

FACTRORS AFFECTING EFFICIENCY OF SMALLHOLDER COTTON  
PRODUCERS IN ZAMBIA

By

Stephen Kabwe

A dissertation Submitted to the University of Zambia in Partial Fulfillment of the  
Requirements of the Degree of Master of Science in Agricultural Economics

THE UNIVERSITY OF ZAMBIA

LUSAKA

2012

**DECLARATION**

I Stephen Kabwe declare that this is my original work and has never been submitted for a degree in this or any other university or institution of higher learning.

Signature.....

Date.....

*© 2012 by Stephen Kabwe. All rights reserved.*

**APPROVAL**

The University of Zambia approves this dissertation of Stephen Kabwe as fulfilling the requirements for the award of the degree of Master of Science in Agricultural Economics.

**Examiner**

**Signature**

**Date**

.....

.....

.....

.....

.....

.....

.....

.....

.....

## ABSTRACT

Agriculture in Sub-Saharan Africa is considered as an engine of economic growth and has the potential to reduce rural poverty of smallholder farmers through increased food security and household income. However, Zambia and other Sub-Saharan Africa countries are faced with low agricultural productivity and that undermines the potential the sector has of reducing poverty. Focusing on smallholder cotton producers of Zambia, the study aimed at determining the efficiency of cotton farmers in Zambia. It further aimed at determining socio-economic and farm specific factors that were likely to influence the efficiency in cotton production. Efficiency in this study was considered as productivity at optimal values and was investigated in three ways; technical, allocative and economic efficiencies. The study used the 2008 supplemental survey data collected by the Ministry of Agriculture and Cooperatives, Central Statistics Office and Food Security Research Project. Using Data Envelopment Analysis (DEA), technical, allocative and economic efficiency indices were determined at 46%, 37% and 20% respectively. This means that Zambia's cotton farmers are relatively inefficient and they could reduce input use and production cost without altering the output but by just improving technical and allocative efficiency by 54% and 63% respectively. Using the Ordinary Least Squares (OLS) regression, the econometric results indicated that female headed households, number of years of formal education, use of crop residues, and productive assets were some of the factors found to positively influenced efficiency. Therefore, the study recommended that cotton stakeholders devise strategies of involving more women in cotton production, improve access to productive assets, and encourage adoption of conservation farming techniques such as the use of crop residues in the field as the means of improving cotton production efficiency.

This study is dedicated to my wife, Prisca and my two daughters, Faith and Grace.  
Guys! You kept me going.

## ACKNOWLEDGEMENTS

I would like to express my appreciation and gratitude for the guidance, support and motivation of Dr. Gelson Tembo my supervisor. Without him this dissertation might not have developed the way it did.

I would also like to thank researchers from Food Security Research Project (FSRP) who gave substantial comments to my first draft. I say thank you! I would like to further thank FSRP management for its support and understanding during the period of my study and for allowing me to use Project's survey data.

Let me also take this opportunity to thank Dr. David Tschirley of Michigan State University who has added value to my career more especially understanding cotton issues.

I also thank my classmates Susan and Thomas whom we struggled together during the time of academic endurance.

I would like also to thank my parents *ba Kateeka* and *ba Pelina* and my mother in-law *ba Estelle* for their spiritual and moral support. Thanks also to my wife Prisca and my two daughters Faith and Grace for your patience during the time of my studies. My wife you were always there to encourage me when things were difficult.

Last but not the least; I would like to thank my HEAVENLY GOD who gave me this opportunity to do graduate studies.

## TABLE OF CONTENTS

<b>DECLARATION</b> .....	
<b>COPY RIGHT</b> .....	
<b>APPROVAL</b> .....	
<b>ABSTRACT</b> .....	<b>IV</b>
<b>DEDICATION</b> .....	<b>V</b>
<b>ACKNOWLEDGEMENTS</b> .....	<b>VI</b>
<b>TABLE OF CONTENTS</b> .....	<b>VII</b>
<b>LIST OF TABLES</b> .....	<b>IX</b>
<b>LIST OF FIGURES</b> .....	<b>X</b>
<b>ACRONYMS</b> .....	<b>XI</b>
<b>CHAPTER 1</b> .....	<b>1</b>
<b>INTRODUCTION</b> .....	<b>1</b>
<b>1.1 Introduction</b> .....	<b>1</b>
1.2 Problem Statement .....	<b>2</b>
1.3 Objectives of the Study .....	<b>3</b>
1.4 Statement of Hypotheses .....	<b>4</b>
1.5 Justification of the Study .....	<b>4</b>
1.6 Organization of the Study .....	<b>4</b>
<b>CHAPTER 2</b> .....	<b>5</b>
<b>LITERATURE REVIEW</b> .....	<b>5</b>
2.1 Introduction .....	<b>5</b>
2.2 Agro-ecological regions of Zambia.....	<b>5</b>
2.3 Evolution of the Cotton Sector .....	<b>7</b>
2.4 Theoretical Framework .....	<b>9</b>
2.4.1 Definition of Productivity.....	<b>9</b>



2.4.2 The Concept of Efficiency .....	10
2.5 Determinants of Technical and Allocative Efficiency .....	13
<b>CHAPTER 3 .....</b>	<b>18</b>
<b>DATA SOURCES AND METHODS .....</b>	<b>18</b>
3.1 Data Sources.....	18
3.2 Methods.....	20
3.2.1 The Variable Returns to Scale DEA Model (First Step Approach).....	20
3.2.2 Second Stage using the Ordinary Least Squares (OLS) .....	24
3.2.3 Variables used in the DEA Model .....	25
3.2.4 Variables used in the Econometric Model.....	26
3.3.0 Statistical Tests.....	28
3.4 Limitations encountered .....	29
<b>CHAPTER 4 .....</b>	<b>30</b>
<b>RESULTS AND DISCUSSION .....</b>	<b>30</b>
4.1 Descriptive Statistics of Cotton Households .....	30
4.2 Summary Statistics of Technical, Allocative and Economic Efficiency level.....	32
4.2.1 Estimated Potential Yield by Province .....	34
4.2.2 Estimated Potential Cost of Production by Province.....	36
4.2.3 Input Use and Technical Efficiency .....	37
4.3 Factors affecting Technical and Allocative Efficiencies in Cotton Production ....	39
<b>CHAPTER 5 .....</b>	<b>45</b>
<b>CONCLUSIONS AND RECOMMENDATIONS.....</b>	<b>45</b>
5.2 Recommendations .....	46
5.3 Further Research .....	47
<b>REFERENCES.....</b>	<b>48</b>
<b>APPENDIX .....</b>	<b>53</b>

## LIST OF TABLES

Table 1: Summary Statistics for the Variables used in DEA .....	25
Table 2: Socio-economic and Farm Level Characteristics of Cotton Households .....	30
Table 3: Summary Statistics of TE, AE, and EE levels by Province.....	32
Table 4: Mean Yield and Potential Yield of Seed Cotton by Province .....	35
Table 5: Average Cost and Potential Cost of Seed Cotton Production by Province .....	36
Table 6: Input Uses and Technical Efficiency .....	37
Table 7: Efficiency Levels by Gender of the Household head .....	38
Table 8: Efficiency Level by Size of the Cultivated Area .....	38
Table 9: Efficiency Levels by Educational level attained by the Household head.....	39
Table 10: Determinants of Technical, Allocative and Economic Efficiency .....	40

## LIST OF FIGURES

Figure 1: Labour and Land Productivity, 1993-2003 .....	1
Figure 2: Zambia's Agro-ecological Zones .....	6
Figure 3: The Evolution of Zambia's Cotton Sector after Sector's Liberalization.....	8
Figure 4: Technical and Allocative Efficiencies.....	12
Figure 5: Cumulative Percent for TE, AE and EE.....	34

## ACRONYMS

AE	Allocative Efficiency
CSA	Census Supervisory Areas
CSO	Central Statistics Office
DEA	Data Envelopment Analysis
DMU	Decision Making Units
EE	Economic Efficiency
FARA	Forum for Agricultural Research in Africa
MACO	Ministry of Agriculture and Cooperatives
MoFNP	Ministry of Finance and National Planning
OLS	Ordinary Least Squares
PHS	Post Harvest Survey
SEA	Standard Enumeration Area
TE	Technical Efficiency
ZMK	Zambian Kwacha (the currency of Zambia)

# CHAPTER 1

## INTRODUCTION

### 1.1 Introduction

In Sub-Saharan Africa, agriculture is considered as an engine of economic growth. It has the potential to reduce rural poverty through increased food security and improved household income. However most of the countries in Sub-Saharan Africa are faced with low agricultural productivity. According to Frisvold and Ingram (1994) and FARA (2006), agricultural productivity has relatively stagnated in much of Sub-Saharan Africa for both land and labour compared with other developing regions in the world (Figure 1).

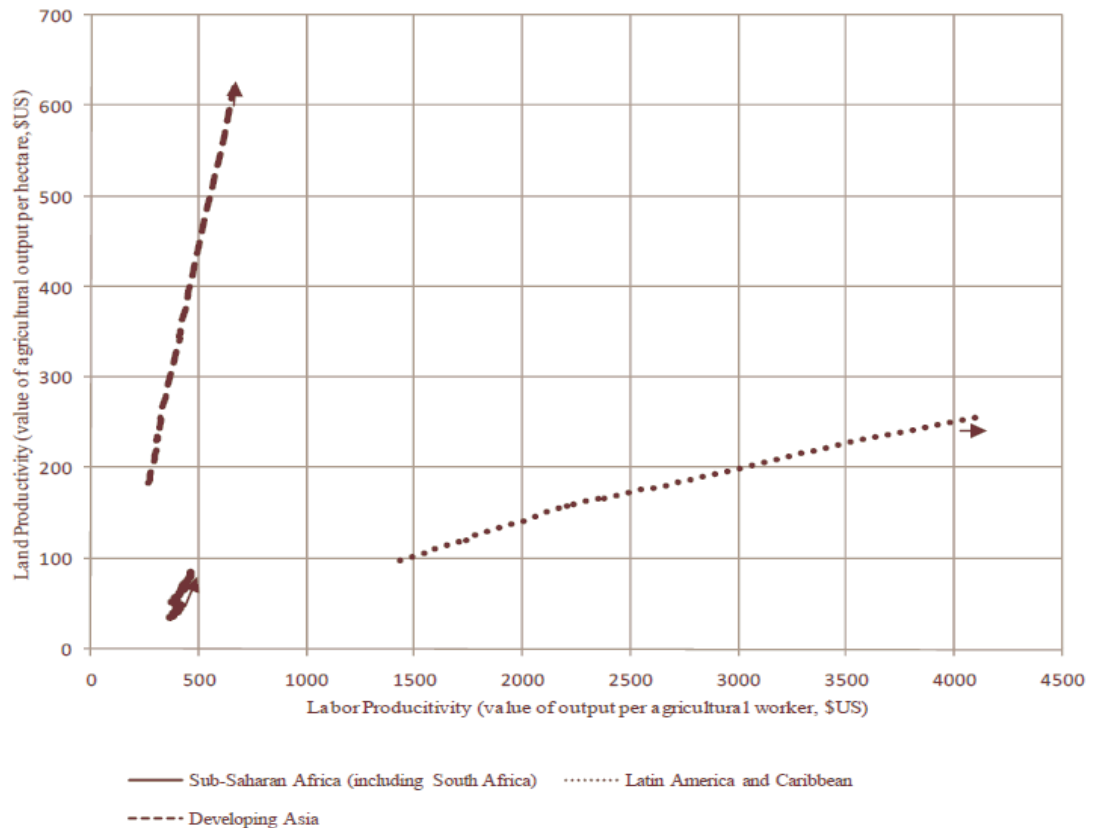


Figure 1: Labour and Land Productivity, 1993-2003  
Source: FARA (2006)

Zambia, just like other Sub-Saharan Africa countries experiences low agricultural productivity despite it being endowed with abundant land resources of about 75 million hectares of which 58% is suitable for agricultural production (Deininger and Olinto 2000; MoFNP 2006). Even when the government liberalized the agricultural sector to allow private sector participation in the sector as a way of improving agricultural efficiency, crop productivity has been stagnant. In the Fifth National Development Plan (2006), government targeted to increase production and productivity of food crops such as maize, sorghum, millet and cassava. It also targeted to promote production of cash crops such as cotton and tobacco in the spirit of diversifying the agricultural sector.

This study focused on smallholder cotton producers in Zambia. Cotton production and processing of seed cotton has grown rapidly after the reforms of the cotton sector in 1994 because of private companies' investments (Brambilla and Porto 2009; Tschirley and Kabwe 2007). The cotton sector contributes over US\$ 60 million on average to the Zambian economy. It also supports over 150,000 households and if we consider 6 people per household (Kuteya *et al.*, 2011), over 900,000 people are likely to directly benefits from the cotton production.

## **1.2 Problem Statement**

The problem the sector is facing is low productivity in cotton production where the average yield is around 550-800 kg per hectare. Improving productivity in the cotton sub-sector is among the major policy objectives in Zambia as that has a bearing on the profitability of cotton cultivation at the farm and ginnery levels. Profitability is a conduit for a viable and sustainable cotton sector (Tschirley, Poulton and Labaste, 2009).

Although investments have been made in research, extension service provision and inputs provision to improve cotton productivity of smallholder farmers, low productivity remains a major challenge and compares unfavorably with potential seed cotton yield of over 2000 kg/ha and a yield of over 1,000 kg/ha attained in most West African countries (Tschirley *et al.*, 2007). This implies that technological advances generated through research and investments in input provision, have not widely translated in improved

productivity among cotton farmers in Zambia. Therefore, there is need to find ways of improving productivity with the same level of technology and investment. According to Bravo-Ureta and Pinheiro 1993, that could be attained by improving the level of efficiency of farmers. Efficiency in this study was investigated in three ways; technical, allocative and economic efficiency. A technically efficient producer is likely to be productive and able to produce a given level of output using minimum amounts of inputs. While, an allocatively or economically efficient producer is likely to have profitable farming enterprises since he/she is able to produce a given level of output with minimum costs. This is key for a profitable and sustainable cotton sector.

Many studies have been done in Zambia to substantiate the influence of cotton sector reforms on the performance of the sector (Tschirley and Kabwe 2007, Brambilla *et al.*, 2009, Tschirley, Poulton and Labaste, 2009). None of these have looked at the efficiency levels and factors affecting efficiency in cotton production. Internationally, the studies looking at efficiency and factors influencing efficiency have been done; though none has gone further to determine the influence of specific farm factors on technical, allocative and economic efficiency (Ngassam *et al.*, 2010, Mohammad 2009, Mevlut *et al.*, 2009, Shafiq *et al.*, 2000). A substantial knowledge gap remains on farm specific factors that may have influence on efficiency in cotton production. Therefore, in order to come up with appropriate policies, there is need to identify farm specific factors as well as socio-economic factors that are likely to influence efficiency of cotton farmers.

### **1.3 Objectives of the Study**

The main objective of the study was to investigate the farm level efficiency of smallholder cotton producers in Zambia. The specific objectives were:

- i) To characterize the socio-economic and farm factors of smallholder cotton farmers
- ii) To determine the technical, allocative and economic efficiency indices of smallholder cotton farmers

- iii) To determine the socio-economic factors and farm specific factors that influence the technical, allocative and economic efficiency in smallholder cotton production

#### **1.4 Statement of Hypotheses**

Demographic, economic or social factors and farm specific factors are likely to positively influence efficiency of cotton farmers in Zambia.

#### **1.5 Justification of the Study**

Though, there are a number of studies done to understand the impact of reforms on the cotton sector's structure and productivity, there has been no study done to estimate technical, allocative and economic efficiency in Zambia's cotton production sector. Understanding the efficiency levels, household and farm characteristics influencing efficiency would help policy makers and other stakeholders formulate policy recommendations that will positively impact agricultural productivity. Improved agricultural productivity among cotton farmers has a multiplier effect on the sector. It is likely to improve income of cotton farmers and subsequently help to reduce poverty. It can also improve the profitability of lint production among ginning companies and consequently improve revenue contribution to the Zambian government.

#### **1.6 Organization of the Study**

This dissertation is divided into five chapters. Chapter 1 gives an introduction and statement of the problem, objectives, hypothesis and the justification of the study. Chapter 2 highlights the areas suitable for cotton production, the evolution of the cotton sector, literature review of efficiency concepts and determinants of efficiency. Chapter 3 discusses the data sources, the methodology employed in this study which was the theoretical basis for the empirical approaches that were used to achieve the study objectives. Chapter 4 discusses the results of the analysis while chapter 5 gives the conclusions, recommendations and suggested areas for further research.



## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

Improved production efficiency is important for developing and developed countries as that has the potential to increase agricultural production. Understanding production efficiency and factors affecting it cannot be emphasized as that could be a prerequisite to determining the extent of raising agricultural production through improved farm level efficiency with the existing resource base and technology (Mohammad 2009).

This chapter highlights the areas suitable for growing seed cotton in Zambia and also highlights the evolution of the cotton sector. It also reviews efficiency studies that have been done in developed and developing countries so that efficiency concepts and estimation procedures were understood and applied well in this study. Sections 2.2 and 2.3 highlight the areas suitable for cotton production and the evolution of the cotton sector in Zambia. Then section 2.4 highlights the productivity concepts and the historical perspective of efficiency measure using Data Envelopment Analysis. Then section 2.5 reviews the studies in which factors that influence technical, allocative and economic efficiency are determined.

#### **2.2 Agro-ecological regions of Zambia**

Cotton is a semi arid crop and is mainly grown in marginal areas, low rainfall or moderate rainfall areas (Mutua *et al.*, 2010). In Zambia the suitable growing areas for cotton covers mainly three provinces and these are Central, Eastern, and Southern. Based on agro-ecological zones, the ideal ones for cotton production are agro-ecological zone one (AEZ 1) and agro-ecological zone 2a (AEZ IIa) (Geob 2010).

The agro-ecological zones are demarcated on the basis of rainfall pattern and soil characteristics. Region I receives less than 800 millimetres of rainfall per annum and constitutes 12 percent of Zambia's total land area. It consists of loamy clayey soils on

the valley floor and coarse to fine loamy shallow soils on the escarpment. It is also characterized by low rainfall, short growing seasons, high temperatures during the growing seasons, and high risk of drought. While Region II receives rainfall between 800 to 1000 millimetres on an annual basis and the region constitutes 42 percent of the country. It is sub-divided into two, namely, Region IIa and IIb. Region IIa covers the Central, Lusaka, Southern and Eastern fertile plateau of the country and generally contain inherent fertile soils. Region IIb covers Western Province and consists of sandy soils. Region III is characterized by high rainfall between 1000 up to 1500 millimetres per annum, long growing seasons, low probability of drought, and cooler temperatures during the growing season. This Region constitutes 46 percent of the country's total land area. It covers the Copperbelt, Luapula, Northern and North-Western Provinces.

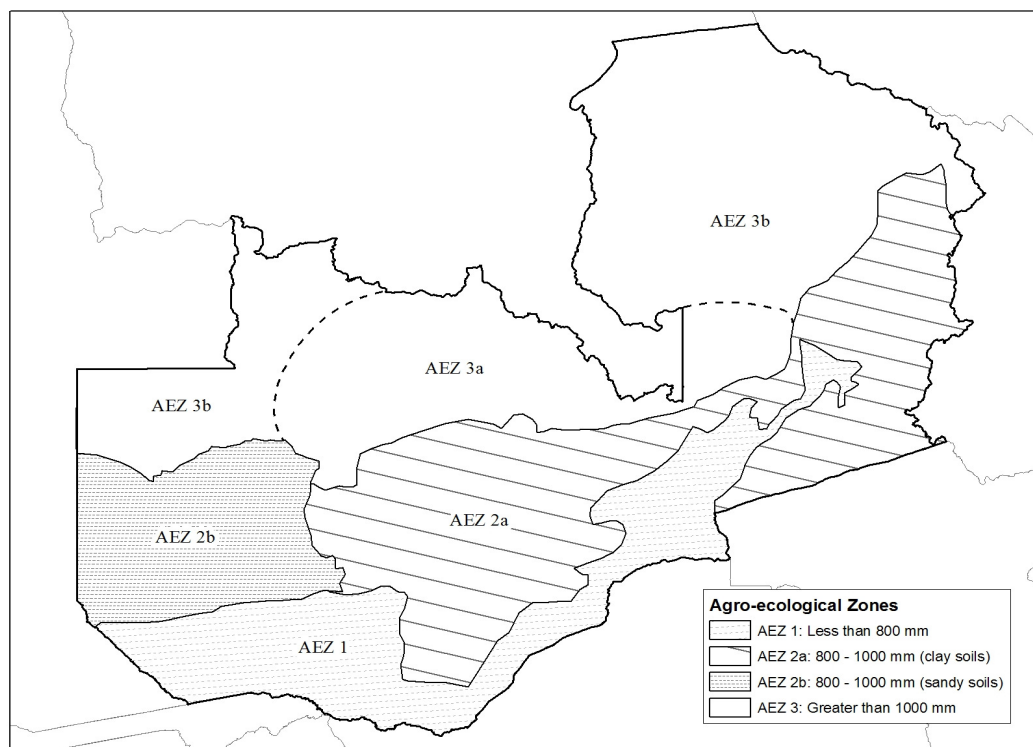


Figure 2: Zambia's Agro-ecological Zones  
Source: Geob 2010

### **2.3 Evolution of the Cotton Sector**

Cotton production is an input intensive crop system. Usually the inputs are expensive for most of the cotton farmers and they rely on the inputs they get on credit from the cotton companies. Before Zambia's cotton sector was liberalized, input provision on credit to smallholder cotton farmers was done by the only parastatal Lint Company of Zambia (LINTCO). This company on behalf of the government purchased seed cotton from the farmers and also provided certified seed, pesticides, sprayers, bags and provided extension services to the farmers. According to available statistical information, production of seed cotton was low, fluctuating, and in secular decline which fell below 20,000 mt in 1995 (Tschirley and Kabwe, 2007).

In 1994, as part of a broad-based effort to restructure Zambia's economy, LINTCO was sold to Lonrho Cotton and Clark Cotton. The two private companies had regional cotton interests. The sale appears to have been designed explicitly to limit competition between the companies, so Lintco's gins in the center of the country were sold to Lonrho, and those in Eastern province were sold to Clark Cotton.

Since the sale of LINTCO, the sector has passed through five distinct phases (Figure 3). According to Tschirley and Kabwe 2007, the first phase consisted the post-reform boom (1995-1998) where the sector remained heavily concentrated and expanded rapidly on an entirely private and unregulated basis. The second phase is where the sector experienced the first crash (1999-2000) which was marked by a severe credit default crisis, brought on in part by the entry of new, small ginners and other cotton buyers committed more to trading cotton than to promoting its production. The third phase was when the second boom (2000-2005) happened. This is period when the credit default crisis was resolved entirely through private innovation by the two leading companies to reduce credit default. During this phase government became increasingly involved in the sector, but their activities are best characterized as adjuncts to the fundamental private sector dynamic, and achieved mixed results. Additionally, larger and better financed ginners entered; by the end of this period, the sector was becoming recognizably less concentrated than at any time since reform.

The fourth phase highlights the second crash (2006 – 2007). This was brought on by several factors: a sharp appreciation of the kwacha, which reduced the profitability of all export crops, unhelpful public statements by government in the midst of mounting conflict between farmers and ginners, and the weight of additional firms in the sector. All these factors led to another serious credit default crisis and plummeting production in 2007. By the end of this period, still more companies had entered the sector, bringing the total to at least 11. The fifth phase (2008-2011) indicates a recovery period even if there was a trough in 2010. Production recovered somewhat in 2008 but remained essentially flat in 2009, then dropped by 18% in 2010. However, production estimates show that production of seed cotton for 2011 is expected to be 130,000mt, meaning that production would increase by 81% from 2010 production. And 2010 production was essentially unchanged from 2007 and less than half the levels of 2005 and 2006.

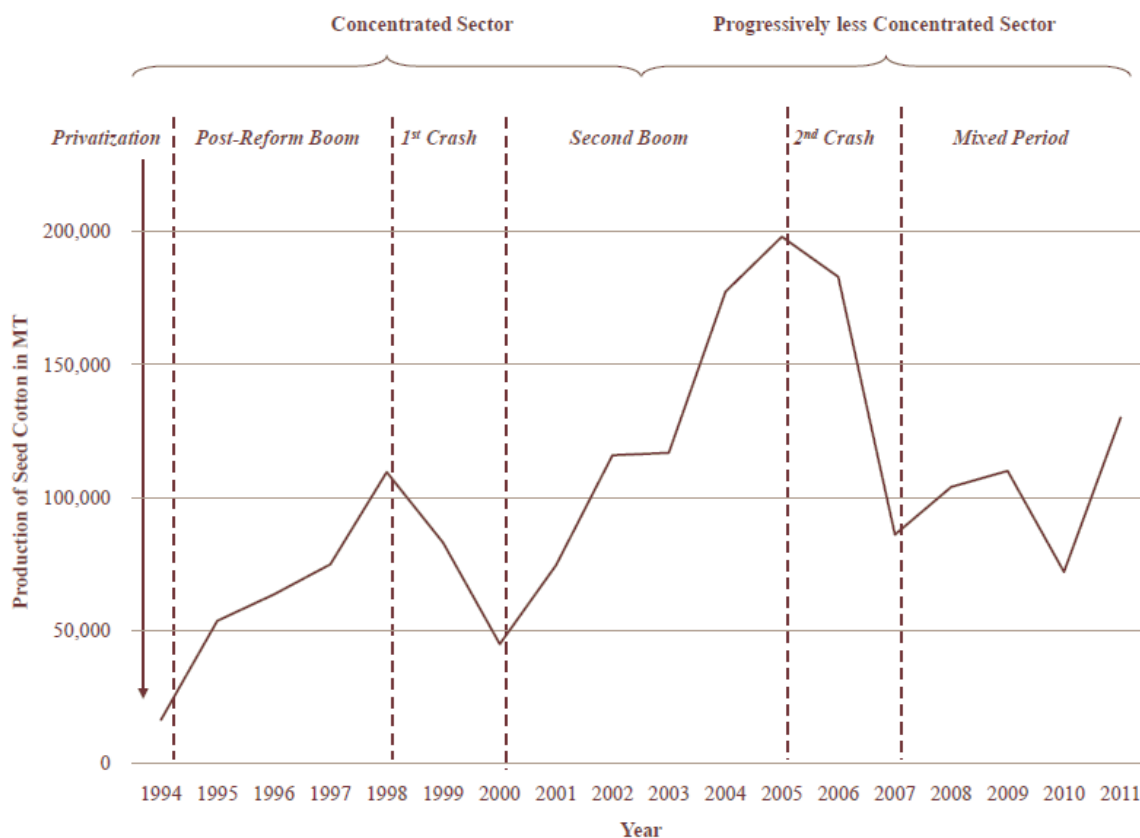


Figure 3: The Evolution of Zambia’s Cotton Sector after Sector’s Liberalization  
Source: Ginners 2011

The recovery of the cotton sector in 2011 is largely due to the unprecedented increase in international cotton prices which are currently in the range of US\$1.65 to US\$1.80 per pound on the international market. In 2010 season, farmers received relatively good cotton prices that ranged from ZMK1,600 to ZMK2,800 per kg of seed cotton. This relatively high price of seed cotton attracted more farmers in cotton production and existing farmers increased their area allocated to cotton production. According to the crop forecast results of 2010/11, area under cotton increased by 53% from what was allocated to cotton production in 2009/10 season. The increase in area and production of seed cotton as a result of increase in international price of lint could not be sustainable especially that when the price at international market tumbles that could affect the profitability of producing seed cotton in local countries. There is need to look at ways and means of renewing the sector's growth and profitability which are sustainable. One such means is improving efficiency among smallholder cotton farmers where efficiency of a farm is its productivity relative to its maximal productivity (Farrell 1957).

## **2.4 Theoretical Framework**

### **2.4.1 Definition of Productivity**

Productivity is one of the terms used to measure performance of a farm. It can be divided into two concepts: Partial factor productivity and total factor productivity. Partial Factor Productivity is the average productivity of a single factor, measured by total output divided by the quantity of a factor applied. Total Factor Productivity is the productivity when all factors are taken in the determination of productivity. Therefore, FARA (2006) defines agricultural productivity as a measure of value of output for a given level of inputs. Agricultural productivity is affected by two broad factors. These are conventional inputs and non conventional inputs. Non-conventional inputs capture the impact of macroeconomic factors such as public investment and agro-ecological specific factors, while conventional inputs are traditional choice variables in the farmers' production decisions process. Conventional inputs could include labour intensity, fertilizer use, tractor use intensity and stock of livestock. While non-conventional inputs include land quality, irrigation, agricultural research, calorie availability, agricultural

export growth and agricultural export instability (Frisvold and Ingram 1994). However, under this study socio-economic factors and farm specific factors are envisioned to have an influence on efficiency.

#### **2.4.2 The Concept of Efficiency**

The efficiency of a firm is defined as the actual productivity of a firm relative to a maximal potential productivity (Farrell, 1957). The maximal potential productivity is defined by a production frontier. Measurement of efficiency involves measurement of distances from observed data points to that frontier (Mohammad, 2009).

The measurement of productive efficiency has important implications for neoclassical theory of production economics and economic policy (Tietenberg, 2006). Measuring productivity efficiency allows one to test competing hypotheses regarding sources of efficiency or differentials in productivity (Farrell, 1957; Rios *et al.*, 2005). Furthermore, such measurements permit quantification of potential increases in output that might be associated with an increase in efficiency (Rios 2005).

The literature suggests several alternative approaches to measuring productive efficiency. According to Farrell 1957, three methods are indentified and these are: 1) the technical efficiency, 2) the price or allocative efficiency, 3) the scale efficiency (that is both price and technical efficiencies). This study used all the approaches. Technical efficiency (TE) is the ability of a firm to produce a maximal output from a given set of inputs or it is the ability of a firm to use as modest inputs as possible for a given level of output. A producer is technically inefficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input; and if a reduction in any input requires an increase in at least one other input or a reduction on at least one output (Koopmans, 1957). Hence a technically efficient producer could produce the same output with less of at least one input, or could use the same inputs to produce more of at least one output.

Allocative efficiency (AE) is the ability of a firm to use inputs in optimal proportion, given their respective prices and the production technology. The use of an input is allocatively efficient if the value of marginal product is equal to its price (Mohammad, 2009). Allocative inefficiency arises when factors of production are used in proportion that does not minimize the cost of producing a given level of output.

Economic efficiency (EE) has technical and allocative components. It is determined by multiplying technical and allocative efficiency. A farm/firm which is both technically and allocatively efficient is said to be an economically efficient farm/firm. The measurement of technical efficiency is important. Alvarez and Arias (2004) noted that the main consequence of technical inefficiency is that it raises production costs and makes a farm or firm less competitive. Therefore, estimating efficiency and deploying the methods to improve it would make a farm or firm more profitable.

Production efficiency measurement is typically implemented by either parametric techniques or non-parametric techniques. Ijibefun (2008) highlights parametric methods to include production, cost, profit and revenue functions as alternative methods of describing the production technology and estimating efficiency. Specifically, the techniques used involve estimation of the stochastic frontier. However, there are also non-parametric techniques that are used to generate efficiency indices. Non-parametric models differ from parametric models because the model structure is not specified a priori but is determined from the data available. As noted by Shafiq *et al.*, (1999) and Fletschner *et al.*, (2002), the non-parametric methods have an edge over the parametric ones. First it does not impose a specific structure on the technology because it does not require assumptions about the functional form or the distribution of the error terms of the frontier production function. Secondly, it allows the use of disaggregated data. And thirdly DEA does not suffer from the problem of multicollinearity and heteroscedasticity. However, there are some disadvantages associated with the non-parametric. According to Flettschner *et al.*, (2002), non-parametric methods have some short comings; firstly statistical tests cannot be determined. Secondly the non-parametric approach provides only an upper bound to the true efficiency measures because all

deviations from the production frontier are attributed to inefficiency. One such non-parametric method is the Data Envelopment Analysis (DEA). DEA is used to measure relative efficiency of decision making units (DMUs) in this study.

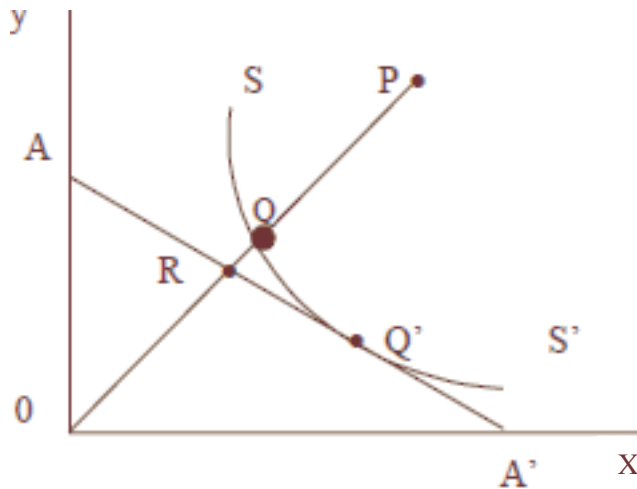


Figure 4: Technical and Allocative Efficiencies  
Source: Ajibefun (2008)

Using figure 4 and considering two inputs  $X$  and  $Y$  to produce an output  $P$ , the ideas of technical and allocative efficiency determination are illustrated. The point  $P$  represents the inputs of two factors, per unit of output, that the firm is observed to use. The isoquant  $SS'$  represents the various combinations of the two factors that a perfectly efficient firm might use to produce a unit output. The point  $Q$  represents an efficient firm using the two factors in the same ratio as  $P$ . However, point  $P$  is a scatter point in terms of using the two factors.  $Q$  produces the same output as  $P$  using only a fraction  $OQ/OP$  as much of each factor. It could also be thought of as producing  $OP/OQ$  times as much output from the same inputs. Borrowing the definition of technical inefficient from Koopman (1951), a producer is technically inefficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input; and if reduction in any input requires an increase in at least other input or a reduction in at least one output. Considering the definition and using figure 4 above, technical inefficiency of a firm could be represented by the distance  $QP$  which is the amount by which all inputs



could be proportionally reduced without a reduction in outputs. Thus a technically efficient producer could produce the same output with less of at least one input, or could use the same inputs to produce more of at least one output. A technically efficient farmer/firm will have a ratio equal to 1 while an inefficient farmer will have a ratio less than 1.

Using the same figure 4, one could also measure the price efficiency or the allocative efficiency of the firm/farm. This measures the extent to which a firm uses the various factors of production in optimal proportions in light of prevailing prices. The budget line is represented by AA' as shown in figure 4 and its slope is equal to the ratio of the prices of the two factors of production. When the price of an input goes up farmers tend to substitute the expensive input by the cheaper input. Defined by Farrell (1957), Fletschner *et al.*, (2002), Ajibefun (2008), price or allocative efficiency is a ratio between minimum cost required to produce a certain level of output and the unit's production costs if it were technically efficient. In the figure above, it is represented by OR/OQ.

The economic efficiency (overall efficiency) of a farm is equal to the product of the technical efficiency and allocative efficiency ( $EE = TE * AE$ ) and is represented by the ratio OR/OP.

## **2.5 Determinants of Technical and Allocative Efficiency**

Many studies have been conducted to determine the technical, allocative, economic efficiency scores and to determine the sources of the variations in technical or/and allocative efficiencies in various countries. The sources could be subdivided into socio-economic and farm specific factors. Under socio-economic, there are attributes such as age, gender, education level, access to extension services, off-farm income, access to credit and household size that influence the efficiency of the farm. Then under farm specific factors, there are: farm size, seed varieties, tillage system used, CF techniques (crop residues) and location of the farm as some of the factors that influence efficiency

at the farm level. Below is the literature with regard to the factors that affect efficiency at farm level.

The age of the household head has some influence in technical and allocative efficiencies. This attribute could affect efficiency positively or negatively. For example, Boris *et al.*, (1997); Nchare (2007); and Amos (2007) found that age had a positive correlation with inefficiency. This implied that older farmers were technically more inefficient than younger farmers. The reason for this could be that older farmers are less likely to have contact with extension agents and less willing to adopt new practices and modern inputs (Hussain 1989). However, other studies have found age to be negatively correlated with inefficiency. Coelli *et al.*, (2002) found age of the farmer to be negatively affecting the inefficiency of the farmer. This means that older farmers tend to be more efficient than younger ones on the farm. The reason for this is that older farmers bring in the experience in doing things which younger farmers do not have. Gul *et al.*, 2009 found that older farmers showed some opportunities of improving resource use efficiency among cotton farmers.

It is assumed that technical efficiency or allocative efficiency would increase with increase in years of schooling of the farmers because more educated farmers are able to perceive, interpret and respond to new information and adopt improved technologies such as fertilizers, pesticides and planting materials much faster than their counterparts. Several studies such as Bravo-Ureta *et al.*, (1997), Coelli *et al.*, (1996), Chirwa (2007), Amos (2007), Nyagaka *et al.*, (2010), found that farmers who had spent more years in school tended to be more efficient than their counterparts who have spent few years. Therefore, we expect the negative sign for those farmers who have not been in school or just spent a few years in school and a positive sign on the coefficients for farmers who had spent more years in school.

Household size can influence the efficiency of the farm in the positive or negative sense. Large family size can negatively affect the technical or allocative efficiencies since

larger households might utilize family labour beyond the point where the marginal value product of labour is equal to the wage rate (Boris *et al.*, 1997).

Access to extension service is also a precursor for improving efficiency because it is assumed that the more a farmer interacts with the extension officers the more efficient that farmer would be. FARA 2006; Gerdin 2002; Uaiene and Channing 2008; Nyagaka *et al.*, (2010); and Mohammad 2009 found the extension service variable to have a positive coefficient in relation to technical efficiency. This implied that technical efficiency increases with the number of visits made to the farm household by extension officers. Extension officers play a central role in informing, motivating and educating farmers about available technologies. Owens *et al.*, (2001) explored the impact of agricultural extension on farm production and determined that access to agricultural extension services raises the value of crop production by 15% in Zambia.

Gender is another important attribute that could influence the efficiency of a farm. This attribute has mixed results, where in some studies it has been found that male headed households have a positive relationship with efficiency (Dzene, 2010). While in other studies, it has been found that male headed households have a negative relationship with technical efficiency, allocative efficiency and economic efficiency (Dolisca *et al.*, 2008; Dhungana *et al.*, 2004; Onyenweaku *et al.*, 2005 and Mochebelele *et al.*, 2000). Where it has a positive relationship, it means that male headed households are likely to be more efficient than their women counterparts. On the other hand, where it has been found to be negatively correlated, it means that female-headed households are more likely to be relatively efficient compared to their male counterparts.

Access to credit can influence the efficiency of farmers positively. Mohammad (2009) found a negative relationship between access to credit and inefficiency in the cotton-wheat system and also in the rice-wheat system. This means that farmers accessing credit were more likely to be less inefficient than those that did not access any credit.

Results on the relationship between farm size and efficiency of the farm have been mixed and have raised a lot of debate among scholars. It has been argued that small farms generally are correlated with a high productivity. Some studies have found negative relationship between farm size and efficiency while in other studies the relationship has been positive. Studies done by Naceur *et al.*, (2009); Amos (2007); and Coelli *et al.*, (1996) from developing countries (Tunisia, Nigeria and India) found farm size to be negatively correlated with efficiency meaning that large farms operated at a higher efficiency levels than small farms. This contradicts the claim which is frequently made for developing country agriculture that smaller farms tend to be more efficient in production than larger farms.

However, Boris *et al.*, (1997); Carter (1984); Pender *et al.*, (2004) found farm size to have a positive and statistically robust relationship between economic efficiency and allocative efficiency which supports the notion that small or medium size farms have efficiency advantage over the relatively larger farms. The explanation to this is that farmers finish farm activities on time in small fields relative to larger fields if similar technology and family size are considered. Some studies have found farm size to have no influence on efficiency. For example, Akinwumi and Djto (1996) found the size of the farm to have no influence on technical and economic efficiency. Reardon *et al.*, (1997) found mixed results where there was a positive influence of small farms for some crops and positive significance with large farms.

Fertilizer application has an impact in influencing efficiency of a farmer. Tschirley *et al.*, (2009) explained that the declining yields in cotton for some West African countries were partly explained by the declining fertilizer use. A study by Chirwa *et al.*, 2007 found that application of fertilizers did not explain the variations in technical inefficiency. This implied that most of the farmers did not use the technology properly.

Asset ownership is likely to impact positively on the yield. For example, draught animals enable farmers to cultivate a relatively larger area than the farmers that do not use animal traction and it also enables farmers to finish land preparations earlier than

their counterparts that may not own such assets. Reardon *et al.*, (1997) found animal traction to positively impact on labour and land productivity of Sub Sahara African countries.

Geographical location variable is normally included in the model to take control of the differences in the quality of soils, amount of rainfall received across provinces or districts or villages. Brazdik (2006) found that farms that were located at the centre of West Java Island with an altitude of 375 meters above sea level had a significant positive influence on efficiency of rice farms compared to farms that were located along the coastal lines or in the central areas of the Island where the altitude was between 600 – 1000 meters above sea level.

Influence of hybrid varieties on efficiency could not be emphasized. Chirwa (2007), Brazdik (2006) found that hybrid varieties had a positive influence on the efficiency in production of maize in Malawi and rice in West Java respectively. Influence could also be found within the types of hybrid seeds (Nchare 2007).

In summary, the previous studies of efficiency have used what is called two stage approaches in determining efficiency using either a parametric or nonparametric method and in determining factors influencing efficiency by using either Tobit or Ordinary Least Squares (OLS) regression. In determining factors affecting efficiency studies in cotton production the studies have focused more on socio-economic factors leaving out farm specific factors. Given the review of previous studies, this study will use the same approach but go further and incorporate the farm specific factors in the regression.

## **CHAPTER 3**

### **DATA SOURCES AND METHODS**

#### **3.1 Data Sources**

The chapter describes the different data sources that were used in this study and it also highlights models that were used in estimating efficiency indices and factors affecting efficiency in cotton production.

The data used in this study were obtained from a nationally representative farm household supplemental survey to the Post Harvest Survey (PHS) of 1999/2000 which was conducted in Zambia in 2008. This was conducted by the Central Statistics Office (CSO) in conjunction with the Ministry of Agriculture and Cooperatives (MACO) and the Food Security Research Project (FSRP). The supplemental survey was based on the new sampling frame recommended by Megill (2004). The past PHSs were based on the Census Supervisory Areas (CSAs) and Standard Enumeration Areas (SEAs) defined for the 1990 Zambia Census for Population and Housing. However, changes in the population distribution during the last decade rendered the 1990 sampling frame for the PHS less efficient. With availability of data from the 2000 Zambia Census of Population and Housing, it was possible to develop a more effective sampling frame for the PHS. The 2000 census questionnaire included a question on whether the household engaged in agricultural activities (crop growing, livestock and poultry raising, and fish farming), as well as check items to identify the specific crops grown and animal raised by the household. These data were helpful for developing an updated sampling frame and more efficient sample design for the PHS and the supplemental of 2008. The SEA is the smallest area with well defined boundaries identified on census sketch maps. For the 2008 supplement survey, a stratified two-stage sample design was used. The primary sampling units were defined as SEAs with a minimum of 30 agricultural households. At the second stage, a listing of households was used to stratify the households by farm size, number of livestock and the growing of 44 special crops within each sample SEA. Unlike the previous sampling frame which had two categories of households, the new sampling frame was increased to three categories. This was because Category A (0 to

4.99 hectares) was subdivided into two groups to have more efficiency. Thus, the categories were as follows: (i) Category A – 0 to 1.99 hectares; (ii) Category B – 2.00 to 4.99 hectares; (iii) Category C – 5.00 to 19.99 hectares. In order to simplify the selection and estimation procedures for the livestock and crop stratification at the second sampling stage, the stratification was integrated with Categories A, B and C based on farm size. The Category C households were generally included in the sample with certainty (up to 10 households), and the Category B households were selected with a higher probability than the Category A households. During the listing operation, it was necessary to collect information on farm size as well as the number of livestock and poultry, and the presence of particular targeted crops. Hence the new sampling design enabled the CSO to improve the efficiency of the allocation of sample households within each sample SEA.

The 2008 supplemental survey sampling methodology selected 20 households per sample SEA. From 407 SEAs sampled for the survey, the total number of households that were sampled came to 8094. The total number of households represented by the survey, properly weighted, was approximately 1,669,861 households. The sampling weights or expansion factors used in this study represent the basic weight for each sample household which is equal to the inverse of its probability of selection (calculated by multiplying the probabilities at each sampling stage). In this study, the weights used were representative of smallholder cotton producers in Zambia.

For the purpose of this study, the sample for data analysis included cotton producing households from Central, Eastern and Southern Provinces where most of cotton growing households are found (Haggblade, Kabwe and Plerhoples, 2010). The sample size was 812 cotton households and when weights were applied the population of cotton producing households was 150,801 representing 10 percent of the agricultural households in Zambia. This was the sample on which the analysis was based.

The other data that was used in the analysis was the price of seed cotton, cost of labour per adult equivalent and cost of land per hectare. The average price of planting seed per

kg was ZMK1,500 and was obtained from the ginning companies. The average cost of labour per adult equivalent was an opportunity cost of family labour and cost of labour of ZMK5,000 and was based on the study by Tschirley and Kabwe (2007). The average cost of land per hectare was ZMK135,000 obtained from the survey data.

### **3.2 Methods**

This study used what McDonald (2008); Hoff (2006); Banker *et al.*, 2008; Fletschner *et al.*, 2002; and Bravo-Ureta *et al.*, 1994 call a “two-step procedure.” The first step consists of measuring efficiency levels and answers the second objective. Then the second step where relationships between socio-economic, farm specific factors and efficiency are determined is carried out using a variety number of models such as one-limit or two-limit Tobit models, Ordinary Least Squares (OLS) regression, Maximum Likely Estimator (MLE) models. However, the use of each of these models depends on how the efficiency scores were generated. When efficiency scores are generated by censoring process, the most suitable model to use is the Tobit as highlighted by McDonald 2008; Bankers *et al.*, 2008 and Hoff 2006. However, if efficiency scores are fractional data like ones generated using the Data Envelopment Analysis (DEA), Ordinary Least Squares (OLS) and Maximum Likely Estimator (MLE) are most suitable models to use in the second stage since they are consistent estimators (McDonald 2008). Since efficiency scores for cotton farmers in this study were generated as fractional data using DEA, OLS was employed in the second stage. The procedure is further explained below.

#### **3.2.1 The Variable Returns to Scale DEA Model (First Step Approach)**

A non-parametric method Data Envelopment Analysis is used to determine the efficiency of the decision making units (DMUs) in this case the cotton farm. In this process DEA approach identifies DMUs based on the technical and allocative efficiencies. According to Fletschner *et al.*, (2002) and Banker *et al.*, (2004), technical efficiency for production unit  $h$  ( $TE^h$ ) is found by comparing unit  $h$  with a combinations



of all other production units and establishing the minimum proportion of inputs that would allow unit  $h$  to produce the level of output actually being produced by  $h$ . Technical efficiency coefficients can either be maximized or minimized. Depending on whether a maximized or minimized method is used, the level of efficiency scores that would be generated would be the same. When the minimization method is used it is possible to aggregate the constraint and replace the objective function with one minimizing the sum of technical efficiency coefficients. The mathematical linear programming used to determine each household/farm technical efficiency measure is given as:

$$\min_{\lambda_t^h, TE^h} \sum_{h=1}^z TE^h \quad (1)$$

$$\text{s.t: } \sum_{h=1}^z \lambda_t^h y_s^t \geq y_s^h \quad \text{for } s = 1, \dots, m; h = 1, \dots, z, \quad (2)$$

$$\sum_{h=1}^z \lambda_t^h x_g^i \leq TE x_g^h \quad \text{for } g = 1, \dots, n; h = 1, \dots, z, \quad (3)$$

$$\sum_{h=1}^z \lambda_t^h = 1 \quad \text{for } h=1, \dots, z, \quad (4)$$

$$\lambda_t^h \geq 0, \quad \text{for } t = 1, \dots, z; h = 1, \dots, z, \quad (5)$$

$$TE^h \geq 0 \quad \text{for } h = 1, \dots, z, \quad (6)$$

Source: Fletschner *et al.* 2002, Fried *et al.* 2008

Based on each individual equation above and where there are  $m$  outputs and  $n$  inputs,  $y_s^h$  is the  $s^{th}$  output of unit  $h$ , and  $x_g^h$  is the  $g^{th}$  input of unit  $h$ . The combination of units against which unit  $h$  is compared is given by the vector  $\lambda^h$ , where each element of vector  $\lambda^h = (\lambda_1^h, \dots, \lambda_h^h, \dots, \lambda_z^h)$  is the weight of each of the  $z$  units in the combination. In other words,  $\lambda^h$  is a  $(h \times 1)$  vector of weights attached to each of the cotton farm (DMUs). The weighted outputs and inputs of these units against which unit  $h$  is compared are given by  $\sum_{t=1}^z \lambda_t^h y_s^t$  and  $\sum_{t=1}^z \lambda_t^h x_g^t$ , respectively, where  $y_s^t$  denotes the production of output

$s$  for each of the  $t=1, \dots, z$  units, and  $x_g^t$  denotes the endowments of inputs  $g$  for each of the  $t=1, \dots, z$  units. The first set of constraints requires that the weighted average of the output of all cotton farm (DMUs) ( $\sum_{t=1} \lambda_t^h y_s^t$ ), less the output of the  $h^{th}$  cotton farm be greater than or equal to zero. This means that, the output of each cotton farm produced by the combination of production units has to be at least  $h$ 's output units. Similarly, the second group of constraint requires that combining production units in the same manner, the inputs used do not exceed unit  $h$ 's level of inputs. The third constraint ( $\sum_{t=1} \lambda_t^h = 1$ ) ensures that an inefficient cotton farm is only benchmarked against cotton farms of similar size, that is, the projected point (for that DMU) on the DEA frontier is a convex combination of observed DMUs. What makes the difference between the constant returns to scale (CRS) and the variable returns to scale (VRS) is the imposition of the third constraint (convexity restriction). The convexity restriction is not imposed in the CRS case. As Coelli *et al.*, (1998) observed in the CRS case, a firm may be benchmarked against firms which could be substantially smaller or bigger than it.

In the case of agriculture, increased amounts of inputs do not proportionally increase the amount of outputs. For example, when the amount of chemical or labour units applied to the cotton crop is increased, a linearly proportional increase in crop volume is not necessarily obtained. This is the one reason why the variable returns to scale option was more appropriate for this study. Coelli *et al.*, (1998) also adds that estimating technical efficiency using constant returns to scale (CRS) is only appropriate when all firms/farms are operating at an optimal scale, which in reality is not likely due to factors like financial constraints and asymmetric information. Such estimations results in measures of technical efficiency confounded by scale inefficiencies. However, the variable returns to scale (VRS) specification permits technical efficiency measures devoid of scale inefficiencies.

Apart from the technical efficiency, there are other measures of efficiency. One of them is the allocative efficiency measure which indicates the extent to which a production unit minimizes the costs of producing a given output vector given the input prices it faces.

Therefore, to calculate the allocative efficiency index, it is necessary to find the minimum cost, given input prices, output levels, and technology. As the case of the technical efficiency measures, the  $z$  individual linear programs used to calculate the minimum costs for each of the  $z$  households are combined into a single computationally efficient linear program as shown below:

$$\min_{x^*, \lambda^h} \sum_{h=1}^z w^h x^{*h} \quad (7)$$

$$\text{s.t: } \sum_{t=1}^z \lambda_t^h y_s^t \geq y_s^h \quad \text{for } s = 1, \dots, m; h = 1, \dots, z, \quad (8)$$

$$\sum_{t=1}^z \lambda_t^h x_g^t \leq x_g^{*h} \quad \text{for } g = 1, \dots, n; h = 1, \dots, z, \quad (9)$$

$$\sum_{t=1}^z \lambda_t^h = 1 \quad \text{for } h=1, \dots, z, \quad (10)$$

$$\lambda_t^h \geq 0, \quad \text{for } h = 1, \dots, z; t = 1, \dots, z, \quad (11)$$

Source: Fletschner *et al.* 2002, Fried *et al.* 2008

where  $w^h$  is an  $n$ -vector of inputs prices,  $x^{*h}$  is the least-cost input combination for household  $h$ , and  $w^h x^{*h}$  is the sum of the minimum cost that would allow household  $h$  to produce the same output level given the available technology. Having obtained the minimum cost for each of the  $z$  households, the allocative efficiency measure for the household  $h$  ( $AE^h$ ) is given by the ratio of the minimum or optimal cost and the farm  $h$ 's observed costs if they had been technically efficient as indicated in equation 12 below:

$$AE^h = \frac{w^h x^h}{w^h x^*} \quad (12)$$

where  $w^h x^h$  is the optimal cost while  $w^h x^*$  is the observed or actual cost for producing the product for farm  $h$ .

After the technical and allocative efficiency measures, there is the Economic Efficiency (EE) measure. Economic efficiency (EE) measure is determined by the product of technical efficiency (TE) and allocative efficiency (AE). The values of Economic Efficiency also lie from 0 to 1 as well.

### **3.2.2 Second Stage using the Ordinary Least Squares (OLS)**

After calculating the efficiency measures, the next step is to express the efficiency indices as the function of socio-economic and farm specific factors. This is known as the second stage procedure. It has been used by several researchers in determining the factors affecting efficiency (Hoff, 2006; McDonald, 2008; Banker *et al.*, 2008; Chavas *et al.*, 2005; Binam *et al.*, 2003; Mohammad, 2009; Fletschner *et al.*, 2000; Ajibefun, 2008; and Rios *et al.*, 2005). The regression models that could be used in the second stage procedure are the Tobit, Ordinary Least Squares (OLS) and Maximum Likelihood Estimator (MLE). However, McDonald (2008), Hoff (2006) and Banker *et al.*, (2008) reviewed these models using efficiency scores generated by either censoring or generated as fractions and made suggestions under which each one is appropriate. In these separate studies, they concluded that Tobit is suitable to use in the second stage when efficiency scores are generated by data censoring process otherwise it is an inconsistent estimator (Green 2004). However, when efficiency scores are generated by using DEA where efficiency scores are not censored or corner solution data, but are fractional data the most suitable models are Maximum Likelihood Estimator (MLE) or Ordinary Least Squares (OLS).

Based on MacDonald (2008), Hoff (2006), and Banker *et al.*, (2008), this study used Ordinary Least Squares (OLS) in the second stage procedure to determine the socio-economic and farm specific factors that are likely to influence efficiency in smallholder cotton production in Zambia. Ordinary Least Squares model is given as:

$$Y = X\beta + \varepsilon \quad (13)$$

where  $Y$  represents the efficiency scores, and  $X$  represents the socio-economic and farm specific factors that are likely to influence efficiency in cotton production,  $\beta$  represents the coefficients and  $\varepsilon$  is the error term which takes care of unobserved variables. As indicated before, the efficiency scores lie from 0 to 1 and  $Y$  is denoted as:  $0 \leq Y \leq 1$ . With limit point  $Y = 1$  implies that the cotton farm is technically or allocatively or economically efficient. But where  $0 > Y < 1$ , the cotton farm is inefficient.

### 3.2.3 Variables used in the DEA Model

An input oriented DEA model was used in determining the efficiency indices. The variables that were used in the DEA model are output, and three inputs as shown in Table 1 below. The output variable is the quantity of seed cotton produced in kg. The mean production quantity of 838 kg (with a yield rate of 930 kg per hectare) of seed cotton was obtained for smallholder cotton farmers. The inputs used in determining efficiency indices included: size of a cotton field measured in hectares with an average size of 0.95 hectares, quantity of planting cotton seed measured in kg with an average of 20 kg and about 22 kg per hectare. Labour available for the household was measured in terms of adult equivalent. To determine adult equivalent, age and gender of household members were used and this is based on the World Health Organization as highlighted by Jayne and Argwings-Kodhek (1997). The average number of adult equivalent is 5 and about 8 adult equivalents per hectare.

**Table 1: Summary Statistics for the Variables used in DEA**

Variable	N	Min	Max	Mean	Std Dev
Production of seed cotton in kg	150,801	30	45500	838	1898
Area of seed cotton in ha	150,801	.13	20	0.95	1.0
Adult equivalents	150,801	.56	25	5.4	2.5
Qty of seed cotton planted in kg	150,801	3.00	360	20	20

As indicated above, the limitation on the inputs used in DEA analysis was lack of quantity of chemicals (pesticides or insecticides) used in seed cotton production. The

main reason for those variables missing was that the data was not collected in the survey.

### **3.2.4 Variables used in the Econometric Model**

The socio-economic and farm specific factors included in the model were: gender of the household head (female=1, 0 otherwise), age of the household head, education level of the household head, household size, value of productive assets and the net off farm income variables. Then farm specific factors included were: total area cultivated by the household, number of weedings, tillage systems used for land preparation, crop rotation and seed variety dummy variables.

The gender variable could be an important variable in influencing efficiency of cotton production. Our hypothesis was that female headed households are likely to influence technical, allocative and economic efficiency positively because they are known to attend meetings and workshops organized by extension officers relatively more than their male counterparts. Therefore, we expected the sign for gender to be positive in relationship to female household heads.

The age of a household head matters in the way the household head makes farming decisions. Older household heads could be considered as risk averters while younger household heads could be considered as risk takers. The farming decisions that might be taken by household heads with different age could have a different impact on technical, allocative and economic efficiency. In this case, age might serve as a proxy for farming experience. As noted by Mohammad 2009 and Coelli (1996), age of a farmer can be expected to have a positive or a negative relationship with efficiency of the farm. This means that older farmers can be more experienced and efficient in doing their farm operations. It was further highlighted by Mohammad 2009 that it is possible that older farmers may be traditional and conservative and show less willingness to adopt new farming technology and hence could be less efficient. We therefore expected the sign to be either positive or negative.

The education variable could matter in influencing efficiency in smallholder cotton farmers. This was included in the model as a proxy for managerial input. It was hypothesized that higher level of education could lead to better management of farming activities and that may have a positive influence on efficiency. This is because educated farmers are likely to access information easily, and use it to make well informed decisions.

Although large household sizes increase the labour availability, it also increases the managerial costs (Benham and Benham, 2001) involved with making decisions. In cases where labour is not a limiting factor of production, it also means that the household may not fully exploit the available labour where as they have to provide food to feed these members. In this study, we use adult equivalent as a source of labour instead of just using household size as that could give inaccurate indicator of labour availability. The expected sign/s on the coefficients of TE, AE, and EE is either positive or negative.

Tillage systems used by farmers could either be conservation farming tillage systems or conventional tillage systems. These have a bearing in influencing efficiency at the farm. In this study, the conservation tillage systems included planting basins, ripping and zero tillage. While the conventional tillage systems were ploughing, hand hoe, ridges and bunding. The expected sign of conservation farming tillage systems on efficiency of a cotton farmer was envisioned to be a positive one while the expected sign of conventional tillage systems on efficiency was envisioned to be negative one.

Seed varieties are also important factors in determining the efficiency of a cotton farmer as highlighted by (Nchare 2007). The varieties included in this study were: *Chureza*, F135, *Ngwezi* and *CDTII*. Based on the performance of these varieties, we expect *chureza* to have a positive sign relative to other varieties.

Productive assets in this study included oxen and farm equipment such as ox-cart, rippers, plough and hand hoes. The variable of productive assets was captured as the

value of all the productive assets and was divided by 1,000,000 to rescale the values so that results were not presented in scientific notation. It was hypothesized that an increase in the number of productive assets would improve efficiency of a cotton farmer. We therefore expected the sign of productive asset to positively influence efficiency of cotton farmers.

Off-farm activity variable is also important in influencing efficiency of farmers. In this study, it was captured as a net off-farm income and was also divided by 1,000,000 to scale it so that results were not presented in scientific notation. It was hypothesized that when farmers are involved in a lot of off-farm activities, labour contributions to on-farm operations is negatively affected and that would also affect efficiency negatively. However, if farmers are reinvesting the income from off-farm activities, that could have a positive influence on efficiency. Therefore, the expected sign of off-farm activities to efficiency could either be positive or negatively depending on how the farmer is using the income generated from off-farm activities.

### **3.3.0 Statistical Tests**

Since Ordinary Least Squares (OLS) was used to determine the statistical estimates, some statistical tests were determined to ascertain whether some OLS assumptions were violated or OLS was BLUE. Among the tests done were heteroskedasticity and multicollinearity.

Heteroskedasticity is a violation of one of the requirement of ordinary least squares (OLS) in which errors variance is not constant (Wooldridge, 2004; Green, 2002; Gujarati, 2004; Maddala, 2002). The consequences of heteroskedasticity are that the estimated coefficients are unbiased but inefficient. The variances are either too small or too large, leading to Type I or II errors under heteroskedasticity hence OLS is not BLUE (Best Linear Unbiased Estimator). Some of the main causes of heteroskedasticity are 1) variance of dependent variables increase in the level of dependent variable. 2) Variance of dependent increases or decreases with changes in dependent variables, 3) Outliers, 4)



Trends in learning or uncertainty and 5) Specification bias (missing variables or incorrect functional form. Heteroskedasticity is mainly common in cross-sectional data set such as the one used in this data.

Using the Breusch-Pagan-Godfrey test, we tested for heteroskedasticity in the technical, allocative and economic efficiency models. The null hypothesis of homoskedasticity was rejected in all the three models at 5%, 1% and 1% significance levels. The implication of these results was that there was a problem of heteroskedasticity in the data. However, the problem was corrected by using the *robust* options in stata 11 to adjust for standard errors (Baum, 2006).

The test for multicollinearity was done using *vif* option. All runs of efficiency categories against the hypothesized covariates yielded *vif* values below 10. The implication of these results confirmed that there was no problem of multicollinearity between any two or more covariates used in the estimates.

### **3.4 Limitations encountered**

Analysis of efficiency requires that the input data applied in each field is documented well so that it could be captured during the efficiency determination. Considering that the data used was from a survey that was not designed for an efficiency analysis, some variables were missing. One notable variable missing was one that captures the quantity of chemicals applied in the cotton fields during the production period.

Despite the above limitation, the research was still adequate and efficient enough to bring out unbiased and required information for policy recommendations in cotton production in Zambia.

**CHAPTER 4**  
**RESULTS AND DISCUSSION**

**4.1 Descriptive Statistics of Cotton Households**

**Table 2: Socio-economic and Farm Level Characteristics of Cotton Households**

<b>Variables</b>	<b>Min</b>	<b>Max</b>	<b>Mean</b>	<b>Std Dev</b>
<b>Socio-economic factors</b>				
Gender (female=1, 0 otherwise)	0	1	0.14	0.33
Mean age of Female head	16	80	54	12.13
Mean age of Male head	20	92	46	14.03
Mean age of Household head	16	92	47	14
Head's Education level	0	18	5.0	3.33
Mean # of prime adults	1	17	3	1.71
Value of Productive Assets in ZMK (000,000)	0.0	132	6.00	11.89
Net off Farm Income in ZMK (000,000)	0	62	1.32	4.56
<b>Farm level factors</b>				
Land Holding Size (ha)	0.38	29.97	4.09	3.84
Number of Weedings	0	7.00	3	0.89
Leaving crop residues	0	1	0.46	0.50
Crop rotation	0	1	0.65	0.48
Conservation framing tillage system <sup>1</sup>	0	1.00	0.06	0.23
Conventional tillage system (Handhoe)	0	1.00	0.15	0.49
Conventional tillage system (Ploughing)	0	1.00	0.41	0.37
Conventional tillage system (Ridges)	0	1.00	0.38	0.49
Planting seed - F135	0	1	0.16	0.38
Planting seed – Chureza	0	1	0.75	0.44
Planting seed – Ngwezi	0	1	0.02	0.13
Planting seed - CDT II	0	1	0.07	0.25
Central Province (Hhs growing seed cotton)	0	1	0.12	0.32
Eastern Province (Hhs growing cotton)	0	1	0.75	0.44
Southern Province (Hhs growing seed cotton)	0	1	0.13	0.35
Sample observations	812	812	812	812
Population estimates	150801	150801	150801	150801

Table 2 shows the descriptive statistics of cotton households. Results show that 14 percent of households were female headed households. This is consistent with other studies which show that there are fewer female headed households than male headed

<sup>1</sup> Conservation farming tillage systems include planting basins, ripping and zero tillage.

households participating in the agricultural related activities (Dhungan *et al.*, 2004, Rahman *et al.*, 2009)

The age of the head of the household is considered a crucial factor in efficiency determination, since it determines whether the household benefits from the experience of an older person, or based the decisions on the risk-taking attitude of a younger farmer in cotton production. The mean age of the male household heads was 46 years while female household heads was 54 years. The age for the youngest and oldest household heads were 16 and 92 years respectively. However, the overall mean age of the sample was 47 years. This shows that the household heads who produce cotton are relatively middle aged ones.

Another attribute of importance is the level of education attained by the head of the household, who are normally the decision-makers. This variable was measured as the number of years spent in school. The mean number of years spent in school was 5 years with a minimum number of 0 years and maximum number of 18 years. For 0 it means some household heads did not attain any former school while for the value 18 it means some household heads reached tertiary schooling. However, considering the mean, it means that the majority of household heads who grew cotton in Zambia spent relatively few years in school.

There are four varieties (F135, *Chureza*, *Ngwezi*, CDT II) of seed cotton that were planted by smallholder cotton farmers in Zambia. Seventy five percent of smallholder cotton farmers used *Chureza* cotton seed, followed by F135 at sixteen percent, then CDT II at seven percent and the least was *Ngwezi* seed at two percent.

Tillage systems used for land preparation by farmers are conservation and conventional tillage systems. In this study conservation tillage systems included planting basins, ripping and zero tillage. Since there were few cases of planting basins, ripping and zero tillage, they were all aggregated into conservation tillage (CF). While conventional tillage systems included ploughing, hand hoe, bunds or ridges. Among all the tillage

systems used, ploughing was the mostly widely used tillage system at 41 percent followed by ridges at 38 percent, then, handhoe was at 15 percent and conservation tillage system (planting basins, ripping, zero tillage) at 6 percent.

As indicated earlier, the components of value of productive assets included the value of animals and equipment assets. While the value of off-farm income included total income from work, total in-kind income, net income from business activities and net income from remittances. The average values of productive assets and net off-farm income were found to be ZMK 6.0 million and ZMK 1.32 million with standard deviations of 11.89 and 4.56 respectively.

For the detailed household characteristics by province see appendix 1 at the end of the report.

#### 4.2 Summary Statistics of Technical, Allocative and Economic Efficiency level

**Table 3: Summary Statistics of TE, AE, and EE levels by Province**

	Statistic	Central	Eastern	Southern	Overall
Technical Efficiency	Mean	0.41	0.53	0.44	0.46
	Min	0.14	0.09	0.10	0.09
	Max	1.00	1.00	1.00	1.00
	Std dev	0.18	0.19	0.20	0.19
Allocative Efficiency	Mean	0.33	0.43	0.34	0.37
	Min	0.08	0.07	0.07	0.07
	Max	0.99	1.00	0.87	1.00
	Std dev	0.18	0.16	0.17	0.17
Economic Efficiency	Mean	0.17	0.26	0.18	0.20
	Min	0.01	0.01	0.01	0.01
	Max	0.99	1.00	0.87	1.00
	Std dev	0.19	0.19	0.18	0.19

Table 3 gives the summary statistics for technical, allocative and economic efficiency scores of cotton farmers by province. In terms of performance, the statistics show that

cotton farmers of Eastern Province had relatively higher technical, allocative and economic efficiency scores than their counterparts from Central and Southern Provinces. The overall mean of technical efficiency scores of cotton farmers varied from 0.09 to 1 with a mean of 0.46. While the overall mean of allocative efficiency scores of cotton farmers varied from 0.07 to 1 with a mean of 0.37. While the overall mean of economic efficiency scores of cotton farmers varied from 0.01 to 1 with a mean of 0.20.

From these summary statistics, it suggests that there were relatively technical, allocative and economic inefficiencies among the cotton farmers in Zambia. The technical efficiency score of 0.46 shows that cotton farmers could reduce their input use by about 54% without reducing output but by improving on the current levels of technical efficiency. While the allocative efficiency score of 0.37 suggests that cotton farmers could reduce the cost of producing cotton by 63% without reducing the level of output but, by improving on the current levels of allocative efficiency. The result on technical efficiency of 0.46 from this study is below the average technical efficiency of 58% and 60% in cotton for other developing countries such as Paraguay (Bravo-Ureta *et al.*, 2007) and Cameroon (Ngassam *et al.*, 2010) respectively. So there is room of improvement for both technical and allocative efficiency scores even with the current technology available.

Figure 5 represents the cumulative percentages graphs of technical, allocative and economic efficiency scores. It is clearly shown that the efficiency score range of 0.1 to 0.49 had the highest number of cotton farmers at 90% who were relatively less economically efficient compared to the relatively high economically efficient cotton farmer who only accounted for 10 percent.

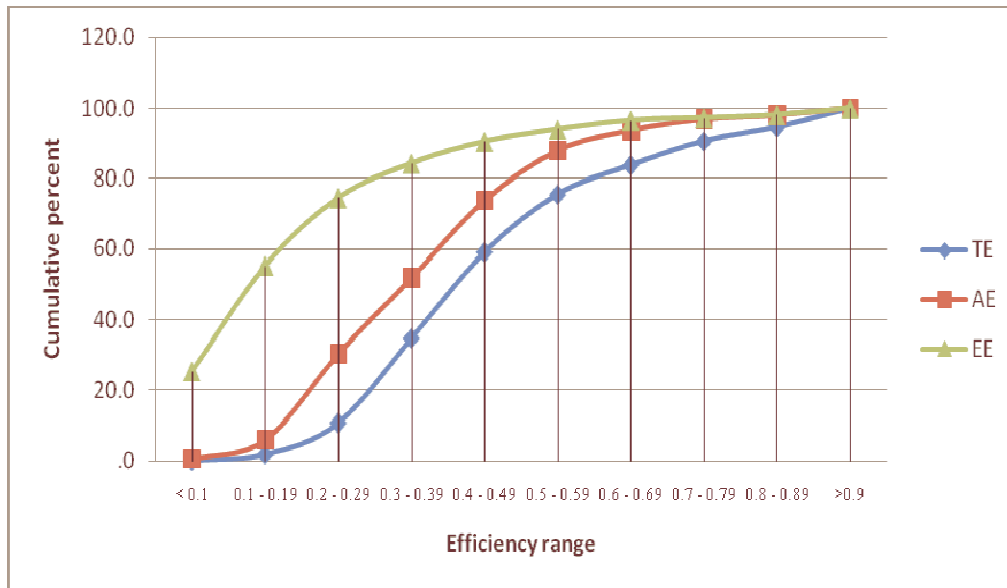


Figure 5: Cumulative Percent for TE, AE and EE

In terms of technical efficiency, the efficiency range of 0.1- 0.49 accounted for 60% of cotton farmers who were less technically efficient as compared to the relatively technically efficient cotton farmers in the efficiency range of 0.9 or more who only accounted for 5 percent. While in terms of allocative efficiency, the efficiency range of 0.1 – 0.49 had about 74% of cotton farmers who were less allocatively efficient as compared to relatively allocative efficient cotton farmers who were in the efficiency range of 0.9 or more and accounted for 2 percent. The average technical, allocative and economic efficiency scores of cotton farmers were 0.46, 0.37 and 0.20 respectively. Based on this analysis, it is most likely that the majority of cotton farmers in the efficiency range of 0.1to 0.49 do not use the inputs efficiently or could be other factors that might be influencing their efficiency hence found in the lower bracket of efficiency levels.

#### 4.2.1 Estimated Potential Yield by Province

The potential yield based on the conditions of technology used and the inputs used by the farmer is calculated using equation 14 for all the cotton farmers and the results are presented by province and are shown in Table 4.

**Potential yield =actual yield/technical efficiency**

**(14)**

Central Province cotton producers have an actual average yield of 842 kg per hectare. If cotton farmers were to improve their technical efficiency by 59% based on the inputs used in this analysis, they could obtain potential yields of over 2,054 kg per hectare of seed cotton. This is relatively higher than current yields ranging 550-800 kg per hectare obtained by cotton farmers.

**Table 4: Mean Yield and Potential Yield of Seed Cotton by Province**

<b>Efficiency Range</b>	<b>% of Cotton Farmers</b>	<b>Technical Efficiency</b>	<b>Actual Yield</b>	<b>Potential Yield</b>
	<b>Percent</b>	<b>Proportion</b>	<b>-----kg/ha-----</b>	
Central	11.9	.41	842	2054
Eastern	76.4	.53	978	1845
Southern	11.7	.44	877	1993

Table 4 also shows that Eastern Province had the largest number of cotton farmers among the three provinces. The average yield of seed cotton in the province was about 978 kg per hectare. If these farmers were to improve technical efficiency by 47%, their yield per hectare would rise to about 1,845 kg per hectare.

Southern Province had almost the same number of cotton farmers as Central Province but performed relatively better in terms of technical efficiency than Central by about 3%. The actual average yield for Southern Province was 877 kg per hectare. If the cotton farmers of Southern Province were to improve efficiency by 56%, their average yield would rise to about 1,993 kg per hectare. Therefore, improving technical efficiency of cotton farmers could enable them improve yield to about 2 tons and this could lower the cost of production.

#### 4.2.2 Estimated Potential Cost of Production by Province

Table 5 shows the potential cost of producing seed cotton for all the cotton farmers by province and is calculated using equation 15.

$$\text{Cost of producing cotton per ha} = (\text{Actual cost/ha}) * (1 - \text{Av. Alloc eff}) \quad (15)$$

**Table 5: Average Cost and Potential Cost of Seed Cotton Production by Province**

Efficiency Range	% of Cotton Farmers	Allocative Efficiency	Actual Cost	Potential Cost
	Percent	Proportion	-----ZMK/ha-----	
Central	11.9	0.33	270,159	181,007
Eastern	76.4	0.43	184,166	104,974
Southern	11.7	0.34	264,097	174,304

The average cost of producing seed cotton based on the cost of the inputs used in determining allocative efficiency for Central Province was ZMK 270,159 per hectare. If the farmers were to improve their allocative efficiency holding other factors constant, their cost of producing seed cotton would reduce by about 67% from ZMK270,159 to about ZMK181,000 per hectare in Central Province. While Cotton farmers from Eastern Province performed relatively better in terms of allocative efficiency and actual production costs than their counterparts from Central and Southern Provinces. Their average allocative efficiency was 43% and this meant that the farmers had the potential to reduce cost by 57% from ZMK184,000 to about ZMK105,000 per hectare. While Southern Province had the potential to reduce the cost of producing seed cotton by 66% from ZMK264,000 to ZMK174,000 per hectare.

The probable reason for high cost could be the intensity use of the inputs by the cotton farmers the cost aspects associated to these inputs. Therefore, improving allocative efficiency of cotton farmers in Zambia would help them improve the profitability of



their cotton enterprises because improved allocative efficiency reduces the cost of producing seed cotton as illustrated in table 5 above.

### 4.2.3 Input Use and Technical Efficiency

Input use varied across the categories of technical efficiency. Results from Table 6 shows that the quantity of cotton seed planted per hectare by cotton farmers from the lowest efficiency category was half that of the farmers from the highest efficiency category. The recommended seed rate is about 15-20 kg per hectare. This means that farmers from the highest efficiency category planted more seed than the recommended rate. The main reason for high seed rate could be that the extra quantity of seed could have been used for gap filling or farmers just plant more than one seed per station.

Another revealing point on input use and technical efficiency was the labour availability in terms of adult equivalency. It is evident that in low efficiency categories, cotton farmers used low number of adult equivalent per hectare, about 3 for the lowest. However, farmers in the high efficient category used more adult equivalency number and they also had the highest quantity of seed cotton produced per hectare.

**Table 6: Input Uses and Technical Efficiency**

Efficiency range	Yield of Seed Cotton	Qty of Cotton Seed planted	Size of Cotton Field	Adult Equivalents
	-----kg per ha-----			Number per ha
0 - 0.1	120.54	16.87	4.03	3.39
0.1 - 0.19	246.23	17.57	3.00	3.53
0.2 - 0.29	434.36	19.92	1.60	5.29
0.3 - 0.39	537.46	20.69	1.12	6.23
0.4 - 0.49	811.40	23.04	0.80	8.70
0.5 - 0.59	1104.04	24.68	0.73	8.55
0.6 - 0.69	1231.61	28.00	0.50	9.87
0.7 - 0.79	1588.05	26.79	0.53	11.15
0.8 - 0.89	1753.02	26.48	0.81	13.82
0.9-1.00	2197.31	31.55	1.03	14.57

Table 7 shows the efficiency levels by gender of the household head. The results show clearly that, female headed households performed relatively better than their male headed counterparts among all the three efficiency categories viz technical, allocative and economic efficiency. The effect of this variable on efficiency would be explained in the next section where multivariate results are presented.

**Table 7: Efficiency Levels by Gender of the Household head**

	Female				Male			
	Mean	Min	Max	Std dev	Mean	Min	Max	Std dev
Technical Efficiency	0.56	0.17	1.00	0.18	0.49	0.09	1.00	0.19
Allocative Efficiency	0.45	0.09	0.97	0.15	0.40	0.07	1.00	0.17
Economic Efficiency	0.27	0.02	0.97	0.18	0.23	0.01	1.00	0.19

Another important variable that might influence efficiency of a farmer is the size of land cultivated. It was hypothesized that farmers who had small cultivated areas could have a high level of efficiency. Results from Table 8 show efficiency levels by the size of cultivated area. Descriptively, households with cultivated area of 2.5 hectares or less had a relatively higher efficiency level for all the efficiency categories than those households with cultivated area of more than 2.5 hectares. The probable reason for this could be that when the cultivated area is relatively large, management of the fields is somehow compromised as farmers do not pay much attention to field operations.

**Table 8: Efficiency Level by Size of the Cultivated Area**

	less than or equal to 2.5ha				Greater than 2.5ha			
	Mean	Min	Max	Std dev	Mean	Min	Max	Std dev
Technical Efficiency	0.54	0.24	1.00	0.18	0.42	0.09	1.00	0.19
Allocative Efficiency	0.45	0.18	0.99	0.16	0.33	0.07	1.00	0.17
Economic Efficiency	0.27	0.05	0.99	0.19	0.17	0.01	1.00	0.18

Education is an important factor that could influence efficiency levels. It was hypothesized that household heads who spent relatively more years in formal school would be more efficient than their counterparts who spent less years in formal school. This is because educated members perceive things differently from their counterparts who may be relatively less educated. For example in terms of accepting new technologies, relatively educated households would accept the technology without difficulties. Results from Table 9 show that efficiency levels of household heads who reached grade 8 and above and those who reached grade 7 and below was almost the same. However, the household with heads who reached grade 7 or below had a slightly higher efficiency level in all the three efficiency categories though the differences are marginal. The main reason for this could be that a lot of household heads had only attained relatively lower grades in formal school averaging 5 years hence no major difference in terms of efficiency.

**Table 9: Efficiency Levels by Educational level attained by the Household head**

	Grade 7 and below				Grade 8 and above			
	Mean	Min	Max	Std dev	Mean	Min	Max	Std dev
Technical Efficiency	0.51	0.09	1.00	0.19	0.49	0.14	1.00	0.19
Allocative Efficiency	0.42	0.07	0.99	0.17	0.39	0.08	1.00	0.17
Economic Efficiency	0.24	0.01	0.99	0.19	0.22	0.01	1.00	0.19

### 4.3 Factors affecting Technical and Allocative Efficiencies in Cotton Production

Although the assessment of the degree of efficiency is important, one cannot count on it for policy recommendation. However, it is necessary to identify the factors that influence technical, allocative and economic efficiency among cotton farmers. Using Ordinary Least Squares (OLS) the factors affecting the efficiency were determined and

Table 10 presents results of the three regression models of technical, allocative and economic efficiency.

**Table 10: Determinants of Technical, Allocative and Economic Efficiency**

VARIABLES	Technical Efficiency	Allocative Efficiency	Economic Efficiency
Constant	0.489*** (0.0529)	0.395*** (0.0468)	0.232*** (0.0511)
Gender (female=1, 0 otherwise)	0.0373* (0.0200)	0.0188 (0.0178)	0.0223 (0.0203)
Age of the Household head	0.000417 (0.000501)	8.41e-05 (0.000442)	0.000338 (0.000502)
No. of years in Formal school of the head	0.00382* (0.00203)	0.00175 (0.00176)	0.00248 (0.00188)
Number of prime age Adults (15 – 59 yrs)	-0.0199*** (0.00490)	-0.0104*** (0.00387)	-0.0159*** (0.00442)
Area of Cultivated Land	-0.0171*** (0.00552)	-0.0188*** (0.00572)	-0.0130** (0.00589)
Number of Weeding	-0.00554 (0.00772)	-0.00301 (0.00676)	-0.00301 (0.00751)
Dummy: Ridges=1, 0=CF tillage	-0.0107 (0.0307)	0.00462 (0.0276)	-0.00826 (0.0314)
Dummy: Plough=1, 0=CF tillage	-0.0220 (0.0312)	-0.00324 (0.0284)	-0.0267 (0.0318)
Dummy: Handhoe=1, 0=CF tillage	0.0276 (0.0335)	0.0428 (0.0295)	0.0309 (0.0344)
Dummy: Crop Residues=1, 0 otherwise	0.0339** (0.0144)	0.0295** (0.0127)	0.0328** (0.0143)
Dummy: Crop Rotation=1, 0 otherwise	-0.0362** (0.0155)	-0.0333** (0.0142)	-0.0382** (0.0157)
Dummy: Chureza seed=1, 0=F135	0.0292 (0.0195)	0.0324* (0.0172)	0.0349* (0.0192)
Dummy: Ngwezi seed=1, 0=F135	0.0665 (0.0496)	0.0703 (0.0465)	0.0610 (0.0506)
Dummy: CDT II seed=1, 0=F135	0.0214 (0.0327)	0.0170 (0.0290)	0.0202 (0.0313)
Dummy: Eastern=1, 0=Central	0.0678*** (0.0251)	0.0475* (0.0245)	0.0335 (0.0272)
Dummy: Southern=1, 0=Central	0.0432 (0.0306)	0.0100 (0.0273)	0.0164 (0.0301)
Value of Production Assets (000,000)	0.00246*** (0.000802)	0.00238*** (0.000766)	0.00254*** (0.000839)
Value of net Off farm Income (000,000)	0.00323* (0.00188)	0.00362** (0.00179)	0.00329 (0.00209)
Observations	812	812	812
R-squared	0.149	0.152	0.105

\*\*\*p < 0.001, \*\*p < 0.01, \*p < 0.1

From the models of technical, allocative and economic efficiency the variables that were significant in terms of influencing efficiency are gender (1=female, 0=male), number of years in formal school of the household heads, number of prime adults, area of land cultivated, crop residues (1=yes, 0 otherwise), crop rotation (1=yes, 0 otherwise), planting *chureza* seed (1=yes, 0=F135), provincial dummy variable (Eastern=1, 0 Central), value of productive assets, and off-farm income.

The gender (female=1, 0 otherwise) variable was only significant with the technical efficiency and not significant with allocative and economic efficiency scores. The positive and significant correlation between technical efficiency and female household heads producing cotton indicated that female-headed households could increase technical efficiency by 4% than their male counterparts. This is consistent with findings from other studies such as Dolisca *et al.*, 2008; Onyenweaku *et al.*, 2005; and Mochebelele *et al.*, 2000. The plausible reason for this could be that female household heads are normally members of farmer groups and are likely to attend meetings organized by extension workers of the cotton companies more regularly than their male counterparts. In that regard, they become more knowledgeable and able to accept new techniques of cotton production as they are introduced.

Education of a household head is an important factor that could influence efficiency of a cotton farmer. The regression results show that there was a positive and significant relationship between education of household head and technical efficiency though the impact was small (*p value = 0.003*). The small impact could be as a result of low number of years (mean of 5 years) attained by cotton farmers. While the plausible reason for positive correlation could be that the more number of years a farmer spent in formal school could enable a him/her interpret extension, financial and price information differently and would allow him/her make better technical decisions on one side and help him/her in allocating inputs efficiently and effectively on the other side. Similar results were found by Mohammad, 2009; Islam *et al.*, 2011; Bravo-Ureta *et al.*, 1997; Coelli *et al.*, 1996; Chirwa 2007; Amos 2007; Nyagaka *et al.*, 2010 where they found a

positive and significant relationship between higher number of years spent in school and high level efficiency.

Household size variable is an important variable especially in crops which are labour intensive such as cotton. Since not every household member is important in taking part in agricultural related activities, a number of adult from 15 to 59 years was considered in the model. The results show that the number of adult is negatively correlated with technical, allocative and economic efficiency scores and it is highly significant at 1 percent probability. The result suggests that as the number of prime age adult increases, efficiency of cotton farmers reduces. The plausible reason for this, could be that as the number of prime age adults of the household increases per unit area, diminishing marginal returns set in where the benefits from an additional prime adult member of the household reduces. Similar results were found by Zahindul *et al.*, (2011) when a standard Tobit regression was used. However, other studies such as Dolisca and Jolly (2010), and Mbanasor *et al.*, (2008), found a positive relationship between large family size and efficiency. Their argument was that large household size enhances the availability of labour which may guarantee increased efficiency.

A lot of studies have been done to ascertain the relationship between the farm size and efficiency. Mixed results have been reported where some have shown a negative relationship while others have shown a positive relationship. In this study the variable captured the land cultivated by cotton farmers. Our hypothesis was that as the land cultivated increases, it would reduce the efficiency of cotton farmers. The study found a negative relationship between farm size and all the three efficiency categories support that hypothesis. The results suggested that large cultivated land may encounter more problems in applying farm inputs such as allocating labour to do farm operations at the right time in specific fields. This could result in an inefficient way of using farm inputs. In other words, when a farm is relatively small, a cotton farmer could combine his/her resources better. The results are similar with what Dolisca and Jolly (2010); Aubibert (1997); Mahldi *et al.*, (2009); Brazdik (2006); Okoye *et al.*, (2006); and Tchale (2009) found where farm size was inversely related with efficiency. However, some studies

found a positive correlation between technical efficiency and farm size such as the study by Bravo-Ureta and Pinheiro (1997) though the results were not statistically significant.

Productive assets in this study included oxen and farm equipment such as ox-cart, rippers, plough and hand hoes. It was hypothesized that an increase in the number of productive assets would improve efficiency of a cotton farmer. The variable of productive assets was captured as the value of all the productive assets and was divided by 1,000,000 to rescale the values so that results were not presented in scientific notation. Ownership of productive assets in this study was found to have a positive and significant influence on technical efficiency. The main reason for this could be that, productive assets may enable farmers to do farm activities on time and could eventually improve technical, allocative and economic efficiency. For example, when cotton farmers have animals (oxen and tillage implements), they are more likely to finish land preparation earlier and on time before the onset of rainfall than those who might not have animals. This could result in improved farm productivity. As noted in Haggblade *et al.*, (2010), dry season land preparation enables farmers to overcome peak season labour bottlenecks and allows the farmers to increase area cultivated. They further found that early planting just before the optimal day enables farmers to increase yield by 1-2%. Therefore, farmers with their own productive assets are likely to do farm operations on time and this would enable them to capture those benefits. Bwalya (2007) also found that ownership of productive assets helps farmers reduce transaction costs. Hence having productive assets could also help to reduce production cost.

Off-farm income is another variable that may have an influence on efficiency of cotton farmers. In this study the source of off-farm income included remittances, business activities and income from employment. The effects of this variable on efficiency could be positive or negative. The regression results from this study showed a positive and significant relationship between off-farm income and technical and allocative efficiency. The plausible reason is that off-farm income could enable cotton farmers to hire extra labour to do some farm activities such as land preparation and weeding which are critical in ensuring higher yield and that could improve efficiency of cotton farmers.

Similar results were obtained by Zahindul *et al.*, (2011) where they found a positive relationship between off-farm income and technical efficiency. However, other studies such as Dolisca *et al.*, (2008) and Abdulai and Eberlin (2001) found a negative correlation between technical efficiency and off-farm income. Their explanation was that when farmers are involved in off-farm work, they tend to devote less time to farm activities and it results in higher inefficiency.

Crop residues in the field improve moisture retention and in some cases it improves the fertility of the soil as the crop residues decompose through improved organic matter content in the field. The regression results show that cotton farmers who were leaving crop remains had a positive and significant correlation with technical, allocative and economic efficiency. The probable reason for this result could be that crop residues improve soil fertility and also enhances water retention.

The variety of seed planted is an important variable in improving productivity among smallholder farmers. In Zambia, there are four cotton varieties planted by farmers and these are *Chureza*, F135, *Ngwezi* and CDT II. Holding F135 constant, it was found that *Chureza* significantly performed better than F135 in improving allocative and economic efficiency. While other varieties (*Ngwezi* and *CDT II*) showed a positive correlation but the results were not significant.

A provincial dummy variable was introduced to capture variations in some characteristics such as size of the fields in the provinces. Holding Central Province constant, the results show that Eastern Province had a positive and significant correlation with technical and allocative efficiency. The results of Southern Province were also positively correlated even though the correlation was not significant. The plausible reason why Eastern Province performed relatively better than Central Province is that the farmers had relatively smaller fields (0.81 hectares) than their counterparts in Central province with 1.29 hectares of a field. With smaller fields, cotton farmers in Eastern Province might have combined the resources efficiently.



## CHAPTER 5

### CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 Conclusion

This chapter highlights the main findings and the recommendations of the study.

The mean technical, allocative and economic efficiency scores of 46%, 37% and 20% were determined respectively and they indicate some relative level of inefficiency among cotton farmers of Zambia compared to other studies done on cotton in West Africa and other developing countries. These results indicated that cotton farmers could reduce physical input use and production cost by 54% and 63% respectively without reducing cotton output of farmers but by just improving their level of technical and allocative efficiency.

Efficiency results across the three provinces indicated that Eastern Province performed relatively better than Central and Southern provinces. This could be explained by a relative smaller cotton fields farmers have in Eastern Province compared to their counterparts on Central and Southern provinces. Efficiency is high in smaller fields because as the size of field increases it diminishes the management aspects of a farmer and that enhances inefficiency.

The socio-economic and farm specific factors were evaluated to determine the ones that would influence farm level efficiency in cotton production. Based on the hypothesis that socio-economic and farm specific factors would have a positive influence on efficiency, the study failed to reject that hypothesis. This is because results from OLS regression, showed that female headed households, years in formal school by the household head, crop residues, value of productive assets, access to off-farm income and the use of chureza cotton seed variety showed a significant and positive influence on the farm level efficiency in seed cotton production. From these results, it was concluded that a higher levels of farm level efficiency was associated with female participation in seed cotton

production, involvement of household heads with more years in formal education, leaving crop residues in the field, increased access and ownership of productive asset and increased access to off-farm income by cotton farmers.

## **5.2 Recommendations**

A sustainable cotton industry depends on the profitability of the sector. Profitability is affected by three factors namely, productivity, price paid to the farmers and the cost of production. Productivity is one such factor which a farmer can manipulate and improve while price paid to the farmers mainly depends on the price (Cotlook A index) at international market which a farmer has no control. Therefore, to improve profitability a farmer has to reduce production costs and one avenue to do that is by improving efficiency of cotton farmers.

Based on the empirical results obtained from this study the following are the recommendations:

- 1) Female headed households have been found to have a positive influence on technical efficiency. Therefore, stakeholders should devise strategies that could encourage female participation in cotton production as their participation is likely to positively influence technical efficiency by up to 4 percent.
- 2) The value of productive assets was found to have a positive influence on efficiency of cotton farmers, meaning that an increase in the number of productive assets would improve efficiency. Therefore, stakeholders should have programs that enhance cotton farmers' access to and owning productive assets such as oxen, tillage implements and ox-carts as these have been shown to influence efficiency. Strategies such as the mechanization program implemented by Dunavant working with Conservation Farming Unit where they give oxen, rippers and tractors on credit to some deserving farmers should be encouraged so that many farmers can access and own these productive assets.
- 3) Leaving crop residues in the field was found to positively influence efficiency of cotton farmers. This is a technique under conservation farming that could help

soil conserve moisture and improve soil fertility when the crop residues decompose in the field. Therefore, farmers should be encouraged to practice this technique as it is likely to improve technical and economic efficiency among cotton farmers by about 3 percent.

- 4) Eastern Province positive and significant influence on the efficiency in seed cotton production should be natured and sustained. This can only happen if farmers are trained in farming techniques such as conservation farming.

### **5.3 Further Research**

Since this study used cross-sectional data; it would be interesting to look at technical efficiency, allocative efficiency and economic efficiency using panel data with at least key variables to evaluate how these efficiency categories would change over time. Considering that the input data used in the DEA analysis did not have the quantities of chemicals applied to cotton fields by the farmers since that variable was missing from the survey data, we recommend a further research on efficiency in cotton production of Zambia. That would enable to ascertain whether efficiency levels would vary.

## REFERENCES

- Adesina A. A. and K. K. Djto. 1996. *Farm Size Relative Efficiency and Agrarian Policy in Cote d'Ivoire: Profit Function Analysis of Rice Farms*. Cote d'Ivoire.
- Ajibefun, I. A. 2008. An Evaluation of Parametric and Non-parametric Methods of Technical Efficiency Measurement: Application to Small Scale Crop Production in Nigeria. *J. Agric. Soc.*, 4: 95-100
- Amos T. T. 2007. An Analysis of Productivity and Technical Efficiency of Smallholder Cocoa Farmers in Nigeria. *J. Soc. Sci.*, 15(2): 127-133
- Antonio A. and A. Carlos 2003. Technical Efficiency and Farm Size: a Conditional Analysis. *Agricultural Economics*, Vol 30, (2004), pp 241-250.
- Banker, R.D., R. Natarajan. 2008. Evaluating Contextual Variables Affecting Productivity Using Data Envelopment Analysis. *Operations Research* Vol. 56, 48-58.
- Baum, C.F. 2006. *An Introduction to Modern Econometrics Using Stata*. Stata Press, College Station, TX.
- Benham, A. and L. Behnam. 2001. *The Costs of Exchange*. Ronald Coase Institute Working Papers, Number 1. <http://www.coase.org/workingpapers/wp-1.pdf> (last accessed March, 2011)
- Binam, J.N., J. Tonyè, N. Wandji, G. Nyambi, M. Akoa 2004. Factors Affecting the Technical Efficiency among Smallholder Farmers in the Slash and Burn Agriculture zone of Cameroon. *Food Policy* 29, 531–545.
- Brambilla I. & G. G. Porto 2009. *Market Structure, Outgrower Contracts and Farm Output: Evidence from Cotton Reforms in Zambia*. Lusaka, Zambia.
- Brazdik F. 2006. *Non-Parametric Analysis of Technical Efficiency: Factors Affecting Efficiency of West Java Rice Farms*. Prague, Cech Republic.
- Bravo-Ureta E. B. and E. A. Pinheiro. 1997. Technical, Economic, and Allocative Efficiency in Peasant Farming: Evidence from the Dominican Republic. *The Dev. Econ.* 34: 48-67.
- Bwalya R. (2007). *Transaction Costs and Smallholder Household Access to Maize Markets in Central Province Zambia*. Thesis, University of Makerere, Uganda.
- Carter R. M. 1984. *Identification of the Inverse relationship between Farm Size and Productivity: An Empirical Analysis of Peasant Agricultural Production*. Oxford

economic papers, New series, Vol 36, # 1 pp 131-145. published by: Oxford University Press.

- Chavas, J., R. Petrie and M. Roth. 2005. Farm Household Production Efficiency: Evidence from Gambia. *American Journal of Agricultural Economics* 87: 160–179
- Chirwa W. E. 2007. *Sources of Technical Efficiency among Smallholder Maize Farmers in Southern Malawi*. AERC, Nairobi
- Chun L. 2005. Measuring the Relative Efficiency and Reorganization – The example of CDFAs of the NAN-TOU Country in Taiwan. *Economic Bulletin*, Vol, 17, No. 9 pp.1-11
- Coelli T. and G.E. Battese. 1996. Identification of Factors which Influence the Technical Inefficiency of Indian Farmers. *Australian Journal of Agricultural Economics*, Vol. 40, No 2, pp 103-128
- Coelli T., D.S.P. Rao and G.E. Battese. 1998. *An Introduction to Efficiency and Productivity Analysis*. Kluwer Academic Publishers, Boston
- Coelli, T., S. Rahman and C. Thirtle. 2002. Technical, Allocative, Cost and Scale Efficiencies in Bangladesh Rice Cultivation: A Non parametric Approach. *Journal of Agricultural Economics*, 53:607-626
- Cooper W. W., M. L. Sieford and J. Zhu. 2002. *Data Envelopment Analysis – History, Models and Interpretations*.
- Dhungana, B.R., Nuthall and G.V. Nartea 2000. *Explaining Economic Inefficiency of Nepalese Rice Farms: An empirical Investigation*. Proceedings for the 44<sup>th</sup> Annual Conference of the Australian Agricultural and Resource Economic Society. January 23-25 2000, Sydney
- Dhungana, B.R., P.L. Nuthall and G.V. Nartea. 2004. Measuring the Economic Inefficiency of Nepalese Rice Farms using Data Envelopment Analysis. *The Australian Agricultural and Resource Economics*. 48: 347-369
- Deininger, K. and P. Olinto. 2000. *Why Liberalization Alone Has Not Improved Agricultural Productivity in Zambia: The Role of Asset Ownership and Working Capital Constraints*. World Bank Policy Research Working Paper No. 2302.
- Dolisca F. and M. J. Curtis. 2008. Technical Efficiency of Traditional and Non-Traditional Crop Production: A Case Study from Haiti. *World Journal of Agricultural Sciences* 4(4): 416-426
- Dzene R. 2010. *What Drives Efficiency on the Ghanaian Cocoa Farm?* Ghana Institute of Management and Public Administration, Ghana

- FARA (Forum for Agricultural Research in Africa). 2006. *Framework for African Agricultural Productivity / Cadre pour la productivité agricole en Afrique*. Accra, Ghana. 72 pp.
- Farrell M. J. 1957. The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society*. Series A (General), Vol. 120, No. 3, (1957), pp 253-290
- Fletschner, D. K. and L. Zepeda 2002. Efficiency of Small landholders in Eastern Paraguay. *Journal of Agricultural and Resource Economics* 27(2):554 – 572.
- Forum for Agricultural Research in Africa (FARA) 2006. *Framework for African Agricultural Productivity*. Accra, Ghana
- Frisvold G. & K. Ingram 1994. *Source of Agricultural Productivity Growth and Stagnation in Sub-Saharan African*. Washington DC, USA.
- Gerdin A. 2002. *Productivity and Economic Growth in Kenyan Agriculture, 1964-1996*. Stockholm, Sweden.
- Goeb C. J. 2010. *Impact of Government Maize Support on Smallholder Cotton Production in Zambia*. Thesis, Michigan State University, USA.
- Green H. W. 2003. *Econometrics Analysis, 4<sup>th</sup> ed*. New Jersey: Pearson Education, Inc
- Gujarati, N.D. 2004. *Basic Econometrics. Fourth Edition*. McGraw-Hill Publishing Co: New York.
- Haggblade S., S. Kabwe and C. Plerhopes, 2010. *Productivity Impact of Conservation Farming on Smallholder Cotton Farmers in Zambia*. Working Paper 47. Food Security Research Project (FSRP), Lusaka, Zambia.
- Hoff, A., 2007. Second stage DEA: Comparison of Approaches for Modelling the DEA score. *European Journal of Operational Research* Vol. 181, 425-435.
- Kuteya A., S. Kabwe, M. Beaver, A. Chapoto, B. Burke, N. Manson and W. Weber, 2011. Statistical Report on Categorization of Rural Cropping Households in Zambia: Section I – Introduction and Methods. Working Paper 51. Food Security Research Project (FSRP), Lusaka, Zambia.
- Ministry of Agriculture and Cooperatives (MACO). 2005. *National Agriculture Policy*. Lusaka, Zambia
- Maddala, G.S. 1988. *Introduction to Econometrics*. Macmillan Publishing Company, London.
- McDonald J. 2008. Using Least Squares and Tobit in Second Stage DEA Efficiency Analyses. *European Journal of Operational Research* Vol. 197, 792-798

- Mevlut G., K. Besir, D. Erdal, M. A. Goksel and P. Oguz. 2009. *Determination of Technical Efficiency in Cotton Growing Farms in Turkey: A case study of Cukurova region*. Cukurova, Turkey.
- Megill, D.J. 2004. *Recommendations on Sample Design for Post-Harvest Surveys in Zambia Based on the 2000 Census*. Working Paper No. 11, Food Security Research Project, Lusaka, Zambia.
- Mochebelele, M. T. and A. Winter-Nelson. 2000. Migrant Labour and Farm Technical Efficiency in Lesotho. *World Development*, 28(1): 143-153.
- Ministry of Finance and National Planning (MoFNP). 2006. *Fifth National Development and Planning*. Lusaka, Zambia
- Mohammad I. J. 2009. *Efficiency Analysis of Cotton-Wheat and Rice-Wheat Systems in Punjab*. Pakistan. Pakistan
- Mutua, N. F., V. H. Craig, and K. David. 2010. Cotton Mapping in Kenya: GPS-Based Data Collection – A Cost Comparison with High Resolution Satellite Imagery Mapping. *International Transaction Journal of Engineering, Management, & Applied Science & Technology*, Volume 2 No.1 eISSN: 1906-9642
- Ngassam B. S., C. J. Nzomo, and C. Neba. 2010. *The Determinants of the Technical Efficiency of Cotton Farmers in Northern Cameroon*. Cameroon.
- Nyagaka O. D., A. G. Obare, M. J. Omiti and W. Nguyo. 2010. Technical Efficiency in Resource use: Evidence from Smallholder Irish Potato Farmers in Nyandarua North District. Kenya. *Africa Journal of Agricultural Research* Vol 5(11), pp. 1179-1186
- Okoye, B.C., C.E. Onyenweaku, and A.E. Agwu. 2006. *Technical Efficiency of Smallholder Cocoyam Farmers: Implications for Agricultural Extension Policy*. Anambra State, Nigeria
- Onumah E. E., G. Hoerstgen-Schwark and B. Brummer. 2009. *Productivity of Hired and Family Labour and Determinants of Technical Inefficiency in Ghana's Fish Farms*.
- Onyenweaku C.E. and E.O. Effiong. 2005. Technical Efficiency in Pig Production in Akwalbom State. Nigeria. *International Journal of Agricultural Rural Development*. Vol. 6: 51-57.
- Rios, A.R. and G.E. Shively. 2005. *Farm Size Non parametric Efficiency Measurements for Coffee Farms in Vietnam*. Proc. America Agricultural Economics Association Annual Meeting. 24-27 July 2005, Providence, Rhode Island

- Shafiq M. and R. Tahir. 2000. The Extent of Resource use Inefficiencies in Cotton Production in Pakistan's Punjab: an Application of Data Envelopment Analysis. *Agricultural Economics*. Vol 22 (2000), pp 321-330
- Speelman, S., D. M. Haese and J. Buysse. 2008. A Measure for the Efficiency of Water use and its Determinants, a Case Study of Small-Scale Irrigation Schemes in North-West Province, South Africa. *Agricultural systems* 98:31-39
- Tchale H. 2009. The Efficiency of Smallholder Agriculture in Malawi. *AFJARE* Vol 3 No. 2 September 2009.
- Tschirley, D., C. Poulton, and P. Lambaste. 2009. *Organization and Performance of Cotton Sectors in Africa*. IBRD/The World Bank. D.C. USA.
- Tschirley, D. and S. Kabwe. 2007. *Cotton in Zambia: 2007 Assessment of its Organization, Performance, Current Policy Initiatives, and Challenges for the Future*. FSRP Working Paper No. 26. Lusaka, Zambia
- Uaiene, R. W. and C. Arndt. 2008. *Farm Household Technical Efficiency Frontier Analysis in Mozambique*. Maputo, Mozambique.
- Pender J., E. Nkonya, P. Jagger, D. Sserunkuuma, H. Ssali. 2004. *Strategies to Increase Agricultural Productivity and Reduce Land Degradation: Evidence from Uganda*. Kampala, Uganda.
- Wooldridge J. 2004. *Introductory Econometrics, 2<sup>nd</sup> ed*. New York: South-western Publishers.



## APPENDIX

### Appendix 1: Household Characteristics by Province

	Province		
	Central	Eastern	Southern
Ratio of female HH head grew cotton	0.01	0.12	0.01
Mean age of HH head	47	46	47
Level of education HH head in years	6	5	6
Number of adults aged 15-59 years	4	3	4
Value of Productive Assets in ZMK	7,704,891	3,155,256	8,985,319
Value of Off-farm income in ZMK	1,532,676	828,610	1,335,229
Total land holding size in ha	4.31	3.08	4.65
Mean number of weeding done	2.53	2.73	2.87
Ratio of total Hh who used CF tillage systems	0.01	0.05	0.00
Ratio of total Hh who used hand hoe	0.01	0.13	0.01
Ratio of total Hh who used plough	0.10	0.21	0.11
Ratio of total Hh who used ridges	0.00	0.38	0.00
Ratio of total Hh who tilled before rain	0.01	0.29	0.02
Ratio of total Hh who tilled during rain	0.11	0.48	0.10
Ratio of Hh owning animals as source of power	.38	.24	.51
Ratio of Hh who used hired animals as source of power	.45	.21	.43
Ratio of Hh who left crop residues in field	.60	.41	.46
Ratio of Hh who practiced crop rotation	.53	.52	.48
Ratio of total HH planting seed - F135	0.06	0.06	0.04
Ratio of total HH planting seed – Chureza	0.05	0.66	0.03
Ratio of total HH planting seed – Ngwezi	0.01	0.01	0.01
Ratio of total HH planting seed - CDT II	0.01	0.03	0.03
Number of cotton households	17,947	115,220	17,634