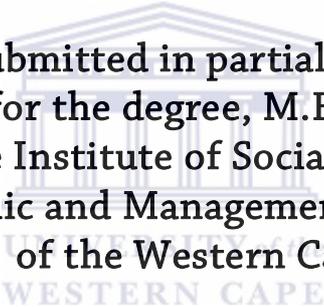


**Access to Irrigation Technology and Technical Efficiency: A
comparison of Households with and without access to
irrigation technology, in 'Gorogutu District', Eastern
Ethiopia.**

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**Mini thesis submitted in partial fulfillment of the
requirements for the degree, M.Econ (Development
Studies) with the Institute of Social Development in the
Faculty of Economic and Management Sciences, University
of the Western Cape**

The logo of the University of the Western Cape is centered behind the text. It features a stylized building with a triangular roof and the text 'UNIVERSITY OF WESTERN CAPE' below it.

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Co-Supervisor: Dr. Leon G. Pretorius

May 2012

ABSTRACT

Access to Irrigation Technology and Technical Efficiency: A comparison of Households with and without access to irrigation technology, in 'Gorogutu District', Eastern Ethiopia.

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Despite its recent remarkable economic growth, Ethiopia remains one of the poorest countries in the world. More than 80 percent of Ethiopians obtain their livelihood from traditional low-productivity agricultural activities. Due to lack of water storage facilities and the erratic nature of rainfalls, most farmers don't have access to water to produce more than one crop per year and hence there are frequent crop failures due to droughts which have made the country one of the highest food insecure nations and receiver of food aid. It is evident that a comprehensive effort is required to increase crop and agricultural production through different intensification and productivity enhancement mechanisms and reduce rural household's food insecurity and poverty. In line with this the Government of Ethiopia and different NGO's have been promoting irrigation technology as a viable option in enhancing farm productivity and efficiency improvements.

By integrating field observations, economic theory, and econometric analysis, this study assess the extent to which access to irrigation technology affects the level of technical efficiency in Gorogutu district of Eastern Ethiopia. The analysis is based on primary household-level data collected from 100 randomly selected households in 2010/11 cropping season. To analyze the effect of the technology on technical efficiency, three different Cobb-Douglas type of Stochastic Production Functions were estimated. More so, to explore different socio- economic and institutional

determinants of technical efficiency in the study district, an inefficiency effect model was estimated using the one step procedure.

The result from the estimated models has shown that farm households in the study area are not technically efficient and there is a chance to increase output by using the technology and mix of production input used by the best farm household (with 20 percent technical inefficiency). In addition, it also showed that households with access to irrigation technology are more technically efficient (84 percent technical efficiency) than those without access to the technology (77 percent technical efficiency). And household's access to irrigation technology, access to extension service and distance travelled from farm plot to homestead are a significant determinant of technical efficiency in the study area.

The study recommended, among other things, as a country that has a huge potential for irrigation development, utilization of this potential and providing irrigation technology to farm households will have a huge impact on the livelihoods of the majority of the poor. Evidently, efforts tailored towards this end would be very essential in militating against the high levels of poverty that is persistent in the communities

KEYWORDS

Agricultural Productivity

Agriculture

Determinants of Technical efficiency

Elasticity of Output

Ethiopia

Gorogutu District

Irrigation Technology

Stochastic Production Frontier

Technical Efficiency

Theory of Production



DECLARATION

I declare that “*Access to Irrigation Technology and Technical Efficiency: A comparison of Households with and without access to irrigation technology, in ‘Gorogutu District’, Eastern Ethiopia.*” is my own work, that it has not been submitted for any degree or examination in any other University, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Gebrekidan, Bisrat Haile

Date: May 2012



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LIST OF ABBREVIATIONS AND ACRONYMS

ADLI:	Agricultural Development Led Industrialization
DA:	Development Agents
DEA:	Data Envelopment Analysis
EHBoFED:	East Hararge Bureau of Finance and Economic Development
ETB:	Ethiopian Birr
GDP:	Gross Domestic Product
GoE:	Government of Ethiopia
GTZ:	Gesellschaft für Technische Zusammenarbeit
Ha:	Hectare
HDI:	Human Development Index
JICA:	Japan International Cooperation Agency
MLE:	Maximum Likelihood Estimation
MoFED:	Ministry of Finance and Economic Development
MoRDA:	Ministry of Agriculture and Rural Development
MoWR:	Ministry of Water Resources
NGO:	Non-Governmental Organization
OECD:	Organization for Economic Co-operation and Development
OLS:	Ordinary Least Square

SPF:	Stochastic Production Function
TE:	Technical Efficiency
UN:	United Nations
UNDP:	United Nations Development Program
USAID:	United States Agency for International Development
WB:	World Bank



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CHAPTER ONE: INTRODUCTION

1.1 CONTEXTUAL BACKGROUND

Two decades into the 21st century, poverty in all its manifestations still remains a global problem of magnitude proportions. According to the World Bank's well known international poverty line "dollar-a-day" which was revised in 2008 to \$1.25 a day, there are still 1.4 billion people, out of the total 6.6 billion, who are living in poverty (UN, 2009:16-20). In the same year in Sub-Saharan Africa 550 million people live below \$2 a day and over 388 million people survive on less than \$1.25 a day. Although the latest poverty estimates show a decline in the level of global poverty; 1.9 billion in 1981 to 1.4 billion in 2005, halving poverty in sub-Saharan Africa remains the major challenge. Actually the sub region saw a significant increase in the number of people living on less than \$1.25 or \$2 a day over the period 1981-2005 (ibid: 17).

Eighty five percent of the sub region's poor live in the rural areas and depend largely on agriculture for their livelihoods. It is apparent that Agricultural production growth is a key to poverty reduction and an engine of the national economic growth. In the 30th series of World development Report (2008:xiii), the World Bank reasserted the role of agriculture in development by alluding that

"In much of Sub-Saharan Africa, agriculture is a strong option for spurring growth, overcoming poverty, and enhancing food security. Agricultural productivity growth is vital for stimulating growth in other parts of the economy but accelerated growth requires a sharp productivity increase in smallholder farming combined with more effective support to the millions coping as subsistence farmers, many of them in remote areas."

Considerable agreement is also reached on the pivotal role of productivity and output growth in the agricultural sector, specifically among smallholder peasants, in

effective economic development strategies and eventual food security and poverty alleviation. It is argued that the role of agriculture is not only for addressing unemployment but also for achieving more equitable distribution of income and effective demand structure for other sectors that placed agriculture at the center of contemporary development debates (Hayami and Ruttan, 1985). This has long been apparent since when McNamara (1973: 15) declare in his speech that *“....essential to the accomplishment of eradicating absolute poverty by the end of this century is an increase in the productivity of small-scale agriculture.”*

Yet agriculture in the region remains largely subsistence, with population growth surpassing production growth, food self-sufficiency declining, and the numbers of malnourished people consequently rising (World Bank,2008a:3-5).

The case is not much different in Ethiopia, one of the most populous nations in the subregion. Despite recent remarkable economic growth (Since 2003/04 growth has been sustained, recording more than 11 percent average growth) (MoFED, 2010a:1), Ethiopia remains one of the poorest nations in the world. According to 2010 World Human Development Report, the country has one of the lowest GNP per capita in the world with purchasing power parity adjusted value of \$ 992 and ranked 159th out of 169 countries. The same report indicates that 39 percent of Ethiopian population lives on less than \$1.25 a day. The Human Development Index is also rated as 0.328 which is much less compared to average HDI of developing countries 0.386 and Sub Saharan countries 0.389 (UNDP,2010).

More than eight out of ten Ethiopians obtain their livelihood from traditional low-productivity agricultural activities. The sector also accounts for 43 percent of GDP and 90 percent of total export (Diao, 2010:5). Among the sub-sectors of agriculture, crop production is a major contributor to GDP accounting for approximately 28 percent in 2005/2006. It is largely characterized by subsistence orientation, low levels of external inputs, limited integration into the market and rainfed agriculture. About 11.7 million smallholder households account for approximately

95 per cent of agricultural GDP and 85 per cent of employment. Only about 11.7 million hectares of land is cultivated; just over 20 per cent of the total arable area. Nearly 55 per cent of all smallholder farmers operate on one hectare or less (MoARD, 2010:3). Due to lack of water storage facilities and erratic nature of rainfall, most farmers don't have access to water to produce more than one crop per year and hence there are frequent crop failures due to droughts which have made the country one of the highest food insecure nations and receiver of food aid (Awulachew, Seleshi, Yilma, Loulseged, Loiskandl, Ayana And Alamirew, 2007:1). According to Dercon (2002), between 1977 and 1994, 78 percent of the rural households in Ethiopia were seriously affected by some form of harvest failure.

An increase in food production and poverty reduction should come from development of the agricultural sector through agricultural intensification i.e., producing more per unit of land, either by generating and adoption of new technologies or by relaxing important constraint such as water availability (World Bank, 2007:8). Irrigation development is therefore perceived by different NGOs and the Government of Ethiopia (GoE) as one of the strategies with the potential to solve the problem. In line with this, the GoE has planned to develop new projects that will add 273,829 hectares to the 197,250 ha already under irrigation, resulting in a countrywide total of 471,079 hectares of irrigated farmland by 2016. Of these projects 48 percent will be small scale irrigation schemes (GoE, 2010:48). In addition, in the new Growth and Transformation plan (2010/11-2015/16) the GoE pledged that *"...expansion of small scale irrigation will be given priority while due attention will be given to medium and large scale irrigation to the extent possible"* (MoFED, 2010b).

As continuous emphasis is being placed by Government and several other NGOs on the viability of small scale irrigation as a key measure for rural poverty reduction by 2016, it will be useful to study technical efficiency and its socioeconomic and institutional determinants of farmers in irrigated agriculture setting. As Nisrane,

Berhane, Asrat, Getachew, Taffesse and Hodidinott (2011) elucidated “...*examining the extent of inefficiency, and identifying the sources of such inefficiency, is an important step forward to improve the livelihood of subsistence farm households in developing countries.*” In addition, Knowledge about the extent of technical efficiency and its determinant among farmers who has access to irrigation technology will guide policy makers to design effective and efficient institutional support services that will help to increase agricultural production and productivity.

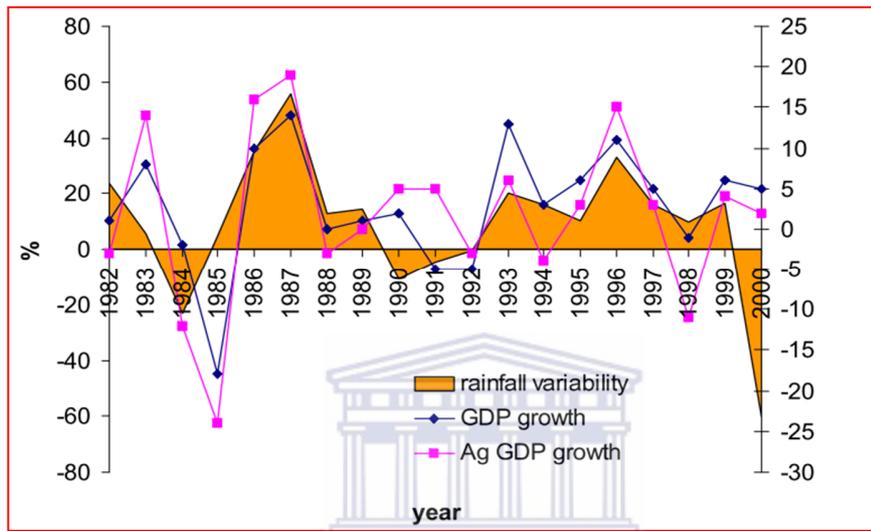
1.2 OVERVIEW OF AGRICULTURAL SECTOR IN ETHIOPIA

It is hard to imagine a farm household with a predominantly multi-crop ox-plough complex, supplemented by more specialized hoe culture and transhumant system in the lowlands; farm of two, three or more plots with yield levels driven largely by the vicissitudes of the rain; employ traditional technologies with occasional application of improved seeds and fertilizer; rely on family labor; and consume some three-fourth of its own output (Abegaz, 2004:335). However, this is a typical farm household in rural Ethiopia unveiling unenviable economic profile in 21st century - the age of information technology.

Like most Sub Saharan African countries the agricultural sector is the main stay of the Ethiopian economy. It greatly influences the overall performance of the whole economy. Being the dominant sector, it contributes about 43 percent to overall GDP, generates 90 percent of export earnings and supplies about 70 percent of the country's raw material to the secondary activities (MoRAD, 2010:30). The sector is entirely dependent on rainfed. Year-to-year variability of rainfall has constrained the countries' ability to prosper. As the World Bank (2005:5) expounded “*The effects of hydrological variability emanate from the direct impacts of rainfall on the landscape, agricultural output, water-intensive industry and power production. These impacts are transmitted through input, price and income effects onto the broader economy.*”

Figure 1.1 below shows the relationship that exists between annual rainfall, country gross domestic products (GDP) and the gross domestic products from the agriculture sector over Ethiopia.

Figure 1.1 Rainfall, Gross Domestic Product and Agricultural Gross Domestic Product in Ethiopia



Source: De Jong (2005) Cited in World Bank (2005), P.5

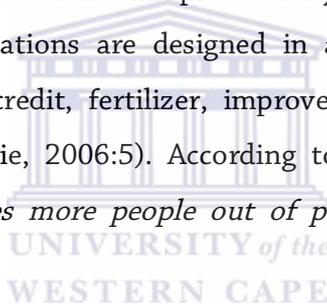
About 64 percent of agricultural value added comes from crops production. Cereals including barley, maize, teff¹, wheat and sorghum are the dominant staples for the majority of Ethiopians and provide 62 percent of average Ethiopians' daily calorie intake and covers about 45percent of food expenditure for an average household (Diao,2010:10).

There are two classification of Ethiopian farms; small holder peasant farms and large commercial farms. The classification is based on the area of land the farmer cultivates. Smallholder farmer are those that cultivate less than 25.2 hectares of land and large farms are those that cultivate more than 25.2 hectares (Taffesse, Dorosh and Asrat, 2011:3). Although the smallholder agriculture accounts for over

¹ Teff is an ancient grain of Ethiopia. Ethiopians grind it into a flour to make their traditional, fermented 'spongy' bread called "Injera". Teff is high in fiber, calcium and protein.

95 percent of the cultivated land and production (MoRAD, 2010:3), low resource base and low productivity are the main characterization of the production system. Low agricultural productivity can be attributed to limited access by smallholder farmers to agricultural inputs, financial services, improved production technologies, irrigation and agricultural markets; and to poor land management practices that have led to severe land degradation (ibid).

Since 1993, Ethiopia has embarked upon an agriculture-based growth strategy called Agricultural Development Led Industrialization (ADLI, to meet the challenges of accelerating overall growth and poverty reduction (Diao, 2010:50). Under the ADLI policy framework, intensification of smallholder agriculture is given priority to increase agricultural production and productivity which in turn reduces rural poverty. These intensifications are designed in a way to give a push through technological packages (credit, fertilizer, improved seed, irrigation etc) to raise productivity (Gebreselassie, 2006:5). According to Diao (2010b) *“agriculture-led growth can lift 1.4 times more people out of poverty than nonagricultural-led growth in Ethiopia.”*



1.3 DEVELOPMENT AND STATUS OF IRRIGATION TECHNOLOGY IN ETHIOPIA

While there is no written and well documented evidence showing when, where and by who the first time water resource was used for irrigation in Ethiopia, the development of modern irrigation is more recent (Awlache, Loulseged, and Yilma, 2008:6). According to Dessalegn (1999), the Imperial government was the first to take the initiative to develop large-scale water project for agriculture and hydropower in the second half of the 1950's. At that time much emphasis was given to large-scale and high technology irrigation projects and it was estimated about 100 thousand hectares of land was under modern irrigation by that time, about 50 percent of which was located in the Awash Valley (Gebremedhin and Peden, 2003:171). These large scale schemes were managed by the state or para-

statal enterprises. In 1975 when the military government took power all large scale schemes were nationalized and handed over to the Ministry of State Farms. In addition the landlord based small-scale irrigation schemes were also handed over to producer co-operatives (ibid). Like the Imperial regime, the military regime (Derg) was also interested in large scale and complex water development projects. Large scale irrigation was taken as instrument of modernization and socialization of the country's agricultural economy (Dessaiegn, 1999). But the occurrence of devastating famine in 1984/85, made the Derg regime to follow a new approach to irrigation development by starting to give emphasis to small scale irrigation projects for the benefits of the farmers (ibid). The current government has given more emphasis to the sector and especially to small scale irrigation systems by involving farmers progressively in various aspects of management of the systems, starting from planning to operation and maintenance (Awlachew et al, 2007:17).

There is no accurate and clear-cut estimate of the total irrigation potential of the country. Different sources provide different estimates. According to recent estimates the total irrigation potential from 12 river basins and groundwater ranges up to 6.6 million hectares. However, the developed irrigation from all these sources is so far, not more than 0.7 million hectares (Awlachew and Ayana, 2011:58).

Based on the command area classification there are three typologies of irrigation in Ethiopia. Large scale schemes that have a total command area of greater than 3000 hectare, medium schemes cover a command area of between 200 hectares and 3000 hectares, and small scale schemes which are less than 200 hectares (Awlachew et al, 2007:17). The large-scale and the medium schemes are developed and managed by the government. Small scale irrigation schemes are further categorized in to traditional and modern schemes. The modern scheme usually have fixed or improved water control or diversion structures. And it is managed by water Users association. The traditional schemes is usually characterized by non-fixed structure

and practiced in the traditional way. Most of the time, they are developed and managed by community tradition (Awlachew and Ayana, 2011:58).

1.4 PROBLEM STATEMENT AND JUSTIFICATION

Being highly dependent on rain-fed agriculture, Ethiopia's agricultural production and even the overall performance of the whole economy is always taken hostage by the magnitude and distribution of erratic rainfall. Evidences are rampant on how rain-fed agriculture is a risky venture. Persistent lack of rainfall is one of the main causes of poverty and widespread famine in rural areas. A study made by Von Braun (1991), for instance shows that a 10 percent decline in the amount of rainfall below its long-term average level results in the decline of national food production by 4.4 percent. The World Bank (2006) also estimates that high rainfall variability costs the total economy over one-third of its growth potential and in addition leads to 25 percent increase in poverty rates.

It is evident that a comprehensive effort is required to increase crop and agricultural production through different intensification and productivity enhancement mechanisms and reduce rural household's food insecurity and poverty. Two broad sources of productivity enhancements in agricultural production are expounded in economic theory. The first is an agricultural intensification in terms of resource use expansion, conventionally by bringing more land under cultivation and increased use of available rural labor force. The second approach involves enhancing farm productivity through technological and efficiency improvements. Increases in output through productivity growth have become increasingly relevant to Ethiopian agriculture as the opportunities to bring additional virgin lands into cultivation have significantly been diminishing. This is especially true to the most part of the country which has long been cultivated and has exhausted its fertility, partly due to the apparent high population pressure. Under such circumstances, alternative approaches to achieve output growth of agriculture, to enhance productivity

through efficiency improvements and/introducing new agricultural technologies, needs to be reconsidered (Haji, 2006, Diao, 2010). Thrilwall (2006:180) perceptively remarked that:

“... The most practical and economical approach to achieving sizeable increases in agricultural productivity lies in enhancing the efficiency of the existing agricultural economy through improvements in the quality of inputs, and by the application of advances in knowledge and modern technology on a broader front.”

However, the viability of such technologies is crucially dependent on the expected profitability of the technology which in turn is determined by the response rate to technology application, the price of output and cost of technology/input applied (Mulat Demeke, 1999:6)

In Asia and Middle East access to irrigation technology has proved its potential to combat the threat of malnutrition and premature death for millions and has demonstrated poverty-reduction effects through increasing agricultural production and productivity (World Bank, 2008b:3).

Based on this revelation, the government of Ethiopia and different international (the Swedish International Development Agency (SIDA), Ireland Aid, USAID, GTZ and JICA) and local (Ethio-Italy Arsi-Bale Integrated Rural Development Program NGOs) (The International Water Management Institute, 2004: 27) have been promoting irrigation technology to extricate the agricultural sector and the economy at large from the manacles of unreliable rainfall. The Ethiopian government, in its agricultural led development program, has enumerated irrigation technology as a viable option that the country has in order to increase crop production and agricultural productivity, achieve sustainable food security and reduce rural poverty. As a result a number of such schemes have been designed and constructed in the previous years by government and different NGOs.

However productivity and yield increases do not depend only on access to irrigation but also the effective and efficient use of the available technology or resource (Thirwall, 2006, Haji, 2008). It is argued that farm households encounter considerable limitations in producing the maximum output possible from a given combinations of input and the technology provided (Haji, 2008; Alene et al, 2003). The ability of a farmer to maximize output from a given level of inputs and technology is known as technical efficiency. Access to technologies also requires asset of skills and knowledge, integration to the input and output market, access to credit and extension services, if their potential to increase agricultural production and productivity are to be technically efficient (Alene and Rashid, 2003).

The justification for this study emanates from the following two facts. The first is, there are a number of studies which confirm that access to irrigation technology has a positive effect on agricultural production and productivity (Hussein ,2004; Hussein and Henjira ,2004; Hussein et al ,2006), however, studies which isolate and examine efficiency component of productivity and relate it with socio economic and institutional determinates are scarce in Ethiopian perspective. Second, since the scope to increase farm production by bringing more land into cultivation has almost reached an insignificant level (Haji, 2006; Gebreselassie, 2006), studying and understanding the level of technical efficiency of farm households is of critical importance. And hence it requires empirical testing through scientific research. As Lovell (1993: 5) pointed out measuring efficiency and productivity has two principal uses

“First, they are success indicators, performance measures by which production units are evaluated. Second, only by measuring efficiency and productivity, and separating their effect from the effect of production environment, can we explore hypothesis concerning the sources of efficiency or productivity differentials. Identification of sources is essential to the institution of public and private policies designed to improve performance.”

The aim of this study is to conduct a comparative analysis of farm level technical efficiency of households with access to irrigation technology and those without

access to irrigation technology and to determine the socio economic and institutional factors that influence farm level technical efficiency in Gorogutu district of Eastern Ethiopia using ‘Erer Mede Tellila’ irrigation scheme as a case study.

1.5 RESEARCH OBJECTIVES AND RESEARCH QUESTIONS

1.5.1 Research objectives

The overall objective of this study is to assess the extent to which access to irrigation technology affects the level of technical efficiency in Gorogutu district of Eastern Ethiopia by integrating field observations, economic theory, and econometric analysis.

The specific objectives of the study include

- ✓ To identify and estimate the determinants of farm level technical (in)efficiency for households with access to irrigation technology and those without access to the technology
- ✓ To estimate the level of responsiveness of output to change in convectional factors of production using elasticities of output
- ✓ To identify other determinants of household agricultural production and productivity in the study area.
- ✓ Finally to provide policy conclusions and recommendations, to policy makers and other interested parties, about how access to irrigation technology will increase technical efficiency and in turn raise agricultural productivity.

1.5.2 General research questions

The following questions will guide the study

- ✓ What is the productivity gain from access to irrigation technology in the study area?

- ✓ Are farm households in the study area technical efficient?
- ✓ Does access to irrigation result in differentiated levels of technical efficiency in the study area?
- ✓ What are the factors that determine farm level technical efficiency in the study area?

1.6 DELIMITATION AND SCOPE OF THE STUDY

This study is a household level analysis aimed to assess the technical efficiency and its socioeconomic and institutional determinants for households with access to irrigation technology in comparison with households without access to the technology. The scope of the study is limited to the analysis of technical efficiency component of farm households and its institutional social and economic determinants. Geographically the study is confined to Gorogutu district in Eastern region of Ethiopia for reasons of novelty and relative familiarity of the researcher to the socio-economic, infrastructural and geographical features of the area besides the comparatively severe poverty and food insecurity problems. Gorogutu is a primarily rural district lying about 115km west of Harar town (the nearest big town), with a range of agro-ecologies: lowland (37% by area), mid-highland (51%) and highland (11%).

1.7 LIMITATION OF THE STUDY

One of the limitations of this study is the sample size. Even though the sample was drawn using simple random sampling technique, 100 sample household is too small relative to the total population of the district. The small sample size that resulted from cost and time constraint can present difficulty in terms of representation of the population. This may mean challenges with drawing inferences from the sample to the region and country as a whole. The second limitation is that the study only used the quantitative method of data collection and analysis tools. The

measurement of technical efficiency is constrained to and relies entirely on the quantitative tools. This makes it difficult to get in-depth and contextual information and analysis on how access to irrigation technology enhances the technical efficiency of farm households in the study district.

1.8 STRUCTURE OF THE MINI THESIS

Chapter One introduces the contextual background of the study, the overview of agriculture sector, status and development of irrigation technology in Ethiopian, and the research problem that led into the formulation of the research questions and objectives of the study.

Chapter Two provides literature related to the role of agriculture in Development from developing countries perspective and How Does Agricultural Output Growth Help Poverty Alleviation? Mechanisms and Empirical Evidences will be reviewed.

Chapter Three is focused on the theoretical underpins of the study. The basic microeconomic ‘Theory of production’, concepts and measurement of Technical efficiency which are the core framework of the study, will be discussed in detail. The aim of these chapters is to provide a wider basis for developing important indicators and causal linkages from more extensive literatures and academic discourse.

Chapter Four presents a general description of the study area Gorogutu district, the research design and more detailed explanation of source and method of data collection that is applied in the study. More so, the empirical models and estimation procedures are also included in this chapter.

Chapter Five is devoted to the data analysis and research findings in a bid to answering the research questions set in the beginning of the research.

Chapter Six presents the conclusion and recommendations drawn from the major empirical findings.

CHAPTER TWO: LITERATURE REVIEW

“If development is to take place and become self-sustaining, it will have to start in the rural areas in general and the agricultural sector in particular.”(Todaro, 1989: 290-91

2.1 INTRODUCTION

In many developing countries, the extremely traditional and consequently low productivity of agriculture is well known as a major cause of poverty and retarded growth and development of the whole economy (Thrilwall, 2006:168). The very fact that most of the world's poor work in agriculture and agriculture is an important industry in most poor countries has placed the sector and its productivity at the center of the development research agenda and policy debates. In this chapter, a brief review of theoretical and empirical literature of selected issues is presented.



2.2 AGRICULTURE AND DEVELOPMENT: DEVELOPING COUNTRIES PERSPECTIVE

For the last 20 years the role of agriculture in the development process of developing countries was neglected by international donors. According to Anríquez and Stamoulis (2007:1), between 1983-1987 and 1998-2000, the annual average allocations of Official Development Assistance for agriculture in the least-developed and other low-income countries fell by 57 percent from USD 5.14 billion to USD 2.22 billion. But the rise of food prices which lead to the majority poor in developing countries to be food insecure coupled with the failure of past paradigms to make mass reductions in rural poverty, have given a new impetus to its role to be revitalized again as engine of development and poverty reduction in these countries (Dethier and Effenberger, 2011; Anríquez and Stamoulis, 2007; Meijerink and Roza, 2007).

The role of agriculture as an engine of economic development and poverty reduction is a contentious issue; empirical results are mixed and even sometimes conflicting. Johnston and Mellor (1961) were among the first to observe the role of dynamic agricultural growth for the development path of a nation. According to these scholars agriculture can play a prominent role in the development path through five different inter sectoral channels;

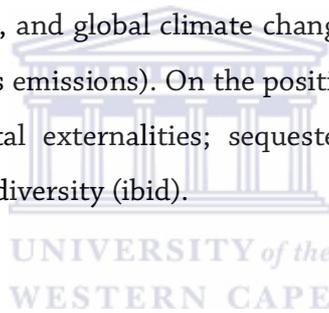
- (i) supply of surplus labour to firms in the industrial sector;
- (ii) supply of food for domestic consumption
- (iii) provision of market for industrial output
- (iv) supply of domestic savings for industrial investment; and
- (v) supply of foreign exchange from agricultural export earnings to finance import of intermediate and capital goods

This linkage between agriculture and development was further strengthened by the idea of Adelman's general equilibrium "agricultural demand led industrialization" (ADLI). According to Adelman (1984), a country's development strategy should be agriculture-driven rather than export-driven as production and consumption linkages are strong. Increased agricultural productivity of small-to-medium-size farmers would be the catalyst of industrialization.

Anríquez and Stamoulis (2007) also pointed out that agricultural growth helps poverty alleviation through four main channels; directly increasing the income/own consumption of small farmers, indirectly by reducing food prices, indirectly by increasing the income generated by the non-farm rural economy and Indirectly by raising employment and wages of the unskilled.

After five decades of the work of Johnston and Mellor (1961), the World Bank through its 2008 World Development Report recapitalizes the role of agriculture by expounding that *"Agriculture has features that make it a unique instrument for development. It contributes to development in three different channels; as an economic activity, as a livelihood, and as a provider of environmental services."* As

the majority of population in developing countries lives in rural areas and depend on agriculture , it constitute an important source of growth for the national economy, a provider of investment opportunities for the private sector, and a prime driver of agriculture-related industries and the rural non-farm economy. As source of livelihoods for an estimated 86 percent of rural people, agriculture also provides jobs for 1.3 billion smallholders and landless workers, a foundation for viable rural communities and when there are urban shocks it is used as “farm financed social welfare”. Agriculture’s role as a provider of environmental services is contentious. It resulted in both bad and good environmental outcome. On the negative side, as the sector is the largest consumer of water, it creates water scarcity for other sectors. It is also a source of underground water depletion, agrochemical pollution, soil exhaustion, and global climate change (it is responsible for up to 30 percent of greenhouse gas emissions). On the positive side agriculture also provides other good environmental externalities; sequestering carbon, managing watersheds, and preserving biodiversity (ibid).



2.3 WHY A RENEWED INTEREST IN AGRICULTURE AND AGRICULTURAL PRODUCTIVITY?

Under first Millennium Development Goal which aims to halving poverty and hunger, the, attention is focused on ‘where the poor live and sources of its livelihood’. It is overwhelmingly in rural areas basing in agriculture which reinforce the pro-poor growth agenda on spotlight. World Bank (2008) recapitalize the case for investing in agriculture to reduce poverty while recognizing the diverse contexts and associated pathways to escape poverty in the world development report for 2008.

2.3.1 Implications for Poverty Reduction

Timmer (2005: 3) reports that “...no country has been able to make a rapid transition out of poverty without raising the productivity in its agricultural sector (Singapore and Hong Kong are exceptions)”. OECD (2006) further elaborates that there are at least four pathways through which agriculture can reduce poverty. It raises farm incomes and thereby benefiting the many farmers living in poverty; creates employment on farms, for agriculture tends to employ more workers per unit of output than other sectors; stimulates the rural non-farm economy through linkages in both production and consumption; and pushes the prices down to the benefit of the many poor.

Mellor (2001) arguably state that it is not the economic growth but rather the direct and indirect effects of growth in agriculture that reduces poverty in developing countries. Typically, per worker GDP grows faster in the agriculture sector than in other sectors in the process of development and most poor people in poor countries depend on agriculture for living. Several studies also revealed that economic growth have generally helped to reduce poverty. However, the composition of growth (sectoral mix) matters substantially in that growth in agricultural income appears especially important.

For instance, a study about the economic importance of agriculture for poverty reduction, examining the effect of per worker agricultural GDP, non-agricultural GDP and Remittances on poverty rates in poor countries; corroborate the normal pattern of development and poverty reduction. It is found that over one-half of the reductions in poverty in the sample countries were due to growth in agricultural income (Cervantes-Godoy and Dewbre, 2010:5)

2.4 AGRICULTURAL PRODUCTIVITY AND POVERTY ALLEVIATION. MECHANISMS AND EMPIRICAL EVIDENCES

Irz, Lin, Thirtle and Wiggins (2001) systemically present the effects of agricultural growth at different levels of analysis. At farm economy level, agricultural productivity growth results in higher incomes for farmers and smallholders, subsequently reducing poverty. This will be coupled with more employment on-farm as labor demand increases per hectare, area cultivated expands, frequency of cropping increases and rise in farm wage rates. At a rural economy level, pervasive growth and development effects can be realized. Some of which includes more jobs in agriculture and food chain at farm; more jobs and higher incomes in non-farm economy as farmers and farm laborers spend additional incomes; better nutrition, health and increased investment in education amongst rural population; improved welfare directly and higher labor productivity indirectly; abundant local tax revenues and demand for better infrastructures leading to second round effects of promoting growth in rural economy; linkages in production chain help facilitate non-farm investment; and reduced food prices for rural people who are net food buyers.

For the national economy, real wages of urban poor rises while wage-cost of non-farm sectors fall due to reduced prices of food and raw materials. Increased investment in non-farm sectors creating jobs and incomes can be realized out of savings and taxes from increased income of farming. Furthermore, foreign exchange earnings from agriculture enable import of capital goods and essential inputs for non-farm production. And, released farm labor due to increased productivity allows production in other sectors viable.

Existing empirical studies also corroborated the theoretical mechanisms and pivotal pro-poor effect of agricultural growth in developing countries discussed in the previous sections. Datt and Ravallion (1996) have established the sectoral composition of economic growth as the key for poverty alleviation in India. Their

result showed that rural growth reduces both rural and urban poverty while urban growth does not. And, sectoral decomposition of growth revealed that growth in agriculture benefits the poor in rural and urban areas while manufacturing growth has showed no impact on poverty. Similar studies Wodon (1999) in Bangladesh and Thorbecke and Jung (1996) in Indonesia reached the same conclusion. In Indonesia, a lion's share of poverty reduction is achieved by agricultural growth and in Bangladesh a pro-rural development is simulated to bring the poverty headcount down by 3 points compared from the baseline scenario of *business-as-usual*.

For a reasonable sample of developing countries, cross-country examinations of the relationship between growth and poverty expounded similar results as the country cases do. Timmer (1997) and Gallup *et al* (1997) reported that a 1 percent increase in agricultural output results a 1.61 percent rise in the income of the poorest quintile but only 1.16 percent and 0.79 percent for manufacturing and service sectors respectively. Irz *et al* (2001) also showed that an increase in annual rate of 2.17 percent in agricultural yield reduces a poverty headcount from 40 percent to 30 percent, typical for least developed countries. Similarly, they estimate that for every 10 percent increase in farm yield there is a 7 percent reduction in poverty in Africa. Examining the effect of total factor productivity growth of agriculture on the incidence of poverty in developing countries, Thirtle, Lin and Piesse (2003) also empirically found substantial impact of agricultural productivity growth on poverty reduction whereas industry and services does not. These results assert that growth in agriculture characterized by productivity gain is the most effective way of fighting poverty in poor agrarian countries. And these countries are expected to reverse recent disappointing trends in agriculture's performance and agricultural productivity if they are to escape the trap of slow growth and poverty (DFID, 2005).

2.5 SUMMARY

The theoretical literature and empirical studies reviewed reveal an evidence of the very relevance of agricultural productivity in poverty reduction and development in developing countries. Ethiopia is not different, as Ethiopian economy highly hinges on rain-fed and traditional agriculture, the study of the effect of access to irrigation technology on technical change and efficiency remained to be crucial to provide a prior information on the relative importance of these sources of productivity change and output growth; the possibility of increasing farm output by improving productive efficiency; and the strength of variables outside the control of the producer firm and those explaining technical efficiency. The next Chapter provides detail discussion of theoretical underpins of the study.



CHAPTER THREE: THEORETICAL AND ANALYTICAL FRAMEWORK

3.1 INTRODUCTION

The main objective of this section is to furnish a generic framework which provides the basis of measuring the technical efficiency of farmers with access to irrigation technology and households without access to the technology. In simple economics, efficiency is measured by comparing observed output to potential output (frontier output). Efficiency here considered as economic efficiency is a combination of Allocative and Technical efficiency. According to Haji (2008) “*Technical efficiency is the ability of the farmer to produce maximum output from a given level of inputs while allocative efficiency measures the ability of the farmer to use inputs in optimal proportions, given input prices*”. The Analytical framework for conceptualizing and measuring technical efficiency is confined on the microeconomic theory of production function. In subsequent section the theory of production, the concept of efficiency and different techniques of measuring technical efficiency will be discussed.

3.2 THEORY OF PRODUCTION FUNCTION

Theory of production function is the most widely used concept in the main stream subject economics. In general production is an economic process of transforming inputs into some exchangeable output in the market (Shahabi, Kakaie, Ramazani and Agheli, 2009). The technical relation which connects these factor inputs with outputs of firms, industry or the whole economy is called the production function. Shahabi et al (2009:20) defines production function as mathematical relationship that either “*indicates technologically possible maximum output from a given set of inputs or specifies the minimum input requirements to produce desired quantities of output with a given available technology.*”

Since Philip Wicksteed for the first time (in 1894) formulate the mathematical relationship between input and output as $P = f(x_1, x_2, x_3 \dots \dots x_n)$, the theory of Production function has been used as an important tool of economic analysis in the neoclassical tradition(Humphrey, 1997:70).

Generally a production function is defined by the following equation

$$Y = f(x_1, x_2, x_3 \dots \dots x_n) \quad (3.1)$$

Where Y is output and $x_i, i = 1, 2, \dots \dots, n$ are the levels of inputs that determine the level of output. But in reality and practice there other unobservable variable inputs which determine the level of output in the production process. These inputs are known as random effects and are represented by μ . Adding the term μ to equation (3.1) modifies it to probabilistic expression (Palanisami, Paramasivam, and Ranganathan, 2002:7),

$$Y = f(x_1, x_2, x_3 \dots \dots x_n) + \mu \quad (3.2)$$

When the nature of relation is between one factor of production and one product output, the analysis is termed as input-output analysis or factor-product analysis. It generally concern itself with nature of changes in output as the level of single factor of production changes, relative to others variables are kept constant. The factor that varies with the level of output is known as variable factor or variable input. The other that remains invariant with output level is called fixed factor or fixed input (ibid). And this can be expressed as follows

$$Y = f(x_1 \perp x_2, x_3 \dots \dots x_n) \quad (3.3)$$

In specific form a production function can be defined by the equation

$$Y = f(K, L, M \dots \dots) \quad (3.4)$$

Where Y is the total output at a particular period of time and K represents the long lived inputs such as land, building and equipment usage during the period, L represents hours of labor input by managers by skilled worker or less skilled worker, M represents raw materials used, and the notation indicates the possibility of other variables affecting the production process (Nicholson, 2005:267).

Production function involves and provides different concepts which are useful tools of analysis in all fields of economics especially agricultural economics. These main concepts among others include: The Average and Marginal productivity of factors of production, production elasticity and return to scale.

Average and Marginal Productivity

Average Productivity is given by dividing total output produced by the input level. It gives the information about the average output per unit of input applied, over the entire range of input applied (Palanisami et al, 2002:8).

Marginal Productivity is the slope of the given production function. It gives information about the response of total output to additional input change at the margin i.e. it measures the change in total output that result from a very small change in one of the factor of production, keeping all other factors constant (ibid:8). Mathematically speaking marginal productivity is the partial derivative of the production function with respect to one of the factor of production. Thus the marginal productivity of labor measures the change in output that results from small change in labor, keeping the other variables constant. And the marginal productivity of capital measure the change in total output that result from a small change in capital input ,keeping the other factors of production constant (Koutsoyiannis, 1975:71).

$$MP_L = \frac{\partial Y}{\partial L} = \frac{\partial f(K, L, M \dots \dots)}{\partial L} \quad (3.5)$$

$$MP_K = \frac{\partial Y}{\partial K} = \frac{\partial f(L, K, M \dots \dots)}{\partial K} \quad (3.6)$$

Apart from the above two concepts, the relationship between input and output can be expressed by the production elasticities. The production elasticity expresses the relative change in production through a relative change in the addition of input (Rasmussen, 2011:18). Since elasticities are measures as the ratio of percentage, it does not depend on the specific units in which the input and output are measured (Debertin, 2002:34).

3.3 THE CONCEPT OF EFFICIENCY

The measurement of the performance of firms or farms is often done using the concepts of efficiency and productivity. These concepts have been used interchangeably by different authors and media (Freid et al, 2008; Coelli et al, 2005; Haji, 2008). But they are not precisely the same thing. In productivity, the comparison is made between the amounts of output produced to the amount of resources used. In other words productivity is the ratio of output to input. However, efficiency is the ratio of the value of output produced to the cost of inputs used. Efficiency in production or productive efficiency is defined as the degree of success producers achieve in allocating inputs at their disposal and outputs they produce (Zhu, Lansink and Van der Vlist, 2006). According to Fried et al (2008:8), the measurement of efficiency involves either “*comparing observed output to maximum potential output obtainable from the input, or comparing observed input to minimum potential input required producing the output or some combination of the two*”. A firm or a farm is efficient if and only if there is no more room to increase the level of output (decrease the level of input) without additional input (or reducing output)(Cooper, Seiford and Tone ,2006). As Kumbhakar (1994) pointed out that even if different farmer use the same level of input they may produce different output. And this variation in output can be explained by difference in

efficiency. Economic efficiency is composed of two components; technical component and allocative component. The technical component refers to “*the ability to avoid waste, either by producing as much output as technology and input usage allow or by using as little input as required by technology and output production. And the allocative component refers to the ability to combine inputs and/or outputs in optimal proportions in light of prevailing prices.*” (Fried et al, 2008:20).

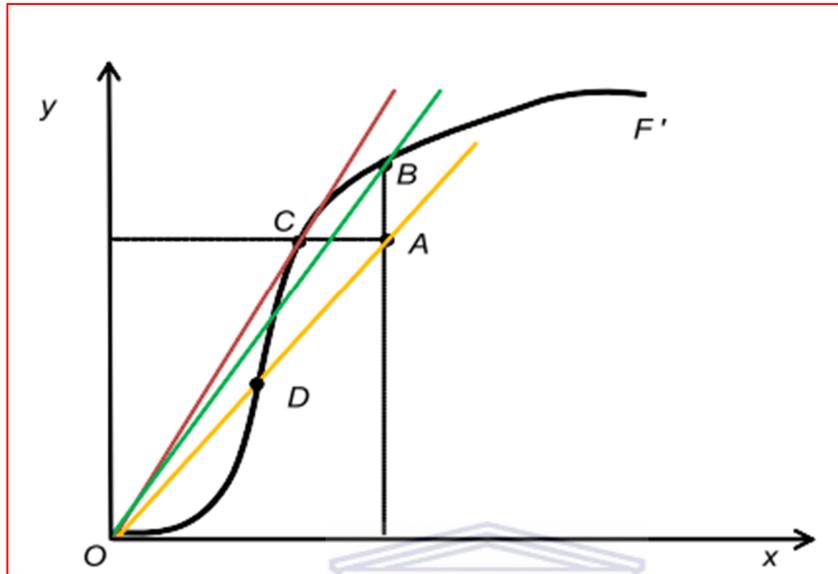
The earliest and formal definition of technical efficiency was given by Koopmans (1951:60). Accordingly he defined it as:

“A producer is technically efficient 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 in at least one output. Thus, a technically inefficient producer could produce the same outputs with less of at least one input or could use the same inputs to produce more of at least one output.”

Given the level of inputs if a farm fails to produce the frontier level of output it will result in Technical inefficiency (also called managerial inefficiency or x-inefficiency) (Jacobs, Smith and Street, 2006).

The following figure illustrates the diagrammatic concepts and differences between productivity and efficiency. Assuming the farm uses one input (x) and one output (Y), the production function or production frontier is depicted by the curve OF' and as explained in the previous section it depicts the maximum output that can be produce from different combination of inputs.

Figure 3.1 Productivity, technical efficiency and scale economies



Source: Coelli et al, 2005, P.5

The rays through the origin are used to measure the productivity at a particular point. The slope of these rays is given by the ratio of X and Y (X/Y) and it provides the measure of productivity. If the firm or the farm is producing at point A, there is room to move to the technically efficient point B. At point B the slope of the green ray is greater than the yellow one implying higher productivity at point B. However, by moving to the point C, where the red ray from the origin is tangent to the production frontier, the farm will produce at the maximum possible productivity. And the movement to the point of maximum possible productivity is an example of exploiting scale economies (Coelli, Rao, O'Donnell and Battese, 2005:5). The point C in the above figure shows the technically optimum scale. And production at any other point in the production frontier will result in lower productivity.

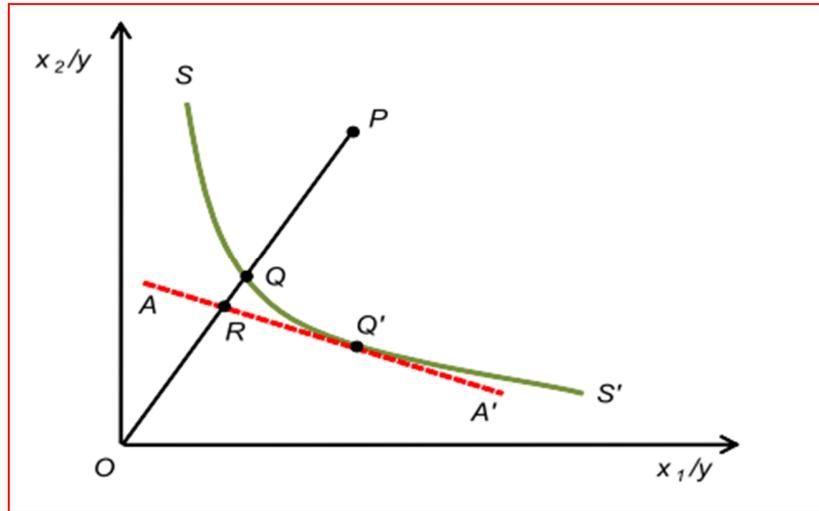
In addition to the technical efficiency, if there is information about the level of price it is possible to consider allocative efficiency. Allocative efficiency in input selection involves selecting the mix of alternative inputs that produces a given quantity of

output at minimum cost (given the input prices which prevail) (ibid). The combination of technical efficiency and allocative efficiency is called economic efficiency (Lovell, 1993:10). But as stated in the first chapter, in this study only technical efficiency will be considered. The fact that the farmers are producing heterogeneous products and heterogeneous objectives (profit maximization, cost minimization or revenue maximization) coupled with difficulty to get price information will make calculation of allocative and economic efficiency impossible.

Debreu (1951) and Farrell (1957) were the first in introducing measures of productive efficiency. According to Lovell (1993:10) the measure suggested by Debreu and Farrell is defined as *“one minus the maximum equiproportionate reduction in all inputs that still allows continued production of given outputs. A score of unity indicates technical efficiency because no equiproportionate input reduction is feasible, and a score less than unity indicate the severity of technical inefficiency.”*

Based on Farell's multi input and single output and constant return to scale, the following figure illustrates the measurement of technical efficiency. Assuming that the farmer uses two inputs (X_1 and X_2) and single output Y , in figure .2 below SS' represents isoquant of fully efficient firms.

Figure 3.2 Measurement of technical efficiency



Source: Coelli et al, 2005, P.55

If a farm household is producing at point defined by P, the technical inefficiency of that farm could be represented by the distance QP, which is the amount by which all inputs could be proportionally reduced without a reduction in output. This is usually expressed in percentage terms by the ratio, QP/OP; it represents the percentage by which all inputs need to be reduced to achieve technically efficient production. The technical efficiency (TE) is given by the ratio

$$TE = \frac{OQ}{OP} = 1 - \frac{QP}{OP}$$

The value of technical efficiency always ranges between 1 and 0. A value of one implies that the firm is fully technically efficient. In the figure 3.2 above, since point Q lies on the efficient isoquant, it is technically efficient (Coelli et al, 2005:51-53).

3.4 TECHNIQUES OF MEASURING TECHNICAL EFFICIENCY

Estimation of technical efficiency involves estimating the frontier function and measuring the efficiencies of the farms relative to the frontiers (Zhu et al, 2006). There are two commonly used methods of measuring technical efficiency in

productivity and efficiency literature; the programming or deterministic methods (based on the pioneering work of Farrell (1957) and developed by Charnes et al (1978)) and stochastic methods (developed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977), independently).

The programming method commonly called Data Envelopment Analysis (DEA) is a mathematical programming approach to the construction of production frontiers and the measurement of efficiency relative to the constructed frontiers. In DEA the performance of a producer is evaluated in terms of the ability of that producer to expand its output vector subject to the constraints imposed by best observed practice (Lovell, 1993). According to Banker et al (1984:1078) *“DEA employs mathematical programming to obtain ex-post facto evaluations of the relative efficiency of management accomplishments; however they may have been planned or executed. Technical inefficiencies are identified with failures to achieve best possible output levels and/or usage of excessive amounts of inputs.”*

Even though there are a number of studies which applied DEA to measure the technical efficiency, the method is subject to certain drawbacks. As Coelli et al (2005), Assefa and Matambalya (2002) pointed out the method is subject to series limitations from four different perspectives. Firstly, it is extremely susceptible to the influence of extreme values or outliers. Secondly, it does not take into account non-constant returns to scale. Thirdly, it does not also take into account uneconomic areas of the production function where the efficiency index is undefined. And finally, it does not lend itself up to standard statistical tests of significance. These limitations coupled with a compelling argument that stochastic frontier models may be the most appropriate choice in agricultural applications, where weather, disease and pest infestation are likely to be significant (Hadley, 2005 cited in Zhu et al, 2006), the econometric method or the stochastic frontier method will be used for this specific study. The following section will provide a detailed explanation of the stochastic production function approach.

3.5 STOCHASTIC FRONTIER PRODUCTION FUNCTION

The stochastic production function, as it is developed independently by Aigner et al. (1977) and Meeusen and Van den Broeck (1977), is specified in such a way that the possible production is bounded above by the stochastic quantity and hence the name stochastic frontier:

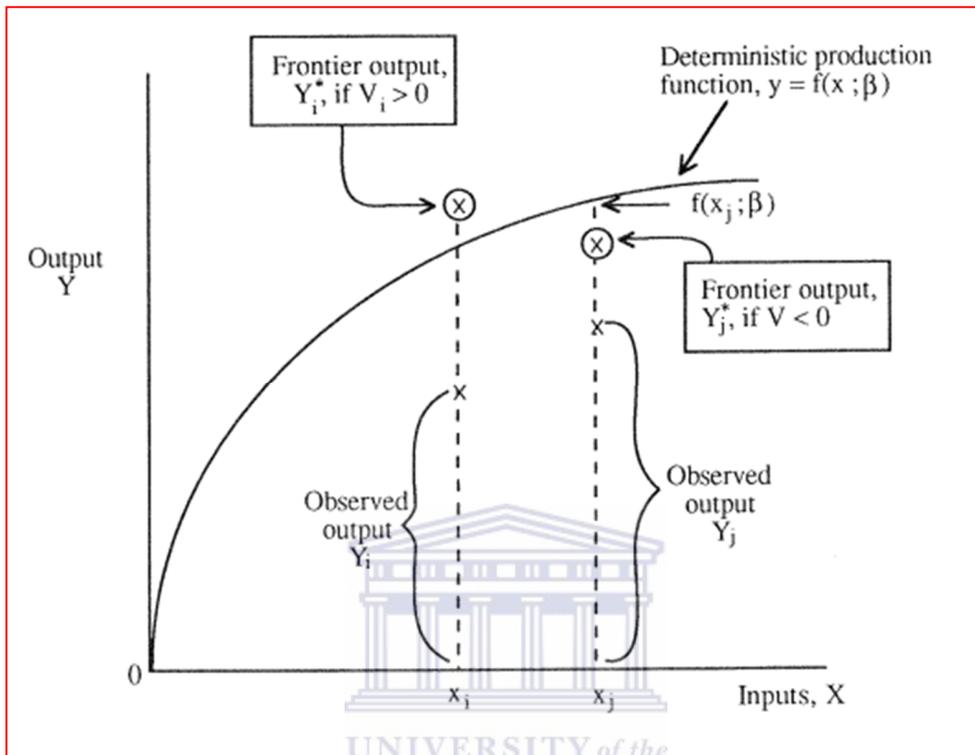
$$Y_i = f(X_i; \beta) \cdot \exp(\varepsilon_i) \dots \dots \dots 3.7$$

Where Y_i is total output of the i^{th} firm; $f(X_i; \beta)$ is a suitable function of the inputs vector X_i ; β is a vector of unknown parameters; and ε_i is a random variable whose distributional properties are given as follows. A residual random ' ε_i ' is split in to two components as:

$$\varepsilon_i = v_i - u_i \dots \dots \dots 3.8$$

where, v_i 's are assumed as a normal random variable having an independent and identical distribution with mean zero and variance σ_v^2 and independent of u_i 's which are assumed to be non-negative truncations of the normal distribution with mean ' μ ' and variance σ_u^2 ; and ' μ ', σ_v^2 and σ_u^2 are unknown parameters to be estimated. Finally, the variance of ' ε_i ' becomes the sum so that $v_i \sim N(0, \sigma_v^2)$ and $u_i \sim N(\mu, \sigma_u^2)$ and where $\sigma_\varepsilon^2 = \sigma_v^2 + \sigma_u^2$.

Figure 3.3: Stochastic frontier production function



Source: Battese, 1991, P.9

The above figure illustrated the production system of two different firms or farm household (represented by i and j). As we can see firm i uses a vector of x inputs and produce output Y_i which exceed the deterministic output. This is the result of its productive activity associated with "favorable" conditions for which the random error, V_i , is positive. In contrast firm j produces an output less than the deterministic frontier output which is the result of "unfavorable" conditions for which the random error, V_j , is negative. In both production activities the observed production frontiers are less than the deterministic production and the unobserved production frontier will lie around the deterministic production frontier associated with respective firms (Battese , 1991:9-10)

The basic idea underlying the stochastic frontier model is that the error term is composed of two parts. The symmetric component (v_i), permitting a random variation of the frontier across firms, captures the effects of measurement error, other statistical noise and random shocks outside the firms' control. The one side component (u_i) captures the effects of inefficiency relative to the stochastic frontier for the i^{th} firm/farm. As such, the decomposition of the residual random variable into (v_i) and (u_i) is the decisive property defining the stochastic frontier production function².

The economic logic behind the formulation of the stochastic frontier in (3.7) and (3.8) is that the production process is subject to two random disturbances having different characteristics, economically distinguishable though. The non-negative firm effects reflect the fact that each firm's output lies on or below its frontier and any such deviations are due to factors under the firm's control, arguably like production and economic inefficiencies and motivation and efforts of the producer and its employees. Thus, the error term u_i measures technical inefficiency in the production process.

The distributional assumption about the ' u_i ' is another issue in the stochastic frontier model as different assumptions are imposed in the literature of empirical research. To mention few, Aigner et al (1977) assume half-normal and exponential distribution while Meeusen and Van den Broeck (1977) considered only exponential. Similar possible distributions like gamma (Richmond, 1974), lognormal (Greene, 1980) are also expounded. Despite a mixed exercise, generally

² In this formulation, if $u_i = 0$, then the production lies on the stochastic frontier and is technically efficient while if $u_i > 0$, then production lies below the frontier and is inefficient. Akin, if the firm effect random term u_i is removed from the specification, then the model turns to be an average production function used often times. The condition, $u_i \geq 0$, indicates that all observations lie on or beneath the stochastic frontier. On the other hand, if the random disturbance term v_i is disregarded, then the model will be reduced to a deterministic frontier where linear programming techniques are in use often times

the distribution can follow either half-normal, $v_i \sim |N(0, \sigma_v^2)|$, truncated normal at zero, $v_i \sim N(\mu, \sigma_v^2)$, or exponential, $Exp(\mu, \sigma_v^2)$. However, Pieri (2010:47) proved that models estimated based on the three most frequently used assumption (half-normal. Truncated normal and exponential) give the same result, so that the specification of the inefficiency distribution does not matter.

Given the above specification (3.7) for the stochastic frontier production function and the distributional assumptions, technical efficiency (TE_i) is defined by:

$$TE_i = \frac{Y_i}{f(X_i; \beta) * \exp(v_i)} \dots\dots\dots 3.9$$

Where, TE_i is the technical efficiency for the i^{th} firm. In order to estimate ‘ TE_i ’, there arises a need to decompose the observable composite error ‘ ε_i ’ in to ‘ v_i ’ as v_i is unobservable. TE_i can then be best predicted by the conditional expectation of ‘ $\exp(-v_i)$ ’ given the values of the random variable ε_i (Jondrow, Lovell, Materov, and Schmidt, 1982; Coelli et al, 2005).

$$E(v_i / \varepsilon_i) = \frac{\sigma_v \sigma_v}{\sigma} \left[\frac{f(.)}{1 - F(.)} - \frac{\varepsilon_i}{\sigma} \left(\frac{\gamma}{1 - \gamma} \right)^{1/2} \right] \dots\dots\dots 3.10$$

Where, ε_i are estimated residuals for each firm/farm; $f(.)$ and $F(.)$ are values of the normal standard density and distribution functions evaluated at $\frac{\varepsilon_i}{\sigma} \left(\frac{\gamma}{1 - \gamma} \right)^{1/2}$.

Furthermore, the maximum likelihood estimation of (3.7) results estimators for γ and β where $\gamma = \frac{\sigma_v^2}{\sigma^2}$ and $\sigma^2 = \sigma_v^2 + \sigma_e^2$. Here, γ measure the total variation in output from the frontier that can be attributed to technical inefficiency and lies in $[0,1]$ Thus, individual technical efficiency measure for each firm relative to the frontier can be obtained by:

$$TE_i = \exp(-E(v_i/\varepsilon_i)) \dots\dots\dots 3.11$$

Following Battese and Coelli (1995) model for technical inefficiency, v_i 's are non-negative random variables, associated with technical inefficiency of production, which are assumed to be independently distributed such that v_i is obtained by truncation at zero of the normal distribution with mean, $Z_i\delta$ and variance σ^2 , $N(z_i\delta, \sigma^2)$; Z_i is a $(1 \times m)$ vector of explanatory variables associated with technical inefficiency of production of firms; and ' δ ' is an $(m \times 1)$ vector of unknown coefficients in the inefficiency effect equation.

That is, the technical inefficiency effects v_i 's are assumed to be functions of a set of explanatory variables, Z_i 's and an unknown vector of coefficients, δ .

The technical inefficiency effect equation is thus:

$$v_i = z_i\delta + \omega_i \dots\dots\dots 3.12$$

Where, the random variable ω_i is defined by the truncation of the normal distribution with zero mean and variance, σ^2 (Coelli and Battese: 1995)

The dynamic optimizing behavior of producers (firms/farms) entails us that a new optimal decision and hence a new economic structure could emerge from a substantial change in economic and policy variables which bring about new production environment. Hence, the stochastic frontier production function defined and explained above is applicable only to cross-sectional data where the data is collected on a cross-section of firms/farms at some particular point in time.

3.6 REVIEW OF PAST STUDIES ON TECHNICAL EFFICIENCY OF FARMERS

Literatures on the study of technical efficiency of farmers are vast and unevenly distributed. These studies are different in terms of method they applied, data they utilize and spatial coverage. Not all the available literature was considered in this review. The focus is limited to a brief review of studies which utilize stochastic production function approach in farm economies. Though studies of technical efficiency from Ethiopia perspective are few, attempt will be made to review the existing ones.

Since the introduction of the stochastic frontier method by Aigner et al. (1977) and Meeusen and van den Broeck (1977), the models have gone through various modifications and developments by different scholars in the area and have been applied to both agriculture and other sectors mostly using cross-sectional and Panel data (Debela et al, 2004). A more detailed review of technical efficiency studies applied to the agriculture sector in developing country is provided by Thiam et al (2001), Battese (1991) and Ozkan, Ceylan and Kizilay (2009).

Battese and Coelli (1995) studied the technical efficiency of paddy rice farms in Aurepalle India using panel data for 10 years and concluded that the technical efficiency of older farmers were less than the younger ones. They also found that farmer's level of education is the most important determinant of technical efficiency. Farmers with higher years of schooling were found to be more efficient but declined over the time period.

Obwona (2006) studied differential in technical efficiency between small and medium tobacco growers in Uganda. He used cross sectional data from 65 farmers and the result showed that the potential for improving the production efficiency of tobacco farmers is immense, as some farmers are operating at as low as 45percent level of efficiency. The study also revealed that education, credit accessibility and extension services contribute positively towards the improvement of efficiency. Tian and Wan (2000) Using survey data from China, estimated frontier production

functions for crops of rice, wheat and corn. They also analyzed technical efficiency and their determinants. The result showed that the scope for output growth through additional input and efficiency gain is quite limited.

A study by Dolisca and Jolly (2008) using a cross sectional data from 243 limited resources farmers in Haiti compared technical efficiency of traditional and not traditional crop production. They found that the non-traditional crop production was technically more efficient and generate higher net returns per hectare than the traditional one. In addition credit access and education level are the most important determinants of technical efficiency for both groups of farmers.

Ngwenya et al (1997) studied the relationship between farm size and technical efficiency using stochastic frontier production functions in Eastern Free State, South Africa from a sample survey of wheat farmers. The result showed that the mean technical efficiency of farmers using the translog specification was 0.671, indicating that there is room to increase production of wheat in the study area by utilizing the existing resources. They also found the technical inefficiency effects are negatively and significantly related to the size of the farms.

A study by Bagi (1984) examined differences in farm level technical efficiency of full-time and part-time farms in West Tennessee. He estimated Technical efficiency relative to a stochastic frontier production function for individual farms in each group. And the findings revealed that there are wide variations in the technical efficiency of individual farms in every subgroup but the average technical efficiency of both full-time and part-time crop farms are almost the same.

Kariuki et al (2008) using stochastic production function analyzed the effect of land tenure status on technical efficiency of smallholder crop production in Kenya. They found the existence of direct relationship between the tenure status of the farm and technical efficiency and parcels with land titles have a higher efficiency level. In

addition to the land tenure, credit availability and membership to groups are important determinants in increasing the farm level efficiency.

Center for Rural Development and Self-help (CRDS) in Nepal (2007) studied the impact of participatory extension program on technical efficiency of farmers using a cross sectional data from two groups of farmer those who participated in extension program and those which did not participate. They reported that farmers that participated in the program are found more technically efficient in rice production than those that did not participate in such trainings.

Amor and Muller (2010) studied the technical efficiency of irrigated agriculture in Tunisia. They employed a cross sectional data of irrigated crops from 218 farmers in 11 provinces of Tunisia. Using Cobb Douglas type of stochastic production function they found that more than 85percent variation in irrigated output among farmers in the study area is because of differences in their efficiency. In addition age, education, irrigation techniques and property of land explain the result of inefficiency among the farmers.

Ahmad (2003) studied differences in technical efficiency and productivity among poor and non-poor farmers in irrigated agriculture in Pakistan. He concluded that the average cost of the existence of technical inefficiencies is about 43 percent in terms of loss in output. Among the inefficient farmers, poor farmers account for the largest share. Moreover, the least efficient group of farmers are characterized by lower number of livestock units and a relatively greater number of farmers is located at the tail-ends of the watercourses.

Kuria et al (2003) using a model of the Cobb-Douglas Stochastic Frontier type examined the technical efficiency of farmers associated with rice production in Mwea irrigation Scheme in Kenya. They compared two groups of farmers in one group consisting of farmers growing a single crop of rice in a year and the other growing a double crop of rice in a year. The result shows that those farmers growing

a single crop of rice were more technically efficient than those growing a double crop of rice in a year. And farmer's education level and farming experience as well as availability of credit and extension facilities were found to be significant variables influencing technical efficiency of farmers in the scheme.

Burki and Nawaz Shah (1998) employed translog type of stochastic production function to examine the technical efficiency of farmers in five irrigated provinces of Punjab, Pakistan. They reported that technical efficiency increases the cost of individual farm by 24 percent and they also concluded that formal schooling of farm operator and abundance of canal water affect technical efficiency positively while age of farm operator has no effect on technical efficiency.

Mariano and Fleming (2010) examined if irrigated farming ecosystems more productive than rainfed farming systems in production of rice in the Philippines. Using Panel data from farmers under irrigated and rainfed ecosystem, they estimated stochastic production function to compare technical efficiency and productivity among and between the two farming ecosystems and the result shows that mean productivity levels differ only marginally between the two farming ecosystems and there is considerable variation in technical efficiency scores between farms within ecosystems, so there is potential for most producers in both farming ecosystems to improve productivity.

Although empirical finding on technical efficiency of farmers from Ethiopia perspective are scarce, they are not entirely missing. Gebreegziabher, Oskam and Woldehanna (2005) studied Technical Efficiency of Peasant Farmers in northern Ethiopia using a stochastic frontier approach. The analysis showed an average technical efficiency of 80.1 percent among peasant farmers in Northern Ethiopia and About 85 percent of the peasant farmers were found to have an efficiency level of greater than 75 percent. Admassie and Heidhues (1996) using stochastic production function tried to investigate and compare differences in the level of technical efficiency of two smallholders groups, one representing modern technology users

and the other consisting of relatively traditional farmers that do not use modern technology in the central highland of Ethiopia.

A study by Alemu, Nuppenau and Boland (2009) tried to examine variation in technical efficiency across agro ecological zones of Ethiopia and investigate the impact of poverty and asset endowment on technical efficiency of farmers in the study area. Based on randomly selected sample of 254 households and stochastic production function approach, they conclude that there exists technical inefficiency with mean technical efficiency of 75.68 percent and there is significant difference in technical efficiency across Agro ecological Zones. They also found that asset endowment in terms of physical, financial and human endowments has a significant and positive effect on technical efficiency while poverty significantly reduces the technical efficiency of farmers.

Seyoum, Battese and Fleming (1998) using translog stochastic production frontier and a Cobb-Douglas production function they examined technical efficiency of two groups of maize producers in eastern Ethiopia, with one sample comprising farmers with in Sasakawa-global 2000 (SG 2000) extension project and the other sample without the project. They found that farmers outside the project (79.4 percent) are less efficient than those enrolled in the project (93.7 percent).

In the most recent study by Nisrane et al (2011), they investigate the sources of inefficiency and growth in agricultural output in subsistence agriculture in Ethiopia using stochastic production frontier. They used panel data from the Ethiopian Rural Household Survey collected during 1994 through 2009. The result revealed that an average farmer produces less than half (with average technical efficiency of 46 percent) of the value of output produced by the most efficient farmer using the same technology and inputs. In addition they conclude that due to reduced labor bottlenecks and increased education average farming efficiency has improved during the 1995–2009 period.

The only study which compares technical efficiency of farm households in irrigation and rain-fed ecosystem from Ethiopian perspective is a study by Makombe, Kelemework, Aredo (2007). Using a cross sectional data from 147 rain-fed and 144 irrigating farmers and applying stochastic production frontier approach, they analyze difference in marginal productivity and technical efficiency in Ethiopia. The result showed that average productivity of irrigated land is more than ten times that of rain-fed and even though the technical efficiency of farmers under both ecosystems varies according to assumption made about the error term, farmers in both setting exhibit very little inefficiency. Though this study will follow the same procedure like Makombe et al' s , it is different in a way that their study failed to consider/ determine the factors of inefficiency which are important in informing policy makers which institutional and socio economic aspects that needed to be considered in improving agriculture production and productivity. This weakness has made itself manifest in a wider research gap and demand a greater effort in investigation and analysis with a view to achieving a more accurate interpretation empirical data for determinants of inefficiency in Ethiopia.

WESTERN CAPE

3.7 WORKING HYPOTHESIS

Based on the theoretical framework outlined and vast literature on the subject this study is based on the following hypothesis:

1. Small holder farmers in the study area are not fully efficient. Hence, there is a strong case for significant output gain from efficiency improvement.
2. Farmers with access to irrigation technology are technically efficient compared to those without access to the technology with respect to their own production frontier.
3. Access to irrigation technology is a significant factor to explain deviations from the frontier output or technical inefficiency.

3.8 CHAPTER SUMMARY

In conclusion this chapter presented the theoretical underpins of the study. The measurement and conceptualization of technical efficiency is based on the microeconomic theory of production. Basically, there are two different measures of technical efficiency, the DEA and SPF. And this is study utilized SPF approach. The chapter also gives an extensive review of different empirical studies which used the stochastic production function in different parts of the world. The next chapter will discuss the methodological issues and empirical models of the study



CHAPTER FOUR: RESEARCH METHODOLOGY

4.1 INTRODUCTION

This chapter presents methodological aspects of the study. The first part describes in detail the socio demographic and economic characteristics of the research setting. And this followed by explanation on the research design, sampling procedure, the research instruments that are used to collect data and the technique of data analysis. It also indicates the empirical models specified and their procedure of estimation.

4.2 DESCRIPTION OF THE STUDY AREA

This study was conducted in the Gorogutu district, which is found in the North Western extreme point of the East Harerge Zone. The East Harerge Zone is situated in the Eastern part of the country 526 kilometers from the capital Addis Ababa. Geographically, it lies between 7°32' - 9°44' North latitude and 41° 10'-43°16' East longitudes. The topography of the Zone is characterized by Plateaus, rugged dissected mountains, deep valleys, gorges and plains with its altitude ranging from 500 to 3405 meters above sea level. The Wabishebele and Awash drainage basins are the two basins that cover the Zone. The Wabishebele drainage basin is the largest and covers about 90 percent of the total areas of the Zone. This drainage includes Erer, Ramis, Mojo and Daketa Rivers that start flowing from the central high land of the Zone to the south eastern part that finally drain to Wabishabele River. Despite the fact that the valleys of these rivers have large areas of potentially irrigable land, the total land area under irrigation is negligible (EHBoFED, 2008:5).

According to the 2007 population and housing census report, the total Population of the zone is estimated to be 2.9 million (with 50.8 percent of male and 49.2 Female). Out of the total population 91.9 percent are residents of rural areas while the remaining 8.1 percent are urban residents. The total population density of the

zone is 97.3 people per square kilometers. With an average household size of 4.6, the Zone's population is composed of 46.9 percent young people, 50.5 percent economically active individuals and 2.5 percent older people (ibid).

In congruence to other parts of the country, the livelihood of the majority in the Zone is based on subsistence agriculture production. According to the Zone's Bureau of Finance and Economic Development (BoFED), the production region is classified in to three general categories. These are the mixed farming (crop and livestock Production), the pastoral and the transitional (between mixed and pastoral farming). The mixed farming region account for about 40 percent of the total zonal area, the pastoral areas accounts for about 50 percent and the transitional accounts for the remaining 10 percent of the total area of the zone. The average land holding size of a farm plot in the East Hararge Zone is less than 0.5 ha. This shows that the land holding size of the zone is small especially in the mixed farming area where the population density and suitability of agro-ecology for farming is higher. (ibid: 8)

The predominant cultivated crops in the zone are sorghum, maize, haricot bean, barely, wheat and field peas. 'Khat'³ is a cash crop that has a long standing tradition of being produced in the area. According to the latest estimates available, in the year 2007/2008, out of the total area of 491723 Ha, Khat production covered 15.4 percent.

The zone is currently subdivided into 19 administrative districts. Gorogutu, where this study is conducted, is one of the 19 districts in the zone. The Gorogutu district lies between 9°18 and 9°53`N latitude and 41°33` and 41°30E longitude. The district shares borders with Deder District in the South and South East, Meta district in the East, West Harerge Administrative zone in the West and Somali Regional state to the North. The study district has a total area of 531.23 km², accounting for about 2.35 percent of the total area of East Harerge zone. Its capital city, Karamile is located at a distance of 108kms from Harar Town which is the nearest big town.

³ a stimulant plant, which is more or less related to "Hashish" as a cash crop

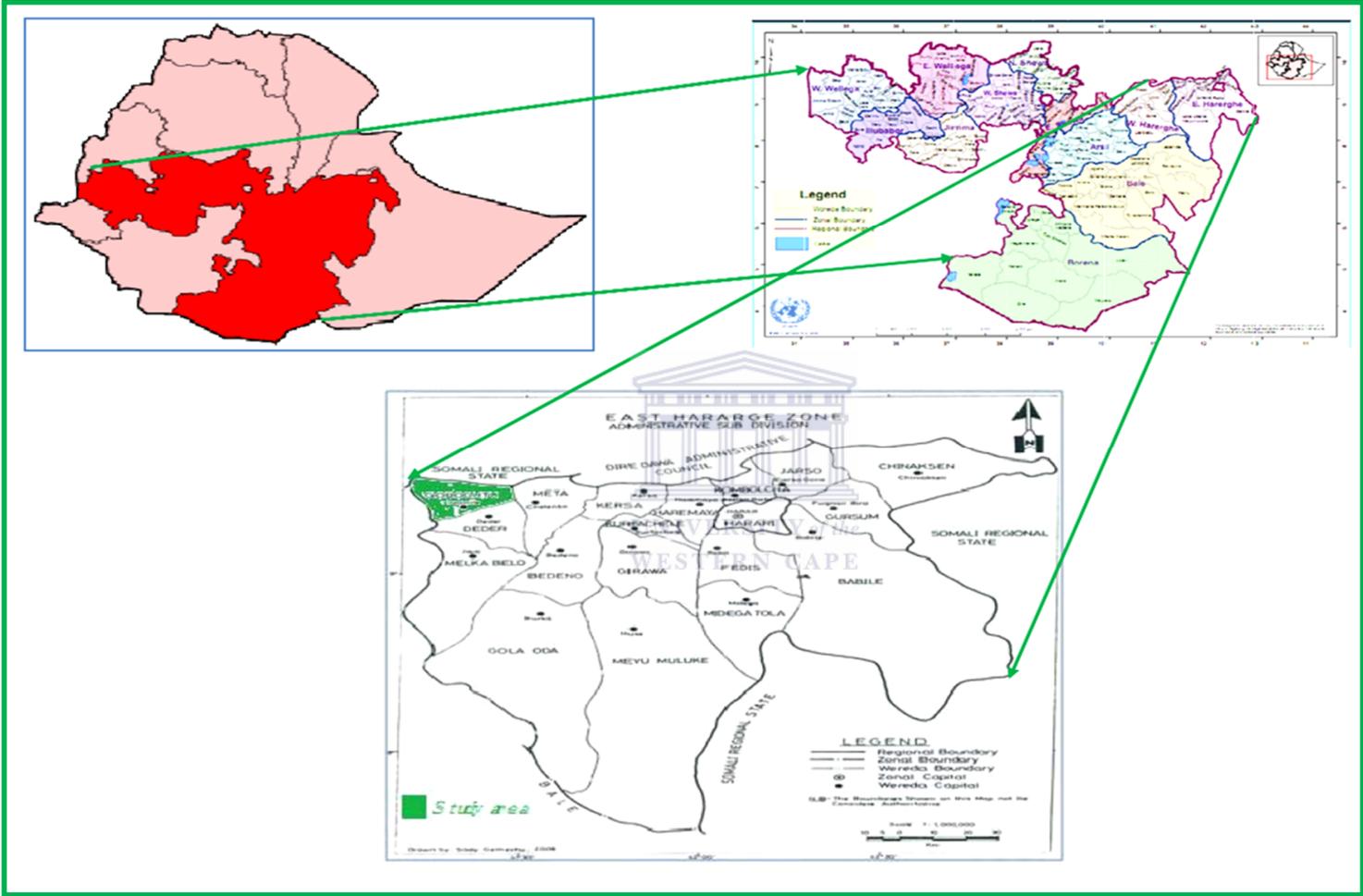
According to the 2007 population and housing census, the population of the district is estimated to be about 152,242 (51 percent male and 49 percent Female). As more than 93 percent of the population lives in the rural area, agriculture is the main source of livelihood for the majority in the study area. The average landholding size per household in the study district is 0.37 (Zelalem, 2010:30).

The study district is drained by permanent rivers such as Erer (about 12 kms of length), Usman Ejersa (about 16.25 kms of length) Burka (about 25.0kms of length) and seasonal steams such as Medisa, oladi, Hora and Laftowaldiya. Despite a number of permanent rivers with high potential for irrigation, their exploitation for agriculture production is negligible (EHBoFED, 2008:7).

Among the existing irrigation schemes in the Gorogutu district, 'Error Mede Telila' irrigation scheme was selected for this study. The 'Error Mede Telila' irrigation scheme was first constructed by the Oromia Regional Water, Mines and Energy Bureau in 1996. Originally, the scheme was built to irrigate about 100ha of land by gravity to benefit 600 households in the area. In year 2004 the Bureau decided to expand the schemes irrigation capacity from 100 ha to 130 ha with the number of beneficiaries also increasing to 1066 households. The scheme has 3 primary canals that transport water to the secondary canals. These secondary canals in turn distribute water to the beneficiary farmers through 40 tertiary canals (Eshetu, Belete, Goshu, Kassa, Tamiru, Worku, Lema, Delelegn, Tucker and Abebe, 2010:11).

Since there was a potential to increase the scheme's capacity to reach to upstream beneficiaries, in 2005 an Italian NGO called 'The Committee for the Development of Peoples' expanded the scheme's total command area and number of beneficiaries by installing power pumps and generating sets, and constructing a water storage facility. The scheme is currently irrigating a total of 166ha of land which is used by 1266 beneficiaries (ibid: 11-12).

Figure 4.1 Map showing the study area



Source: EHBoFED, 2008

4.3 RESEARCH DESIGN

In exploring and identifying technical efficiency and its socio economic and institutional determinants for farm households in the Gorugutu district, a cross sectional research design was adopted. According to Bryman and Bell (2007:55) “A *cross-sectional design entails the collection of data on more than one case and at a single point in time in order to collect a body of quantifiable or quantitative data in connection with two or more variables, which are then examined to detect patterns of association.*” The main challenge in exploring the effect of access to irrigation technology on technical efficiency is to determine what would have happened to the farmers if they didn’t have accesses to the technology. That is, determining the counterfactual will be necessary. For this specific study the “with and without” scenario is adopted. The data needed for the study was collected from two groups, those with access to irrigation technology (the treatment group) and those without access to irrigation technology (Control group). The control group was selected from adjacent rainfed farmers, to make sure that they are working under the same climate condition, ecological risk and uncertainties that may determine their agricultural productivity and efficiency. Two villages which are relatively homogenous were selected. Selecting sample respondents from these two relatively homogenous villages using random sampling technique helps to draw unbiased estimates for comparison between the treatment and the control group (Urama and Hodge, 2004:486)

4.4 DATA SOURCE AND METHOD OF DATA COLLECTION

The analysis in this study is principally based on primary data. The primary cross sectional data for the study was collected for 2010/2011 cropping season using structured household level questionnaires. The same questionnaire is administered for both groups of farmers, with access to irrigation technology and without access

to the technology. The questionnaire elicited information about household demography and education status, crop production, household income and asset ownership, expenditure on inputs, extension and credit services etc (refer to Appendix V). The questionnaire was pre-tested on 16 households who were randomly selected from the two groups to detect errors for correction before being finally administered to the respondents.

The data collection took place between the period of June 2011 and August 2011. The data collection was possible with the help of four development agents (DA) who were recruited to collect the data under close supervision of the researcher. The fact that these development agents are stationed in survey area and had extended knowledge about the geographical, cultural context and language of the community, made it easy to elicit sensitive information from the selected farm households.

In addition to the primary data, the study also used secondary data. The secondary data was collected from the Central Statistical Agency, District and regional level government offices and implementing NGOs in the study area.

4.5 SAMPLE SIZE AND SAMPLING TECHNIQUE

In order to make valid inferences and increase the degree of precision of the results, a well-designed sampling frame is a pre-requisite. In obtaining the sample for this study, a multistage sampling technique was followed. In the first stage the 'Erer Meda Telila' irrigation scheme was selected purposively due to its high performance level, high command area and its location and accessibility. It was also easy to find communities with relatively homogenous socio economic, climatic and ecological conditions. In the second stage two Kebele associations were selected purposively from the existing associations around the scheme. Each of the Kebele associations selected represented two different farming environments. While the first Kebele association represented households with access to the irrigation technology, the

second Kebele association represented farmers entirely without the technology. At the final stage using the list from the 'Kebele Associations', 50 household farmers were selected from each associations using simple random sampling technique. The information collected from the households was coded and cleaned on Microsoft Excel before it was imported to STATA and FRONTIER 4.1 for analysis.

4.6 EMPIRICAL MODEL SPECIFICATION AND VARIABLE DESCRIPTION

As stated in the third chapter, this study used the stochastic production function. In modeling the stochastic function, the first thing to consider was which the functional form to use. The Trans-logarithmic and Cobb-Douglas (CD) stochastic production function are two of the widely used functional forms to represent the production process. Coelli (1996) argued that both functional forms are important in modeling agricultural frontier functions. In this study, CD functional form, against translog specification which suffers from multicollinearity and hence implausible coefficient sign and magnitude, is pursued in the specification of the stochastic frontier.

Following Coelli and BATESSE (1995) specification the model specified will have two parts; the stochastic production function (SPF) and the inefficiency model. The stochastic production function will relate the technical relation between output and convectional inputs. Based on prior literature and economic theory, a typical smallholder agricultural production activity in developing countries, specifically Ethiopia, involves factor inputs of a plot of land, labor (usually family labor), a sort of capital (farm implements to till and cultivate land) and modern inputs of which fertilizer needs mention. The Stochastic Production function estimated in this study is generally specified as follows

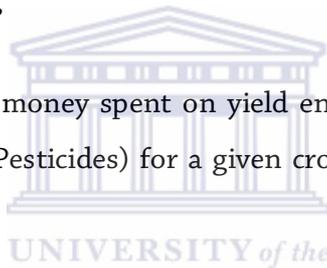
$$Y=(LAND,LABOUR,FERT,KPTL) \quad [4.1]$$

Where 'Y' is the gross value of all crops produced, since the farmer produces different crops it is difficult to aggregate into one common measure. As a result in this study the value of output in Ethiopian birr⁴ is used to measure the total production of the household.

'LAND' is the total area cultivated by the farm household for the given cropping season. It is measured in terms of hectares.

'LABOR' is the total labour days (either family labour or hired labour) spent on cleaning, ploughing, weeding and harvesting. It is measured in terms of man days for 2010/11 cropping season. According to Weir (1999:16) measuring labor in man days has an advantage that "*...it counts actual time spent on farm activities, rather than just potential effort.*"

'FERT' is the amount of money spent on yield enhancing technologies (fertilizer, high yield variety seeds, Pesticides) for a given cropping season. It is measured in Ethiopian birr (ETB).



'KPTL' is the value of all physical capital (hoes and ploughs used for cultivation) for each household per cropping season. It is measured in Ethiopian birr.

The specific Cobb-Douglas stochastic production function is specified as follows:

$$\ln Y = \varphi_1 + \varphi_2 \ln(LAND_i) + \varphi_3 \ln(LABOR_i) + \varphi_4 \ln(FERT_i) + \varphi_5 \ln(KPTL_i) + V_i - U_i \quad [4.2]$$

In the above equation the subscript, i, indicates the ith farmer in the sample. *ln* is natural logarithm and φ s are coefficients to be estimated. Since the value of output is in natural logarithmic form, the coefficients $\varphi_2, \varphi_3, \varphi_4, \varphi_5$ measures percentage changes in output that result from a change in the respective factors of production. The maximum-likelihood estimates for the Parameters of the above Cobb–Douglas

⁴ \$1=17.25 Ethiopian Birr (1 EUR=24.15 Ethiopian birr)

stochastic frontier production functions for the farmers with access to the technology and without access to the technology were estimated separately. These two stochastic production functions are used to drive technical efficiency scores of each of farmers in their respective groups. In addition the coefficients of the two production functions are used to compare differential in output elasticities between farmers with access to the technology and those without access.

A common stochastic frontier model for all farmers, irrespective of whether they have access or not to irrigation technology was also estimated. Specifically the following Cobb- Douglas stochastic production function was estimated

$$\ln Y = \varphi_1 + \varphi_2 \ln(LAND_i) + \varphi_3 \ln(LABOR_i) + \varphi_4 \ln(FERT_i) + \varphi_5 \ln(KPTL_i) + \varphi_6 ACC_IRG + V_i - U_i \quad [4.3]$$

In addition to the variables described in the previous equation, the above equation involves one additional variable, *ACC_IRG*. This variable is a dummy variable that captures the effect of access to irrigation technology on farm household's output. The variable takes the value 1 if a household has access to irrigation technology and it takes a value of 0 if the household is without access to irrigation technology.

As the variable *ACC_IRG* is a qualitative dummy variable, φ_6 must be adjusted before it is interpreted as the resulting percentage change in value of output. Following Halvorsen and Palmquist (1980:474) when the independent variable is a qualitative dummy variable and output is in logarithmic form, the output elasticity is calculated by taking the anti-log of the coefficient of the dummy variable and subtracting 1 from the result. Multiplication of the result by 100 will give us the percentage change in output due to the change in value of the dummy variable from 0 to 1. The output elasticity of the variable *ACC_IRG*, here denoted by φ_6 , is given by

$$\hat{\varphi}_6 = 100 * (e^{\varphi_6} - 1) \quad [4.4]$$

The above production function which is estimated based on the pooled sample of all the respondents irrespective of their access to technology is also used to estimate the technical inefficiency effect model.

Inefficiency Model

Following prior practices and reviewed literature on inefficiency effect models, farm productive inefficiency is linearly explained by household characteristics, farm specific factors, village and infrastructural factors which influence the organization and management of farming. The age and sex of household head is included to see whether efficiency differentials among the farm household can be explained by such household characteristics. Similarly, the level of education is included to determine whether human capital, enabling farmers to effectively communicate innovations and to embrace holistic attitudinal change towards improved organization and management of farms, explain productive efficiency and output. Access to irrigation technology is also introduced in the inefficiency equation to test if variation in this indicator explains farm efficiency of a given household through enabling double cropping and effective utilization of resources. Access to extension and credit service is believed to contribute and explain productive inefficiency. So, they are included as a dummy variable in the inefficiency equation as well.

The inefficiency model is specified as follows

$$\begin{aligned} \mu_i &= \delta_i Z_i + \omega_i \\ \mu_i &= \delta_0 + \delta_1 AGE + \delta_2 SEX + \delta_3 Yr_SCHOOLING + \delta_4 ACC_IRG \\ &+ \delta_5 EXTN_SRVS + \delta_6 ACC_CREDIT + \delta_7 DISTANCE_PLOT \\ &+ \omega_i \quad [4.5] \end{aligned}$$

Where δ_i s are coefficients to be estimated and μ_i is technical efficiency score.

'AGE' is age of household measured in years. The effect of age on technical efficiency of farm households is expected to be either positive or negative.

According to Gebregzabehe et al (2005) as the farmer get older, the experience effect within farm practice will increase which potentially increases the technical efficiency. On the other hand with an increase in age, the capacity and ability to work on the farm might decrease. More so, old aged farmers are less receptive to new inputs and technologies which will result in negative effect on technical efficiency.

'SEX' is sex of the household (0 if household head is female and 1 otherwise). This variable is included in to inefficiency effect model to examine if the gender of the household has any bearing effect on efficiency. In rural Ethiopia female become a head of a household only when males are deceased or not around. Therefore when females are head of a household they take responsibility of farming in addition to their traditional homemaking role. As a result such households will face scarcity of labor during picking periods to timely apply inputs.

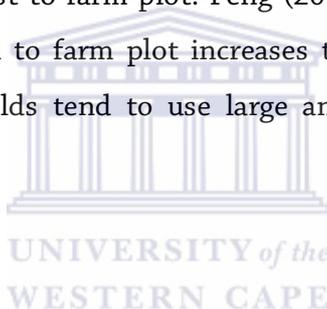
'Yr_ SCHOOLING' is a continuous variable referring to the years of schooling of the household head. It is measured in terms of the maximum number of years the household head spent in school. Here it is posited that education proxied by year of schooling will have a positive effect on the technical efficiency of farm households. Education has the potential to enhance farm productivity directly "*...by improving the quality of labour, by increasing the ability to adjust to disequilibria, and through its effect upon the propensity to successfully adopt innovations.*"(Weir, 1999:1)

'ACC_IRG' is a dummy variable capturing household's access to irrigation technology. It takes the value 1 if a household has access to the technology and 0 otherwise.

'EXTN_SRVS' - this variable refers to the number of visits the household gets from development agents (DA) during a given cropping season. Development agent's visit helps the farmer to get information on selection and timely application of inputs and how to improve productivity therein.

'*ACC_CREDIT*' is a dummy variable that capture access to credit service. It takes a value of 1 if a household has access to credit service and 0 other wise. Access to credit service will reduce capital constraints and facilitate investment of new technologies on farm. Compared to households without access to credit, households with access to credit should move closer to the production frontier (Brummer and Loy, 2000).

'*DISTANCE_PLOT*' is the average distance the farmer travels from his homestead to the farm plot. The variable is measured using kilometers distance from the homesteads to the farm plot. Here it is hypothesized that farmers with long distance to travel from his homestead to farm plot is less technical efficient compared to those nearest to farm plot. Feng (2008) noted that longer travelling distance from homestead to farm plot increases the cost of applying input from home and farm households tend to use large amount of input but with lower frequencies.



4.7 ESTIMATION PROCEDURE FOR THE STOCHASTIC PRODUCTION FUNCTIONS AND INEFFICIENCY EFFECT MODEL

The Stochastic production function specified under equation [4.2] is estimated for both groups of farmers separately. And equation [4.3] and [4.5] were estimated using the one step approach (estimated simultaneously). There are two approaches in estimating the inefficiency models; a one-step procedure and a two-step procedure. For the two-step procedure the stochastic production frontier is first estimated alone and then the technical efficiency of each farm household is predicted. In the second step the technical efficiency scores are regressed on a set of explanatory variables which are posited to affect the technical efficiency of farm households. However, the two step approach is criticized for its inconsistency in the assumptions about the distribution of the inefficiencies score. As Herrero and

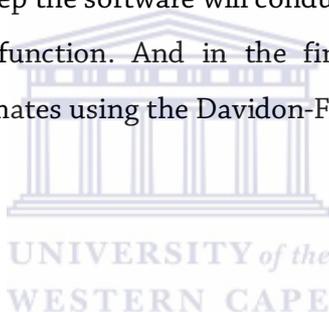
Pascoe (2002:15) pointed out “*In the first stage, the inefficiencies are assumed to be independently and identically distributed (iid) in order to estimate their values. However, in the second stage, the estimated inefficiencies are assumed to be a function of a number of firm specific factors, and hence are not identically distributed unless all the coefficients of the factors are simultaneously equal to zero*”. On the other hand the one step approach estimates all of the parameters of the production function and technical inefficiency effect model simultaneously. To decipher the inconsistency that arises with the two step approach, in the one step approach the inefficiency effects are defined as a function of the farm specific factors (as in the two-stage approach) and are incorporated directly into the maximum likelihood estimation (Herrero and Pascoe, 2002).

In estimating all these equations rather than Ordinary Least Square estimation (OLS) maximum likelihood estimation (MLE) procedure was used. According to Viet Le (2010) maximum likelihood estimation is more efficient in estimating the coefficients of stochastic production function and also it is possible to estimate the inefficiency effect model simultaneously. More so, MLE have many desirable large sample properties and is preferred to other estimators like OLS (Le Viet, 2010:148)

Prior to running the estimation of all the Stochastic Production Functions and the inefficiency effect model, the independent variables were diagnosed for possible existence of multicollinearity. The problem of multicollinearity arises when the explanatory variables of the model have a “perfect” linear relationship or are intercorrelated but not perfect among some or all variables (Gujarati, 2004:342). Estimation of the models in existence of multicollinearity causes the estimators to have larger standard errors (unstable estimators), smaller t ratio and their confidence interval to be much wider (ibid:259). According Field (2009) existence of multicollinearity problem can be detected using either Variance Inflation Factor (VIF). The value of VIF shows how much the standard error of an estimator is inflated by the presence of multicollinearity. Although there are no specific tests

about what value of the VIF should cause concern of multicollinearity, the commonly given rule of thumb is that, VIFs of 10 and higher (tolerances of 0.10 or less) pose a concern that multicollinearity is a problem (Field, 2009:259).

In addition to STATA 12, a well-known software package in efficiency and productivity analysis called FRONTIER 4.1 was used in estimating the maximum likelihood estimators of all the models in this study. This software, developed by Coelli, is a single purpose package specifically designed for the estimation of stochastic production frontiers and nothing else (Herrero and Pascoe, 2002). The software uses three steps in estimating the coefficients of the stochastic production function. In the first step, Ordinary Least Square (OLS) estimates of the model are obtained. In the second step the software will conduct a two phase grid search of the value of the likelihood function. And in the final step it calculates the final maximum likelihood estimates using the Davidon-Fletcher-Powell algorithm (Coelli, 1996:12).



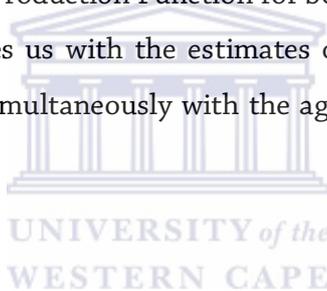
4.8 CHAPTER SUMMARY

In line with the theoretical frame work and literature reviewed, this study used entirely a quantitative method for collecting and analyzing the data. Using stochastic production function approach three different empirical models were specified. Each model is aimed to answer the research question set in the beginning of the study and to test the hypothesis of the study. More so, this chapter discussed the socio economic description of the study district, the specific research design applied and sampling technique In the next chapter discusses the empirical findings from the descriptive statistics and the estimated stochastic production functions.

CHAPTER FIVE: RESEARCH FINDINGS AND DISCUSSION

5.1 INTRODUCTION

The first section of this chapter provides descriptive statistics on the sampled household's demographic and socio economic characteristics. The descriptive statistics provide an insight about the context within which the estimates from the stochastic production function and the efficiency effect models are found. The first section also provides comparisons of means between the treatment and control groups with respect to the continuous variables. A chi square test is also employed for nominal variables. The second section provides the result from the estimated Cobb Douglas Stochastic Production Function for both groups of farmers separately. The third section provides us with the estimates of the technical efficiency effect model which estimated simultaneously with the aggregated production function of all farmers.



5.2 SOCIO-ECONOMIC AND DEMOGRAPHIC CHARACTERISTICS OF SAMPLE HOUSEHOLDS

5.2.1 Demographic characteristics of respondents

In countries where agriculture is a mainstay for the majority, demographic characteristics (family size, size of land, and age and sex of the family head) are the most important features that affect productivity and efficiency of farm households. Table 5.1 below shows the basic demographic characteristics of the sampled households in the study area.

Table 5.1 Demographic characteristics of sample households (Average)

	With Access to the technology	Without access to the technology	Total	t value
Age of Household Head	35.48	43.12	39.3	5.3149*
Household Size	6.52	5.72	6.12	2.3357*
Household size Adult equivalent	5.12	4.764	4.942	1.5674**
Dependency ratio	1.60	1.61	1.60	0.0505

Source: Field survey, 2010/11

[*and ** significance at 1% and 5% level of significance respectively]

The result from the sample survey demonstrates that the age of the respondents ranged between 25 and 58 years with an average age of 39 years. The disaggregation of age across the two groups (with and without the technology) also reveals that the average age for the household head for households with access to the technology is lower than for those without the technology (36 years for households with access compared to 43 years for household head without access to the technology). Those with access to the technology are younger than those without access to the technology.

The average household size of the sampled respondents is 6 persons per household. Households with access to irrigation have higher average household size compared to those without access to irrigation. The average household size for households with access to the technology is found to be 6.5 persons while for those without the technology it is 5.7 persons per household. The difference in average household size between the two groups is also statistically significant at 1percent.

More so, household size in adult equivalent scale⁵ is higher for households with access to irrigation than households without. On average 4.9 adult equivalent persons live within a household. The average number of adult equivalent persons in household with access to irrigation technology is 5.1, while for those without it is 4.7. The difference in adult equivalent household size is also statistically significant between the two groups with 5 percent level of significance.

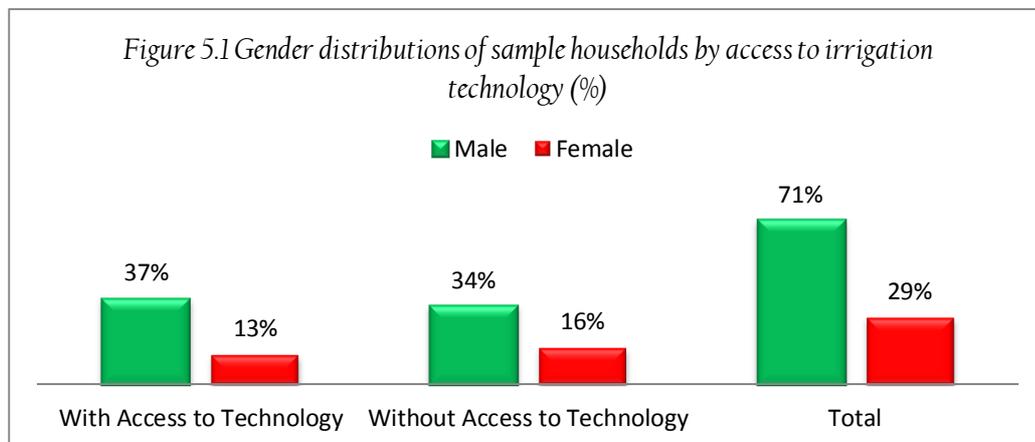
When comparing the dependency ratio (the ratio of the number of adults to the number of children and old people within the household) between households with access to irrigation and households without, the result from the survey shows that on average those with access to irrigation have a dependency ratio of 1.61 while non-irrigators have 1.6. The average dependency ratio for the entire sample respondents is however 1.6. The difference in average dependency ratio between irrigators and non-irrigators is not statistically significant at any acceptable level of significance (1 percent, 5 percent, and 10 percent).

Table 5.2 Gender distribution of sample households by access to irrigation technology (%)

Sex	With Access to the technology	Without access to the technology	Total	Chi2
Male	37(74%)	34(68%)	71(71%)	0.4371
Female	13(26%)	16(26%)	29(29%)	
Total	50	50	100	

Source: Field survey, 2010/11

⁵ The adult equivalence scale is used to capture economies of scale associated with larger households. The equivalence scale suggested by OECD for countries which have not established their own scale was used to calculate the household size in adult equivalent. This equivalence scale called "OECD equivalence scale" or "Oxford scale" assigns a value of 1 to the household head, value of 0.7 to each additional adult and of 0.5 to each child. And it is given by the formula $AE = (1 + 0.7(a-1) + 0.5(c))$, where 'a' is total number of adults and 'c' is total number of children with in the household.



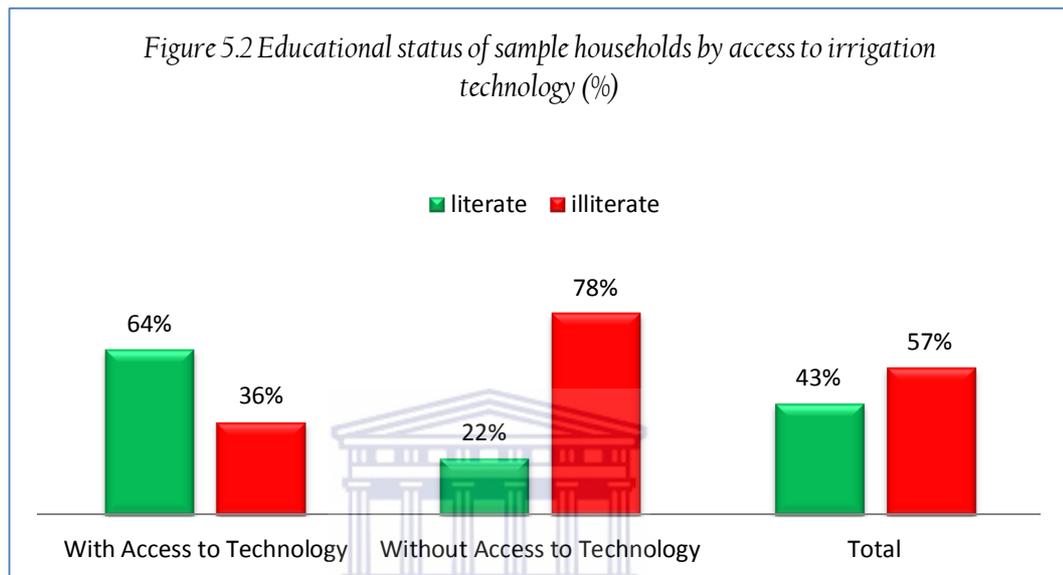
Source: Field survey, 2010/11

Looking at the gender distribution of respondents, from the total 100 households sampled, 71 percent of the households are headed by men and the remaining 29 percent are female headed. Furthermore, the disaggregation of the Gender by access to irrigation also shows that, while 74 percent of irrigators and 68 percent of non-irrigators are headed by male household heads, the remaining 26 percent of the irrigators and 32 percent of non-irrigators are female headed households. The above table and figure shows gender distribution of households by access to irrigation. The chi square value in the table also shows that there is no statistically significant relationship between gender of the household and access to irrigation technology in the study area at any acceptable level of significance level.

5.2.2 Educational status of household head

Access to education is one of the factors that make a difference in farm productivity and technical efficiency. According to Weir (1999:1) education has the potential to enhance farm productivity directly “by *improving the quality of labour, by increasing the ability to adjust to disequilibria, and through its effect upon the propensity to successfully adopt innovations.*” For this study respondents were

asked if they attended any formal education and if so the maximum number of year they spent in school. The figure 5.2 below shows the distribution educational status of households by access to irrigation.



Source: Field survey, 2010/11

The result from the survey showed that 43 percent of the total respondents have attended basic education and the remaining 57 percent have never attained any form of formal education. For those households with basic education, the number of years spent in school ranged from a minimum of 1 year to a maximum of 8 years. The average number of years spent in school is found to be 2.15 years for the entire sample. A cross tabulation between the education status of households and access to irrigation reveals that, 64 percent of households with access to the technology and 22 percent of those without the technology are literate and the remaining 36 percent of irrigators and 78 percent of non-irrigators are illiterate. The chi square value of 17.992 from the cross tabulation also shows that there is statistically significant relation between educational status and access to irrigation technology at 1 percent level of significance.

The disaggregation of average years of schooling of a household head by access to irrigation technology shows that on average a household head with access to irrigation has spent 3.04 years in school and a household head without access to irrigation has spent on average 1.26 years. The t test for difference in the mean values revealed that, statistically there is significant difference in average years of schooling by the two groups at 5 percent significance level.

Table 5.3 Average year of schooling of household head by access to irrigation

	With Access to the technology	Without access to the technology	Total	t values
Years of Schooling	3.04	1.26	2.15	3.5686**

Source: Field survey, 2010/11 [** significance at 5% level of significance]

5.2.3 Access to credit

Development theory often claimed that access to credit mitigate the problem associated with liquidity and enhances the use of inputs and agricultural technologies in production (Alemu et al, 2009). In this study farm households were asked if they received credit during the given cropping season. The Table 5.4 below shows the cross tabulation between access to irrigation technology and access to credit services.

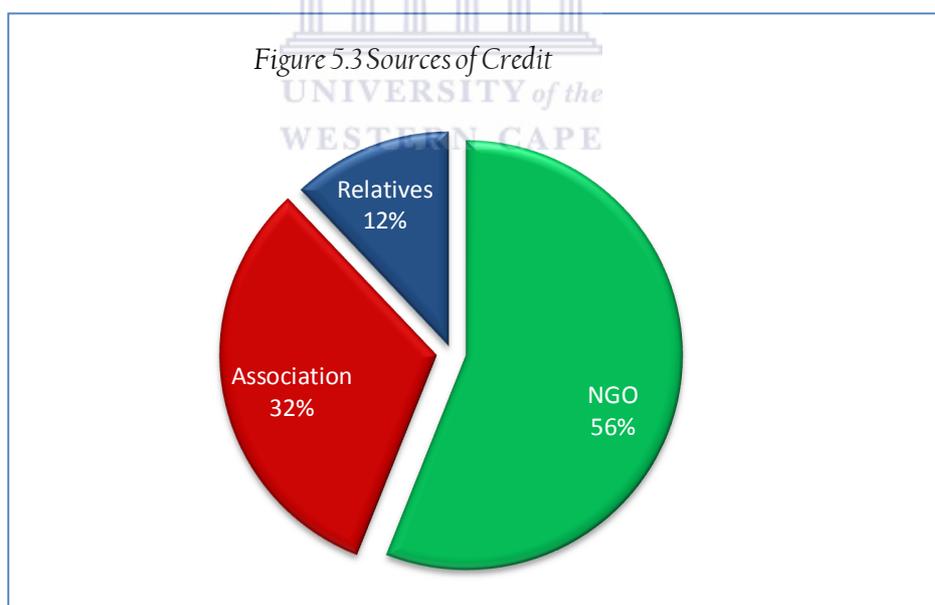
Table 5.4 Access to credit by access to irrigation technology (%)

Access to Credit services	With Access to the technology	Without access to the technology	Total	Chi2
Yes	35(70%)	30(60%)	65(65%)	1.0989
No	15(30%)	20(40%)	35(35%)	
Total	50	50	100	

Source: Field survey, 2010/11

The result indicates that 65 percent of the total respondents have received credit from different sources and 35 percent didn't receive any form of credit during the cropping season. The cross tabulation between Access to credit services and irrigation technology shows that 70 percent of household with access to irrigation technology and 60 percent of households without the technology have access to credit and remaining 30 percent of households with access to the technology and 40 percent without access to the technology didn't have access to any form of credit. The chi square test statistics of 1.0989 is not significant at any acceptable level of significance. This shows that statistically there is no relationship between access to irrigation technology and access to credit services.

Households who received credit during the given production period were also asked from where they accessed the credit. Graph 5.3 below shows the distribution of households by sources of credit service.



Source: Field survey, 2010/11

The result indicates that majority of the respondents, 56 percent, received the credit from NGO implementing in the study area. While 32 percent of them mentioned

farm association as source of credit the remaining 12 percent received credit from relatives.

5.2.4 Access to extension services

Access to extension service provides huge gains to farmer's productivity and efficiency through the mechanisms of providing access to technical knowledge and new skill and as a facilitator of new technology adoption. In the rural Ethiopia in general and in the study area specifically extension service is provided by Development Agents (DA). These agents are typically trained professional in agriculture who acts as a coordinator, communicator, educator and translator; connecting farm households to government, NGOs, credit mechanisms, and other related services (Belay and Abebaw, 2004). During the survey the respondents were asked the number of extension visits they received from DAs during the given production period. Table 5.5 below summarizes the extension service received by households with and without access to irrigation technology.

Table 5.5 Average number of visits by access to irrigation technology

	With Access to the technology	Without access to the technology	Total	t values
Number of Visits	6.96	6.66	6.81	0.6325

Source: Field survey, 2010/11

The finding indicates that on average households have received 7 days of visit from the development agents. The number of days visited ranges between 3 and 10 days. The disaggregation between households with access to irrigation technology and households without also reveal that, there is no significant difference in the number of visits they received from the agents during the production period.

5.2.5 Farm household's input utilization and output produced

A typical farm household's production activity in Ethiopia involves the use of different conventional and intermediate inputs. Among others the conventional factors of production that the farm households use in the study area include land to cultivate, labour, capital goods and improved seeds and fertilizer. Respondents were asked the amount of these inputs they used during the 2010/11 cropping season. The following table displays the average amount of factors of production utilized by the sample respondents.

Table 5.6 Input utilization of farm households (mean) by access to irrigation technology.

Input utilized	With Access to the technology	Without access to the technology	Total	t value
Land (in Hectares)	0.32	.24	.28	1.85**
Labour (in man days)	74	48	61	10.05*
Vale of capital goods (in birr)	189	136	162	4.83*
Value of improved seed and Fertilized applied (in birr)	156.9	142	149.83	1.102
Value of Output (in birr)	12792	10,099	11445.5	2.3462*

Source: Field survey, 2010/11 [*and ** significance at 1% and 5% level of significance respectively]

Landholding size of the household

In rural Ethiopia where agriculture is source of livelihood for the majority, the size of landholding is one of the factors that significantly affect the level and

productivity of agricultural production (Gebreselassie, 2006). The result from the survey shows that the average landholding size for the respondents in the study area is 0.28 hectares. This size of land is smaller compared to the districts average land holding size (0.37 hectares). Although both groups of farmers are producing on fragmented plots, the average land holding size for households with access to the technology (0.32 hectare) is higher than that of without access to the technology (0.24 hectares). The t test also shows that the mean landholding size of irrigators is greater than that of the non-irrigator at 5 Percent level of significance.

Labour utilization

The Table 5.6 above also shows that on average the sampled households spent 61 man days of labour in ploughing, weeding and harvesting of their farm for the given cropping season. In addition, farm households with access to irrigation technology spent more man days of labour than those without access to the technology. While households with access to the technology spent on average 74 man-days of labour for the cropping season those without access spent 48 man-days. The t test also shows that statistically there is significant difference in the mean values of the two groups at 1 percent level of significance.

Utilization of capital goods

The third row of Table 5.6 above indicates the monetary value of basic capital goods used by the sampled households for the given cropping season. On average, the sampled households used capital goods worth 162 Ethiopian birr. The value confirms the fact that generally smallholder farmers in the study area use less capital goods in their production process. In comparison of the average value capital goods utilized by with and without access to the technology reveals that households

with access to the technology have used more capital goods than those without during the given production period. While the former used capital goods worth of 189 Ethiopian birr, the later used capital goods worth of 136 Ethiopian birr. The result from the t test also confirms that statistically there is significant difference in the value of capital good used between the two groups at 1 Percent level of significance.

Application of improved seed and fertilizer

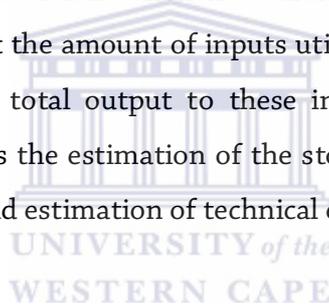
Household's utilization of improved seeds and technologies is measured by the amount of money spent on these technologies for the 2010/11 cropping season. The findings in Table 5.6 above show that on average the respondent spent 150 Ethiopian birr on improved seed and fertilizer. Furthermore, the finding also shows that households with access to irrigation spent much more than household without access to irrigation on improved seed and fertilizer. While the former group spent on average 156 Ethiopian birr for the given season, the latter group spent around 142 Ethiopian birr. The result from the t test shows that statistically there is no significant difference in the mean value of money spent on improved seed and fertilizer between the two groups at any acceptable level of significance.

Value of output produced

In this study output was measured in value terms (in birr). Since households produce different products during the given cropping season, the output from these products was aggregated using individual prices. In general, the result from the survey shows that on average households has produced an output with an estimated value of 11,945 Ethiopian birr during the 2010/11 production period. The disaggregation of the output value between households with access to irrigation

technology and those without access reveals that the former households have produced output with value of 12792 Ethiopian birr and the later households has produced 10,099 Ethiopian birr. The result from the mean comparison test also asserts that the difference in production between the two groups is statistically significant at 1 Percent.

In general, the above descriptive analysis of input utilization by households allows an insight as to whether households with access to technology utilize relatively higher conventional inputs compared to households without access. Households with access to the technology were reported to have used higher labour in man days, higher capital goods and have spent much money in improved seeds and fertilizers and cultivated larger size of land than households without access to irrigation. However, rather than just the amount of inputs utilized, the productivities of these inputs and responses of total output to these inputs are more important. The following section presents the estimation of the stochastic production function for both groups of farmers and estimation of technical efficiency scores.



5.3 ESTIMATION OF STOCHASTIC PRODUCTION FUNCTION FOR HOUSEHOLDS WITH ACCESS TO IRRIGATION TECHNOLOGY

As stated in the fourth chapter, a Cobb Douglas type of stochastic production function was estimated for households with access to irrigation technology separately. The following table shows the maximum likelihood estimation of the production function. This production function is estimated based on half normal distributional assumption of the efficiency error term.

Table 5.7 Maximum likelihood estimates of the Cobb-Douglas stochastic frontier production function for farmers with access to irrigation technology

Ln_OUTPUT	Parameters	Coefficients	Standard error	t- ratio
CONSTANT	φ_1	8.038	1.780	4.52*
Ln(LAND)	φ_2	0.213	0.029	7.29*
Ln(LABOUR)	φ_3	0.53	0.125	4.21*
Ln(KPTL)	φ_4	-0.12	0.202	-0.611
Ln(FERT)	φ_5	0.076	0.004	19.02*
Variance parameters				
	σ_s^2	0.0402	0.042	9.5*
	γ	0.997	.55	18.09*

Source:

Study Findings, 2010/11 [* and ** is significant at 1% and 5% respectively]

The coefficients of the maximum likelihood estimation are all positive as expected except the capital input. Since the production function specified is Cobb Douglas type, the coefficients are interpreted as output elasticities. The coefficient of the input land, 0.213, shows that a percentage increase in the size of land cultivated, increases output by 0.213 Percent. The highest output elasticity is for labour which shows that labour is the dominant factors of production for households with access to irrigation technology. On the other hand, the output elasticity of capital input shows that a percentage increase in value of money spent on capital goods will

result in a reduction of output by 0.12 percent but this result is not statistically significant at any acceptable level of significance. Investment in improved seeds and fertilizer also has a positive impact on output. A percentage increase in money spent on this input will result in an output increase by 0.07 percent. And the result is also statistically significant at 1 Percent.

The overall technical efficiency scores with respect to the stochastic production frontier are also estimated. The coefficients associated with the variance parameters (σ_s^2, γ) are estimated to be 0.0402 and 0.997 respectively and both are statistically significant. The variance parameter σ_s^2 indicates whether there is technical inefficiency or not. If σ_s^2 is equal to zero it means that all farmers are fully efficient and if σ_s^2 is greater than zero it means that all farmers are not technically efficient. The value 0.0402 shows that all farmers with access to irrigation technology are not efficient. In addition the value is statistically significant, indicating the goodness of fit of the model and the correctness of the assumption of the distribution of the error term. The other variance parameter γ determines the percentage deviation from the frontier output that is caused by technical inefficiency rather than random error. The value 0.997 of γ shows that 99 percent of variation from frontier is caused by technical inefficiency rather than random errors.

The average technical efficiency score of households with access to irrigation is found to be 84 percent. This implies that on average households with access to irrigation technology are able to obtain 84 Percent of potential output from given mix of production inputs. It is also entails that there is a potential and scope for increasing output by 16 percent, by adopting the technology and the techniques of production implemented by the best farm household with access to irrigation technology. The maximum technical efficiency score attained by farm household with access to irrigation is 99 percent and the minimum score is found to be 55

percent. The following table gives the summery statistics of efficiency estimates from stochastic frontier function.

Table 5.8: Summery statistics of efficiency estimates

Statistics	Efficiency Score
Mean	0.84042
Minimum	0.55018
Maximum	0.99369
Standard Deviation	0.09878

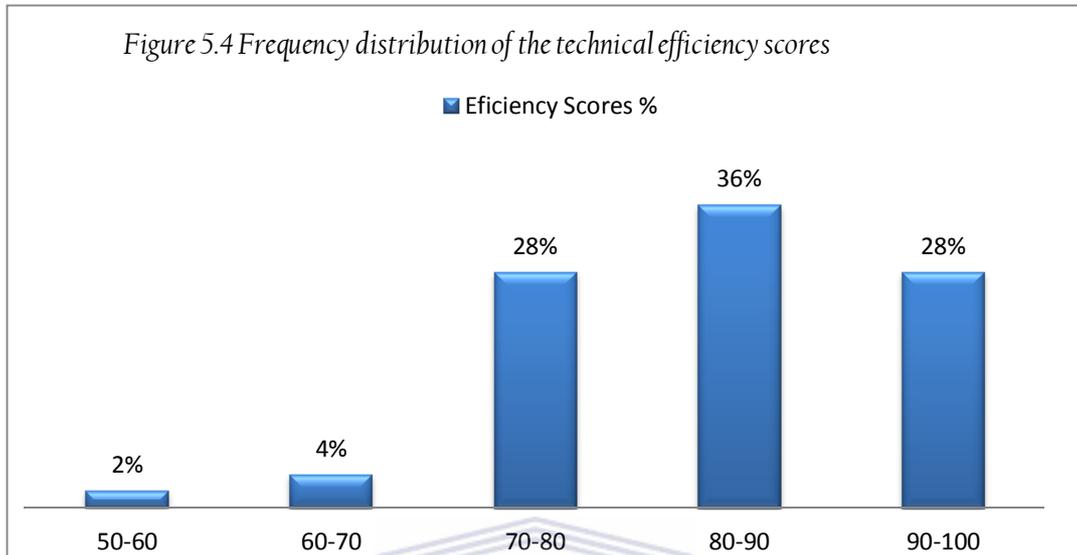
Source: Study Findings, 2010/11

Table 5.9 Frequency distribution of the technical efficiency scores

Efficiency score	Number of firms	Percentage
50-60	1	2%
60-70	2	4%
70-80	14	28%
80-90	19	36%
90-100	14	28%

Source: Study Findings, 2010/11

The frequency distribution of the technical efficiency scores for farm households with access to irrigation technology is presented in the following table. It can be seen that 66 percent of the total farm households with access to irrigation operates with efficiency level of more than 80 percent. It is also observed that 52 percent of farm households with access to irrigation technology are operating below the average technical efficiency score and 28 percent of the farm households are operating above 90 percent of technical efficiency score.



Source: Study Findings, 2010/11

5.4 ESTIMATION OF STOCHASTIC PRODUCTION FUNCTION FOR HOUSEHOLDS WITHOUT ACCESS TO IRRIGATION TECHNOLOGY

A Cobb Douglas type of stochastic production function was also estimated for households without access to irrigation technology. The maximum likelihood estimates of the parameters of the Cobb Douglas stochastic production function is given in Table 5.10 below.

Table 5.10 Maximum likelihood estimates of the Cobb-Douglas Stochastic Frontier Production Function for farmers without access to irrigation technology

Ln_OUTPUT	Parameters	Coefficients	Standard error	t- ratio
CONSTANT	φ_1	9.2	0.42	22.3*
Ln(LAND)	φ_2	0.26	0.018	14.2*
Ln(LABOUR)	φ_3	0.32	0.13	2.25*
Ln(KPTL)	φ_4	-0.033	0.66	-0.507
Ln(FERT)	φ_5	.083	0.035	2.39*
Variance parameters				
	σ_s^2	0.13	0.022	5.76*
	γ	0.99	.0005	190.07*

Source: Study Findings, 2010/11 [*and ** is significant at 1% and 5% respectively]

All parameter estimates of the inputs included in the production frontier have the expected sign and all are significantly different from zero at 1 percent except for the input capital. The coefficients of the estimated production function show the output elasticities of respective inputs. Output respond higher for change in labour unit compared to other factors of production. A one percent increase in the number of man-days spent by household without access to irrigation technology output will increase by 0.32 percent keeping the other factors of productions constant at their mean values. Following to the input labor, output responds higher to land with output elasticity of 0.26. This implies that a percentage increase in the land holding

size of the farm household will result an increase in output by 0.26 percent keeping other factors of production constant at their mean values. The other interesting result from Table 5.10 above is the output elasticity of capital. The coefficient is negative indicating that an increase in amount of money spent in capital inputs, output will decrease. But this value is not significantly different from zero at any acceptable level of significance.

In addition to coefficients of the production frontier, the technical inefficiency scores were also estimated for each farm household without access to irrigation technology. The variance parameters (σ_s^2 and γ) included in the Table 5.10 above are indicators of the technical efficiency effects in the production frontier. Since the value of the first variance parameter σ_s^2 , 0.13, is different from zero, it implies that all households without access to irrigation are not technically efficient. More so, this value is statistically significant, indicating the goodness of fit of the model and the correctness of the assumption of the distribution of the error term. The value of the second variance parameter (γ), 0.99, indicates that 99 percent of deviation in output from the frontier for households with access to irrigation is caused by technical inefficiency rather than random error.

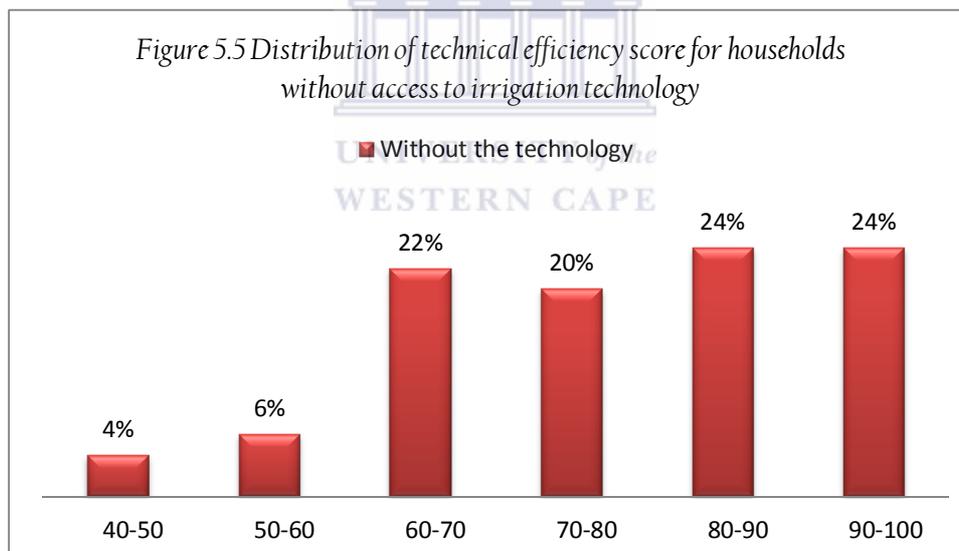
The predicted technical efficiency of farm households without access to irrigation ranges between 43 percent and 100 percent, with mean technical efficiency estimated to be 77 percent. This implies that farm households without access to irrigation technology are producing 77 percent of the potential output that they can produce with a given mix of factors of production. The result also shows that in short run there is a potential to increase output by 23 percent using the technology and technique of production used by the best farm household without access to irrigation technology. The following table and graph provide us with the summery statistics and distribution of the technical efficiency score.

Table 5.11: Summery statistics of efficiency estimates

Statistics	Efficiency Score
Mean	0.7704
Minimum	0.43
Maximum	1.00
Standard Deviation	0.141288

Source: Study Findings, 2010/11

The frequency distribution of the technical efficiency scores estimated from the stochastic production function is depicted in the following graph. It can be seen that 48 percent of households without access to irrigation technology are producing at technical efficiency of greater than 80 percent.



Source: Study Findings, 2010/11

In this section we estimated the individual Cobb Douglas stochastic frontier for each group of farm households separately. In addition we also estimated the predicted efficiency score for each farm household with respect to their own group production frontier. In line with the hypothesis set in this study the next section will compare

the output elasticities and efficiency scores between households with access to irrigation and households without access to the technology.

5.5 COMPARISON OF TECHNICAL EFFICIENCY BETWEEN HOUSEHOLDS WITH ACCESS TO IRRIGATION TECHNOLOGY AND HOUSEHOLDS WITHOUT

In the above section a stochastic production function was estimated for both groups of farmers based on the assumption that they are producing under their own specific technology. In this section we will compare the output elasticities and technical efficiency scores between households with access to irrigation technology and households without the technology. The following tables present the output elasticities and mean inefficiency scores for each group of samples.

Table 5.12 Output elasticities and mean technical efficiency for households with and without access to irrigation technology

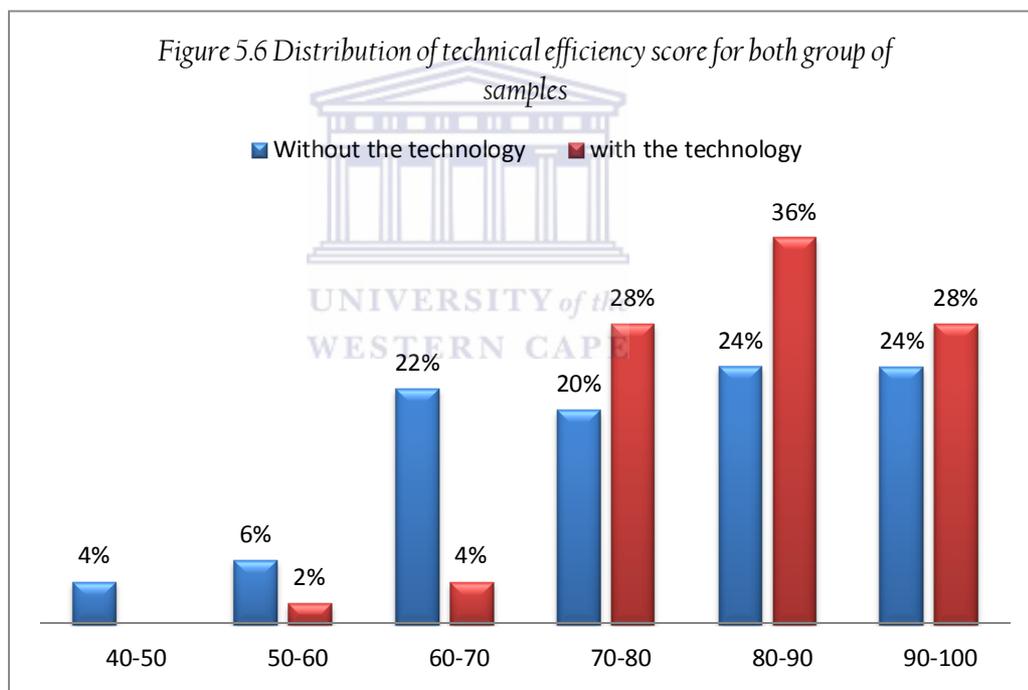
	With Access to the Technology	Without Access to the Technology
Output elasticities		
<i>LAND</i>	0.21	0.26
<i>LABOUR</i>	0.53	0.32
<i>KPTL</i>	-0.12	-0.03
<i>FERT</i>	0.08	0.08
Mean Technical Efficiency	0.84	0.77

Source: Study Findings, 2010/11

The above table shows that output respond higher to land for households without access to irrigation technology compared to households with access to technology. A percentage increase in size of land cultivated will increase output by 0.26 percent for households without access to irrigation while it will increase output by 0.21 percent

for the other group of farmers. In contrast, output responds higher with respect to input land for households with access to technology compared to those without access to the technology.

The estimated mean technical efficiency scores also show that on average households with access to irrigation technology have higher technical efficiency than households without access to the technology, relative to their own production technologies. In addition to the mean values of the technical efficiency estimates the following graph depicts the distribution of the technical efficiency scores between the minimum and the maximum scores.



Source: Study Findings, 2010/11

It is clear that the distribution of the technical efficiency scores for households with access to irrigation technology is more closely clustered between 80 to 100 percent compared to households without access to the technology. This indicates that there is a high technical efficiency of farmers with access to irrigation technology than households without access to irrigation technology. The high technical efficiency for

the former group might be the result of access to the technology which enables farmers to produce more than twice the amount during the cropping season and boost of output thereof.

5.6 ESTIMATION OF AGGREGATED STOCHASTIC PRODUCTION FUNCTION FOR ALL SAMPLES IN THE STUDY AREA

As explained in the fourth chapter, Cobb-Douglas stochastic production frontier was estimated for all sample households irrespective of their access to irrigation technology. This production function is used to estimate the technical efficiency scores and determinants of technical efficiency in the study area. More so, a variable that captures the contribution of access to irrigation technology towards output is also included in this model. The maximum likelihood estimation of this model is presented in the following table.

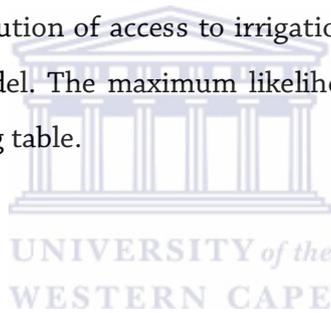


Table 5.13 Maximum likelihood estimates of the Cobb-Douglas stochastic frontier production function for all sampled farmers.

Ln_OUTPUT	Parameters	Coefficients	Standard error	t- ratio
<i>CONSTANT</i>	φ_1	8.5	0.309	27.34*
<i>Ln(LAND)</i>	φ_2	0.29	0.021	13.36*
<i>Ln(LABOUR)</i>	φ_3	0.45	0.075	6.03*
<i>Ln(KPTL)</i>	φ_4	-0.091	0.043	-0.209
<i>Ln(FERT)</i>	φ_5	0.0131	0.035	0.37
<i>ACC_IRG</i>	φ_6	0.13	0.042	3.04*
Variance parameters				
	σ_s^2	0.077	0.017	4.40*
	γ	0.97	0.043	22.06*

Source: Study Findings, 2010/11 [* and ** is significant at 1% and 5% respectively]

Similar to the individual stochastic production frontier the coefficient of the aggregated model are positive as expected except for the capital input. The result shows that output has the highest responsiveness to labour followed by land. While a percentage increase in man-days of labour will increase output by 0.45 percent, a percentage increase in size of land cultivated will lead output to increase by 0.29 percent *ceteris paribus*⁶. These values are also significant at one percent. Even

⁶ A Latin term meaning that all other factors are held unchanged. The *ceteris paribus* assumption is used to isolate the effect one economic factor has on another.

though output responds positively to an increase in the amount of money spent on fertilizer and improved seeds, the result is not significant at any acceptable level of significance. The other fascinating result from the above model is that output responds negatively to an increase in the amount of money spent on capital good. A percentage increase in the amount of money spent on capital goods, output will decrease by 0.091 percent *ceteris paribus*. The result from the above model also shows that all the input elasticities are inelastic: it means that a one percent increase in each input results in a less than one percent increase or decrease in the value of output in the study area.

The output elasticity of the input 'ACC_IRG' is calculated separately. Since this variable is an indicator variable (dummy variable) that captures households access to irrigation technology, it must be transformed before interpreting the value as output elasticity. Using equation 4.4 the output elasticity of access to irrigation technology is 12 percent. This value is interpreted as on average households with access to irrigation technology are producing 12 percent higher output value compared to their counterpart who don't have access to the technology. In other words providing access to irrigation technology for households without access to the technology will result an in increase of output by 12 percent *ceteris paribus*.

The maximum likelihood estimates of the variance parameters are also given in the above table. The value 0.077 of the first variance parameter confirms that all farm households are not technically efficient. And, the second value of the variance parameter shows that 97 percent of variation of output from frontier is because of technical inefficiency rather than random errors. In addition the two parameters are statistically significant, indicating that a good fit of the model and correctness of the distributional assumption of the error term.

The estimated technical efficiency score for the whole farmers ranges between 45 percent and 98 percent with mean technical efficiency of 81 percent. These implies that farm households in respective of their access to irrigation technology, are

producing 81percent of their potential. In other words, farm households in study area(Gorogutu District) can reduce their current usage of input by 19 percent to achieve the same level of output during the given production period. Table 5.14 below presents the summary statistics of the technical efficiency scores for all households in the sample.

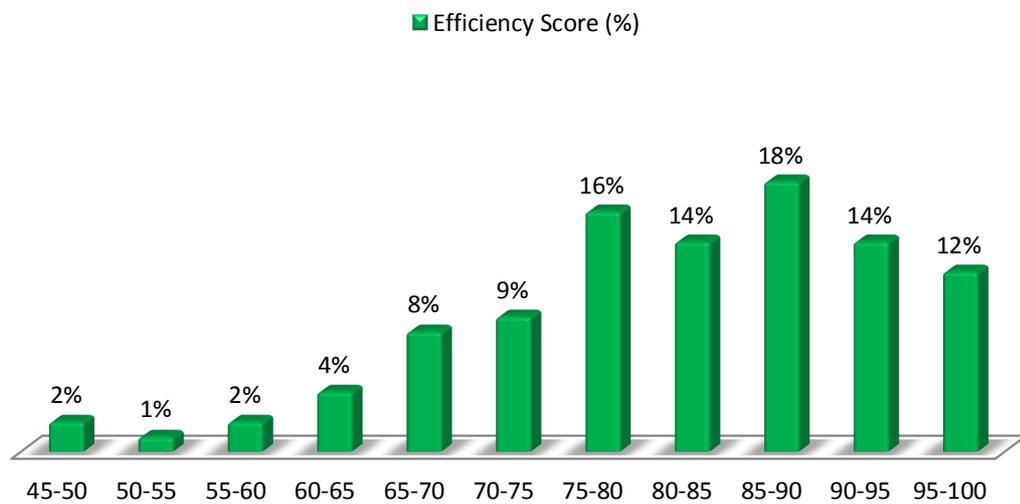
Table 5.14 Summery statistics of efficiency estimates

Statistics	Efficiency Score
Mean	0.814
Minimum	0.457
Maximum	0.975
Standard Deviation	0.117

Source: Study Findings, 2010/11

The distribution of technical efficiency score shows that around 53 percent of total farm households are producing with technical efficiency score of above 81 percent (above the mean technical efficiency score). And the remaining 47 percent are producing below 81 percent. The largest percentages of farm households are producing within the range of 85 to 90 percent technical efficiency score. Please refer to figure 5.7 to get detail information on the distribution of technical efficiency scores for all sampled households in Gorugutu district, Ethiopia.

Figure 5.7 Distribution of technical efficiency score for pulled sample of households



Source: Study Findings, 2010/11

5.7 ACCESS TO IRRIGATION TECHNOLOGY AS A DETERMINANT OF TECHNICAL EFFICIENCY

This section attempts to explain determinants of technical efficiency in Gorogutu district of Eastern Ethiopia. In line with the hypothesis set in the beginning of this study, it is argued that access to irrigation technology is an important factor to explain deviations from the frontier output or technical inefficiency. In testing this hypothesis, the technical efficiency effect model specified under equation 4.5 was estimated simultaneously with the Cobb-Douglas stochastic production. Here in addition to access to irrigation technology, the model also include other determinant factors which arguably to affect technical efficiency of farm households in the study.

Before explaining the maximum likelihood estimates of the coefficients of the inefficiency effect model, a simple pairwise correlation coefficient was calculated to explore the correlation between the technical efficiency score and the determinant factors claimed to affect technical (in) efficiency. The value of pairwise correlation coefficient ranges between -1 and +1. A value near to these values shows strong

positive and strong negative correlation between the variables under consideration respectively. Table 5.15 below indicates the pairwise correlation coefficients between the technical efficiency score and the determinant factors.

Table 5.15 Pairwise correlation coefficients between the technical efficiency score and the determinant factors.

	Technical Efficiency Score
<i>ACC_CREDIT</i>	0.8102
<i>EXTN_SRVS</i>	0.9475
<i>ACC_IRG</i>	0.7361
<i>DISTANCE_PLOT</i>	-0.9216
<i>AGE</i>	-0.0386
<i>SEX</i>	-0.0352
<i>Yr_SCHOOL</i>	0.0735

Source: Study Findings, 2010/11

The above table shows that there is strong and positive correlation or association between the technical efficiency scores and access to credit service, number of extension contacts, access to credit technology and households year of schooling. And the statics also reveal a strong negative relationship with distance from farm plot to household's homestead and weak negative correlation with age and gender of respondent.

Using the specification under equation 4.5 the above variables were also include in efficiency effect model and simultaneously estimated with stochastic production function. Table 5.16 below summarizes that maximum likelihood estimation of the technical efficiency effect model.

Table 5:16: The Maximum Likelihood Estimates of the inefficiency effect model

<i>Variable</i>	<i>Parameters</i>	<i>Coefficients</i>	<i>Standard Error</i>	<i>t- ratio</i>
<i>CONSTANT</i>	δ_0	-2.2304	3.363	-0.66
<i>AGE</i>	δ_1	0.0072	0.0373	0.19
<i>SEX</i>	δ_2	0.0274	0.5276	0.05
<i>Yr_SCHOOL</i>	δ_3	-0.0222	0.098	-0.23
<i>ACC_IRG</i>	δ_4	-1.4562	0.6765	-2.15**
<i>EXTN_SRVS</i>	δ_5	-0.6004	0.2695	-2.23**
<i>ACC_CREDIT</i>	δ_6	-0.3529	1.2035	-0.29
<i>DISTANCE_PLOT</i>	δ_7	1.5213	0.6184	2.46**

Source: Study Findings, 2010/11 [** is significant at 5%]

The result indicates that most of the determinant factors are not statistically significant at any acceptable level of significance. But it is worth to examine the signs of these coefficients to explain the direction of relationship between this factors and technical inefficiency scores. Here the signs of the coefficients are interpreted differently from the conventional usage. While a positive sign of the estimated coefficient shows that the variable increases technical inefficiency or reduce technical efficiency a negative sign of estimated coefficient shows that the variable increase technical efficiency and reduce technical inefficiency. The main variable of interest in this study, access to irrigation technology (*ACC_IRG*) is found to be a negative and significant determinant of technical efficiency. The negative sign of the estimated coefficient implies that, access to irrigation have the effect of reducing technical inefficiency or the effect of increasing technical efficiency. In other words, households with access to irrigation technology are more efficient per se than households without access to the technology.

The variable *AGE* was included to explore the impact of household head's age on technical efficiency. Though the estimated coefficient is not statistically significant in affecting technical efficiency, the positive sign shows that as farmer gets older, the technical efficiency will reduce. This might be the result of reduction of the capacity and ability to produce and refusal to use new technology and techniques of production by older farmers.

The variable *SEX*, which is a dummy variable, captures the effect of sex of the household on technical efficiency. The estimated coefficient is negative and not statistically significant at any acceptable level of significance. The negative sign of the estimated coefficient shows that households headed by female are less technically efficient than their counterparts who are headed by male. This might be the result of female household heads taking responsibility of farming in addition to their traditional homemaking role. As a result such households will face scarcity of labor during pick periods to timely apply inputs.

The estimated coefficient of the year of schooling spent by a household head (*Yr_SCHOOL*) implies that households who spent longer numbers of years in school are more technically efficient compared to those who spent less number of years in school. The negative sign of this coefficient was as expected. It was hypothesized that households with higher number of schooling will have higher human capital and better attitudes towards modern technology which enables them to produce closer to the production frontier. More so, higher year of schooling has an impact on unobserved labour quality and management skill of farm households which will in turn increase their technical efficiency. But the coefficient is not statistically significant at any acceptable significance level.

The analysis also indicates that households with access to credit service are more technically efficient than households without access to credit. Though the negative sign of the credit variable is as expected, statistically the estimated coefficient is not significant. Access to credit service enable households to reduce the problem of

liquidity and enables them to purchase and timely apply input during production process.

A key characteristic of a plot that needs to be considered as a determinant of technical inefficiency is distance travelled from homestead to the farm plot by farm household. The empirical finding from this study indicates that the distance travelled by farm household from the homestead to farm is positively related to technical inefficiency. And the estimated value is also statistically significant. This implies that households who traveled long distance from homestead to their farm plot are less technically efficient than those who travelled shorter distance. In other word, as the distance the farm household travels from his homestead to farm plot increase, the technical efficiency tends to decrease.

The number of day spent by extension workers (Development Agents) with farm household is found to have a positive and significant effect on technical efficiency. The negative sign of the estimated coefficient shows that with an increase in number of days of contact with Development Agents, the technical efficiency of farm household tends to increase. And the result is also statistically significant. A positive and significant effect of extension service might be the result of it reduces the gap between potential and actual output of farm households by hastening technology transfer and by enabling them to become better farm managers.

5.8 CHAPTER SUMMARY

This chapter demonstrated that households with access to irrigation technology are more technically efficient than those without access to the technology. More so, household's access to irrigation technology is a significant determinant of technical efficiency. In addition to access to irrigation technology, other different socio economic variables that affect technical efficiency of farm households was also identified. This chapter also conveys the descriptive and inferential statistics of the

sampled households in terms of their socio economic characteristics. The next and the final chapter will present the summery and conclusion of the main research findings and also possible policy implication for different stakeholders.



CHAPTER SIX: SUMMARY, CONCLUSION AND POLICY IMPLICATIONS

6.1 SUMMARY AND CONCLUSIONS

The primary aim of this study was to conduct a comparative analysis of farm level technical efficiency of households with access to irrigation technology and those without access to irrigation technology and to determine the socio economic and institutional factors that influence farm level technical efficiency in Gorogutu district. Using quantitative method of data analysis the researcher tested three different hypotheses that are in line with the basic research questions which motivated the study.

Three different Cobb-Douglas Stochastic Production functions were estimated to explore and compare technical efficiency of farm households with access to irrigation technology and those without access to the technology. The first stochastic production was estimated to explore the technical efficiency of households with access to irrigation technology with their own group production frontier. The findings from the model indicate that though the households are not technically efficient, the average technical efficiency score is more than 80 percent. Specifically the mean technical efficiency score is found to be 84 percent indicating that households with access to irrigation technology are able to produce 84 percent of potential output from a given mix of production inputs. The second stochastic production function is in turn estimated to examine the technical efficiency score of the control group (households without access to irrigation technology). The finding reveals that all households without access to irrigation technology are also not technically efficient. The average technical efficiency score is found 77 percent indicating that there is a potential to increase output by 23 percent using the technology and the technic of production used by the best farm household without access to the technology.

The results from these two models are used to test the first two hypotheses. In line with the first hypothesis, the result from the individual production function confirmed that farm households in the study area are not technically efficient and there is a chance to increase output by using the technology and mix of production input used by the best farm household. Furthermore the result from the aggregated model also reveals that household in the study area irrespective of their access to irrigation technology exhibits some extent of technical inefficiency (20 percent of technical inefficiency). The empirical finding is in line with other studies conducted in different parts of Ethiopia (Gebreegziabher et al (2004), 20 percent mean technical inefficiency in Northern Ethiopia; Alemu et al (2009), 25 percent mean technical inefficiency in different agro ecological zones of Ethiopia and Seyoume et al (1998), 20% percent technical inefficiency for farmers outside Saskawa-global project).

The estimated individual stochastic production functions also conveys that households with access to irrigation technology are more technically efficient compared to households without access to the technology. The mean technical efficiency score of 84 percent for household with access to irrigation technology is higher than 77 percent mean technical efficiency of households without access to the technology. More so, the distribution of the technical efficiency scores for households with access to the technology is more clustered between 80 to 100 percent technical efficiency scores compared to households without access to the technology. These empirical findings affirm the hypothesis that farmers with access to irrigation technology are technically efficient compared to those without access to the technology with respect to their own production frontier. These results also concur with similar studies made by Makombe et al (2007) in Ethiopia and Mariano and Fleming (2010) in Philippines.

In addition, the study also attempt to explore socio economic and institution factors that determine the technical efficiency of farm households in Gorogutu district in

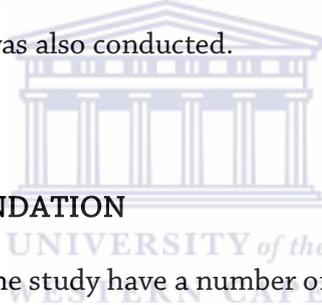
Eastern Ethiopia. Even though the empirical finding from the estimated models show those households with access to irrigation technology are more technically efficient than those without access to the technology, the inefficiency effect model is estimated to examine the effect of access to the technology on technical efficiency of farmers. The inefficiency effect model was estimated using one step approach simultaneously with aggregated stochastic production function. In addition to access to the irrigation technology other socio economic and institutional determinants argued to affect technical efficiency are included in the model. The estimated coefficient of the variable access to irrigation technology (*ACC_IRG*) is negative and statistically significant indicating that having access to irrigation technology is associated with increase in technical efficiency. And this empirical finding from confirms the third hypothesis that states access to irrigation technology is a significant factor to explain deviations from the frontier output or technical inefficiency.

This study also revealed that access to credit and extension services, and number of years spent in school (level of education) has the effect of reducing technical inefficiency. In line with different studies that examined determinants of technical efficiency (Seyoum et al (1998), Nisrane et al (2011) and Kuria et al(2003), households who received more number of extension visits from the Development Agents (DA) are deemed to be more technically efficient compared to those who received less number of visits. Access to reliable credit service has also a significant effect on technical efficiency. It reduces the technical inefficiency by reducing capital constraint and enabling them to access production inputs timely during the peak seasons.

Although the effect of education level on technical efficiency is statistically insignificant, the study indicate that the number of years spent in school by farm household head has the effect of reducing technical inefficiency. When farm households spend more number of years in school, their quality of labour and

propensity to adopt agricultural technology and innovation will also rise. This in turn will have a positive effect on technical efficiency of farm households. More so the study showed that the distance traveled by farm household from his homestead to farm plot has a negative effect on technical efficiency. Households with long distance between farm plot and homestead spend a large percentage of the available production hours on traveling, thereby wasting time that could have been usefully engaged in production and better management of their farm.

In addition to the estimation of technical efficiency scores and its determinants, the responsiveness of output to factors of production (elasticities of output) was estimated. And comparison in terms of demographic, social and economic characteristics between households with access to irrigation and those without access to the technology was also conducted.



6.2 POLICY RECOMMENDATION

The research findings in the study have a number of policy implications for different government organs and implementing NGOs. In a country where the economy and the livelihood of the majority is dependent on agriculture sector and recurrent draught and starvation are common agendas every year, access to reliable irrigation technology is one of the viable options in increasing agricultural efficiency and productivity and in turn reducing rural poverty. The result of this study suggested that access to irrigation technology has positive impact on technical efficiency and agricultural production. As a country that has a huge potential for irrigation development (Awlachev and Ayana, 2011: 58), utilization of this potential and providing irrigation technology to farm households will have a huge impact on the livelihoods of the majority of the poor. Evidently, efforts tailored towards this end would be very essential in militating against the high levels of poverty that is persistent in the communities.

More so, in view of the fact that, the findings of this research clearly support the proposition that access to extension service has a significant effect in reducing household technical inefficiency, the researcher duly recommends that government, agricultural agencies and NGOs operating in the sector should put in place concrete mechanisms to motivate and encourage Development Agents (DA) to create good environment in order to increase the exchange of information and experience among the stakeholders (researchers, NGOs, farmers etc.).

The study also showed that access to credit service has positive effect on technical efficiency. It is thus recommended that formal credit institution needs to be established in order to mobilize savings and maximize the availability of credit to farm households in the rural area. The existing credit sources (NGO and farm associations) need to be encouraged to continue lending to smallholder farmers in the study area. And commercial banks, both privates and government owned, has to take a leading role in opening up credit facilities and make bank loans more accessible and affordable to for the rural farm households.

Acknowledging the limitations of this specific study, the researcher is optimistic that the findings from this study will be informative and contribute to the existing literature of the irrigation -poverty nexus.

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ANNEX I: HOUSEHOLD QUESTIONNAIRE



UNIVERSITY of the
WESTERN CAPE

Questionnaire for Households

This questionnaire is designed to obtain information about impact of access to irrigation technology on technical efficiency and productivity in your district. The information will be used to learn about the household characteristics, production, expenditure on input and income. And Please be aware that participation in is voluntary and that the information you and other households provide in this survey will be strictly confidential. At the analysis stage of the study, specific names will not be attached to any results and the information you provide will be used only for statistical reporting purposes.

We really appreciate your willingness to answer our question!

Data Collector

Name _____

Date _____

Part 1 Background Information

1. Household identification number _____
2. Date of interview _____
3. 'Kebele' Association _____
4. Status of the household with regard to access to irrigation technology
1= with Access 2=Without Access
5. Name of the household Head _____
6. Age of the household Head _____
7. Sex of the household Head
1=Male 2=Female
8. Marital Status
1=single 2=Married 3=Divorced 4=Separated 5=Widowed
9. Formal Education status of the head
1=Never attended
2=Primary Total Number of years of schooling _____
3=Secondary
4=Tertiary
5=other _____
10. For how many years you have been working as a farmer _____
11. Number of people living in household _____
12. Age distribution of household members
1=Children less than 10 year _____
2= Age between 10 and 20 _____
3=Age between 21 and 30 _____

4=Age between 31 and 65_____

5= More than 65 years _____

13. Occupation of the household head

1= Cultivates own land or family land

2= Herding

3= Student

4= Other paid work (handicraft, trader, wage worker, artisan, etc)

5=Other_____

14. Did your household participate in any nonfarm activity last year

1=Yes 2=No

15. If yes on which ones?

Activity

Income received in Birr

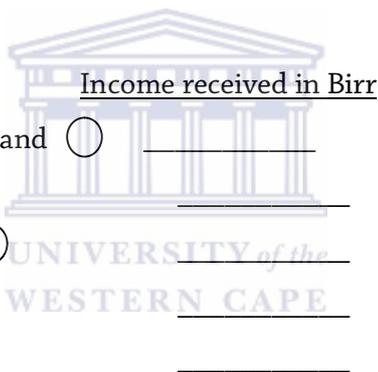
1=Working on others land

2=handicraft

3=Small business

4=petty trade

5=Other _____



Part II: Farm size

1. Total Area owned (in hectares) _____

2. Total Cultivable land(in hectares)_____

3. Total land cultivated in 2009/10 cropping season (in hectares) _____

4. Average distance from the homestead (in km)_____

5. Do you have any rented land for the 2009/10 cropping season?

1= Yes

2=No

6. If yes what is the size of the rented land (in hectares)_____

7. Amount of money paid for the rented land (in birr)_____

8. Have you rented *out* land for the 2009/10 cropping season?

1= Yes 2=No

If yes what is the size of the rented *out* land (in hectares)_____

9. Amount of money received from rented land (in birr)_____

10. How many times did you cultivate your land last year?

1=Once 2=Twice 3= Three times 4=More than three times

Ask the following question (12-16) if the household has access to irrigation technology

11. What is the size of the irrigated land (in hectares)? _____

12. Number of irrigation per year _____

13. Total amount of money paid for irrigation water (in birr)_____

14. Average distance from irrigation site to the farm plot (in Km)_____

15. Location of the farmer within the irrigation site

1=Head 2=Middle 3=Tail

Part III: Input Acquired

1. Have you used the following farm inputs during 2009/10 cropping season

Type	Quantity in Kg	Mode of Acquisition 1=Purchased 2=donated 3= borrowed	Total Value in Birr		
			1=Purchase d	2=Donated	3=Borrowe d
1=Seeds <input type="radio"/>					
2=Organic Fertilizer <input type="radio"/>					
3=Chemical Fertilizer <input type="radio"/>					
4=Pesticides <input type="radio"/>					
5=Other _____					

2. Have you used the following farm equipments and tools last year?

Type	Quantity	Mode of Acquisition 1= Purchased 2=donated 3= borrowed	Total value in Birr
1=Hoes <input type="radio"/>			
2=Axes <input type="radio"/>			
3=Animal Power (Oxen) <input type="radio"/>			
4=Ploughs <input type="radio"/>			
5=Tractor <input type="radio"/>			

3. Labour used in production for 2009/10 cropping season

<u>Activity</u>	<u>Family Labour in man days</u> (Number of people X Number of days)	<u>Hired labour in man days</u> (Number of people X Number of days)
1=Clearing		
2=Land preparation		
3=Planting		
4=Weeding		
5=Harvest		
6=Other activity		

4. Total amount of money paid for hired labour (in Birr) _____

5. Have you used animal power in the production of crops last year?

1 = Yes 2 = No

6. If your answer is "yes" for question 5 how much (in oxen days) _____

7. Do you have access to rural credits? 1 = Yes 2 = No

8. If your answer to question 7 is "Yes", how much did you obtain in the last 2 years?

Birr _____

9. If your answer to question 7 is “Yes”, what are the sources?

- 1=Banks 2= Association 3= Coopera 4='Equip'
 5='Mahber' 6=Relative 7=othspecify_____

10. Have you received any training and agricultural extension service in 2009/10 cropping season 1= Yes 2=No

11. If your answer in pervious question is “yes” How many times did you get the service last year? _____

Part IV: Yield and Income

1. How much income does the household generated from the following sources for the cropping season 2009/10?

Source	How much income did the household receive (in Birr)?
1=Crop production	
2=Sale of animals	
3=Milk, butter and cheese, Egg production	
4=Remittance/transfer received	
5=Wage payments to all family members	
6=From Non-Farm activities	
7=Other _____	

2. Number of livestock owned

Type of livestock	Number of livestock owned	Value of livestock owned in Birr
1=Cattle		
2=Goat/Sheep		
5=Oxen		
4=Poultry		
5=Other_____		

3. Crop production for 2009/10 cropping season

Crop Type	Total Area cultivated in hectares	Output in Kg	Price/Kg	Value of Output in Birr	Output used for home consumption in Kg	Output sold in the market in Kg
1=Teff						
2=Maize						
3=Sorghum						
4=Barley						
5=Wheat						
6=Pulses (horse beans, peas...)						
7=Oilseeds (linseed, sesame...)						
8=Fruits (papaya, banana, mango...)						
9=Vegetables (Potato, cabbage, carrot, tomato...)						
10=Khat						
11=Others_____						
Total						

Thank You Very Much!