) found that parcels with land titles had a higher efficiency levels than those without. Apart from land titles, other determinants of inefficiency such as education of the household heads, access to fertilizer and group participation were found to be significant. It was recommended that the process of land registration should be extended to other regions of the country in order to improve efficiency of crop production. In addition, there should be efforts to improve education and access to inputs for the farmers.

In estimating technical efficiency in resource use among smallholder Irish potato farmers in Nyandarua North District in Kenya, Nyagaka et al (2011) found that efficiency ranged from 21.2-92.9% with an average of 66.7%. This implies considerable production inefficiency. According to this study, there was substantial potential for enhancing profitability by reducing costs through improved efficiency. It was also found that the level of education of the household heads, number of extension visits, access to credit and membership in farmers
associations were important factors that could improve levels of technical efficiency. It was recommended that a mid-term policy intervention should be formulated and geared towards promoting formal education as a means of enhancing efficiency in agricultural production. Two-limit-Tobit method was used as the analytical model in this case and was found effective in giving the parameters of factors influencing efficiency.

A study to determine factors influencing technical efficiency among selected wheat farmers in Uasin Gishu district, Kenya, was undertaken by Njeru (2010). The SFA was employed to estimate the technical efficiency, whereas the maximum likelihood was used to determine the inefficiency resources. It was found that wheat farmers in Uasin Gishu experienced significant levels of technical inefficiency. The mean technical efficiency was 0.872 implying that close to 13% of the potential output could not be exploited due to inefficiency of the farmers. The main cause of inefficiency was found to be education levels, access to credit, age of the farmers and ownership of the capital equipment. It was thus recommended that improvements in education levels and access to credit would increase wheat productivity in the district and the country at large.
2.4.2 Studies undertaken using Data Envelopment Analysis

Various studies have been conducted on efficiency using Data Envelopment Analysis (DEA) method. Chimai (2011) for example, estimated the technical efficiency of sorghum production and its determinants in the growing of sorghum in Zambia using the DEA approach and the Ordinary Least Squares (OLS) to achieve the set objectives. It was found that technical efficiency was low averaging 34% and only about 5% of the sampled farmers were 100% efficient, while 78% of them were at least 50% technically efficient. This shows that there were low efficiencies in production indicating potential for improvements. It was also revealed that high number of dependants, access to agricultural credit, and value of household assets had a positive correlation with technical efficiency. Household size, use of animal draught power for tilling and family size had a negative association on technical efficiency, while household heads’ formal education levels, ages and gender were not significantly important in explaining technical inefficiency. Chimai’s research, however failed to include variables like amount of labour and fertilizer used in production of sorghum when estimating the efficiency scores yet these variables are important in the estimation of efficiency scores.
Technical and allocative efficiency levels of smallholder maize farmers in Zambia were estimated by Chiona (2011) applying the DEA approach. An OLS regression equation was employed to identify factors associated with efficiency. The study found that technical efficiency, on average, was 23% while allocative efficiency (AE) was 27%. It was also found out that only 15% of the sampled population was fully technically efficient (i.e. 100% TE) and only 12% were fully allocative efficient (i.e. 100% AE). This scenario offered a tremendous opportunity to improve both allocative and technical efficiencies among the farmers. It was observed that efficiency was influenced by mechanized tillage methods, use of fertilizers and certified seeds, formal education of the household heads and involvement in agricultural activities. All these variables were positive for both technical and allocative efficiencies. Improving formal education and use of certified seeds could increase both efficiencies. Although the OLS was employed in this study, it is argued that it gives biased parameter estimates since technical efficiency scores range from 0-1.

Efficiency of farm households was investigated (Chavas et al., 2005) and the results exhibited significance of off-farm earnings with an application to the Gambian situation using non-parametric measurements. An econometric analysis
based on Tobit model was used to identify factors associated with efficiency. The study found that technical measures at household level ranged from 0.08 to 0.95 with 85% of households being technically efficient. Households appeared to be less allocative efficient ranging from 0.51 to 0.64 and only 31% of the households being allocative efficient. The study also revealed that presence of inefficiency could be due to poor managerial abilities, poorly functioning of factor markets (labour and credit markets) and also poor household organization, which did not support bargaining among household members. It was also found that idiosyncratic factors like gender of household, poverty status and food insecurity had a significant influence on efficiency. Chavas only looked at the households in general, both smallholder and largescale farmers, without considering the difference in farm and farmer characteristics of the two categories.

Yusuf and Malomo (2007) estimated the technical efficiency of poultry production in Ogun state in Nigeria. Their main objectives were to determine the profitability of egg production in Ogun state and estimate technical efficiency of poultry farming, while looking at the constraints facing the enterprise. They used DEA and OLS regression to analyze their data. The results showed that large farms were most efficient with efficiency score of 0.89 followed by the medium
farms with 0.87 and lastly small farm sizes with 0.86. Years of farming experience positively affected efficiency, while household size affected efficiency negatively. It was concluded that levels of efficiency could be increased as farmers gain more farming experience and have smaller household sizes. The study was based on poultry enterprise, which is an input intensive enterprise as compared to sorghum enterprise.

Padilla-Fernandez and Nuthall (2009) investigated the efficiency of sugarcane farms in the use of inputs and determining factors influencing such efficiency using DEA and Tobit model respectively. It was found that almost 81% of the households surveyed were inefficient. The average efficiency was 78% TE and hence 22% incurred losses through technical inefficiency in the farms. It was concluded that input use differences between the technically efficient and inefficient farms were highly significant in terms of area, seeds and labour inputs. There was no significant difference in the use of fertilizer and power inputs. It was noted that for many farms, labour is the most binding constraint, followed by land and power inputs, while seeds and NPK fertilizer were not binding. By using the DEA and Tobit approaches, the researchers were able to identify many variables that influenced efficiency.
Javed et al. (2010) measured the technical efficiency of rice-wheat system in Punjab, Pakistan using DEA and Tobit regression model to identify determinants of technical efficiency. It was found that technical efficiency was low with a mean of 32%. According to this study, if farmers operated in full efficiency level then inputs could be reduced by 17% without reducing the level of output with existing technology. Years of schooling, number of contacts with extension agent and access to credits were found to have a negative impact on technical inefficiency, while farm sizes, ages of the farm operators and distances from markets had a positive impact. It was recommended that government should focus on attracting young and educated people into farming by providing incentives in form of soft loans. The government should also allocate more funds to strengthen the extension departments and expand net of extension services.

2.4.3 Summary of technical efficiency studies
There is a growing body of literature on technical efficiency, using different approaches, in African agriculture so far. Technical efficiency studies have been conducted on various crops such as maize, wheat, rice, Irish potatoes, coffee and millet. Most of these studies however have reported low to moderate technical efficiencies ranging from as low as 0.24. This confirms the findings that most
countries in the developing world in general and Sub Saharan Africa (SSA) in particular still experience relatively low efficiency levels in agriculture. Many factors have been cited to influence technical efficiency. Among the factors given priority includes farmers’ education levels, farmers’ access to improved technology, access to extension services, credit access, market access and size of land holdings.

According to the various studies reviewed, both SFA and DEA have been used. Stochastic frontier approach has an advantage over other parametric frontier measures because it gives allowance for stochastic errors due to statistical noise or measurement errors. The main weakness of stochastic frontier analysis lies in its parametric nature. SFA has many disadvantages as argued in most of the empirical literature (Chiona, 2011; Coelli, 2002; Charnes et al., 1978). They have criticized this method on the basis of a priori specification of the functional form. This makes it susceptible to bias resulting from functional form misspecifications. Another argument in the literature is that SFA fails to allow for analysis of technical efficiency in multiple outputs without output price information. Output variables are usually measured as an aggregate monetary value rather than
physical units. This has been argued to be inappropriate as it may underestimate efficiency especially with the fluctuating prices.

Basnayake and Gunaratne, (2002) in their study to estimate technical efficiency and its determinants in the smallholder tea sector in the mid country wet zone of Sri Lanka, also studied the robustness of the technical efficiency estimate with respect to form specification. They found that the technical efficiency was highly sensitive to functional form specification.

As pointed out by various authors (Abu, 2011; Chimai, 2011; Chiona, 2011; Yusuf and Malomo, 2007; Coelli et al., 2002; Charnes et al., 1978;), DEA approach has several advantages. It uses mathematical programming to measure relative efficiency of DMUs. It does not make priori assumptions about the functional form of the production function and the inefficiency term. Instead, it makes general assumptions of monotonicity and convexity, which result in a flexible frontier that allows the production function to vary across DMUs. Few empirical studies have argued on the disadvantages of DEA. One of the disadvantages lies in its deterministic nature where it fails to account for stochastic noise in data, which could be a potential bias to the estimated efficiency scores. Another disadvantage is that it is less robust to outliers and extreme...
values. However, a large number of empirical studies have extended and applied the DEA technology in the study of efficiency worldwide (Abu, 2011; Chimai, 2011; Chiona, 2011; Mussa et al., 2011; Javed et al., 2010; Yusuf and Malomo, 2007; Chavas et al., 2005; Donthu and Yoo, 1998).

2.5 Review of Factors Influencing Technical Efficiency

For purposes of policy implications in efficiency analysis, it is not only the level of efficiency that is important, but also the identification of the factors that influence it. Several studies have measured technical efficiency and its determinants among different types of farmers and countries, which provide useful information for this study. However, efficiency in these studies is relative and tends to be specific to the farmers’ groups and country under study. A number of empirical studies have attempted to investigate the relationship between technical efficiency and the various socio-economic variables and demographic factors such as levels of education, age, family size, access to credit, extension services and experience (Abu, 2011; Chimai, 2011; Chiona, 2011; Nyagaka et al., 2011; Yusuf and Malomo, 2007; Chavas et al., 2005 and Kibaara, 2005). However, technical inefficiency may arise primarily due to managerial incompetence and therefore, efficiency differences could be explained in the
context of the management characteristics such as training, experience and motivation (Chavas et al., 2005; Tyler, 1979). Other factors identified include membership to agricultural associations, land ownership, value of household assets, use of fertilizers and tillage methods adopted (Chimai, 2011; Nyagaka et al., 2011; Kariuki et al., 2008; Chirwa, 2007). While some of the factors identified in studies can provide a general idea of what affects efficiency, generalization may not be possible because each country and agricultural product has unique characteristics.

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

Based on the literature reviewed, DEA approach was chosen in order to achieve the first objective of this study. This is because it is flexible and can allow variations in the production functions across decision-making units hence avoid problems associated with functional form misspecification. It allows for analysis of multiple inputs and outputs without the introduction of prices, which SFA cannot. In addition, it can identify the sources and the levels of inefficiency for each farm unit if a two-stage DEA model is used. Furthermore, several studies have compared the results of SFA and DEA methods and have reported no significance difference in scores obtained. Relative efficiency of the DMUs (farms in this study) was measured by estimating an empirical production frontier from the actual input and output data from each farm. The efficiency score of a farm was then measured by the distance between the actual observation and the frontier obtained from all the farms under evaluation. DMUs always face financial limitations or imperfect competitive markets where increased amount of inputs do not proportionally increase the amount of outputs obtained (Coelli et al., 2002). In order to account for these effects this study used the DEA model for VRS, which was developed by Banker et al (1984). Since the main goal is to produce
maximum output from given quantities of input, output orientation DEA model was used.

To achieve the second objective, Tobit model was used. Since technical efficiency scores lie between 0 and 1, the dependent variable in the regression model did not have normal distribution. This suggests that OLS regression was not appropriate and estimation with OLS would have led to biased parameters estimates. The technical efficiency scores were continuous; hence, Probit and Logit models could not be used in this case because they are only used when the dependent variable takes two values (Gujarati, 2006). Therefore, Tobit regression model offered the most preferred option. In addition, most DEA based studies present the second stage regression as Tobit model as the efficiency scores fall in the range of 0 to 1 (Mussa et al., 2011; Javed et al., 2010; Padilla-Fernandez et al., 2009 and Chavas et al., 2005). This study therefore used Tobit model in identifying the various farm and farmer characteristics that influence efficiency.

2.7 Conceptual Framework

Production process involves a transformation of inputs into outputs. Inputs as well as outputs vary from one type of production to another. In crop production, inputs
include land, seeds, labour and fertilizer, which are all combined in different ratios to produce outputs. The effectiveness with which the inputs are transformed into outputs does not only depend on inputs used but also on the managerial practices that the farmer uses to combine these inputs. Managerial practices are influenced by farm and farmer characteristics, which together with the inputs determine the quality and quantity of outputs produced. Households (HHs) are the DMUs where all decisions on types and amounts of inputs to be used in production process and managerial practices to be done are made. The decisions made in turn influence how inputs are efficiently transformed into outputs i.e. technical efficiency. This scenario is represented in a pictorial form as a conceptual framework (Figure 1) to guide this research study.
Key: DMU=Decision Making Unit

Figure 1: Conceptual framework

Source: Modified from (Zhengfei, Lansink, & Van Ittersum, 2006)
CHAPTER THREE

METHODOLOGY

3.1 Introduction

The methodology used in this study is presented in this chapter. It is described in terms of the study site, population, sampling procedure and the sample size, research design, and the model description used in this research. Data collection tools and data analysis techniques that were used are also discussed.

3.2 Study Site, Population, Sample Size and Sampling Procedure

This study was conducted in Makindu and Machakos districts of Makueni and Machakos counties respectively. They are situated in semiarid parts of Eastern Kenya. They both experience bi-modal rainfall distribution pattern with two main distinct cropping seasons. Normally the long rains of these districts fall from March to May, while the short rains fall from October to December. Machakos district lies at 1°35'1"S and 37°10'1"E and has a mean annual rainfall of 690mm, with average annual temperatures ranging from a minimum of 11.0°C and a maximum of 27.6°C. Makindu district lies at 2°0'1"S and 37°40'1"E with a mean annual rainfall
of 580mm, and average annual minimum and maximum temperatures of $14.5^0C$ and $31.5^0C$ respectively (Kwena et al., 2011\textsuperscript{a} and 2011\textsuperscript{b}).

Figure 2: Study site indicating the location of Machakos and Mukindu districts

Agriculture in the study area is mainly rain fed and crop and livestock production are constrained by low soil moisture and poor pastures because of erratic and unreliable rainfall. Largely, the majority of the households populations are classified as poor given that approximately 52\% of HHs in Machakos district and
64% in Makindu district survive under poverty line (below US$1.00 per person per day). The types of crops normally planted in Machakos district are mainly cereals (maize, sorghum) and legumes (beans, pigeon peas, and cow peas); while in Makindu district the commonly planted crops are mainly cereals (maize, sorghum, millet), legumes (green grams, cowpeas, pigeon peas, dolichos), and cotton (Kwena et al., 2011a, 2011b). The Machakos and Makindu sites present greater opportunities for improved production of appropriate HYSVs. Hence, the sites were among the districts in which the projects on promotion of sorghum farming were initiated in the Eastern Kenya.

The population of interest for this research comprised of sorghum growing households, especially the HHs that grew sorghum in the 2010-2011 cropping season. In Machakos district, only a total of 700 farm households out of a total of 41,454 households grew sorghum during the March 2010 to March 2011 cropping season while in Makindu district only 900 households from a total of 54,632 households produced sorghum during the same cropping season according to respective districts statistic records (GoK, 2011a GoK, 2011b).
To get research samples from the Machakos and Makindu districts sampling frames, Cochran’s sampling technique (Cochran, 1977) of the following formula was applied:

\[ n = \frac{Z^2pq}{e^2} \]

Where: \( n \) = desired sample size, \( z \) = the standard deviation at the desired confidence level, e.g. at 95%, \( z \) is 1.96, \( e \) = desired level of precision of 0.029270, \( p \) = the proportion in the target population (\( q = 1-p \)).

Applying the formula:

The sample size for Machakos district was therefore calculated as follows:

\[
\frac{1.96^2 \times (700/41454) \times (1 - 700/41454)}{0.029270} = 74.43 \approx 74
\]

While the sample size for Makindu district was:

\[
\frac{1.96^2 \times (900/54,632) \times (1 - 900/54,632)}{0.029270} = 72.65 \approx 73
\]

Thus, total sample size of 147 farm households was achieved through various sampling procedures. First sorghum farming households were selected using
purposive sampling method with the help of extension officers in the two districts and then the selected farm households were subjected to systematic simple random sampling to achieve 73 and 74 farm households in Makindu and Machakos districts, respectively.

### 3.3 Research Design

The study employed quantitative descriptive research design. Household survey method was used in collection of data under this design. Descriptive research design is a type of research method that is used when one wants to get information on the current status of a person or an object. It is used to describe what is in existence in respect to conditions or variables that are found in a given situation. The researcher does not have direct control of independent variables as their manifestation has already occurred. According to Kothari (1999), descriptive research design describes the state of affairs as it exists. Mugenda (2008) explains descriptive studies as the study performed within communities with the main aim of establishing the extent of the range of problems, issues or concerns that have not been investigated earlier. In this regard, this research design was considered appropriate for the study because the researcher was to establish the current state
of affairs on the level of technical efficiency and the factors influencing it in Machakos and Makindu districts.

3.4 Data Collection Procedure

Data were collected from both primary and secondary sources. Primary data was collected from sorghum farmers by use of semi-structured questionnaires (Appendix II). Information on demographic, institutional, physical and socio-economic factors, yields and inputs used to grow sorghum by each household were collected by use of the semi-structured survey questionnaires. Other information collected included farmers opinions on current and preferred prices for sorghum grains. Information on constraints that the sorghum farmers faced from planting to marketing of the produce and their suggestions on how to improve the sorghum enterprise in the study sites were also collected. Secondary data were collected as part of the description of the study sites. The information collected includes climatic conditions of the region such as temperatures, rainfall and socio-economic activities of the households in the region. This information was collected from relevant publications, which included the project baseline survey report conducted in 2011 in the study sites (Kwena et al., 2011a, 2011b).
Questionnaire administration was implemented by enumerators who were recruited through an interview just before the start of the survey exercise. The successful enumerators were then trained on how to administer the questionnaires, the nature and content of the questionnaire and any ambiguities were clarified. The questionnaires were pre-tested with the help of the trained enumerators and necessary adjustments made before beginning the actual field survey. Pre-tested questionnaires were administered with the assistance of trained enumerators in the two study sites and the whole exercise was completed in three weeks.

3.5 Data Analysis

After the collection of data, the questionnaires were checked for missing data. Four questionnaires were rejected and hence not used in the analysis. This was because the households who filled those questionnaires experienced 100% loss in sorghum output. This was occasioned by either birds eating all the grains or sorghum drying up due to lack of enough rain for those who planted late. A total of 143 questionnaires from the original 147 surveyed were therefore coded and converted into electronic forms. Data cleaning was done using Microsoft EXCEL. The cleaned data was first imported to the Statistical Package for Social Scientists (SPSS) software for simple descriptive statistics and frequency analyses.
Thereafter, some of the results from SPSS were imported to the Microsoft EXCEL for graphical analysis, which were then used in the descriptive analysis of the research.

Second, a non-parametric Data Envelopment Analysis was used to determine the levels of technical efficiency among the smallholder sorghum farmers with the help of Data Envelopment Analysis Program (DEAP) version 2.1. Data on output and inputs in sorghum production were listed by observation (i.e. one row for each household) in the data file. An instruction file was constructed to capture all the necessary commands by typing in the relevant information and then the programme was commanded. An output file containing the mean technical efficiency and technical efficiency indices (TEI) for all the individual households surveyed was generated. This command was repeated three times; one for Machakos district households, another for Makindu districts households and finally for the overall in both districts (combined data from both districts).

Thirdly, an econometric analysis (censored regression model) based on the two-limit Tobit model was used to identify farm and farmers characteristics affecting smallholder efficiency in sorghum production. This was undertaken with the help of STATA software program. The TEI generated from DEA model were then
regressed on the selected farm and farmer characteristics variables in order to identify their influence on technical efficiency. The results and interpretations are presented in Chapter 4 of this thesis.

### 3.5.1 Data Envelopment Analysis model

This study used Data Envelopment Analysis (DEA) model to analyze its databases for objective one. The model involves use of linear programming methods to conduct a non-parametric piecewise surface (or frontier) over the data to calculate efficiencies relative to this surface (Coelli et al., 2002). DEA can be either Constant Return to Scale (CRS) or Variable Return to Scale (VRS). CRS is appropriate when all decision-making units are assumed operating at an optimal scale, or otherwise VRS is appropriate. Sorghum farmers in the study areas were found to experience variations in agricultural production occasioned by factors such as financial constraints, imperfect competition, fluctuating input prices and unreliable labour supply. The use of VRS, which was developed by Banker et al. (1984) was assumed appropriate in order to account for these variations. Technical efficiency was estimated based on output-orientation where a household produces maximum output given a level of inputs and it determines the maximum proportional increase in output produced with inputs level held fixed.
In DEA, the performance of a farm is evaluated in terms of its ability to either shrink usage of an input or expand the output level subject to restrictions imposed by the best-observed practices (Gul et al., 2009).

Practically, the DEA model can be explained using an example of smallholder farms. For instance, smallholder farmers are assumed to operate under the same policy and institutional environments and face exogenous variables $Z_i$. It is assumed that these conditions determines farmers decision to choose a set of inputs $x$ they will use to produce output $y$. Farmers considered to be fully efficient operate along the boundary of the frontier $Y^*$. In this case the output of efficient farm $Y_i$ to the potential output along the frontier is $Y^*=Y_i$. Relative efficiency measure is computed as a ratio of $Y^*/Y_i=1$. Those farms that are inefficient compared with the best practice will operate at a point in the interior of frontier and the scores will be less than 1 i.e. $Y^*/Y_i<1$. Therefore, zero being the lower limit and unity the upper limit, the distribution is censored at both tails $0 < Y/Y_i \leq 1$.

Assuming that there were $n$ DMUs each with $m$ inputs and $s$ outputs, the relative efficiency score for each DMU was obtained as shown below by solving an
output-oriented equation with VRS of DEA model developed by Banker et al. (1984).

\[
\text{Max } \sum_{k=1}^{s} V_k Y_k
\]

Where \( k = 1 \) to \( s; j = 1 \) to \( m; i = 1 \) to \( n; \)

\[
V_k = \text{weight given to output } k;
\]

\[
U_j = \text{weight given to input } j
\]

\[
\sum_{k=1}^{s} \sum_{j=1}^{m} V_k Y_{ki} - \sum_{j=1}^{m} U_j X_{ji} \leq 0 \quad \forall i
\]

\[
V_k, U_j \geq 0 \quad \forall k, j
\]

An output-oriented linear programming (LP) model developed by Charnes et al. (1978) as defined below was solved \( n \) times – once for each farm household in the sample:

\[
\text{Max } \sum_{k=1}^{s} V_k Y_{kp}
\]

\[
s.t \quad \sum_{j=1}^{m} U_j X_{jp} = 1
\]

\[
\sum_{k=1}^{s} V_k Y_{ki} - \sum_{j=1}^{m} U_j X_{ji} \leq 0 \quad \forall i
\]

\[
V_k, U_j \geq 0 \quad \forall k, j
\]
All the DMUs with a score of 1 were regarded as being technically efficient, while all the others with scores of less than 1 were regarded as technically inefficient.

**Operationalization of variables used in DEA**

To estimate technical efficiency in sorghum production, the input-output data used were treated as follows:

**a. The Output** The farmers' dry grain harvest from the sorghum fields measured in Kilograms (kgs)

**b. The Inputs** The cultivation of sorghum involves use of various inputs and a number of farm operations. The inputs were grouped into land, seeds and labour. Another input, which could have been included was quantity of fertilizer used, but this was not included because its use in sorghum production was limited to very few farmers only. In Machakos about 71% of all the DMUs surveyed did not use inorganic fertilizers, while Makindu district all the surveyed DMUs (100%) did not use it.
The DEA model variables used in the study are summarized in Table 1.

Table 1: Description of variables used in the DEA Model

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y$ (Output)</td>
<td>Quantity of sorghum harvested in kgs</td>
</tr>
<tr>
<td><strong>Inputs</strong></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>Cultivated land planted with sorghum in hectares (ha)</td>
</tr>
<tr>
<td>Seeds</td>
<td>Quantity of seeds used during planting in kgs</td>
</tr>
<tr>
<td>Labour</td>
<td>Quantity of labour used for all operations during production of sorghum in person days</td>
</tr>
</tbody>
</table>

3.5.2 The Tobit model

Since technical efficiency scores lie between 0 and 1, the dependent variable in the regression model did not have normal distribution hence OLS regression was not appropriate. The estimation with OLS would have led to biased parameters estimates. The technical efficiency scores were continuous; hence, Probit and Logit models could not be used in this case because they are only used when the dependent variable takes two values (Gujarati, 2006). Therefore, Tobit regression model offered the most preferred option.

The two-step procedure that is the most commonly used procedure was used in this study. In this first case, technical efficiency scores were estimated using the
DEA, input-oriented model and secondly technical efficiency scores obtained were then regressed on farm and farmer characteristics variables to identify their influence on technical efficiency. Technical efficiency scores ranges between 0 and 1, hence the two-limit Tobit regression model (as shown below) was used

\[ U_i^* = \beta_0 + \sum_{j=1}^{k} \beta_j Z_{ij} + \mu_i \]

Thus as Coelli et al (2002),

\[ U_i = \begin{cases} 
1 & \text{if } U_i^* \geq 1 \\
U^* & \text{if } 0 < U_i^* < 1 \\
0 & \text{if } U_i^* \leq 0 
\end{cases} \]

Where \( i \) refers to the \( i^{th} \) DMU; \( U_i \) is the efficiency scores of the \( i^{th} \) DMU; \( U_i^* \) is the latent efficiency; \( \beta_j \) are parameters that were estimated and \( \mu_i \) was an error term that was independently and normally distributed with mean zero and common variance of \( \delta^2 (\mu_i \sim N(0;\delta^2)) \); \( Z_{ij} \) were host of farm and farmers characteristics variables. Thus, the Tobit model used in this study was specified as:

\[ \text{Eff score} = \beta_0 + \beta_1 \text{Malehd} + \beta_2 \text{H/age} + \beta_3 \text{H/edu} + \beta_4 \text{HHsize} + \beta_5 \text{Prodadvice} + \beta_6 \text{Adptill} + \beta_7 \text{Hlabortill} + \beta_8 \text{Offincm} + \beta_9 \text{Asset} + \beta_{10} \text{Agrcredit} + \beta_{11} \text{Othrincm} + \beta_{12} \text{Srgmfarm} + \beta_{13} \text{NDep} + \beta_{14} \text{Srmsg} + \beta_{15} \text{Manure} + \beta_{16} \text{Impro} + \beta_{17} \text{Clubbm} + \beta_{18} \text{Expr} + \mu_i \]
<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
<th>Description of variable</th>
<th>Expected hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malehd</td>
<td>Male head</td>
<td>Dummy variable: If the household is male headed=1 or 0 if female headed</td>
<td>+</td>
</tr>
<tr>
<td>H/age</td>
<td>Household age</td>
<td>Age (years) of household head</td>
<td>-</td>
</tr>
<tr>
<td>H/size</td>
<td>Household size</td>
<td>Household size (continuous)</td>
<td>-</td>
</tr>
<tr>
<td>H/edu</td>
<td>Household education</td>
<td>Number of years spend in formal schooling</td>
<td>+</td>
</tr>
<tr>
<td>Prodadvice</td>
<td>Production advice</td>
<td>Dummy = 1 if received production advice, 0 if otherwise</td>
<td>+</td>
</tr>
<tr>
<td>Adptill</td>
<td>Adopted tillage</td>
<td>1=Hand digging; 2= animal draught power; 3= Not ploughed</td>
<td>+/-</td>
</tr>
<tr>
<td>H/land</td>
<td>Hired labour</td>
<td>Dummy: 1 if tilled with hired labor 0 if otherwise</td>
<td>+</td>
</tr>
<tr>
<td>Offincm</td>
<td>Off farm income</td>
<td>Income from off farm activities in KES (Kenya shilling)</td>
<td>+</td>
</tr>
<tr>
<td>Asset</td>
<td>Household Assets</td>
<td>Value of all household assets in KES</td>
<td>+</td>
</tr>
<tr>
<td>Agrcredit</td>
<td>Agricultural credit use</td>
<td>Dummy: 1 if received an agricultural credit/loan, 0 if otherwise</td>
<td>+</td>
</tr>
<tr>
<td>Otherpincm</td>
<td>Income from other crops and livestock</td>
<td>Dummy: 1 if farmer got income from other crops and livestock; 0 if otherwise</td>
<td>+</td>
</tr>
<tr>
<td>Srgmfarmsize</td>
<td>Farm size used to produce sorghum</td>
<td>Sorghum farm size in Ha</td>
<td>-</td>
</tr>
<tr>
<td>Ndependents</td>
<td>Number of dependants</td>
<td>Number of persons who depended on the household head (continuous)</td>
<td>+</td>
</tr>
<tr>
<td>Seedrate</td>
<td>Sorghum seed rate</td>
<td>Quantity of sorghum seed used per hectar</td>
<td>-</td>
</tr>
<tr>
<td>Manure</td>
<td>Manure</td>
<td>Dummy = 1 if used manure, 0 if otherwise</td>
<td>+</td>
</tr>
<tr>
<td>Improvseed</td>
<td>Improved seed varieties</td>
<td>Dummy = 1 if used improved seed varieties, 0 if local varieties</td>
<td>+</td>
</tr>
<tr>
<td>Clbmbbr</td>
<td>Club/association membership</td>
<td>Dummy =1 if the household head belonged to any club, 0 if otherwise</td>
<td>+</td>
</tr>
<tr>
<td>Expr</td>
<td>Experience in sorghum farming</td>
<td>Dummy = 1 if more than 5 years, 0 if less than 5 years</td>
<td>+</td>
</tr>
<tr>
<td>Region</td>
<td>District where the DMU belonged</td>
<td>Dummy = 1 if Makindu and 0 if Machakos</td>
<td>+/-</td>
</tr>
</tbody>
</table>

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

RESULTS

4.1 Introduction

This chapter presents the descriptive and econometric analyses of the sampled population. Descriptive analysis focuses on socio-economic characteristics, various economic activities engaged by farmers, farm characteristics, access to agricultural credit, and transport and communication. Other information analyzed includes farmers’ perceptions on the current prices and the preferred prices for sorghum grains. Information on constraints that the sorghum farmers faced from planting to marketing of the produce and their suggestions on how to improve the sorghum enterprise in the study region are also analyzed. Finally, results of the econometric analysis are also presented. The econometric analysis results include the technical efficiency score levels from the DEA model and farm and farmer characteristics influencing technical efficiency from the Tobit model and their marginal effects using post estimation test.
4.2 Descriptive Analysis Results

A number of results-oriented issues for the descriptive analysis of the sample households are presented in this section. Descriptive statistics results describe the socio-economic characteristics of the sorghum farmers, economic activities the farmers were engaged in, how they accessed information and infrastructure available at their disposal; and finally a comparison of the various characteristics of the farmers in the two districts.

4.2.1 Farmer socio-economic characteristics/ profiles

Overall, majority of the households surveyed in the region were male headed with less than a quarter of the total sampled population being female headed as shown in Figure 3. Specifically, approximately 72% of the households in Machakos and 80.3% in Makindu were male headed.
Most of the sampled household heads had low levels of education. Almost half of all the farmers captured in the survey terminated their formal education at primary level, a quarter of the HH heads (HHHs) having not attended any formal school at all (Figure 4). Very few sampled HHHs attained tertiary education (post secondary school education), with almost a third of them having reached secondary level of education. In Machakos district, 60% of the sample had attained a maximum of primary education level and below.
Figure 4: Level of education of the household heads overall in both districts

Source: Survey results (2012)

It is noted that overall majority of the sampled HHs had less than 5 years of sorghum farming experience, while a few had more than 5 years of the same farming experience (Figure 5). The number of years of sorghum farming experience differs across the region. For instance, a high number of the sampled farmers (86.1%) had less than 5 years of the farming experience in Machakos district, while less than 14% had more than five years experience in the same district. In Makindu, 61% of the sample had more than five years of the sorghum farming experience.
In terms of age, most of the sampled HHHs were relatively old as indicated by the mean age in each category. The youngest sampled HHHs were 28 and 32 years old, while the oldest HHH was 100 and 94 years old in Machakos and Makindu districts respectively, with an average age of 55 years in both districts as shown in Table 3. Among all the surveyed HHHs, the young HHHS in the 18-35 years age bracket were only 5%, middle aged HHHs between 36-50 years old constituted more than a third, while the majority of the sampled HHHs, were in the age bracket of 51-70 years age bracket. Only 8% of the HHHs were above 70 years of old.

Source: Survey results (2012)
Table 3: Summary descriptive statistics of selected farmer characteristics in Machakos and Makindu districts

<table>
<thead>
<tr>
<th>Dist</th>
<th>Variables</th>
<th>Unit of measure</th>
<th>N</th>
<th>Mean</th>
<th>Std. dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machakos</td>
<td>Age of HH head</td>
<td>Years</td>
<td>72</td>
<td>55.28</td>
<td>12.70</td>
<td>28</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Household size</td>
<td>No. of persons</td>
<td>72</td>
<td>5.57</td>
<td>2.03</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>HH dependants</td>
<td>No. of persons</td>
<td>72</td>
<td>3.75</td>
<td>2.20</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>HH wealth</td>
<td>Kenya Shillings</td>
<td>72</td>
<td>601.46</td>
<td>472.75</td>
<td>104</td>
<td>2,147</td>
</tr>
<tr>
<td></td>
<td>Dist</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Makindu</td>
<td>Age of HH head</td>
<td>Years</td>
<td>71</td>
<td>54.61</td>
<td>12.78</td>
<td>32</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>Household size</td>
<td>No. of persons</td>
<td>71</td>
<td>6.66</td>
<td>2.651</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>HH dependants</td>
<td>No. of persons</td>
<td>71</td>
<td>5.38</td>
<td>2.925</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>HH wealth</td>
<td>Kenya Shillings</td>
<td>71</td>
<td>704.35</td>
<td>437.03</td>
<td>125</td>
<td>1,725</td>
</tr>
<tr>
<td></td>
<td>Dist</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>Age of HH head</td>
<td>Years</td>
<td>14</td>
<td>3</td>
<td>54.94</td>
<td>12.70</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Household size</td>
<td>No. of persons</td>
<td>14</td>
<td>3</td>
<td>6.11</td>
<td>2.028</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>HH dependants</td>
<td>No. of persons</td>
<td>14</td>
<td>3</td>
<td>4.56</td>
<td>2.199</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>HH wealth</td>
<td>Kenya Shillings</td>
<td>14</td>
<td>3</td>
<td>652.54</td>
<td>456.67</td>
<td>104</td>
</tr>
</tbody>
</table>

Notes: $^a$ = 1 personday=8hrs work per day for an adult person; HH=household, Dist = District

The HHs with small household sizes had two persons in both sites, while those with large HH sizes had 17 persons, with an average of six members per household as summarized in Table 3. About 96% of the total sampled HHs had at most 10 persons in the household. Approximately 25% of the household surveyed
had six persons per household in the region. Household assets ranged from KES104 thousand to KES2.1 million with a mean of about KES650 thousand (Table 3). Eighty percent of the households had assets value falling below KES1 million.

4.2.2 Farm characteristics

Most of the land parcels used for sorghum production was individually owned. Only six percent of the sampled households owned land communally, while one percent owned land through leaseholds. Land under sorghum crop ranged from 0.03 ha, while the largest was 4.04 ha, with 0.35 ha being the average (Table 4). Ninety seven percent of the sampled HHs used less than 1 ha of land to grow sorghum out of which majority of them (about 30%) used 0.1 ha to grow sorghum. It is observed that most of the households used improved varieties of sorghum seeds. The farmers used a seed rate ranging from 0.08 kg/ha to 39.60 kg/ha with a mean seed rate of 10.2 kg/ha as summarized in Table 4. Twenty-six percent of the farmers used the recommended seed rate of 10 kg/ha. Twenty five percent used seed rate of 5 kg/ha which is half the recommended seed rate, while 18 percent used double the recommended rate i.e. 20 kg/ha.
Table 4: Summary descriptive statistics of selected farm characteristics in Machakos and Makindu districts

<table>
<thead>
<tr>
<th>Dist</th>
<th>Variables</th>
<th>Unit of measure</th>
<th>N</th>
<th>Mean</th>
<th>Std. dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machakos</td>
<td>Land sizes for Sorghum production</td>
<td>Hectares</td>
<td>72</td>
<td>0.17</td>
<td>0.17</td>
<td>0.03</td>
<td>0.81</td>
</tr>
<tr>
<td></td>
<td>HH off-farm income</td>
<td>Kenya Shillings (000)</td>
<td>72</td>
<td>26.68</td>
<td>34.12</td>
<td>0</td>
<td>134</td>
</tr>
<tr>
<td></td>
<td>Sorghum labour use</td>
<td>Persondays(^a)</td>
<td>72</td>
<td>21.55</td>
<td>17.60</td>
<td>2</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>Sorghum output</td>
<td>Kilograms</td>
<td>72</td>
<td>117.32</td>
<td>170.53</td>
<td>4</td>
<td>720</td>
</tr>
<tr>
<td></td>
<td>Seed rate</td>
<td>Kg/ha</td>
<td>72</td>
<td>12.58</td>
<td>7.59</td>
<td>0.08</td>
<td>39.60</td>
</tr>
<tr>
<td>Makindu</td>
<td>Land sizes for sorghum production</td>
<td>Hectares</td>
<td>71</td>
<td>0.53</td>
<td>0.17</td>
<td>0.10</td>
<td>4.04</td>
</tr>
<tr>
<td></td>
<td>HH off-farm income</td>
<td>Kenya Shillings (000)</td>
<td>71</td>
<td>26.70</td>
<td>29.71</td>
<td>0</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>Sorghum labour use</td>
<td>Persondays(^a)</td>
<td>71</td>
<td>37.74</td>
<td>31.473</td>
<td>4</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>Sorghum output</td>
<td>Kilograms</td>
<td>71</td>
<td>322.30</td>
<td>302.35</td>
<td>18</td>
<td>1350</td>
</tr>
<tr>
<td></td>
<td>Seed rate</td>
<td>Kg/ha</td>
<td>71</td>
<td>7.95</td>
<td>4.63</td>
<td>1.24</td>
<td>20</td>
</tr>
<tr>
<td>Overall</td>
<td>Land sizes for sorghum production</td>
<td>Hectares</td>
<td>143</td>
<td>0.35</td>
<td>0.443</td>
<td>0.025</td>
<td>4.04</td>
</tr>
<tr>
<td></td>
<td>HH off-farm income</td>
<td>Kenya Shillings (000)</td>
<td>143</td>
<td>26.69</td>
<td>34.89</td>
<td>0</td>
<td>134</td>
</tr>
<tr>
<td></td>
<td>Sorghum labour use</td>
<td>Persondays(^a)</td>
<td>143</td>
<td>29.59</td>
<td>26.632</td>
<td>2</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>Sorghum output</td>
<td>Kilograms</td>
<td>143</td>
<td>219.09</td>
<td>264.92</td>
<td>4</td>
<td>1350</td>
</tr>
<tr>
<td></td>
<td>Seed rate</td>
<td>Kg/ha</td>
<td>143</td>
<td>10.28</td>
<td>6.69</td>
<td>0.08</td>
<td>39.60</td>
</tr>
</tbody>
</table>

Notes: \(^a\) = 1 personday=8hrs work per day for an adult person; HH=household; W/shed = Watershed
Land sizes planted with sorghum were conspicuously different among households in the two districts. As observed in Table 4, the average land sizes planted with sorghum were 0.17ha and 0.52ha in Machakos and Makindu, respectively. Many households in Makindu planted sorghum on 0.40ha sizes, while those in Machakos planted sorghum on 0.1ha sizes. Methods of land preparation varied among the surveyed HHs, but the most common method was ox-plough practiced by up to 60% of the respondents. Thirty percent of the surveyed households did not prepare their land before planting. Not more than 10% of the sampled HHs used hand digging as a land preparation method before planting as presented in Figure 6. In more specific terms, majority of the households in Makindu district never prepared their land before planting. This was observed when it was found that 62% of all the sampled households in Makindu district did not plough their farms before planting, while those who ploughed, used ox-ploughing method. None of the sampled HHs in Makindu used hand digging as a land preparation method, but approximately 20% of the sampled HHs in Machakos district prepared their sorghum planting land using hand digging.
Most often some farmers spread manure in their farms before planting. Half of the sampled households used manure, while the remaining half did not use manure. The labour used in the sorghum production was provided mainly by family members. Only 36% of the sample used hired labour in one or more of the activities done during sorghum production processes. Hired labour was engaged mainly during land preparation, especially by those households who used ox-plough. More labour was used in sorghum farms, especially during bird scaring where up to 10 hours a day could be spent in the farm during that period, which lasted for approximately 3-4 weeks.
4.2.3 Economic activities

Households in the surveyed region engaged in various economic activities as sources of incomes. These activities ranged from crop farming, livestock keeping, charcoal burning, small businesses, and formal employment to casual labour employment. Most of the households depended on farming as their only source of income. More than half of the sampled population depended on farming as a sole income source in order to meet the household daily requirements, while the rest of the sampled population were either employed, having small businesses or involved in casual labour employment in addition to farming as shown in Figure 7.

Figure 7: Occupation of household heads overall in both districts

Source: Survey results (2012)
Most of households earned less than KES3000 per month as off-farm income. Approximately a third of them did not access any off-farm income. Crops mostly grown in the region were maize, green grams, pigeon peas, beans, sorghum, sweet potatoes and vegetables such as kales, spinach and tomatoes. Livestock kept by the farmers were mainly goats, chicken and bees with a few farmers having cattle especially oxen to provide animal power for ploughing, and pulling ox-cart used to transport water and other farm produce. More than half of the households surveyed did not get any income from their crops and livestock because they produced mainly for subsistence and only surplus were sold. Only a few earned less than KES5000 per month from livestock or per season in case of crops as shown in Figure 8.
The market proximity from the farms was on average 20km away where the sampled farmers spent an average KES150 in one return journey. The return distances travelled by the sampled HHs to markets ranged from half a kilometer to about 40km. The most commonly used available means of transport was motorcycles. However, a motor vehicle was available once or twice a week only during the open market days for those HHs living in the most interior regions.
4.2.5 Access to agricultural credits and extension services

While it is known that access to credits for sorghum production and marketing is important, it was observed that only a few sampled HHs (7%) accessed necessary agricultural credits. A majority of the sampled HHs (93%) did not access any credits for sorghum production and marketing.

It was also observed that a reasonable proportion of sampled households (50%) received production advice from extension services. The most common advice given was on agronomic practices and the best varieties to grow in the ASALs environment. These pieces of advice were received by a majority of the sampled respondents (80%). Only 28% of the respondents were given information on availability of good markets. In addition, household belonging to farmers clubs or association were 57%.

4.2.6 Constraints faced by sorghum farmers in the region

There were many constraints faced by sorghum farmers in Machakos and Makindu districts. The constraints were of varied nature starting from planting to consumption or marketing (Figure 9).
From planting of the crop to maturity stage, it was noted that few of the sampled HHs lacked inputs, especially inorganic fertilizers and good quality seeds. Approximately 44% of the sampled households experienced labour intensity of sorghum production. Labour intensity was most experienced especially during planting, thinning and bird scaring stages of the sorghum production. A large proportion of the sampled HHs (52%) cited that disease and pest attacks were the main constraints faced during the sorghum production activities. The most common constraint faced by the majority of the sampled HHs (82%) was the birds eating of the sorghum grains especially from milk-stage to harvesting periods. Inadequate rains were also mentioned as a constraint to sorghum production by a few of the sampled HHs (17%). Lack of knowledge on agronomic practices was cited by even fewer of the sampled HHs (3%).
Figure 9: Constraints faced by sampled farmers from planting to maturity of the sorghum crop

Source: Survey results (2012)

There were some constraints faced by farmers during the harvesting of mature sorghum and also during the carrying out of other post-harvest practices. These included piece-meal harvesting as reported by about 20% of the respondents. This was occasioned by the constraint of lack of tarpaulins to use during threshing (15%). A few farmers (5%) cited irritation of the skin as a constraint, especially during harvesting and threshing.
A major cited constraint was that a large number of the sampled farmers (72%) did not sell their sorghum output. Nevertheless, those who sold reported two major problems during the marketing and selling of the sorghum output in which about 22% of the sampled HHs faced the constraints of poor prices, while 26% of them found market distances as a major constraint.

Most of the sampled HHs sold their grain at a price between KES11 and KES20/Kg, while only two percent sold their sorghum grains at KES60/kg, which was actually a contracted farming by KARI-Katumani (Figure 10). EABL had offered a price of KES17/kg, which according to the farmers was very low; hence, price was a demoralizing factor to farmers who may have wanted to engage in sorghum enterprise farming as a business.
Most of the surveyed households were willing to engage in sorghum farming as a business only if prices were better than they were offered currently. As shown in Figure 11, most farmers would prefer to sell their output at a price ranging from KES41 to KES60/Kg. Only 4% of the respondents preferred a high price of more than KES100/kg. The lowest price the surveyed HHs were willing to sell their output was between KES21 and KES40/kg as suggested by approximately 29% of the HHs surveyed. A few other HHs surveyed preferred prices of between KES81-KES100/kg, and KES61-KES80/kg to sell their sorghum produce.
4.2.7 Suggestions on how to improve sorghum enterprise overall in both districts

Farmers gave various suggestions on how the sorghum enterprise could be improved in Machakos and Makindu districts. As shown in Figure 12, more than half of the sampled households believed that if, as a top priority, there is good and reliable market in place then sorghum enterprise could be improved further. A number of the respondents believed that provision of appropriate materials and labour to scare away birds could greatly increase production of sorghum, while

Figure 11: Farmers’ preferred prices per kg of sorghum grain

Source: Survey results (2012)
about a third of sample household reported that provision of the right types and amounts of inputs could also increase the performance of sorghum enterprise. At the same time, almost a third of the sampled population believed that limited knowledge on agronomic practices for sorghum production contributed to the dwindling performance of the enterprise. Other suggestions from respondents on how to improve sorghum production and marketing included provision of loans practicing collective farming and provision of education and training on sorghum farming in the ASALs.
4.2.8 Selected comparative characteristics of sorghum farmers in the two districts

Some of the characteristics of the sorghum farmers in Machakos and Makindu districts differed quite greatly. The household sizes differed between the two districts. In Makindu, for instance, the mean household size was seven persons that ranged from a minimum of two to a maximum of 17 persons. In Machakos
the average household size was six persons, ranging from a minimum of two to a maximum of 10 persons.

Sorghum farming experience was also an important farmer characteristic that was compared between the two districts. As indicated on Figure 13, the years of sorghum farming experience differed substantially between the two districts. More than 80% of the sampled HHs in Machakos district had a sorghum farming experience of less than five years as compared with less than 50% HHs in Makindu district. It is further observed that most of the sampled HHs in Makindu districts had more than five years of sorghum farming experience, while only about a quarter of the sample had the same duration of experience in Machakos. This implies that farmers in Makindu district had longer sorghum farming experience than those in Machakos district.
Membership of the sampled farmer HHs in farmer associations is described in Figure 14 in which it is shown that more than two thirds of the sampled HHs in Makindu district were members of farmer associations, clubs or cooperatives as compared with about a third of the sampled population in Machakos. In the same token, it was observed that there were more sampled HHs in Machakos who did not belong to any farmer association, club or cooperative than those in Makindu district.
It thus appears that there existed more organized associations or groups in Makindu than in Machakos district. Farmers in Makindu therefore could have been more active and organized than those in Machakos district. It was observed that many farmer associations or clubs in Makindu district had organized themselves into smaller groups, which could pool resources like labour together. The pooled labour was used to perform various farming activities such as digging cut-off drains on each member’s farm to conserve soil and water for better production. It also made it easier and cheaper to get information from the

Figure 14: Membership of sampled HHs to farmer associations

Source: Survey results (2012)
extension agents either from government or NGOs who mainly targeted such
groups. This is evident by the number of farmers who received production advice
being higher in Makindu than in Machakos.

4.3 Econometric Analysis Results

In this section econometric analysis results are presented. First the results showing
technical efficiency from the DEA model are presented and later the two limit
Tobit analysis results from STATA are presented.

4.3.1 Technical efficiency indices

The variables used in DEA analysis were subjected to descriptive statistics as
presented in Table 5, before the technical efficiency score were generated. These
variables were similar in both districts and the same variables were used in the
computation of the technical efficiency indices (TEIs) or scores using DEA
model. As shown in the table, there were three inputs and one output. The inputs
used included the land area in hectares planted with sorghum, the quantity of
sorghum seeds planted and the labour used during production processes. As
indicated, the size of the land used was as small as 0.03ha in Machakos and as
large as 4ha in Makindu with an average of 0.17ha and 0.52ha in Machakos and
Makindu respectively. The mean quantity of seeds planted in Machakos was 1.67kg. In Makindu the mean quantity of seed used for planting was 3.54kg. Labour was measured in terms of persondays where one personday was equivalent to 8 hours of work in a day. Output was the sorghum grains harvested measured in kilograms. The mean quantities of sorghum output harvested were 322.3 and 117.3kgs in Makindu and Machakos districts respectively (Table 5).

Table 5: Summary statistics of variables used in the technical efficiency analysis

<table>
<thead>
<tr>
<th>Input / Output variables</th>
<th>Makindu District</th>
<th>Machakos District</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorghum grains harvested (Kgs)</td>
<td>18 1350</td>
<td>322.3 302.35</td>
</tr>
<tr>
<td><strong>Inputs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorghum land size (Ha)</td>
<td>0.10 4.04 0.52 0.55</td>
<td>0.03 0.80 0.17 0.17</td>
</tr>
<tr>
<td>Seed Quantity (Kgs)</td>
<td>0.5 30 3.55 4.64</td>
<td>0.25 5 1.68 1.03</td>
</tr>
<tr>
<td>Amounts of labour used (persondays)</td>
<td>4 180 37.74 31.47</td>
<td>2 79 21.55 17.60</td>
</tr>
</tbody>
</table>

Technical efficiency scores summarized in Table 6 shows that out of 143 households surveyed, 15% were efficient, i.e. were 100% technically efficient. The overall mean technical efficiency (TE) was 41%. The efficient households, defined the efficient frontiers and they represent the best practices of DMUs for
combining land, seeds and labour to produce the maximum sorghum output possible.

Table 6: Frequency distributions of technical efficiency scores obtained with DEA model

<table>
<thead>
<tr>
<th>Efficiency scores</th>
<th>OVERALL TE VRS</th>
<th>Makindu TE VRS</th>
<th>Machakos TE VRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>22</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>&gt;0.90≤1.00</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>&gt;0.80≤0.90</td>
<td>6</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>&gt;0.70≤0.80</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>&gt;0.60≤0.70</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>&gt;0.50≤0.60</td>
<td>9</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>&gt;0.40≤0.50</td>
<td>11</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>&gt;0.30≤0.40</td>
<td>16</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>&gt;0.20≤0.30</td>
<td>16</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>&gt;0.10≤0.20</td>
<td>28</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>&lt;0.10</td>
<td>25</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>Total DMUs</td>
<td>143</td>
<td>71</td>
<td>72</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVERALL TE VRS</td>
<td>0.015</td>
<td>1</td>
<td>0.410</td>
</tr>
<tr>
<td>Makindu TE VRS</td>
<td>0.032</td>
<td>1</td>
<td>0.479</td>
</tr>
<tr>
<td>Machakos TE VRS</td>
<td>0.019</td>
<td>1</td>
<td>0.433</td>
</tr>
</tbody>
</table>

N/B: TE VRS – Technical efficiency under variable return to scale assumption

Approximately 67% of the entire households sampled was operating with a TE of not more than 0.5. Majority of the households (approximately 48%) were found to operate below 0.3 TE. Only 20% of the households surveyed could be termed as
being relatively technically efficient as they were operating with a TE greater than 0.8.

To emphasize, again only 20% and 17% were identified as technically efficient in Machakos and Makindu, respectively, relative to all other households (Table 6). These households, defined the efficient frontier and represents the best practice farms for combining available inputs to produce maximum possible sorghum output. When these inputs are held constant, the households produce more output per unit area as compared with their counterparts who had been deemed inefficient. The average technical efficiency in these cases were about 0.43 and 0.48 for Machakos and Makindu districts respectively. This also implies that more than 0.5 of the output was lost due to technical inefficiency. The TE levels of the inefficient DMUs ranged from a minimum of about 0.02 to a maximum of about 0.978. This implies that there exits tremendous opportunity to improve technical efficiency among the HHs. On average, there was potential to increase farm output by 56.7% in Machakos and 52.1% in Makindu from the existing levels of inputs use.
As presented in Figure 15, technical efficiency indices varied widely between the two districts. As indicated, most of the surveyed households in Machakos district were below 10% TE against a few in Makindu district. Most of the households in Machakos (more than 50%) were found operating below 0.3 TE, while in Makindu district the households operating below 0.3 TE were only 35%. Majority of the technical inefficient household in Makindu operated between 0.3 and 0.39, while in Machakos majority of the HHs operated between 0.1 and 0.19 TE. Households termed as being relatively technical efficient were 23 and 24% in Machakos and Makindu respectively, with only 2 and 7% of them operating between 0.8 and 0.99 TE in the respective districts.
4.3.2 Output and input slacks

Slack problems arise when it is questionable whether a farm is on efficient point on the frontier or not. For example, input slack, which is also referred to as input excess, is the excess amount of any input that can be reduced and still produce the same output. The results of the DEAP model produce both the radial Farrell technical efficiency scores and residual slacks to provide an accurate indication of
a DEA analysis. As indicated in Table 7, there were no output slacks as shown by the zero values in all output slacks (Makindu, Machakos, and Overall). This implies that the outputs were not optimized.

<table>
<thead>
<tr>
<th>Input / Output variables</th>
<th>Slacks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Makindu district</td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td></td>
</tr>
<tr>
<td>Harvested sorghum grains (Kgs)</td>
<td>0</td>
</tr>
<tr>
<td><strong>Inputs</strong></td>
<td></td>
</tr>
<tr>
<td>Sorghum land size (Ha)</td>
<td>0.03</td>
</tr>
<tr>
<td>Seed quantity (Kgs)</td>
<td>0.48</td>
</tr>
<tr>
<td>Labour persondays used</td>
<td>7.79</td>
</tr>
</tbody>
</table>

On the other hand, the average land sizes planted with sorghum, the quantity of seeds planted and the labour persondays used in the entire sorghum production process in the study region had positive slacks, implying that these inputs were not optimally used in the production process. This implied that the farms were radically inefficient in their input usage; hence; the sampled households were under utilizing their resources. The households were not optimizing their outputs.
Based on the slack results, sizes of land planted with sorghum had least input slacks. This means that land was the most effectively utilized input as compared with the other two inputs, while labour was the most under-utilized input. With these input slacks, it implies that more outputs could be produced with the same quantity of inputs than what was produced.

4.4 Factors Influencing Technical Efficiency

Although the assessment of the degree of efficiency is important, one cannot rely on it alone to ensure relevant conclusions and make recommendations. In order to make appropriate recommendations for relevant policy review and implementation, it is necessary to identify sources of variation in technical efficiency among various DMUs and estimate their marginal effects. As it follows from the DEA, the efficiency scores fall between 0 and 1, hence making the dependent variables (technical efficiency scores from DEA model) a limited dependent variable. In this regard, censored regression model (the Tobit model) was applied as the most appropriate analytical model.

Selected farm and farmer characteristics were regressed against the TE scores of each DMU using the Tobit model and censoring was done at 0 (zero) on the left
side and 1(one) on the right side. The results describing the influence of the selected variables and their direction of influence on TE overall in the two districts and per district are presented in Table 8. The results from Tobit were then subjected to post estimation test using marginal effect analysis in order to estimate the trivial change from each factor that influence TE. Marginal effect results for the overall region and per district are presented in Table 9.

Over 18 variables expected to influence technical efficiency of sorghum production were estimated by the Tobit model (Table 8). Some of these variables that yielded positive and significant coefficient at 5% level in the overall region include education levels of HHHs in terms of years spent in formal schooling, years of experience in sorghum farming, HH membership in farmer associations, hired labour, use of manure and production advice on sorghum production. This implies that these variables influenced technical efficiency positively such that their increase respectively improved technical efficiency of sorghum production. Other variables such as male HHHs, age of the HHHs, number of dependents, assets possessed by the HHHs, seed rate used, use of improved seed varieties, size of land planted, use of credits and region (belonging to Makindu district) were all
positive to technical efficiency although they did not display significant differences at 5% level.
Table 8: Tobit model results showing farm and farmer characteristics that influence technical efficiency

<table>
<thead>
<tr>
<th>Variables</th>
<th>Overall Coefficient</th>
<th>t-ratio</th>
<th>Overall Coefficient</th>
<th>t-ratio</th>
<th>Makindu District Coefficient</th>
<th>t-ratio</th>
<th>Machakos District Coefficient</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male-headed HHs</td>
<td>0.015</td>
<td>0.25</td>
<td>0.013</td>
<td>0.14</td>
<td>-0.128</td>
<td>1.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age of the HHH</td>
<td>0.003</td>
<td>0.166</td>
<td>-0.004</td>
<td>-1.17</td>
<td>0.004</td>
<td>1.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education of the HHH</td>
<td>0.340*</td>
<td>3.03</td>
<td>0.316*</td>
<td>2.25</td>
<td>0.386*</td>
<td>2.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HH size</td>
<td>-0.011</td>
<td>-0.65</td>
<td>-0.016*</td>
<td>-2.61</td>
<td>-0.014</td>
<td>-0.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of dependents</td>
<td>0.019</td>
<td>0.67</td>
<td>0.034</td>
<td>1.10</td>
<td>0.001</td>
<td>0.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assets</td>
<td>1.41e-08</td>
<td>0.25</td>
<td>2.81e-08</td>
<td>0.25</td>
<td>1.48e-07</td>
<td>1.70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experience in sorghum farming</td>
<td>0.135*</td>
<td>2.55</td>
<td>0.046*</td>
<td>2.26</td>
<td>0.142*</td>
<td>2.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Membership to farmer associations</td>
<td>0.145*</td>
<td>2.84</td>
<td>0.193*</td>
<td>3.29</td>
<td>0.316*</td>
<td>2.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed rates used</td>
<td>0.062</td>
<td>0.90</td>
<td>0.009</td>
<td>0.06</td>
<td>0.024</td>
<td>0.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of improved seed variety</td>
<td>0.138</td>
<td>1.89</td>
<td>0.560*</td>
<td>3.05</td>
<td>0.421</td>
<td>1.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of land planted with sorghum</td>
<td>-0.063</td>
<td>-1.07</td>
<td>-0.043</td>
<td>-0.47</td>
<td>-0.046</td>
<td>-0.46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land preparation method</td>
<td>0.109*</td>
<td>2.01</td>
<td>0.197*</td>
<td>2.44</td>
<td>0.279*</td>
<td>2.62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manure use</td>
<td>0.182*</td>
<td>3.45</td>
<td>0.166*</td>
<td>3.07</td>
<td>0.271*</td>
<td>3.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production advice</td>
<td>0.261*</td>
<td>4.76</td>
<td>0.247*</td>
<td>3.64</td>
<td>0.221*</td>
<td>2.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HH off-farm income</td>
<td>-9.26e-07</td>
<td>-1.22</td>
<td>1.28e-06</td>
<td>1.04</td>
<td>1.38e-08</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Credit use</td>
<td>0.102</td>
<td>1.1</td>
<td>0.106</td>
<td>0.69</td>
<td>0.116</td>
<td>1.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income from other farm activities</td>
<td>-0.006</td>
<td>-0.12</td>
<td>0.116</td>
<td>1.16</td>
<td>-0.062</td>
<td>-0.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region</td>
<td>0.101</td>
<td>1.44</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.426*</td>
<td>2.29</td>
<td>1.114*</td>
<td>4.13</td>
<td>0.537*</td>
<td>2.20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Software used: STATA
* Significance at 5%

Notes: HH=Households, HHH=Household head

N=143; Left censored=0; Uncensored=121; Right censored=22
N=71; Left censored=0; Uncensored=59; Right censored=12
N=71; Left censored=0; Uncensored=57; Right censored=15
On the other hand, HH sizes, land preparation methods, amount of HH off-farm incomes and the amounts received by the HHs from other farm income were all negative to technical efficiency and insignificant at 5% level.

According to the results indicated in Table 8, the variables that influenced technical efficiency varied only slightly between the households in the two districts. In Makindu, for example, the positive variables displaying the 5% significant levels included the education of the household heads, experience in sorghum farming, membership to farmer associations, size of land planted, manure use and farmers receiving production advice. Household size was found to have a negative sign but significant at 5% level. Other variables such as male-headed households, number of dependants, household assets, use of improved seed varieties, seed rate, household off-farm incomes, income from other farm activities, and use of credits were positive to technical efficiency but not significant at 5% level. Variables such as age of the household head and land preparation methods were negative to technical efficiency and insignificant at 5% level.
In Machakos district, education of the household head, experience in sorghum farming, membership to farmers associations, manure use and farmers receiving production advice were all positive and displayed 5% significant levels. Other variables such as age of the household head, number of dependants, assets possessed by the households, seed rate of sorghum used, use of improved seed varieties, size of land planted, use of credits and amount of household off-farm income were all positive to technical efficiency although they did not display significant differences at 5% level. Variables such as male-headed households, household size, land preparation method and income from other farm activities were negative to technical efficiency and were not significant at 5% level.

The differences in the two districts occurred in variables such as size of land planted with sorghum, which was positive to technical efficiency in Machakos district while negative in Makindu district though not significant at 5% level in both districts. Household size was negative to technical efficiency and significant at 5% level in Makindu while in Machakos though negative to technical efficiency was not significant at 5% level. Other variables that displayed differences were male-headed households and income from other farm activities, which both were positive to technical efficiency in Makindu district but negative
to technical efficiency in Machakos though they were all insignificant at 5% level in both districts.

**4.5 Marginal effect analysis**

The estimated parameters on the Tobit model presented in Table 8 only indicates the direction of the influence that the variables have on TE. Quantification of the marginal effects of these variables is important in order to estimate the change that will occur with respect to a change in one unit of that variable. As shown in Table 9, the variables that were significant at 5% level in the Tobit model have the highest change in Kg/Ha. This implies that a change of one unit in the variable in question would cause a bigger change in terms of Kg/Ha of sorghum harvested. For instance if hired labour is improved by one unit it will increase sorghum output by approximately 120Kg/Ha and 192Kg/Ha in Makindu and Machakos respectively.
Table 9: Marginal effect results showing the change expected from a unit change in each variable

<table>
<thead>
<tr>
<th>Variables</th>
<th>Overall</th>
<th>Makindu District</th>
<th>Machakos District</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Δ in TE</td>
<td>%Δ in TE</td>
<td>Δ in Kg/Ha</td>
</tr>
<tr>
<td>Male-headed HHs</td>
<td>0.0151</td>
<td>1.51</td>
<td>9.47</td>
</tr>
<tr>
<td>Age of the HHH</td>
<td>0.0031</td>
<td>0.31</td>
<td>1.95</td>
</tr>
<tr>
<td>Education of the HHH</td>
<td>0.3397*</td>
<td>33.97</td>
<td>212.65</td>
</tr>
<tr>
<td>HH size</td>
<td>-0.0109</td>
<td>-1.08</td>
<td>-8.99</td>
</tr>
<tr>
<td>Number of dependents</td>
<td>0.0187</td>
<td>1.86</td>
<td>11.68</td>
</tr>
<tr>
<td>Assets</td>
<td>1.4108</td>
<td>14.45</td>
<td>90.51</td>
</tr>
<tr>
<td>Experience in sorghum farming</td>
<td>0.1346*</td>
<td>13.46</td>
<td>84.27</td>
</tr>
<tr>
<td>Membership to farmer association</td>
<td>0.1446*</td>
<td>14.45</td>
<td>90.51</td>
</tr>
<tr>
<td>Seed rate used</td>
<td>0.0001</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Use of improved seed variety</td>
<td>0.0617</td>
<td>6.17</td>
<td>38.61</td>
</tr>
<tr>
<td>Size of land planted with sorghum</td>
<td>0.1318</td>
<td>13.18</td>
<td>82.48</td>
</tr>
<tr>
<td>Land preparation method</td>
<td>-0.0626</td>
<td>-6.26</td>
<td>-39.20</td>
</tr>
<tr>
<td>Hired labour</td>
<td>0.1096*</td>
<td>10.96</td>
<td>68.59</td>
</tr>
<tr>
<td>Manure use</td>
<td>0.1832*</td>
<td>18.32</td>
<td>114.65</td>
</tr>
<tr>
<td>Production advice</td>
<td>0.2610*</td>
<td>26.10</td>
<td>163.38</td>
</tr>
<tr>
<td>Credit use</td>
<td>0.1021</td>
<td>10.22</td>
<td>63.96</td>
</tr>
<tr>
<td>Income from other farm activities</td>
<td>-0.0057</td>
<td>-0.57</td>
<td>-3.58</td>
</tr>
<tr>
<td>Region</td>
<td>0.1015</td>
<td>10.15</td>
<td>63.52</td>
</tr>
</tbody>
</table>

Current mean productivity (Kg/Ha) 625.97 608.11 690.12

Notes: * Significant at 5%, HHs=Households, HHH=Household head
CHAPTER FIVE

DISCUSSION

5.1 Technical Efficiency

Overally, technical efficiency of sorghum producers in Machakos and Makindu districts is quite low averaging 41%. This implies that, on average, the DMUs were able to obtain around 41% of full potential output from a given input mix with the existing technology. On the other hand, this also implies that around 59% of the potential production is lost by the DMUs due to technical inefficiency. There is thus a possibility of increasing technical efficiency in sorghum production in this region by a whole 59% through better use of available resources given the existing state of technology. This potential suggests a tremendous opportunity to improve technical efficiency among the DMUs in the study region. These results appear to concur with those of Chimai (2011) who estimated a 34% TE of sorghum production in Zambia. Amaza et al (2010) also found the TE of sorghum production in Borno State in Nigeria to be averaging 37%, while Wakili (2012) found an average TE of 72% for sorghum production in Adamana State in Nigeria.
Out of the total 143 DMUs surveyed only 15% of them were identified as being DEA efficient, while the technical efficiency level of the inefficient DMUs ranged from 1.5 – 95%. There is therefore a potential to increase farms output from 5 – 98.5% from the existing levels of inputs use. Policy strategies aimed at improving technical efficiency in the short run should emphasize on an effective and efficient use of the existing technology transfer instruments, which enhance capacity of the farms to efficiently use the physical inputs.

In overall, input slacks were experienced in the two districts. All the slacks were positive. Positive slack indicates that the linear combination can produce at least much of every output using no more of any input (Thrall, 1996). This implies that more output could be produced with the same quantity and mix of inputs than what was achieved. The households were not optimizing their outputs. As evident from the results, labour input was the most underutilized, while land sizes planted with sorghum were most effectively utilized inputs.

Each of the two districts in the region, however, has different estimated mean efficiency. Disaggregating data by sites reveals that there existed site variations in technical efficiency. For instance, in Makindu district, the mean technical efficiency was 47.9% compared with 43% in Machakos district. On average, there
is potential to increase farm output by 52.1% in Makindu and 57% in Machakos from the existing levels of input use. The observed variations between Machakos and Makindu districts could be explained by the observed variations in some of the farm and farmer characteristics in the two districts. These characteristics included membership to farmer associations, land preparation methods and years of sorghum farming experience, which differed between the two districts. These characteristics were found to have a significant influence on technical efficiency at 5% level.

5.2 Farm and Farmer Characteristics that Influence Efficiency

Based on the results in Chapter 4, many variables were found relevant in explaining technical inefficiency obtained for sorghum production Machakos and Makindu districts. Out of the 18 variables, seven were found to influence technical efficiency positively and statistically significant at 5% level. These variables include education levels of household heads in terms of years spent in formal schooling, years of experience in sorghum farming, HH membership in farmer associations, size of land planted with sorghum, hired labour, use of manure and production advice on sorghum production. This implies that their increase respectively improved technical efficiency of sorghum production. Only one
variable, the size of HHs, was found to influence technical efficiency negatively and significant at 5% level. Most of the variables were found to influence technical efficiency in the expected directions by possessing the expected signs, although other variables influenced efficiency in the direction not expected.

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

Household heads with more years of formal schooling were found to be more efficient than their counterparts with less years of formal schooling. These results are in agreement with the findings of Nyagaka et al (2011), Mussa et al (2011), Shehu et al (2010), Njeru (2010), Ajewole and Folayan (2008), Elibariki and Shuji (2008), Chirwa (2007), Idiong (2007) and Amaza et al (2006). All these studies have argued that high formal education levels (12 years and above)
reduces inefficiency. Educated farmers are generally better placed to receive, interpret and respond to new information. More educated farmers tend to adopt and respond rapidly to the use of improved technologies such as water harvesting and soil conservation technologies and the agronomic practices such as appropriate spacing and thinning, which could positively influence the technical efficiency of sorghum. According to Wakili (2012) and Njeru (2010), farmers with low levels of education are often less receptive to improved farming techniques. These farmers provide poor supervision and are often very slow in responding to emergencies such as outbreak of crop diseases or pests.

The existence of positive and significant relationship between membership to farmer associations and technical efficiency was an important finding. This suggests that the households who belonged to farmer associations or clubs or related organizations were more likely to benefit from better access to inputs such as improved sorghum varieties and information on improved farming practices. Similar results were also realised by Wakili (2012), Chiona (2011), Nyagaka et al (2011), Shehu et al (2010), Kariuki et al. (2008), Nchare (2007), Idiong (2007), and Chirwa (2007). In fact, Nyagaka et al (2011) further explained that being a member of farmer associations or local groups provides an avenue for information
and technology transfer by extension agents and even among members themselves. Consequently, being a member of a particular farmer organization more often leads to sharing of information especially on farming technologies through interaction and peer learning processes, which, in turn, tend to influence the production practices of the members. This makes the household heads to make appropriate decisions, which in the long run enhance productivity and efficiency. In some farmer associations, certain farming practices and new technologies are undertaken together as a group. This enhances learning. For instance, a certain farmer association in Makindu district had adopted the digging of cut-off drains, which is a form of soil and water conservation technology, which were dug in every member’s farm to conserve soil and moisture for plant growth. Such pooling of labour resources could only be achieved through farmers organizing themselves into clubs or associations.

The area planted with sorghum had a significant direct relationship with technical efficiency only in Makindu district. This indicates that efficiency of sorghum production increases with increase in size of land under sorghum in Makindu, but this relationship was not significant in Machakos. Notably, most of the households in Makindu planted sorghum on larger farms as compared with those
in Machakos. Similar positive results of farm size and technical efficiency were realised by Chiona (2011), Gul et al (2009), Elibariki and Shuji (2008) and Chirwa (2007), but on the contrary Chimai (2011) and Javed et al (2010) found that size of land planted with sorghum had a negative influence to technical efficiency. This positive relationship could simply be explained by households with large farms under sorghum engaging hired labour in the production of sorghum. Hired labour is highly associated with efficiency because of its high productivity per unit labour. Another explanation could be that households with large farms may want to maximize production from their farms because they may have compromised on other crops to plant sorghum.

Hired labour had a positive and significant coefficient at 5% significance level. This implies that those households who used hired labour were more efficient than those who only used family labour in the production processes of sorghum. This could be attributed to the fact that hired labour acts as an incentive for the households to be more efficient as the cost of hired labour is expensive, hence, the productivity per unit of hired labour is high. Comparable results were reported by Chimai (2011) and Elibariki and Shuji (2008).
Production advice on sorghum given to the households had a direct and significant relationship with technical efficiency. This implies that those households that received production advice on sorghum were more technically efficient than their counterparts who never received any advice. This corroborates with the work of Wakili (2012), Chiona (2011), Javed et al (2010), Ajewole and Folayan (2008), Nchare (2007) and Amaza et al (2006). Through production advice from the extension agents, farmers were able to get first hand information on new agricultural innovations and techniques that would ensure increased sorghum production in the study area.

Interestingly, the size of the household was negative and significant at 5% level in explaining the technical efficiency, implying that as the household size expanded, the technical efficiency of sorghum production decreased. Similar results were obtained by Chimai (2011), Mussa et al (2011), Nchare (2007), and Yusuf and Malomo (2007) who all found out that HH size had a negative influence to technical efficiency. On the contrary, Wakili (2012), Shehu et al (2010) and Ajewole and Folayan (2008) found that household size was positive and significant in explaining technical efficiency. The researchers argued that household size increased the labour available, hence increase in the technical
efficiency. However, according to Nchare (2007), it is observed that although household size increases the labour available for production, it is usually associated with production inefficiency hence technical inefficiency. This can be explained by the abundance of that available labour at farm level, which will lower the productivity per unit labour.

Although expected to influence technical efficiency negatively, age of the HHH was found to vary between the districts. In Makindu, age of the HHH had the expected sign although was not significant. Amaza et al (2006) argued that older farmers were likely to be less efficient than younger ones. This is because younger farmers were likely to be more progressive and more willing to adopt new agronomical practices hence higher efficiency in production. On the other hand, Elibariki and Shuji (2008) found age of the household head to have a positive influence to technical efficiency. This argument was based on the assertion that as farmers grow old they gain more experience in the production of various agricultural practices, hence more efficient.

Assets possessed by the household had the expected positive sign though not significant. According to Chimai (2011), assets are taken to indicate the household wealth status. In regard to smallholder farmers, assets are expected to
influence technical efficiency positively. This is because assets act as shock absorbers, especially when sold off in times of needs. The income from the assets could be used to purchase inputs and to hire various production practices.

Credit use was found to have the expected positive sign though not significant at 5% level. As argued by Nchare (2007) and Amaza et al (2006) credit was expected to reduce the financial difficulties the farmers usually face especially at the beginning of the production process. The credit could enable the farmers to have the capital to purchase inputs and to have resources to prepare their land on time before planting. Padilla-Fernandez and Nuthall (2009) argued that credit to the farmers may act as an instrumental motivation to produce more efficiently apart from being able to purchase the required inputs for production.

Seed rate was expected to influence technical efficiency negatively but on the contrary, it had a positive sign although not significant at 5% level. This could be attributed to most of the households found using low seed rate compared with the recommended rates. Overall, household sites were tested and those households residing in Makindu were positive but not significant. This mean that belonging to
Makindu was not enough to significantly influence a farmer to attain higher levels of efficiency.

5.3 Constraints Faced by Smallholder Sorghum Farmers overall in both districts

Majority of the HHs surveyed were faced with various constraints during the entire period of sorghum production. Most of the surveyed households (82%) found birds to be a major constraint to sorghum production. Sorghum grains were heavily eaten by birds, especially from the time of grains formation all through to harvesting and drying. Birds could contribute to total loss (upto 100%) of the sorghum output if necessary measures were not put in place early enough to prevent and scare birds out of the sorghum farms. Diseases such as sorghum head smut and pests attack was also another major constraint faced by sorghum farmers in which approximately 52% of the sampled HHs reported it as one of the major constraints.. Another constraint cited by many households (44%) was, unlike crops like maize, beans and pigeon peas, sorghum was a highly labour-intensive enterprise. The labour intensiveness of sorghum production is particularly experienced at land preparation and bird scaring stages. Being a small seeded crop, sorghum requires a finer tilth than crops like maize and beans. Further,
failure to guard maturing sorghum from bird will result in a total loss of the production.

Approximately 20% of the surveyed HHs cited piecemeal harvesting as a major constraint. Unlike other crops harvested at once, sorghum harvesting is done in stages. Main sorghum plants grow with branches and younger stems that mature at different times necessitating pieceal harvesting. Further, during threshing about 15% of the surveyed households reported faced with the constraint of limited drying materials (tarpaulines). Given that most of the sampled sorghum farmers had planted the Gadam sorghum variety whose quality spoils quite easily because of its white colour, proper handling during threshing is therefore critical.

The farmers were also faced with marketing and selling constraints in which 22% of the sampled HHs reported experiencing poor prices of their soughum outputs. The respondents claimed that the prices offered for their sorghum grains were as low as KES5/kg. However, a majority of the sampled HHs (47%) sold their produce at a price ranging from KES11-20/kg of grain sorghum, while only approximately 8% of the HHs sold the grain sorghum at a price above KES30/Kg.
5.4 Farmer Suggestions on How to Improve Sorghum Production in the study sites

Several suggestions were given by the surveyed HHs on how sorghum enterprise could be improved in the surveyed region. Among the most important suggestions given by majority of the surveyed HH (60%) was market availability and access with competitive prices for the sorghum grains. The households believed that more farmers could engage in sorghum production if the prices were good. Most of the respondents (37%) preferred improving sorghum grain prices ranging from KES41-60/kg. Many respondents (45%) believed that provision of appropriate inputs, particularly labour to scare away birds could greatly improve production of sorghum. The sampled farmers believed that provision of the right types and amounts of inputs at the right time could greatly improve the performance of sorghum production. It is observed that fertilizer input was not used by all the surveyed HHs in Makindu district, while 71% of sampled HHs in Machakos did not use fertilizer input in the production of sorghum. The farmers blamed the non-usage of fertilizers (especially the inorganic fertilizers) to high input prices. Most of the surveyed households believed that if inputs such as fertilizers and certified seeds were provided at subsidized prices, most farmers could afford the inputs for improved sorghum production. At the same time, 36% of the sampled HHs
believed that if farmers had good knowledge on sorghum agronomic practices the performance of the sorghum enterprise could not be dwindling. Knowledge on agronomic practices such as timely and proper tillage, spacing and thinning was necessary for the sorghum farmers. Other suggestions given by respondents on how to improve sorghum production and marketing included provision of loans (30%), practicing collective farming (14%) and provision of appropriate education and training on sorghum farming (10%) in the ASALs.
CHAPTER SIX

CONCLUSIONS, RECOMMENDATIONS AND POLICY IMPLICATIONS

6.1 Introduction

Sorghum enterprise has been performing dismally in these regions and the reasons for this have not been well established and understood. Yield gaps between the on-station and on-farm research on one side and the farmer practice on the other are wide. This study, therefore, was undertaken to provide an assessment of technical efficiency among smallholder sorghum producers in Machakos and Makindu districts in Kenya. The study estimated technical efficiency using the DEA model and also identified and described farm and farmer characteristics affecting technical efficiency using two-limit Tobit model. This study helps stakeholders in understanding better some of the factors that contribute to the yield gap differences; and this will go a long way to improving production performance of sorghum enterprise in the respective districts. Since sorghum is one of the crops that is being promoted in the ASALs owing to its ability to thrive well in such climatic conditions, high technical efficiency is critical in order to improve food security and rural income in the ASALs of Kenya. Consequently,
some conclusions, recommendations and policy implications drawn from the findings of this study are presented and in the following three sections.

6.2 Conclusions

The major conclusion on the findings of this study is that many sampled smallholder sorghum producers were technically inefficient. They were found operating on a mean technical efficiency of 41%, with some HHs in fact operating in as low as 1.5% technical efficiency regime. Most sampled households (48%) operated below 30% technical efficiency, while only 20% of them operated above 80% technical efficiency. In general, the technical efficiency levels found in these districts in Kenya were low but were quite comparable with those obtained in other African countries whose mean technical efficiency ranged from 30 – 70%. Consequently, the results of this study rejected the null hypothesis that there is no significantly high level of technical efficiency of sorghum production among smallholder farmers in Machakos and Makindu districts.

It is further concluded that farmers in these districts were not optimizing on their sorghum outputs mainly because most of the inputs used for sorghum production were underutilized. Though labour was the most underutilized resource, land was the most effectively utilized as compared with other inputs used.
The results of this study also reject the second null hypothesis that farm and farmer characteristics are not statistically significant in explaining the technical efficiency. Some variable results on the farm and farmer characteristics such as the formal education levels of the HHHs, years of sorghum farming experience, membership to farmer associations, land sizes planted with sorghum, hired labour, use of manure and farmers receiving production advice were all found operating in positive technical efficiency regimes and were statistically significant at 5% level. This implies that an increase or a decrease in any of these variables would cause an increase or a decrease in technical efficiency of sorghum respectively. Although negative, the household size was found statistically significant at 5% level implying that an increase of the household size would decrease the technical efficiency and vice versa.

There were important constraints facing farmers in the production process of sorghum. The most reported constraint was that of birds eating the grains as well as high smut disease prevalence. Most sampled sorghum farmers were not satisfied with the price offered by EABL of KES17/kg, but preferred a competitive price ranging from KES41-60/kg. This could motivate sampled households to engage more seriously in sorghum farming as a business.
6.3 Recommendations

1. Since use of manure proved to have a positive influence on technical efficiency and most sampled farmers could not afford inorganic fertilizers, farmers are encouraged to use organic manure, which is locally and cheaply available. Farmers should be trained on how to make farmyard manure or compost manure using local materials at their disposal. These trainings should be conducted through demonstrations during the field days or agricultural shows.

2. While the majority of the sampled households complained of poor market prices, it is recommended that an in-depth study on profit analysis be carried out to determine the break-even point levels of sorghum enterprise. The study will help determine the most competitive price, which farmers can demand for their sorghum output in order to make profits.

3. Since this study only addressed technical efficiency of sorghum, allocative and economic efficiency have not been addressed. It is thus recommended that further studies be conducted to determine allocative and economic efficiency of sorghum enterprise in the ASALs of Kenya. It is also
recommended that similar research be replicated in various parts of the country where sorghum is grown.

6.4 Policy Implications

Sorghum farmers are not fully technically efficient and therefore there is room for efficiency improvement, which can be undertaken by addressing important variables that either positively or negatively influence levels of technical efficiency in the districts through policy formulation or review.

1. Education of the HHHs who are the decision makers in family setups had positive correlation with technical efficiency and hence basic education should be emphasized for them. In addition, the educated youth should be encouraged to take up agricultural farming as a business by creating market diversification programmes through value addition. Thus appropriate policy formulation and/or review should be undertaken to provide an enabling environment to encourage related basic education for both the old and young farmers.

2. Membership to farmers association had positive influence on technical efficiency and therefore there should be creation and implementation of
policies that encourage farmers to form and join cooperatives and farmers’ associations.

3. Production advice through provision of appropriate extension services should be encouraged since this was found positively associated with technical efficiency. The Government is thus advised to increase the deployment of more extension officers to rural areas to facilitate dissemination of new agricultural technologies.
REFERENCES


APPENDIX 1: QUESTIONNAIRE

Introduction

This study is being undertaken to find out the level of technical efficiency and identify factors affecting efficiency among smallholder sorghum farmers in Machakos and Makindu districts, Kenya. The information provided will assist the project recommend the formulation and review of policies and programmes that will improve sorghum production efficiency in the region. The information needed is for the period March 2011–March 2012 and all information will be treated confidentially.

Questionnaire identification

Questionnaire number ____________________________________________

District _______________________________________________________

Division _______________________________________________________  

Watershed _____________________________________________________

121
1.0 Household head’s background information

1.1 Gender/sex: Male [_____] Female [_____] (Tick appropriately)

1.2 Occupation (Tick where appropriate)
   i) Farmer [_____]  
   ii) Business man [_____]  
   iii) Employed [_____]  
   iv) Others (specify) ____________________________ [_____]  

1.3 Age (in years) ____________________________ years

1.4 Formal education level (Tick where appropriate)

   1. None [_____]  
   2. Primary school [_____]  
   3. Secondary school [_____]  
   4. College [_____]  

122
5. University        [______]

1.5 Household size (number of people living and eating together) ___________

1.6 Number of dependants (those who depend on the household head) __________

1.7 Household wealth (household assets / possession and their value)

<table>
<thead>
<tr>
<th>Properties</th>
<th>Description</th>
<th>Estimated Value (KES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>House(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Livestock</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall farm size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others (specify)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: KES=Kenya shillings

1.8 Sorghum farming experience: <5 yrs [_____] >5 yrs [______]

1.9 Did you belong to any farmers association or cooperative? Yes [____] No [____]

2.0 Physical and economic factors

2.1 What kind of land tenure did you have? Individual [____] Leasehold [____] Communal [____]

2.2 What size of land did you use to plant sorghum? ________ acres

2.3 What did you use to prepare your land before planting? (Tick where appropriate)
Hand digging [____]  Ox-plough [____]  Tractor [____]  Not ploughed [____]

2.4 What quantity of seed did you plant? ____________________ Kgs.

2.5 What kind of seeds did you plant? *(Tick where appropriate)*

   Improved varieties [____]  Local varieties [____]

(a) Did you use any fertilizer during planting?  Yes [___]  No [___]

(b) If yes how much did you use? ____________________ Kgs

(c) Did you use manure?  Yes [____]  No [____]

2.6 Extension services:

   (a) Did you have an extension contact before starting sorghum production? *(Tick)*  Yes [____]  No [____]

   (b) If yes, what information did you obtained that influenced your sorghum production?

      (i) _____________________________________________________________

      (ii) ___________________________________________________________

2.7 Marketing
(a) Name of the nearest sorghum market _________________________

(b) Distance to the nearest market in Kms _________________________

(c) Total transport cost to the market (KES) ________________________

2.8 Sources of household off-farm income

<table>
<thead>
<tr>
<th>Sources</th>
<th>Number of days/months</th>
<th>Total annual amount (KES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remittances</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gifts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others specify</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Amount</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.9 a) Was the source of capital used in production of your sorghum enterprise a credit/loan?

(Tick) Yes [_____] No [_____]

b) If yes, was it agricultural loan or normal loan?

Agricultural Loan [_____] Normal Loan [_____]  

2.10 Did you have any other source of income from farming i.e. from livestock or other crops?

Yes [_____] No [_____] [If no skip to part 3.0]
i. If Yes, livestock income (KES) falls in what range per month?
   1 = Less than 5,000 [___],  2 = 5,001-10,000 [___], 3 = 10,001-15,000 [___]
   4 = 15’001-20,000 [___], 5 = >20001[___]

ii. How much did you get from other crops?
   1 = ≤ 5,000 [___]  2 = 5,001-10,000 [___] 3 = 10,001-15,000 [___]  4 = 15,001-
                                    20,000 [___] 5 = >20,0001 [___]

3.0 Resource use and output level

3.1 Labor use information in sorghum production

<table>
<thead>
<tr>
<th>Activity</th>
<th>Labor type (f=family and h=hired)</th>
<th>Quantity (hours, days, months)</th>
<th>Cost (KES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearing of land</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ploughing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harrowing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weeding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disease control (spraying)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bird scaring</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harvesting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threshing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport to the market</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others specify</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.0 Constraints in sorghum enterprise

4.1 What were some of the constraints you faced in sorghum farming?
   (a) During planting:______________________________________________
(b) During harvesting:_______________________________________

(c) During marketing and selling:______________________________

4.2 How much did you harvest? __________Kgs

4.3 Where did you sell your produce?____________________________

4.4 What was the current going price per kg of sorghum grains? KES_______

4.5 Were you satisfied with the price offered? Yes [_____] No [____]

4.6 If your answer is No, what would be your minimum price per kg of dry sorghum grain? KES __________________________

4.7 In your own opinion what suggestions can you give that will help improve the sorghum enterprise in this region?

________________________________________________________________

Thank you very much for your cooperation, time and answers!