Technical Efficiency Analysis of Teff Production by Smallholder Farmers in Case of Awabel Woreda, East Gojjam, Amhara Region, Ethiopia

By: Habtamu Abebe Genberu

Advisor: Addisu Mekonnen (PhD Candidate)

A Research Thesis Submitted to the Department of Economics in Partial Fulfillment for the Requirements of Master of Science (MSc) Degree in Project Planning and Management

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DECLARATION

I Habtamu Abebe Genberu ,ID.No. GSS /10/13 who certify that this thesis entitled "Technical Efficiency Analysis of Teff Production by Smallholder Farmers in Awabel Woreda East Gojjam Zone Ethiopia". This thesis has been submitted in partial fulfillment of the requirements for MSc. Degree at Debremarkos University. I declare that this thesis is my own work and I declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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This is to certify that the thesis entitled "Technical Efficiency Analysis of Teff Production by Smallholder Farmers in Awabel Woreda". Submitted in partial fulfillment of the requirements for the degree of Master's in Economics with specialization in Project Planning and Management, the Graduate Program of the Department of Economics, and has been carried out by Habtamu Abebe under my supervision. Therefore, I recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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As a member of the board of examiners of MSc Thesis open defense Examination, we certify that we have read and evaluated the thesis prepared by Habtamu Abebe Genberu and examined the candidate. I recommended that the thesis be accepted as fulfilling the thesis requirements for the degree of Master of Science in Project Planning and Management.

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ACRONYMS

ACSI	Amhara Credit and Saving Institution
CSA	Central Statistical Agency
CV	Coefficient of Variation
DEA	Data Envelopment Analysis
ECSA	Ethiopian Central Statistical Agency
EDHS	Ethiopia Demographic and Health Survey
GDP	Growth Domestic Product
HDI	Human Development Index
HDR	Human Development Report
IFAD	International Fund for Agricultural development
NBE	National Bank of Ethiopia
NNP	National Nutrition program
NRC	National Research Council
SFA	Stochastic Frontier Analysis
SPF	Stochastic Production Frontier
TE	Technical Efficiency
UNDP	United Nations Development Program
USAID	United States Agency for International Development
USAID	United States Agency for International Development
WB	World Bank
WFP	World Food Programme

ABSTRACT

The main objective of this thesis is to assess smallholders' technical efficiency of endemic teff crop production in Awabel Woreda East Gojjam, Ethiopia. To achieve this objective, cross sectional farm and plot level data were collected from Awabel woreda 354 smallholder farmers. Stata 14 software was used for econometric regression of stochastic frontier trans-log function. A stochastic frontier analysis result showed that the use of agricultural technologies and inputs like application of quality seed, fertilizer, oxen labor , the deployment of land management practices, for instance, application of manure, are efficiency improving. Moreover, socioeconomic variables, for instance, sex, education of household head, and credit access are increasing farmers' technical efficiency. The high mean technical efficiency of 90.3% implies that farmers can increase teff output by 9.7% without changing input use by applying technologies and land management practices applied by outperforming farmers. The value of gamma 80.5% indicates the deviation from the frontier due to the inefficiency of the farmer which is under their control. The other difference 19.5 % occurred due to external noise out of the control of the farmers. The results suggest that farmers can increase efficiency by employing land management practices and agricultural technologies, particularly less efficient farmers. Technology application is improving both yield and efficiency; therefore, the regional government can increase yield and efficiency of smallholder farmers by increasing their access to agricultural technology and providing extension training on improved land management practices at the farmers training centers (FTC). Generally this study suggest that the policy to increase the efficiency level of teff producing farmers prioritized on the application and practice of land management activities, use of improved seed, access formal and informal education, addressing micro finance institutions and preparing manure with recommended manner including timely transporting to the plot.

Keywords: smallholder farmers, technical efficiency, stochastic frontier, Teff, Ethiopia

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

There are over 50,000 known edible plants in the world. However, two-thirds of plant derived food at a global level comes from three major cereals, maize (Zea mays), wheat (Triticum aestivum) and rice (Oryza sativa). Their increasing dominance has contributed to a declining number of crop species as potential food sources (Lee, H, 2018).

In Ethiopia agriculture dominates a large portion of the population, income, foreign exchange, and job creation. The sector is crucial in the economy characterized by developed economic policy of agricultural growth leading to industrialization (Mulatu, N. T. (2023).

Between 8,000 and 5,000 BC, the people of the Ethiopian highlands were among the first to domesticate plants and animals for food and teff was one of the earliest plants domesticated. Teff is believed to have originated in Ethiopia and Eritrea between 4,000 BCE and 1,000 BCE. Genetic evidence points to Eragrostis pilosa the most likely wild ancestor. A 19th century identification of teff seeds from an ancient Egyptian site is now considered doubtful; the seeds in question (no longer available for study) are more likely of Eragrostis aegyptiaca, a common wild grass in Egypt (Lombamo, T.2020).

Ethiopia, located in eastern Africa, is considered the center of origin of teff. The word 'teff' comes from the Ethiopian word 'teffa', which means 'lost' because of its minute grain size .Teff grains are manually harvested by sickles and threshed with ox tramping on them. From 25-30% of teff would be lost before and after harvest, and lodging may contribute to the yield loss up to 30%.The high losses along the production processes can reduce the available quantity of teff by up to 50%. Ethiopia is the largest teff producer in the world. Teff accounts for 24% of the grain area, followed by maize 17% and sorghum 15%. Amhara and Oromia are the two major regions, and collectively, the two regions account for 85.5% of the teff area and 87.8% of the teff production (Lee, H, 2018).

Teff was first introduced to the USA in the 1980s. At least, 25 states including Idaho, Kansas and Nebraska are known to grow the crop. Their main purpose of production is forage for horses, cattle and other livestock. Another purpose is for the large Ethiopian diaspora communities in the USA. Anecdotally, their increasing demand drives the expansion in teff acreage. Teff is

relatively a new crop to Australia. In 2014, experimental quantities of teff were cultivated in northern New South Wales, and cultural and marketing practices suitable to Australian conditions are being explored(Lee, H, 2018).

Studies so far carried out on morphological, cytological and biochemical characters of wild and cultivated species of teff revealed that Ethiopia is the origin and center of diversity of teff even though the wild relative, Eragrostis pilosa, a weedy species, occurs throughout the world in tropical and temperate regions. This wild relative is the closest relative of the cultivated teff, Eragrostis tef. Eragrostis pilosa is also an allotetraploid and has a karyotype similar to Eragrostis tef. These two species are similar morphologically. The only known consistent morphological distinction between E. pilosa and E. tef is spikelet shattering of Eragrostis pilosa (Lombamo, T.2020).

Teff contains nutritionally, 100 g of teff grains have 357 kcal, similar to that of wheat and rice and has high as well as unique nutritional values which will meet the need health conscious consumers. It is also a low risk crop which resists many biotic and abiotic stresses. Currently Ethiopia is the largest teff producing country and value chain in Ethiopia largely rely on traditional practice, and the teff market is limited by the government`s export ban. Instead, other countries such as USA are increasingly participating in the teff market (Lee, H, 2018).

The last 20 years have seen the consumption of agricultural commodities expand, driven mainly by population and income growth in low- and middle-income economies. These countries have also rapidly increased their production through technology and innovation advances, and by increasing the use of their natural resources. The resulting shifts in agricultural production and consumption locations have led to changes in international agricultural trade patterns (Ivetic, et al, 2024).

For most developing countries, enhancing the total production and productivity is not an option rather it is a necessity and the first concern in their policies. Theoretically; there are two possible alternatives to increase total production and productivity. The first method is through increased use of inputs and/or improvement in technology at certain level of input. The other option is to develop the efficiency of producers or farmers (Ayele, A.,2022).

Food insecurity in Ethiopia in 2022 is already severe, with an atypically high population in need of food assistance during the peak of the Meher lean season. While assistance needs will be slightly lower after the lean season, they will remain historically high. One round of assistance distribution took place in the first half of 2022 across much of Ethiopia, and while this helped to mitigate food consumption deficits among those who received assistance, it did not provide widespread and significant improvements in household food consumption (Nyssen , J. 2024).

Agriculture is one of Ethiopia's key sectors accounting for 35% of the country's GDP, providing 75% of employment, and generating 80% of total exports.Teff, maize, and wheat are the most important staple foods for crops that make up the majority of Ethiopia's agricultural outputs in terms of cultivated area, yield, and consumption. Out of the total acreage of grains, teff , maize , and wheat accounted for 23%, 20%, and 15%, respectively *(*Tekeste,. et al., 2023).

The most common utilization of teff in Ethiopia is the fermented flatbread called injera. This traditional flatbread as a soft,thin pancake with a sour taste. The most preferred form of the injera is one made from pure teff flour. Injera mixed with other flour such as wheat or sorghum is considered inferior. Other utilizations of teff include local alcoholic beverages called tela and katikala, and porridge. Additionally, teff plant residues could be used as fodder for livestock, and often incorporated as construction materials (Lee, H. 2018).

The national productivity of teff in Ethiopia is about 1.756 tone/hectare. In Amhara Region from the total cereal crop area, teff accounts more than 1 million hectare and in terms of production it accounts more than 2 million tone. In addition, more than 2 million farmers are producing teff in the region and the productivity of teff is 1.8 tone/hectare (Tesfaw , et al, 2021).

East Gojam is the leading zone in teff production constituting more than 10% of the national annual teff production and its total production was 5.09 million quintals with a productivity of 19.23 quintal per hectare (Nitsuh, H,2019).

Awabel woreda is endowed with favourable climatic and natural resource conditions for cereal crops and livestock raring. The major crops produced in the area include teff, chickpea, sorghum, wheat, pea, vetch and beans. teff is the main crop in the area mostly for consumption and market because of the high price it fetches compared with other cereals. Therefore, this study is to

evaluate technical efficiency and to identify factors affecting smallholder farmers in teff production in Awabel woreda.

1.2. Problem Statement

Demand for both food and energy is quickly rising and will continue to rise with increases in global population and average income. World population is projected to reach its maximum (10 billion people) by the year 2050. This 45% increase of the current world population (approaching seven billion people) will boost the demand for food and raw materials. However, Modern agriculture is fundamentally based on varieties bred for high performance under high input systems (fertilizers, water, oil, pesticides), which generally do not perform well under low-input situations (Begna, T. (2020).

Ethiopian population will exceed 126 million by the year 2030. This increase in population will impose additional stress on the already depleted resources of land, water, food and energy. Teff is an important crop in terms of cultivated area, share of food expenditure, and contribution to gross domestic product. Despite the remarkable growth in teff production in the last decade, the drivers of this growth are not well understood. In particular, there is a lack of evidence on the contribution of improvements in productivity to this growth and the link between farm size and productivity (Moges et al., 2018).

Teff is Ethiopia's most important staple crop. Teff has the largest value in terms of both production and consumption in Ethiopia and the value of the commercial surplus of teff is second only to coffee. However, despite its importance in Ethiopia, teff yields are low. There are several reasons for this; one of the major reasons is the way farmers are sowing teff.The others are limited knowledge about possible avenues for improving teff productivity, combined with problems inherent to teff botany, limited national and international attention on teff research, its localized importance in Ethiopia, agronomic constraints that include, lodging, low modern input use, and high post-harvest losses (Lobamo, T,2020).

The yield, productivity and efficiency levels of Ethiopia's agriculture are generally below the world's mean due to poor attention given to the sector. The output, productivity, and efficiency status of the sector are, well below the world average. For example, in cereal production, which is the largest in the sector, the global average cereal yield is 3.574 t/ ha, while Ethiopia's average

cereal yield is 2.538 t /ha. In general , teff (Eragrostis tef (Zucc.) Trotter) growers face problems with management inefficiency inputs, poor extension, the output variations per hectare, insufficient credits, inadequate marketing, backward teff growing technology, weak infrastructural access, and inappropriate agricultural development policies (Mulatu, N. T. (2023).

The expansion of production and productivity can be achieved through two essential techniques. Firstly, by amplifying the utilization of inputs and introducing technological improvements at a specific input level. Secondly, it enhances farmers' efficiency. The measurement of efficiency provides a means to quantify and compare each farmer's performance while identifying factors that explain any inefficiencies and disparities in performance. Recognizing the factors influencing inefficiency can aid stakeholders in enhancing productivity by identifying controllable and uncontrollable factors affecting efficiency that need consideration in intervention design. Improving production efficiency empowers farmers to elevate their output without additional inputs or alterations to production technologies, ultimately leading to increased productivity (Fikadu,& Gebre,2024).

Teff is gluten-free and rich in iron and fiber, and its demand has been flowing into the international market in recent years. It contributes 16% of the nation's overall grain production and 18% of the total cereal crops. Approximately 25 to 30 million people rely directly on teff production, and Ethiopia's productivity is still low. For instance, in the 2020/21 production year, the yields was 1.9 tons/ha, significantly lower than maize and wheat due to socio-economic issues, low utilization of modern ideas, outdated seeding approaches, post-harvest damage, and lack of high-yielding cultivars (Tekeste ,et al 2023).

Despite the importance of teff in Ethiopia, yields are remarkably low. Several factors explain for this low yield. First, modern input use in teff production such as inorganic fertilizer and improved seed is low. Latest national estimates show that only two percent of teff farmers used improved seeds, although more than one third applied fertilizer for teff production. Second**,** plant lodging, to which teff is susceptible, is perceived to be detrimental for teff grain production, especially during the grain-filling period. Third, land is repeatedly ploughed before sowing to prepare the seedbed and control weeds, but this leads to increased erosion and lower soil fertility. Fourth, soil erosion has led to nutrient (mainly nitrogen and phosphorus) deficiencies in the drier

areas of the country. Finally, there are significant post-harvest and processing losses (Lobamo T, 2020).

The agronomic practices to cultivate teff have little changed, slowing improvement in teff productivity. One such practice is broadcasting for sowing. Broadcasting is a traditional method commonly used for teff sowing in Ethiopia due to its small grain size. A teff grain measures 0.9-1.7 mm long and 0.7-1.0 mm wide, and 150 teff grains weigh equal to one wheat grain. The current averaged seed rate in broadcasting is around 40-50 kg per ha. This rate compares to 3-4 kg per ha, a suggested teff sowing rate in Australia. Broadcasting scatters seeds unevenly in the field, and establishes irregular stands. It in turn makes a proper farming a challenge. Instead, row planting is recommended as a good alternative to the broadcasting (Fikadu,& Gebre,2024).

Moreover, given the shortage of land and unavailability of fertile soil in densely populated highlands of Ethiopia. To meet the food demand of the growing population, increasing productivity and efficiency are available choices for farmers. In the past increasing of the crop production is possible through bringing more fertile land under' cultivation. While this approach is unsustainable and leading to a reduction of pasture land and deforestation which have negative environmental consequences. However, currently, the shift is towards the use of sustainable land management practices and agricultural technologies, for example; legume-teff rotation, terracing and modern input (such as quality seed) use to increase crop yield per hectare and increase farmers efficiency.

We have ample of studies on technical efficiency and productivity of Cereal production. For example; Ayele, A.,.,(2020); Bäckman e t al.,(2017) ; (Lobamo T, 2020). Aragow, Y. (2017); Hagos (2015) ; (Tekeste ,et al 2023).; (Fikadu,& Gebre ,2018) ; (Fikadu,& Gebre,2024). (Lee, H. 2018) , (Tesfaw , et al, 2021). (Begna, T. (2020).; (Moges et al., 2018). (Mulatu, N. T. (2023). explained technical efficiency and productivity of Cereal teff in various regions of Ethiopia but none of them used manure application as a factor technical efficiency and also agro ecological factor except Argaw Y. (2017). Therefore my study added manure application and agro ecological zone as a factor of technical efficiency of small holder farmers in study area.

Although teff production is endemic to Ethiopia and used to make staple unique food 'injera' and millions of Ethiopians rely on teff for their livelihood, studies on the technical efficiency of teff

production are inadequate. Moreover, the effect of sustainable land management practices on technical efficiency of teff production is unknown.

Production constraints have been identified that contribute to explaining the yield gap, i.e. limited water availability, limited nutrient availability, inadequate crop protection, insufficient or inadequate use of labor or mechanization, and deficiencies in knowledge. Water shortages during the growing season can be reduced using irrigation; nutrient limitations can be lifted by applying organic or inorganic fertilizers. Yield reductions due to inadequate control of weeds, pests and diseases can be avoided by introduction of proper crop protection including the use of biocides, methods and crop rotations. Especially for operations where timeliness is crucial, such as sowing or planting, limited application may result in yield reductions, In other cases, seasonally specific cultivation patterns may cause temporal labour shortages that, in their turn, reduce the adoption of new technologies. In Africa, where many production situations are based on manual labour, the availability of labour may be limited during the period crucial for weeding. Under these conditions, poorly controlled weed populations may reduce crop yields. The relative contribution of production constraints contributing to the gap between potential and current yields differs among crops and regions. The crop growth and development are constantly influenced by environmental conditions such as stresses which are the most important yield reducing factors in the world (Begna, T. (2020). .

Therefore, understanding the level of technical efficiency among small holder farmers is essential to identifying the gaps between actual and potential output. However, there is no empirical study that quantifies these efficiency levels and explores the factors influencing them in study area. Without such analysis, efforts to enhance productivity and ensure food security may be misdirected or ineffective.

This study aims to address this gap by analyzing the technical efficiency of teff production among smallholder farmers, identifying key determinant factors, and offering policy recommendations to improve resource utilization and productivity in the sector.

1.3. Research Questions

- What is the level of technical efficiency of Teff production among smallholder farmers in Awabel Woreda?

- What are the factors affecting technical efficiency of smallholder Teff producers in the study area?

1.4. Objective of the study

The General objective

The General objective of the study is to examine the technical efficiency of teff production of smallholder farmers in Awabel Woreda

The Specific objectives

The specific objectives of the study are

- To estimate the level of technical efficiency of teff production among smallholder farmers in Awabel Woreda
- To determine factors affecting technical efficiency of smallholder teff producers in Awabel Woreda.

1.5. Hypothesis of the study

Standing from the literature reviewed, the following hypotheses were formulated for the objectives to perform the study:-

Hypothesis 1: Teff producer farmers in Awabel woreda are technically efficient and no production loss attached to teff producer farmers.

Hypothesis 2: The determinants included in the inefficiency effect model are not jointly affecting the technical efficiency of farmers in Awabel woreda. This means the variables age of household head, gender household head(sex), education level of household head, farm size(plot), agro ecology, credit access, improved seed application and manure application do not significantly influence technical efficiency of teff producer farmers.

1.6. Significance of the study

The world population is increasing, but the potential to increase production by bringing more land resource under cultivation is impossible. Thus, this study has several contributions**:** first, the

study examines the possibilities to increase the yield of teff per hectare without increasing input usage. Second, the study identifies factors that affect the efficiency of teff crop which is endemic to Ethiopia and used to prepare staple food for millions of Ethiopians. Third the result of the study can be used as reference for future studies in the area. Fourth, this study can identify the research gaps in the area. Fifth**,** the result of the study could help farmers, agricultural extension workers, researchers and policy makers by providing information to increase productivity and efficiency of teff production.

1.7. Scope of the study

The study was limited to the analysis of productivity and technical efficiency of teff production in Awabel woreda, East Gojjam zone. The study limited to single woreda selected kebeles due to time and budget shortage. Moreover, the result drawn from teff production could be used to infer technical efficiency and productivity of cereal production in the study area and other areas in the country with similar agro-ecological characteristics. The study applies stochastic frontier analysis (SFA) to explain productivity and technical efficiency of teff production.

1.8. Organization of the thesis

The thesis was organized as follows. The first chapter deals with background of the study, statement of the problem, research questions, objectives, hypothesis, significance of the study, and scope of the study organization of the paper. Chapter two of the thesis presents the theoretical and empirical literature review. Chapter three presents the methodological approach of the study comprising, description of the study area, data source, sampling techniques and data analysis. Chapter four presents the results and discusses the main findings of the study. The fifth chapter was briefly presents the summary, conclusions, and recommendations of the study.

CHAPTER TWO: LITERATURE REVIEW

2.1. Theoretical Literature

2.1.1. Concept and Definition of Efficiency

The mean technical efficiency of farmers was 76.4% indicating that in the shortrun technical efficiency could be increased by 23.6% through better use of labor, oxen power, land allocated for teff, and seed. Moreover, the result of the inefficiency model confirmed that technical inefficiency of teff production was negatively affected by early harvesting, the experience of farmers, use of the improved seed, and education level of farmers while positively affected by the participation of farmers in non/off-farm activities, distance to district market and lodging (Tesfaw , et al, 2021)..

A production function is defined as the technical relationship between the alternative combination of inputs used for production (i.e. land, labor, and capital) during a specified period and the maximum possible output produced, given the state of technical knowledge. Efficiency analysis becomes the core issue of evaluating performance since the works of Farrell (1957). According to Coelli (1995) and Coelli et al., (2005) productivity and efficiency are different indicators used to measure the performance of a firm.

Productivity is measured as the ratio of output(s) to input(s). The measures of productivity involve either total factor productivity, which is a productivity measure involving all factors of production or other traditional measures of productivity such as labor productivity in a factory and land productivity (yield) in farming which are often called partial measures of productivity. These partial productivity measures can provide a misleading indication of overall productivity when considered in isolation (Coelli et al., 2005).

Technical efficiency focuses on getting the maximum output from the given set of input; it is the precondition for economic efficiency. Technical efficiency can be increased by improving knowledge, skill; training and updated information. Allocative efficiency describes the optimal combination or allocation of inputs and out puts. Farmers to be economically efficient they have to be technically and allocatively efficient Coelli et al., (1998).

Efficiency can be explained in terms of technical efficiency, allocative efficiency and economic efficiency. Technical efficiency refers to the minimum combination of inputs required to produce a given level of output. Allocative efficiency refers to the least cost combination of inputs required to produce a given level of output. Determination of allocative efficiency, in this case, requires knowledge of the market prices of all inputs used in the production process. A technically efficient way of production is not necessarily allocatively efficient and an allocatively efficient way of production is not necessarily technically efficient. If the production method is both technically and allocatively efficient, we call it economically efficient (Weldegebriel, H, 2015).

For most developing countries, enhancing the total production and productivity is not an option rather it is a necessity and the first concern in their policies. Theoretically; there are two possible alternatives to increase total production and productivity. The first method is through increased use of inputs and/or improvement in technology at certain level of input. The other option is to develop the efficiency of producers or farmers. The measurement of efficiency has remained an area of important research, especially in developing countries, where resources are scanty and opportunities for developing by inventing or adopting better technologies are dwindling (Ayele, A.,2022).

Technically efficient farmers are those farmers that are operating on the production frontier that represents the maximum output attainable from each input level. Technical inefficiency can be defined as the quantity by which a firm lies below its production frontier or profit frontier. The firm is more inefficient, when it is more distant from the frontier (Argaw,Y., 2017)

Technical efficiency of a firm at a given period is the ratio of its mean production (conditional on its levels of inputs and firm effects) to the corresponding mean production if the firm applied its levels of inputs most efficiently (Fikadu,& Gebre, 2018).

2.1.1.1. Measuring Efficiency

There are two main ways to measure technical efficiency. These are input oriented and output-oriented.

Input oriented (IO) approach

In his first work on efficiency, Farrell (1957) illustrated his idea about measuring efficiency with figure, as follow. The SS′ is an iso-quant, representing technically efficient combinations of inputs, X_1 and X_2, used in producing output Q. SS′ is also known as the best practice production frontier. AA′ is an iso-cost line, which shows all combinations of inputs X_1 and X_2 to be used in such a way that the total cost of inputs is equal at all points. However, any firm intending to maximize profits has to produce at Q′, which is a point of tangency and representing the least cost combination of X_1 and X_2 in production of Q. At point Q′ the producer is economically efficient.

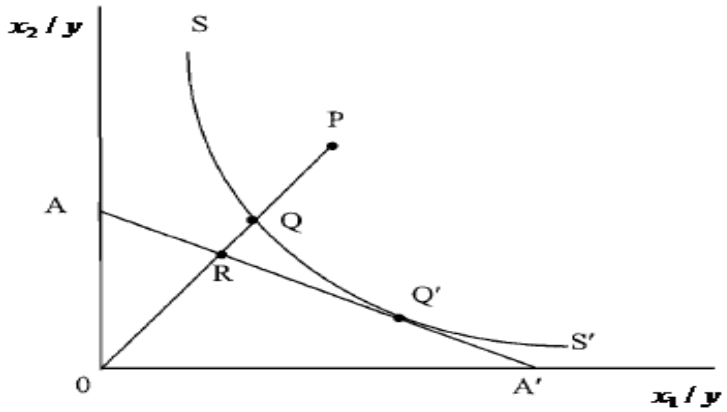


Figure 1: The Input-Oriented Measurement of TE

Source: Coelli *et al*. (1995)

Given figure 1, suppose a farmer is producing his output depicted by iso-quant SS′ with input combination level of (X_1 and X_2). Production at input combination at point P is not technically efficient because the level of inputs needed to produce the same quantity is Q on iso-quant SS′. In other words, the farmer can produce at any point on SS′ with fewer inputs (X_1 and X_2), in this case at Q in an input-input space.

$$TE = \frac{OQ}{OP} \quad (1)$$

However, technical inefficiency (TI) score of a farmer is given by

$$TI = 1 - TE = 1 - \frac{OQ}{OP} \quad (2)$$

The distance QP represents the TI of the farmer observed. TI is the magnitude of input use that can be decreased without decreasing the level of output to be produced (Coelli et al., 1998). The value of TE ranges between 0 and 1. When a farmer is technically efficient the value of TE is equal to 1 and its value lies between 0 and 1 when there is wastage of input use. For instance when a value of technical efficiency(TE) increasing from let say 0.2 to 0.8 technical inefficiency is decreasing. The TE value of 75% or 0.75 means that the firm can increase output by 25% by avoiding wastage without increasing input usage.

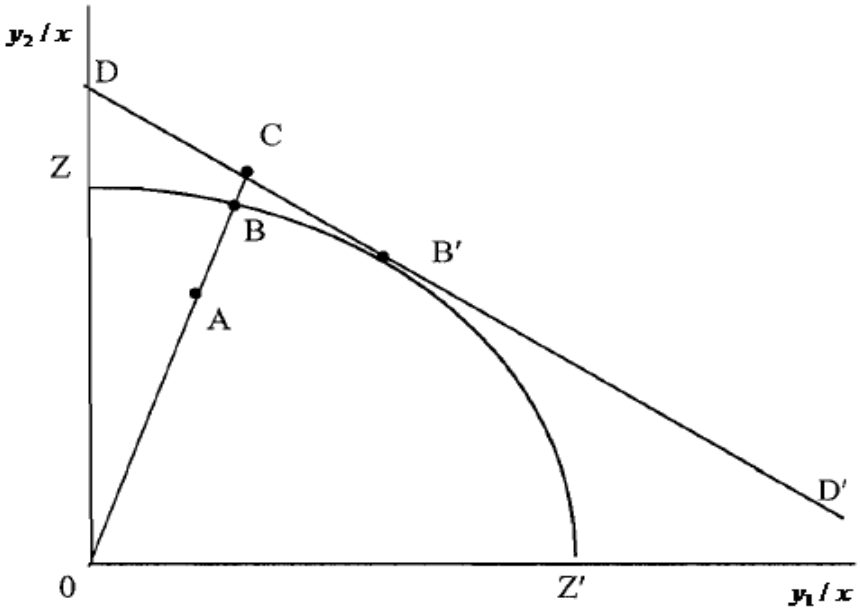
Output Oriented (OO) approach

Output oriented (OO) approach analyzes the ability of a farmer to maximize output without changing the use of inputs. Figure 2 illustrates OO measurement of TE of a farmer producing two outputs (i.e., y_1 and y_2) using input χ_t. A production possibility curve (PPC) given by ZZ′ showing possible combinations of the two outputs produced using a given level of input x_1. A farmer that is producing on the curve is said to be a technical efficient. Whereas a farmer that producing inside or below the PPC, such as point A is technically inefficient.

To describe a TE of a farmer using graph and equations we draw a line 0C from the origin to point C. This line crosses the PPC at point B. A farmer operates at point A uses the same input level as is used by an efficient farmer, operating at point B. The technical efficiency of farmer is the ratio of distance 0A to 0B.

$$TE = \frac{OA}{OB} \qquad (3)$$

The distance AB represents the size of technical inefficiency of farmer . TI of farmer is the size of outputs could be increased by farmer without changing the use of input x_i



Source: Coelli *et al*. (1998)

Figure 2 The output-oriented measurement of TE

2.1.1.2. Specification of Efficiency

Technical inefficiency refers to the failure to operate on the production frontier and is generally assumed to reflect inefficiencies caused by timing and method of application of production inputs (Liewelyn and Williams, 1996). We apply frontier methods to measure efficiency. These are the parametric and nonparametric frontier models. As described by (Coelli et al., 1998) stochastic frontier analysis have more advantage than the data envelop analysis in agricultural production especially in developing countries, that the data collected influenced by measurement error and effect of environmental changes and pests.

The parametric models are estimated based on econometric methods and the nonparametric efficiency model, often referred to as data envelopment analysis (DEA), involves the use of linear programming method to construct a non-parametric 'piecewise' surface (or frontier)

over the data. First we discuss the Non-parametric frontier models and then we discuss the parametric models.

Non-parametric frontier models, usually involves data envelopment analysis (DEA). DEA applies a mathematical programming technique, (i.e., a linear programming technique) to estimate the relationship between inputs and outputs, to estimate mean TE and to explain factors that determine technical inefficiency. Unlike parametric frontier models DEA doesn't require any distributional assumption for technical inefficiency term (Coelli et al., 1998).

The DEA frontier is both non-parametric and non-stochastic since it does not impose any a priori parametric restrictions on the underlying frontier technology (because doesn't necessitate any functional form to be specified for the frontier methodology) and doesn't require any distributional assumption for the technical inefficiency term. Therefore, the method avoids the imposition of unwarranted structures on both the frontier technology and the inefficiency component that might create distortion in the measurement of efficiency (Fare et al., 1985). The minimum assumptions required for this DEA frontier methodology are monotonicity and convexity of the efficient frontier (Banker et al., 1984).

The parametric frontier model classified into deterministic and stochastic frontier methods. The deterministic model assumes that any deviation from the frontier (i.e. maximum level output for a given input use) is due to inefficiency, while the stochastic approach allows for statistical noise. In other words, a stochastic frontier model assumes not only inefficiency of a farmer or a manager but also factors that are beyond the control of a farmer are the reasons of deviation of observed output from the maximum possible output for a given input use. For instance, weather shocks, drought and natural calamities are beyond the control of farmer but results in less output than maximum output. Moreover, random error or noise includes random shocks especially in agriculture as well as measurement errors and misspecification of models (omitted variables for example). However, the deterministic frontier model assumes that technical efficiency of farmers are the only causes the deviation of actual output from the frontier (that is the maximum possible output). That is, the ratio of the observed output for the i^{th} farmer to the potential output is used to define frontier function.

A Cobb-Douglas specification of a parametric frontier production model for the i^{th} farmer that uses x_i inputs is given by

$$\ln y_i = x_i'\beta - u_i \quad (4)$$

Wherei=1, 2, 3……N

Where $\ln(y_i)$ is output for the i^{th} firm, x_i is a vector of k-inputs used by the i^{th} farmer, β is a vector of parameters to be estimated, and u_i is a non-negative random variable represents technical inefficiency.

TE is the ratio of the observed output for the i^{th} farmer to the potential output which was given by:-

$$TE = \frac{y_i}{\exp(x_i\beta)} = \frac{\exp(x_i\beta - u_i)}{\exp(x_i\beta)} = \exp(-u_i) \quad (5)$$

The model represented by equation 4 is called deterministic frontier model because the observed output y_i s bounded above by the deterministic (non-stochastic) quantity $\exp(x_i\beta)$. Deterministic model assumes that any deviation from the frontier is due to farmers' inefficiency; therefore, they are very sensitive to outliers Farrell (1957). All measurement errors and shocks beyond the control of a farmer are capture by the one-sided component u_i, . As a result, outliers may have profound effects on the efficiency estimates.

The stochastic frontier approach describes that the deviation from the frontier are due to the inefficiency of the production units and the factors which are outside the farmers' control such as weather shocks. This indicates that stochastic frontier model considers the error term which include two additive components, the pure random factor (v_i) commonly

known as a random error and effect of inefficiency term relative to the stochastic frontier u_i ( ) Aigner et al., (1977).

The stochastic frontier model is specified as:

$$\ln y_i = x_i\beta + v_i - u_i \quad (6)$$

The inefficiency terms u_i assumed to be identically and independently distributed exponential or half normal random variables. Also discuss here the assumptions for v_i .The main point added to the stochastic frontier model from the deterministic model is the systematic random error. The Cobb-Douglas stochastic frontier model takes the form

$$\ln y_i = \beta_o + \beta_1 \ln x_i + v_i - u_i \quad (7)$$

$$yi = \exp(\beta_o + \beta_1 \ln x_i + v_i - u_i)$$

Or

$$y_i = \exp(\beta_o + \beta_1 \ln x_i) \times \exp(v_i) \times \exp(-u_i)$$

Even though the decision made after testing hypothesis theoretically we preferred to use the stochastic frontier model as agricultural production is vulnerable to different disease and weather shocks and climate change impacts. Moreover, specifically stochastic frontier model is considered to take account of random error and inefficiency components together.

2.2. Review of Empirical Literature

The literature review focuses on explaining factors that affect either technical efficiency or productivity.

Bäckman et al., (2017) specified quadratic stochastic frontier model and assessed technical efficiency of rice production in Bangladesh. The study found that younger farmers are more efficient than older farmers and higher off-farm income increases the technical inefficiency of rice farmers. However, land fragmentation has a significant negative impact on technical inefficiency. Access to microfinance also leads to higher inefficiency.

(Fikadu,& Gebre, 2018) showed that among the estimated inputs; seed, labor, land, and mineral fertilizer are positively significant at 1% and 5% level of significance. The seed has more impact on the efficiency of teff farms than other inputs. The second, third, and fourth influential inputs in teff production are labor, land, and mineral fertilizer application, respectively. However, surprisingly, the input variable, oxen, is not significant in the model.

(Argaw Y, 2017) the SPF model showed that production can be improved by increasing the use of inputs. There is considerable room to improve the efficiency of farmers in teff production. The implication is that, there will be considerable gain in production level if introduction and distribution of agricultural technologies are joined with improving the existing level of efficiency and also the existing level of efficiencies in teff production in the study area as the whole, in midland and in lowland areas are high and this calls for better attention of policy makers and researchers in tackling the sources of these inefficiencies to improve the welfare of teff producing farmers in both agro-ecological zones in Legehida woreda.

(Lombamo, T.2020). increasing agricultural productivity is absolutely necessary to feed the increasing population by increasing land productivity. Teff is Ethiopia's most important staple crop. Teff has the largest value in terms of both production and consumption in Ethiopia and the value of the commercial surplus of teff is second only to coffee. However, despite its importance in Ethiopia, teff yields are low. There are several reasons for this; one of the major reasons is the way farmers are sowing teff. The others are limited knowledge about possible avenues for improving teff productivity, combined with problems inherent to teff botany, limited national and international attention on teff research, its localized importance in Ethiopia, agronomic constraints that include, lodging, low modern input use, and high post-harvest loss.

(Mulatu, N. T. (2023) explained that the study aimed to investigate determinants influencing the productivity and technical efficiency of teff yield in the Kache Birra district, Kambata Zone.The stochastic yield frontier model is mostly conducted model the finding evaluated that productivity was affected by age, sex, education status, landholding, livestock holding, credit uses, extension uses, off-farm activity, land ownerships and fertilizer uses. Results revealed that technical efficiency was associated with significant improvements in household food security as reflected in significantly increased household per capita income. The estimated average value of technical, allocative and economic efficiencies was 71.52%, 67.23%, and 63.54% respectively. Moreover,

key household characteristics such as age, sex, education status, and off-farm income; institutional factors such as the use of credit and use of extension services; and farm characteristics such as land ownership and landholding; input variables such as livestock holding and fertilizer uses were found to be important factors affecting technical inefficiency in the study area. Therefore, the agricultural sector and other concerned bodies should give important attention to technical efficiency, which is a key indicator to alleviating poverty and achieving food security in Ethiopia, especially, in the study district.

(Tesfaw , et al, 2021). showed that the stochastic frontier model output indicated that teff output was significantly affected by land, labor, oxen power, seed rate and interaction of land and labor. The inefficiency model confirmed that early harvesting, education level of household heads, use of improved teff seed and experience of farmers were negatively and significantly affects technical inefficiency of teff production while participation of farmers in non/off-farm activities, distance to district market and lodging were positively and significantly affects technical inefficiency of teff production in Raya Kobo district.

Okuyamaa et al., (2012) DEA showed that productivity and TE of farmers producing five crops (i.e. upland rice, lowland rice, groundnut, maize, and pearl millet) in Senegal are affected by socioeconomic variables. For instance, farming experience, amount of nitrogen fertilizer applied, and participation in a farmers' association increase TE. However, hours allocated to weed, seeding rate, size of cultivated area, and delays in sowing time are negatively associated with TE. Moreover, the factors that affected TE are not uniform across crops.

Rahman et al., (2008) stochastic frontier analysis for rice production in Bangladesh indicated that land fragmentation decreases efficiency and resource ownership including land, draft animal and adoption of new technology and family labor increase efficiency of farmers.

Manjunathah et al., (2012) estimated stochastic frontier production and found that land fragmentation increases inefficiency and land ownership and crop diversity decreases inefficiency. They also noticed that farmers with less land size are more efficient. Nyemeck et al.,(2004) estimated Cobb-Douglas function and observed that farmers with education level more than grade four, membership to farmers' association, owned fertile land and have access to credit

are more efficient. The distance of the plot from the main road and access to extension service decrease technical efficiency.

Beyan et al.,(2013) Cobb-Douglas specification found that education, livestock holding, extension contact, farmers access to training, cultivated land size and access to irrigation are technical efficiency improving while social status of the farmer is technical efficiency impeding.

Leulsegged (2014) estimated Cobb Douglas stochastic frontier model and explained wheat production is responsive to plot size, seed type, fertilizer application, and agro-chemicals in Ethiopia. Moreover, technical inefficiency variations are explained by age and education level of household head, a number of cultivated plots, and degree of wheat production specialization, livestock income, soil quality, and cooperative membership.

Endrias et al., (2013) assumed non-parametric specification (i.e., DEA model) and parametric specification (i.e. translog production function) and explained that planting method, use of hybrid maize seed and application of integrated soil fertility management practices have positive significant influence on maize productivity. On the other hand, off or non-farm income has negative significant influence on maize productivity. This is also in line with the hypothesis that increased off or non-farm opportunities take away farm resources and farmers effort that could otherwise be used for maize production and hence reduce maize productivity. Size of farm size, oxen holding and use of hybrid maize variety were highly significant at positively affecting the technical efficiency.

Fekadu (2004) stochastic frontier model with Cobb Douglas specification found that fertility status of the plot, age, age square, land ownership status, training, number of plots per farm, family size and livestock significantly determine efficiency level of farmers in wheat production in the study area. The negative coefficient of fertility status of the plot, age, land ownership, training, and extension means these factors are important in determining the existing efficiency of farmers positively and significantly. While the positive coefficients of age square, family size, fragmentation, and livestock indicate that the increments in these factors increase inefficiency.

Shumet (2012) applied stochastic frontier model for Translog specification for crop production in Tigray region. This study found that education of household heads, family literacy, family size, sharecropping, credit access, crop diversification, and land fertility are found to enhance

efficiency. On the contrary, households' age, dependency ratio, livestock size, and off-farm activity are found to increase inefficiency.

Musa et al.,(2014) estimated Cobb-Douglas stochastic frontier model for maize production in Ethiopia showed that, education was found to determine allocative and economic efficiencies of farmers positively while the frequency of extension contact had a positive relationship with technical efficiency and it was negatively related to both allocative and economic efficiencies. Credit was also found to influence technical and economic efficiencies positively and distance to market affected technical efficiency negatively. The model output also indicated that soil fertility was among significant variables in determining technical efficiency in the study area.

Wudineh et al., (2016) specified translog model and estimated technical efficiency of barley farmers. Farmers' living far away from all-weather roads operate more efficiently than farmers close to these roads. Those who have got opportunity Access to credit could improve technical efficiency. Membership in more than one farmers' group could improve technical efficiency. More frequent extension contact and participating in training activities could improve technical efficiency of farmers. Farmers having more plots of barley were more efficient and farmers produce barley on own plots were more efficient than farmers rented/ sharecropped plots.

Mesay et al., (2013) estimated translog model and explained source of technical inefficiency of smallholder wheat farmers located in waterlogged areas of Ethiopia found that the number of wheat plot used increased TE. The result implying that as the number of wheat plot increases, then the likelihood of allocating wheat varieties across heterogeneous plots increases and is more likely to increase the efficiency of wheat production.

Generally from those literatures abroad and in Ethiopia we have seen that the measurement of technical efficiency of agricultural products in different area and at different time varies according to different socioeconomic factors and that different researchers in different place at different time using the same variables have different results and those factors are not equally important and similar in all places at all time. A factor in one place at a certain time may not necessarily be a significant factor in other places or even in the same places after some time and the findings of researchers are not consistent with each other.

Additionally, we have seen most empirical studies did not consider land management practices. Standing from these to decide in the specific area and those areas have the same socio-economic and agro-ecological characteristics further study will be necessary to prove the main determinants and the mean technical efficiency level of teff production with the available technology. Therefore, this study intends to fill these gaps.

2.3. Conceptual Framework

We provided here brief conceptual framework of the study. The conceptual framework shows briefly how socioeconomic characteristics of farmers, institutional factors and national policies are interrelated to reduce poverty. For example, 10 year leading plan in Ethiopia has been implemented in such a way to influence socioeconomic characteristics of farmers, institutional services to be provided for farmers and land management practices. Moreover, specifically the agricultural sector targets of 10 year leading plan aims to increase productivity and efficiency of farmers and hence to reduce poverty and food insecurity. The overall objective of this plan is in line with United Nations Sustainable Development Goals.

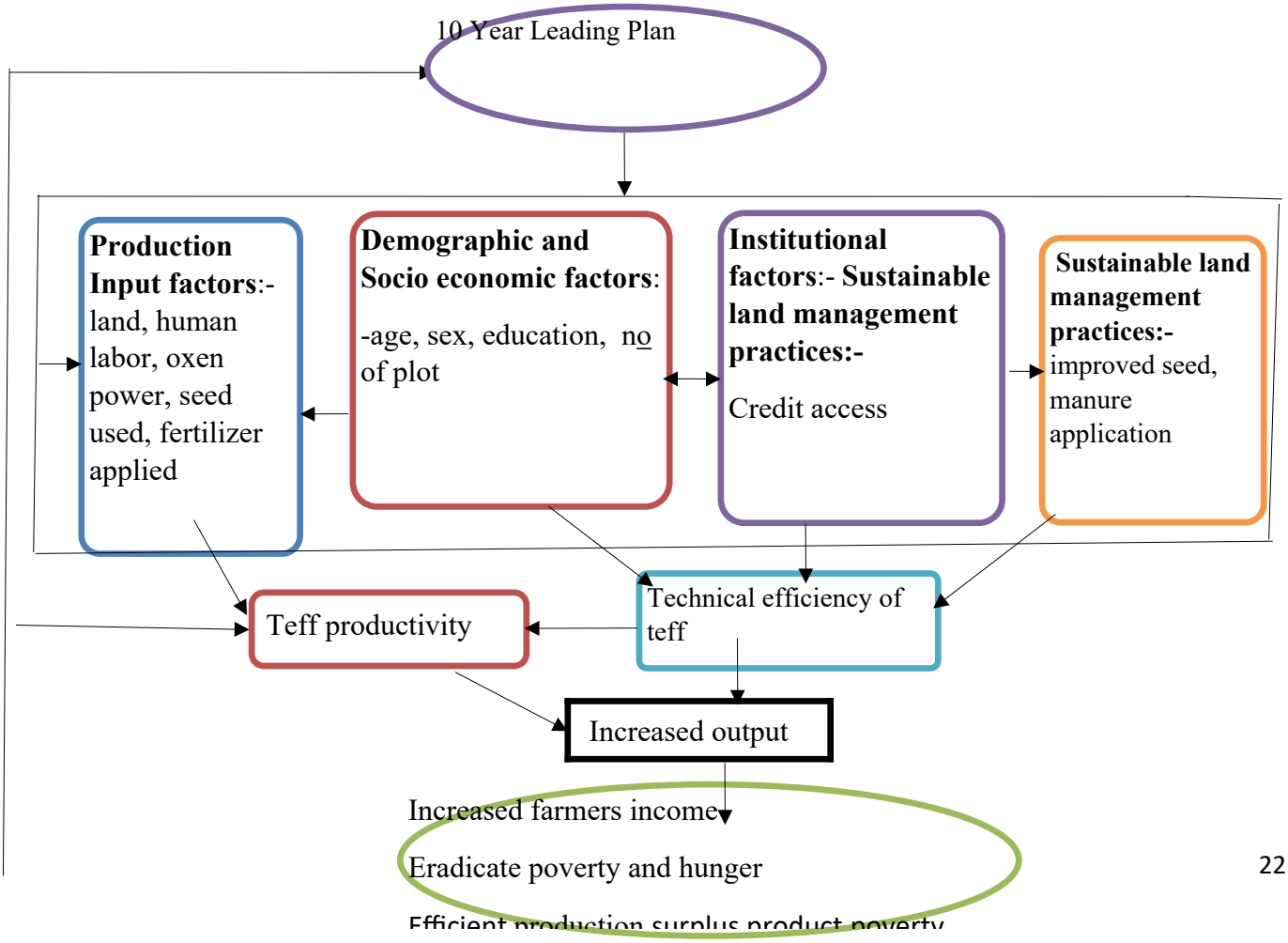


Figure 3: Conceptual Framework of the Study

Source Own Standing from the Literature

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Description of the Study Area

The study area Awabel Woreda is located in East Gojjam Zone, Amhara National Regional States of Ethiopia. The district is bordered by the Blue Nile River from the south, Aneded woreda from the west, Gozamen woreda from the northwest, Debay Tilatgin woreda from the northeast and Dejen woreda from the east. The Woreda level administrative organizations of the Awabel Woreda are located in Lumame.

The totol population size of Awabel woreda is 147,431 divided into 72,947 men and 74,484 women population based on the 2023 projection national census survey by the Central Statistical Agency (CSA). The rural population accounts for 86 percent (126794) while the share of urban inhabitants is 14percent (20637). The total land size of the district is 787.22 km^2 or 78,722 hectares. According to CSA (2007), the district is classified into dega (15percent), Weyinadega (60percent) and kola (25percent) agro-climatic zones.

The center of the Awabel woreda is woreda level administrative units located is 40 km east of Debre Markos town, 306km from Bahirdar and 259km to Addis Ababa. Awabel woreda has 28 rural kebeles and 1 small town. The altitude of the woreda ranges from 1068 to 3200 meters above sea level. The woreda annual rainfall ranges from 1100-1400 millimeters and its annual temperature ranges from a minimum of 10°C to a maximum of 25°C. The District is dominated by black soil type that constitutes 55 percent; red and brown soil types constitute 30 percent and 15 percent, respectively. The land use constitutes 1485 hectare of grazing land, 8440 ha of forest

land, 2500 ha permanent crops such as 45,339 for annual cropping (such as teff, wheat..) and 5571.73 ha is residential area and roads.

The farming system of Awabel woreda is mixed farming (i.e. a combination of crop and livestock production), but crop production is the dominant source of income to farmers. The dominant crop in the area includes teff, wheat, barley, maize, sorghum, bean, pea, and chickpea. According to CSA (2023) projection, the total number of farm households in the district is 19689; among those 16703 and 2986 respectively are male and female-headed households. Teff is produced in all agro-ecological zones of the woreda but dominantly in the Weyinadega (i.e. midland) part of the district. Livestock production is also the second major source of income and oxen are used for plowing and threshing. Livestock and crop diversification are risk reduction strategies employed by farmers. Farmers use cow dung as a source of fuel (i.e. firewood) and for composting. The livestock production in the study area involves cow, ox, sheep, goat, donkey, and horse rearing.

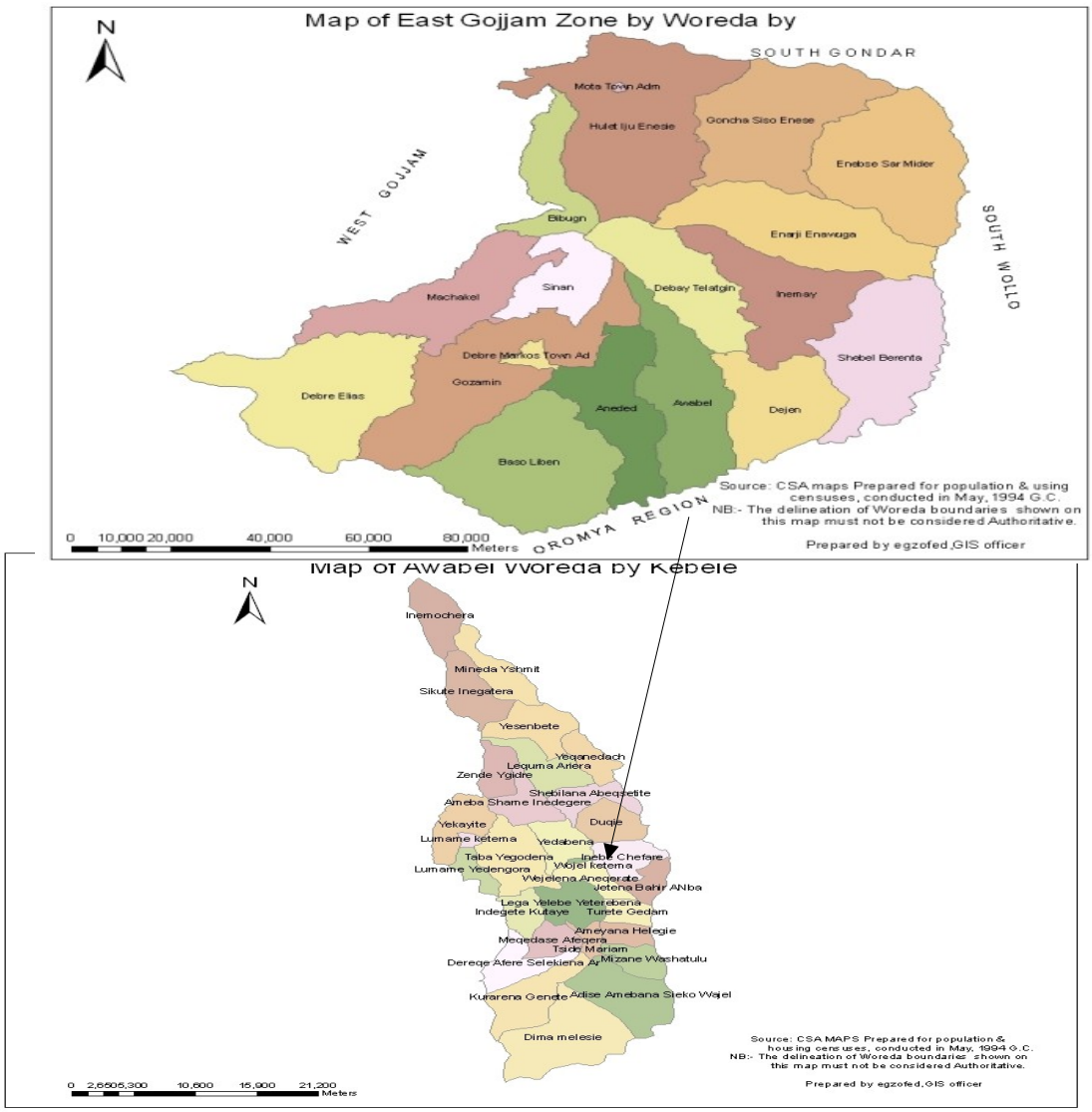


Figure 4: Geographical Location of the Study Area.

3.2. Data Type and Source

Both primary and secondary sources of data were used in generating the required data. For this study, both primary and secondary data were used. The primary data was collected from randomly selected sample farmers from the selected kebele administrations. The secondary data was obtained from studies conducted and information documented at various levels of Central Statistical Agency, Agriculture and Development Offices in the study area. Important literatures on technical efficiency were also assessed from the internet. Before the field study, the instrument was rigorously reviewed and necessary changes were made. The questionnaires were administered in 354 teff grower-headed households in the Awabel woreda, Ethiopia. Both open and close-ended questionnaires were conducted to achieve all objectives of the study.

Enumerators were recruited in each kebeles to collect the primary data. The selected enumerators were trained on the techniques of administering the questionnaire. Moreover, focus group discussions were held during the survey with farmers, local administrators and development agents. During the survey, information was gathered on issues related to the socioeconomic factors that affect efficiencies in teff production in the study area, farmers' knowledge about the production of teff, inputs used and output produced.

3.3. Instruments of Data Collection

Both qualitative and quantitative types of data were collected using primary source of data. Qualitative data like sex of household head and the like; and quantitative data were number based data collected from respondents like current year used of fertilizer, improved seed , quantity produced, numbers of oxen owned and the like. Secondary data both qualitative and quantitative were collected from published and unpublished documents. Secondary data on

population size of the district, data on production and list of major teff producer kebeles were collected from district office of Agriculture. Secondary data were also collected from different journals, books, and other published and unpublished sources.

3.4. Sampling Techniques and Sample Size

The study was followed multistage sampling technique in which combination of purposive and simple random sampling applied to select the study area and the specified households.

Awabel woreda was purposively selected from 16 woredas located in East Gojam Zone as teff is the dominant cereal crop. In the first stage by using stratifying sampling, the woreda is stratified into Dega, Weynadega and kola based on agro- ecological zone. In the Woreda teff is produced the whole area. Since, there is difference in teff production between in the three agro ecological zones using stratifying sampling is appropriate in the study area. At the second stage, since producers in each stratum are homogenous four kebeles were selected randomly from the strata (i.e., 1 kebele was selected from 6 Dega agro-ecological zone kebeles and 1 kebele was selected from 8 Kola agro-ecological zone kebeles while 2 kebeles were selected from 14 Weynadega agro-ecological zone kebeles of the woreda. Finally in the third stage, 354 farmers were selected randomly from these four kebele administrations. The total sample size was distributed to each sampling unit based on the probability proportional to size sampling technique. The sample size was determined by using the formula given by Yamane (1967) that is $n = \frac{N}{1 + N(e)^2}$

Where 'n' is the sample size, N is a total number of population in the in 4 selected kebeles, 'e' is level of precision. Once the total sample size is determined, the sample to be taken from each kebele was allocated proportionately to the number of populations dwelling in each kebeles. In this process, the first sample was selected randomly and the rest were determined by taking every **k** unit of observation. Where K=H/n. H is the number of households in each Kebele and n is the sample size taken. According to CSA 2007 and regional projection of 2023, the woreda has 19689 households and the sample Kebeles have 3106 households. The representative sample size for the aforementioned household size is approximately 354 farmers at 95 percent confidence level and 5 percent precision.

That is, $n=\frac{N}{1+N(e)^2}=\frac{3106}{1+3106(0.05)^2}=354$

Sample size is taken from each Kebele					
No	**Name of Kebele**	Agro-ecological zone	Sample frame of Household Size	Proportion In %	Allocation of Sample Size
1	**Minda**	Dega	877	28.3%	100
2	**AdisAmba**	Kola	737	23.7%	84
3	**Legga**	Weyinadega	733	23.7%	84
4	**Enebi**	Weyinadega	759	24.3 %	86
	Total		**3106**	**100**	**354**

Table 3.1: Sample Size taken from Each Kebele

3.5. Model Specification

A stochastic frontier production model proposed by Battese and Coelli (1995) was applied to cross-sectional data to determine the efficiency of the teff production by smallholder farmers. We consider the stochastic frontier approach because it is capable of capturing measurement error and other statistical noise influencing the shape and position of the production frontier. This technique better suits an agricultural production and technical efficiency largely influenced by exogenous shocks (such as weather condition). The technique assumes that farmers may deviate from the frontier not only because of measurement errors, statistical noise or any non-systematic influence but also because of technical inefficiency.

The general stochastic production frontier model including the noise term described as

$$\ln y_i = f(\ln x_i) + v_i - u_i \quad (9)$$

Where , y_i is the output produced by the farmer, x_i is a vector of a factor of production (i.e., inputs); v_i is the stochastic (white noise) error term. It is a stochastic component that describes random shocks affecting technical efficiency. These shocks are not controlled by the producer or the underlying technology. These shocks may come from weather changes, economic adversities and ui are a one-sided error representing the technical inefficiency of firm i. Both and are assumed to be independently and identically distributed with variance σ_V^2 and σ_u^2 respectively.

Given that the production of each farmer *i* can be estimated as:

$$\ln \{\hat{y}_i = f(\ln x) - u_i ¿ \quad (10)$$

While the efficient level of production (i.e. no inefficiency) is defined as

$$\ln y* ¿ f(\ln x) \quad (11)$$

Then technical efficiency (TE) can be given by:

$$\ln TE_i = \ln \{\hat{y}_i - \ln y* ¿ - u_i ¿ \quad (12)$$

Hence, $TEi = e^{-\hat{i}¼i}$ and is constrained to be between zero and one in value. If u_i equals zero, then TE equals one, and production is said to be technically efficient. Technical efficiency of the i^{th} firm is, therefore, a relative measure of its output as a proportion of the corresponding frontier output. A firm is technically efficient if its output level is on the frontier, which implies that equals one in value.

In order to estimate the level of technical efficiency in a way consistent with the theory of production function, we specified a Cobb- Douglas type stochastic frontier production function. The Cobb-Douglas form of production function has some well-known properties that justify its wide application in economic literature (Henderson and Quandt, 1973). It is a homogeneous function that provides a scale factor enabling one to measure the returns to scale and to interpret

the elasticity coefficients with relative ease. It is also easy to estimate and mathematically manipulate. The Cobb-Douglas production function makes several restrictive assumptions. It is assumed that the elasticity coefficients are constant, implying constant shares for the inputs. The elasticity of substitution among factors is unity in the Cobb- Douglas form. Moreover, this being linear in logarithm, the output is zero if any of the inputs is zero, and the output expansion path is assumed to pass through the origin. It is also argued that if interest rests on efficiency measurements and not on an analysis of the general structure of the underlying production technology, the Cobb-Douglas specification provides an adequate representation of the production technology. In addition, its simplicity and widespread use in agricultural economics outweigh its drawbacks. It is less affected by multicolinearity problem and less suffered from degrees of freedom.

On the other side, there are conditions where translog production function best fits the data if the interaction and cross product of the independent variables role is significant in the estimation of the model. The translog functional form also has flexibility and ability to capture interaction among input variables.

Standing from the advantage and disadvantage of each functional form in order to select the best functional form best fits the data the selection performed after testing hypothesis. Stochastic frontier analysis (SFA) has more advantage than the data envelopment approach (DEA) in that it uses inferential statistical hypothesis testing.

We applied likelihood ratio test to test this hypothesis by imposing constraints. The likelihood ratio tests are given by:-

$$LR = -2\left[L(Ho) - L(H1)\right] \qquad (13)$$

Or $LR = -2\left[L(CD) - L(TL)\right]$

Where LR; is the Generalized log likelihood ratio

Ho; Log-likelihood ratio of cob-Douglas

and H1-Log-likelihood ratio of translog

Finally, the decision was made by comparing with the critical value of chi2 from a table based on the existed degree of freedom. (Greene, 1980).When the null hypothesis accepted cob-

Douglas production function become more appropriate than translog and when the null hypothesis rejected translog production function fits the data for the survey.

The second hypothesis was testing the existence of technical inefficiency in the stochastic production function. Testing the null hypothesis states teff producer farmers in Awabel woreda were technically efficient or that there was not production loss due to inefficiency in teff producers. Ho: γ =0 and the alternative H1: γ ≠0 and the decision performed based on the value of gamma. Since $\gamma = \sigma_u^2/(\sigma_u^2+\sigma_v^2)$ the value of gamma greater than 0 indicates the null hypothesis rejection tells existence of inefficiency. It was also testing stochastic production function or the conventional or average response function best fits the data. The hypothesis test performed based on computing LR test. The decision made based on a test result that if the calculated LR was greater than the critical value at 1 degree of freedom the decision rejected the null hypothesis implies that there was inefficiency in teff producing farmers in the study area and stochastic frontier model best fits the data.

The third hypothesis states that the variables in the inefficiency model simultaneously equal to zero (i.e. Ho: = δ0 = δ1 = δ2 … = δ8= 0), with the alternative hypothesis, that all variables in the inefficiency model different from zero. In other words, variables included in the inefficiency model are not jointly affecting the technical efficiency of farmers in the study area. Meaning education,and agro ecology are do not significantly affect technical inefficiency of teff producing farmers. The hypothesis tests also performed based on the LR test and the decision be if the null hypothesis rejected implies coefficients of the inefficiency model simultaneously different from zero or there is at least one variable which determines inefficiency variation.

The fourth hypothesis when applying SFA testing for the distribution of one-sided inefficiency effect error term weather half normal distribution or truncated normal more appropriate was tested. The null hypothesis was that half normal distributional form best fits for the distribution of one-sided inefficiency effect error term and the alternative were truncated normal distribution appropriate for the study. The test also based on the LR and if the null hypothesis accepted half normal fitted for the data and if rejected truncated normal best fits.

The other necessary hypothesis was that checking the returns to scale weather there were constant returns to scale or variable returns to scale. The test was performed using the null hypothesis H0:β1 +β2 + β3+ β4+ β5=1 and the alternative hypothesis H1:β1 +β2 + β3+ β4+ β5 ≠ 1 and the decision made based on the test result p (value) and the sum of the coefficients of input variables. If p(value) significance and the sum of coefficients far from one implies the null hypothesis rejection and there were variable returns to scale.

After identifying the presence of technical inefficiency, the determinant factors that farmers characterized differently and made them attain different efficiency level need to be identified. The main concern of identifying these factors has implication to design and advise necessary solutions to the inefficiency problem.

The maximum likelihood estimates (MLE) of the parameters of SPF and the inefficiency effect was simultaneously done using Stata 14. The total descriptive and econometric results interpreted in the paper generated using Stata 14 software

The study was done by applying one stage maximum likelihood estimation procedure in order to estimate simultaneously the parameters of both SPF and inefficiency model. The two-stage estimation method has drawbacks like lack of consistency in assumption about the distribution of the inefficiencies, and estimated inefficiencies are assumed to be a function of different firm-specific factors that not identically distributed. The one-step estimation method overcomes this consistency.

Even though the estimation procedure using OLS gives consistency estimation for all parameters, estimating the intercept was biased; In order to solve this biased estimation the maximum likelihood estimation is appropriate for this study. When applying the maximum likelihood estimation procedure the assumptions of the distribution of the error components considered. The u_is are independently and identically distributed with half normal random variables with zero mean and σ_u^2 variance and also v_is are assumed to be identically and independently distributed with zero mean and constant variance.

After estimation of the parameters, the technical efficiency of the farmers in the study woreda estimated and also the mean technical efficiency determined.

The explicit trans-log stochastic frontier production function is given below

$$\ln y_i = \beta_0 + \sum_{m=1}^{5} \beta_m \ln x_{mi} + 1/2 \sum_{m=1}^{5} \sum_{r=1}^{5} \beta_{mr} \ln x_{mi} \ln x_{ri} + \varepsilon_i \quad (14)$$

$$\varepsilon_i = v_i - u_i$$

(15)

Where $\beta' s$ were coefficients of input variables , v_i is the "noise" component, which always consider as a two-sided normally distributed variable and u_i is the non-negative technical inefficiency component. It is also assumed that the inefficiency effects are independently distributed with a half-normal distribution $u \approx |N(0, \sigma_u^2)$

Thus u_i is derived from equation (15) using simple mathematics as follows:

$$u_i = \delta_0 + \sum_{i=1}^{n} \delta_k z_{ik} + \sum_{j=1}^{m} \eta_j s_{i_j} + \varpi_i$$

(16)

Where z_{ik} is socioeconomic characteristics k of farmer i and s_{ij} sustainable land management practices j applied by farmer i, $\delta \text{ and } \eta$ are coefficients of factors affecting inefficiency and ω_i is the error term for inefficiency model.

The β and δ coefficients are unknown parameters to be estimated, together with the variance parameters which are expressed in terms of:

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \quad (17)$$

$$\gamma = \sigma_u^2 / \sigma^2 \quad (18)$$

Where the parameter has a value between zero and one. A value of 0 for γ indicates that deviation of teff output from the frontier output is entirely due to random noise, while a value of 1 indicates that all deviations from the frontier are due to technical inefficiency.

3.6. Definition and Measurement of Variables

3.6.1. Output and Input Variables

The output and input variables measured for 2023/2024 Meher production season are as follows;

Teff yield: refers to the actual quantity of teff produced during 2023/24 production season. It was a continuous variable measured in quintals (i.e., 1 quintal is equal to 100 kg.). Teff yield was the dependent variable for production function.

Cultivated Land (LAND): It refers to total cultivated land allocated to teff production by the households during 2023/24 production year. The land may belong to the farmer, obtained by means of hiring, leasing or through sharecropping arrangements. It was a continuous variable and measured in hectares.

Oxen power Oxen (OXEN): Primarily oxen are used as a source of drought power in teff production process in the study area. It refers to the number of drought power used for different activities in teff production that include a plowing and threshing and it was measure in a number of oxen owned.

Labor (LAB): This represents the total labor (family, exchange and hired) utilized in various farm activities (plowing, sowing and fertilizer application, weeding, harvesting, and threshing). The record was done by the number of family members who are active and participate in farm activities. The sex and age of each working-class family member were recorded correctly.

Seed (SEED): It refers to the quantity of teff seed used in kg by the household head. Farmers mainly used local and improved teff seed in production. It was a continuous variable measured in kg.

Fertilizer (FERT): It refers to the application of inorganic fertilizer for the teff production. Farmers mostly applied Di-Ammonia Phosphate (DAP) or NPS Nitrogen Phosphorus Sulfur currently added to and UREA (a crystalline solid nitrogen fertilizer manufactured from

ammonia) for teff production in the study area. Its unit of Measurement is kg. It was hypothesized that farmers apply fertilizer were more technically efficient in teff production than those not applied.

3.5.2. Definition and Hypothesis of Inefficiency Variables

Age (AGE): Age of household head in years is hypothesized to reflect experience and physical strength of the farmer on efficiency. The farmer becomes less efficient as he/she gets older and his ability to manage farming activities were expected to decrease. Younger farmers were tending to be more opened and likely exposed to methods and techniques fekadu (2004) and Kinde (2005); this study has been performed to check contradicted evidence which side of the variable was influential.

Sex of the household head :(SEX): This is a dummy variable that was measured as 1 if the household head was male and 0, otherwise. Male-headed household heads have more accessed to resources and information related to better production technologies than female-headed household heads due to their social position. Since women are the one who were responsible for the many household domestic activities, they may not accomplished the farming activities on time and efficiently for the workload on them. Therefore, it was hypothesized that male-headed households were more technically efficient in teff production than female-headed households.

Formal education of household head (EDU): It refers to the formal schooling of the household head during the survey period. Those household heads that had formal education determined the readiness to accept new ideas and innovations and enhances willingness to use the recommended agronomic practices. It was assumed that through education, the quality of labor is improved and he/she become active to adopt new technologies. Access to education together with increased experience could guide to the better management of farm activities. Exposure to education was expected to increase farmers' ability to use relevant information for a production decision. Educated farmers usually have better access to information about prices, and the state of technology and its use. Better-educated people also have higher tendency to adopt and use modern inputs more optimally and efficiently. A study was done by Argaw Y. (2017) and Desale et al.,(2017) education level of household heads and technical inefficiency having a

negative relationship. Hence, education level of household head was expected to determine the technical efficiency of teff production positively.

Land Fragmentation (PLOT): This is the number of teff plots the sample farmer owned, rented and shared. Fragmented lands are difficult for effective management of the crop. Increased land fragmentation leads to inefficiency by creating a shortage of family labor, costing time and other resources that should have been available at the same time. A study was done by Argaw Y. (2017) also confirms that fragmentation has a negative impact on efficiency. On the other hand Tan et al., and Wudineh et al.,(2016) they have done on the impact of land fragmentation and the result of those researchers confirms that an increase the no of plots increase technical efficiency. The empirical two side contradict ideas will be checked by further this study and the expected hypothesis was land fragmentation as negatively affected efficiency.

Agro-Ecology (AGECO):-It is a spatial classification of the landscape into area units with "similar" agricultural and ecological characteristics. Depends on this factors the district divided into three agro-climatic zones these are dega, weyinadega, and kola. From this research weynadega climatic zone was expected more positively affect the efficiency of teff production.

Improved seed (IMPSD): The improved seed that scientifically introduced were necessary for enhancing productivity and quality of the output. It was dummy variable which has the value of one if the farmer was used improved seed and zero otherwise. Hence, in this study improved seed was expected to have positively related to technical efficiency or negatively related to technical inefficiency Argaw Y. (2017) and Desale et al.,(2017) .

Credit (CRDT): This continues variable that represents the amount of credit received for farm-related purposes by the farmer from micro faineance in the production year. Since farmers in developing countries have not sufficient working capital to run agricultural activities unlike developed countries, farmers need to have that potential to engage in such business. Hence, credit is an important source of financing the agricultural activities of smallholder farmers and this is supported by empirical studies conducted by Argaw Y. (2017) and Desale et al.,(2017) amount of credit is positively and significantly related to level of technical efficiency of crop production. Hence, in this study credit was expected to have positively related to teff production efficiency.

Manure application (MANR);- It is animal dung used for fertilizing the land, Any animal or plant material used to fertilize land especially animal excreta usually with litter material. The higher manure application amount had a positive effect on developing production potential of rainfall resource and could improve soil water condition and increase rainfall used efficiency at each growth period of the crop to obtain the goal of efficient utilization of rainfall resource, which laid foundations for increasing crop biomass yield. In the present study, the combined use of inorganic fertilizers and organic manure enhanced rainfall use efficiency and the rainfall use efficiency increased as manure application rate increased. It was measured as a dummy variable that takes a value of 1 if the farmers practice manure application and 0 otherwise. In this paper, those farmers who practice manure on their farm were expected to be efficient.

Table 3.2: Summary of Inefficiency Variables Used in the Model

Variable	Definition of variables	Measurement	Exp sign
AGE	represents the age of the household head in the	Year	-/+
EDU	represents education level of household head	Grade level	-
SEX	Indicates sex of the HH which is a dummy variable that is measured as 1 if the household head is male and 0 if female	Dummy	-
IMPSD	is amount of Improved seed used in teff production in	Kg	-
PLOT	is number of plots of land that the farmer has cultivated in 2016 E.C 'Meher' season	No of plot	+
CRDT	is the amount of credit used for teff production from microfinance in birr	Birr	-

MANR	It is the application of manure for fertilizing land 1 if apply and 0 otherwise,	Dummy	-
AGECO	it refers to the agro-climatic zones and described as 1= kola 2= weyinadega and 3= dega	Dummy	-/+

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Descriptive Statistics

4.1.1. Socioeconomic Characteristics of Farmers

Age

Age of the sample farmer also has implication on farm economy and agricultural productivity. Because availability of work force and other socio-economic factors in the agricultural society might be determined by age of the household.

Table 4.1: Age of Household Head with an Output

Variable	Obs	Mean	Std. Dev.	Min	Max
AGE	354	47.071	9.602	21	78

The survey result on age of the sample farmer shows that mean age 45 years, min age 21 years and max of 78 years and 9.30 standard deviation.

Sex

The other demographic factor that considered in the study was sex of the household head. Moreover, agricultural activities are more challenging for females compared to those male-headed because women indifferently involved in both productive and domestic tasks where male rarely involve in domestic works.

Table 4.2: Sex of Household Head with an Output

SEX	Mean	Std. Dev.	Freq.
Female	2.738	0.055	77
Male	2.997	0.027	277
Total	2.940	0.025	354

Because of different reasons like divorced, widowed and unmarried, there are 77 female-headed and 277 male-headed households included in the survey. As the result indicated the mean output of the female-headed households were 2.738 and that of male-headed farmers have 2.997 mean output level. The result of t-test indicates the mean output of male and female farmers were significantly different from zero at 5% level of significance (t=-4.364,p=0.000).

The Education Level of Household Head

The education level of the household head hypothesized to affect efficiency positively. Education increases the ability of farmers to adopt new agricultural practices and technologies and to share knowledge from their relatives. Educated farmers have the opportunity of management skill and also input supply periodically by gathering information quickly than those illiterate farmers.

Table 4.3: Descriptions of Demographic Factors

Variable	Category	frequency.	Percent
Sex	Female	77	21.75
	Male	227	78.25
Education status4	Illiterate(1)	198	55.93

Grade 1-4 (2)	106	29.94
Grade 5-8(3)	37	10.45
Grade 9 and above(4)	13	3.67

The survey result in the study area shown table 4.3 indicates that from the total 354 respondents 198 were illiterate and read and write the remaining have different education level. They distribution were 1-4 educated 106 in number and covers 29.94 percent,5-8 educated 37 in number and 10.45 percent and those educated in secondary education and above were 13 and covers 3..67 percent of the households.

Agro-Ecology

It is a spatial classification of the landscape into area units with similar agricultural and ecological characteristics. As hypothesized the district has three agro-climatic zones these are Dega, Weynadega, and kola. In this study, one kebele included from Dega and kola and two kebeles from Weynadega.

Teff was produced in all agro-ecology zone areas of the study area. As one moves across agro-ecological zone, the level of mean output is slightly low in the kola and Dega area than Weynadega area but not significantly.

Table 4.4: Mean Output with Agro Ecology

climatic zone	Mean	St dev.	Freq.
Kola(1)	2.953	0.376	84
Weynadega (2)	2.987	0.526	170
Dega (3)	2.853	0.441	100

As indicated in table 4.4 kola agro ecology have 2.953 mean output Dega 2.853 and Weynadega have 2.987 mean output level.

The related reasons from the survey were variation is slight because these agro ecological zones are nearly the same in rainfall and soil fertility, Even though those kebeles located in Weynadega

have better fertile soil and well rainfall access as well as better soil moisture contents as a result has better productivity potentials.

4.1.2. Soil and Land Management Practices

Manure Application

The conservation method considered as organic fertilizer called Manure application that contains animal and plant material have a periodical and sustainable role for soil fertility and environmental conservation. The higher manure application amount had a positive effect on developing production potential of rainfall resource and could improve soil water condition and increase rainfall use efficiency at each growth period of the crop to obtain the goal of efficient utilization of rainfall resource.

Table 4.5: Manure, Improved Seed and credit Application for Teff Output

Activities	Response	Freq.	mean output	Std. Dev
Manure application	No	179	2.830	0.453
	Yes	175	3.054	0.466
Improved seed usage	No	263	2.855	0.451
	Yes	91	3.190	0.446
Credit Used	No	269	2.902	0.496
	Yes	85	3.063	0.365

The responsible agricultural sectors continuously increase the awareness of farmers to properly prepared and apply but still, they did not effective. The main reasons for not using properly reflected in the survey was the preparation process was difficult, fear for Weed infestation, distribution of compost to land also required transportation and also use of crop residues for animal feed leads shortage of raw materials for preparation. Respondents in table 4.5 above indicate that they had not distributed even the prepared compost in the production year. From the total sample in the study, 49.44 percent of the farmers apply manure in a different amount in their teff farm and the remaining 50.56 percent did not apply because of above-mentioned reasons. The result of t-test indicates that the mean output level of the two groups of farmers were significantly different from zero (t=-4.578, p=0.000).

Improved Seed

Farmers use both local and improved seed as an input. However, farmers understand and practically approved the advantage of using improved seed the application in the area was limited. The main reasons collected from the survey indicate a shortage of supply, a quality problem related to seed multiplication organizations and expensiveness of the seed. The main variety of improved seeds supplied and adapted to the farmers in the area was Kunhco and Etsub. As alternative farmers are tried to recycle improved varieties they have got previously. From the sample households in table 4.5 above shows that, 25.71 percent apply improved teff seed in a different amount in the production year. The remaining 74.29 percent used the local seed and by exchanging the seed they count as better in growing period of their relative land. The mean output of improved seed users and non users were significantly different from zero(t=-6.126 , p=0.000).

Credit utilization

Access to credit used to address the problem of finance to supply agricultural inputs in production. Farmers that get credit periodically have the chance to produce efficiently when the credit is applied for agricultural activities. Then farmers who have got credit expected to be more efficient than others who have to want and did not get. In the survey in table 4.5 above states that, 75.99 percent have not used and 24.01 percent of the households have got credit from formal financial institutions. The formal sources of credit in the study area were Amhara Credit and Saving Institution (ACSI) currently called Tsedey Bank. The reasons for households that have not use credit were higher interest rate and the procedures of credit suppliers and few having owned enough resource bases.

Credit distributed with groups and the responsibility of the individual is including the responsibility of all group members. If one of the members did not pay back the credit the group member obligated to repay back. The farmers use the credit for different activities like school expenses for their family, for the purchase of farm inputs and for weeding and other conditional activities. The value of t-test indicates that the two groups that credit users and non users were significantly different from zero (t-test=-2.757, p=0.006).

Number of Plots

Land fragmentation; leads to wastage of labor and inputs as plot dispersion increases the time of commuting. If farmers have fragmented plots it leads soil erosion and declining of productivity.

Table 4.6: Plots in the sample farmers

Variable	Obs	Mean	Std. Dev.	Min	Max
PLOT	354	3.107	0.881	1	6

Moreover, plot dispersion hold farmers back application of land management practices such as terracing, manure application and local tree planting. However, plots per farm across different agro-ecological zones results in production risk reduction. The mean size of plots per farm as shown above table 4.6 was 3.12 and ranging from 1 to 6 plots with standard deviation of 0.881.

Discussion on input output variables

The production function variables or the input variables that used in the physical year of teff production was land measured in a hectare, human labor in man-day, oxen power in oxen day, seed in kg and fertilizer in kg. The result of the survey indicates the average output of the farmers in the study area 2.941 Qt/ha with the standard deviation of 0.473 and the difference between the minimum and maximum ranges from 1.386 to 4.094 Qt/ha. The result shows that there was the great variation of output in farmers (Table 4.7 below).

Table 4.7: Summary of Variables Used in the Estimation of Production Functions

Variable	Observation	Mean	Std. Dev.	Min	Max
OUTPUT	354	2.941	0.473	1.386	4.094
LAND	354	0.086	0.389	-1.386	0.916
OXEN	354	3.740	0.466	0.574	4.942
LABOR	354	4.671	0.400	3.654	5.460
SEED	354	3.391	0.464	1.609	4.564
FERTILIZER	354	0.455	0.480	-1.798	1.946

The allocation of the input variable land from different sources owned and rented was in average 0.086 with minimum -1.386 and maximum 0.916 in the standard deviation of 0.388, the labor used for the total teff production activities starting from plowing to threshing on average 4.671 man days with minimum 3.654 and maximum 5.460 having standard deviation 0.400. The seed both local and improved applied in teff production was on average 3.391 in minimum 1.609 and maximum 4.56 with 0.464 standard deviation. Finally, the application of chemical fertilizer also has a mean of 0.455 with minimum -1.798 and maximum 1.946 with 0.480 standard deviations.

Table 4.8: Summary of Continuous Variables Used in the Inefficiency Model

Variable	Obs	Mean	Std. Dev.	Min	Max
AGE	354	47.071	9.602	21	78
PLOT	354	3.107	0.881	1	6

Table 4.9: Summary of Socio-economic Characteristics of forCategorical Variables

Variable	Category	Freq.	Percent
SEX of household head	Female	77	21.75
	Male	277	78.25
Education status	Illiterate(1)	198	55.93
	Grade 1-4 (2)	106	29.94
	Grade5-8 (3)	37	10.45
	Grade 9 and above (4)	13	3.67

Credit access	No Got credit	259	75.99
	Got credit	85	24.01
Agro-ecology	Kola (1)	84	23.73
	Weyna Dega (2)	170	48.02
	Dega (3)	100	28.25
Manure application	No applied	179	50.56
	Yes applied	175	49.44
Improved seed usage	No applied	263	74.29
	Yes applied	91	25.71

4.2. Stochastic Frontier Analysis

This section presents preliminary tests, hypothesis tests, output elasticities, and the mean technical efficiency and factors affecting the technical efficiency of farmers**.**

4.2.1. Preliminary Tests

Before interpreting the results of the model in the stochastic frontier model and inefficiency model for the validity and fulfillment of important pretest for both the input variables and inefficiency variables was done

The first multicollinearity test checked for the linear relationship of variables that have the same role in describing the dependent variable. In order to check multicollinearity effect variance inflation factor (VIF) applied for continuous variables and contingency coefficient for dummy variables. The decision is done based on the value of VIF that if greater than 10 indicates higher

multicollinearity and if less than 10 indicates there is no higher multicollinearity. The results of the VIF for both the stochastic frontier and the inefficiency model continuous variables were less than 10 that indicate no higher multicolinearity, also the result of contingency coefficient indicates there were no inflated multi collinearly.

The second test performed for checking the assumption of hetroscedasticty which states constant variance of the error term. Most of the time efficiency scores are sensitive to specification error which may cause hetroscadacity.The measure of inefficiency in SFA are based on residuals in the estimation of frontier which are sensitive to specification that may passed to efficiency score. In order to solve such problems the breusch –pagan test hold for hetroscadacity. The result of the test in the stochastic frontier model indicates there is no hetroscadacity.

Since agricultural production have different determinants related to the farmer's characteristics and the socio-economic and environmental impacts, checking whether the model is estimated correctly both in the production function and inefficiency model or not were necessary. In order to check the stochastic frontier model variable sufficiency Link test was applied and the result indicates there is no specification error. For the inefficiency variable case omitted variable test applied and result also indicates no model specification error. The results of all tests indicated in the appendix part of the paper.

4.2.2. Hypothesis Tests

Stochastic frontier analysis requires some important hypothesis tests. We presented these hypothesis test results as follows: First, we tested to choose between Cobb-Douglas versus Trans-log specification. For this test we applied, the log likelihood ratio test was conducted and we found that Cobb-Douglas specification was rejected at the 5% significance level in favor of Trans-log specification as shown in (table 4.9).

The second hypothesis was testing the existence of technical inefficiency. The test result indicates that the assumption that states no technical inefficiency was rejected at the 5% significance level. It implies that the stochastic frontier model was not reduced to linear

regression. Implies that there was inefficiency in teff producing farmers in the study area and stochastic frontier model best fits the data.

The third null hypothesis states that there are no technical efficiency effects. That is the variables in the inefficiency model simultaneously equal to zero.

$Ho:(i.e,Ho:=\delta_0=\delta_1=\delta_2=\ldots=\delta_{14}=0)$.The null hypothesis was rejected in favor of the presence of inefficiency effects at the 5% significance level. The implication is that there are factors that are affecting the technical efficiency of teff production.

For the distribution of one-sided inefficiency error term half normal distributional form best fits for the survey data and applied in the study.

The fourth null hypothesis states that the production technology is the constant return to scale was rejected in favor of decreasing return to scale implying that 1% increase in the usage of all inputs together results in less than 1% increase of output (see table 4.11).

Table 4.10: Summary of Hypothesis Test Results

Null hypothesis	p-value	Decision
$H_0:\beta_1=\beta_2=\beta ii=0$ $H_1:\beta_1=\beta_2=\beta ii\neq 0$	0.0000	rejected
H_0: $\gamma = 0$ there is no inefficiency H_1 ; $\gamma \neq 0$ there is inefficiency	0.000	rejected

H_o;$\delta_0=\delta_1=\delta_2=\delta_3...=\delta_8=0$ H_1; at least one $\delta\neq0$	0.0000	rejected

4.2.3 Estimating Output Elasticity

Because of the existence of the second order or cross products of the variables in the trans-log production function the coefficients did not directly interpreted.

Partial derivation of each input with respect to output was applied to obtain output elasticity. As shown in table 4.11, output elasticity of land was highest and followed by the use of fertilizer. A 1% increase of land owned increased output by 0.77% this is supported by findings of (Argaw Y.2017) and Moges Dessale. (2017) and also fertilizer was highest and followed by the use of oxen power. A 1% increase of fertilizer application increased output by 0.167%. Technical efficiency in teff production: in Jamma District, South Wollo Zone and Leulsegged (2014) while a 1% increase of oxen use increased output by 0.106% and 1% increase of improved seed used increased output by 0.15% holding other inputs constant. The output elasticity of seed and labor was lowest coppering to other production inputs of output elasticity.

Table 4.11: Output Elasticity and Return to the Scale

Variable	elasticity	Std. Err.	Z-value
lnLAND	0.77	0. 057	13.54
lnLAB	-0 .091	0.039	- 2.35
lnOXN	0 .109	0.036	3.06
lnSEED	0.064	0.041	1.56
lnFERT	0.167	0.036	4.65
Return to scale	1.11		

From the described factors of teff production in the above table 11 showed that land covers had the highest role for the farmers' productivity. The role of land magnifies more than the others because of that the farmers start to apply with appropriate size relative to the past periods. The fertilizer input applied also have a role next to land that farmers start applying fertilizer and the role was great in changing the productivity of teff in the study area. The role of oxen also have better for farmers productivity and labor was lower than the other factors to increase productivity which has negative relation. The reason related to the surplus labor and labors have not intensively utilized or labor was allocatively inefficient in the study area. This indicated that a 1% decrease in labor will increase teff output by 0.091% assuming other inputs constant. Fertilizer usage has the highest effect on teff yield next to land. This implies that providing credit to buy fertilizer and providing fertilizer to farmers at competitive price allow farmers to increase teff yield. When we see the role of seed usage was lowest but highly significance. This indicated that seed usage rate in the woreda was good but still it requires decreasing rate as recommendation stats 8 kg per hectare .In 1% decreasing teff seed usage rate increase teff output by 0.094%.

The total variation of the actual output from the frontier is for two reasons: inefficiency of the farmer and shocks, measurement errors or disturbances beyond the control of farmer. The variation because of the inefficiency of the farmer is the ratio of the variance of the inefficiency component to the total error term represented by sigma. The other necessary result from the trans-log stochastic frontier was the value of Gamma (γ) 0.805 or 80.5% which indicates that the deviation from the frontier was due to the inefficiency of the farmers. The remaining 19.5.% also interpreted as the deviation from the frontier due to external noise that agricultural sector

characterized effects from climatic changes, pests and natural hazards which are out of the control of the farmer. The value of gamma in table 4.12 below was 80.5% and the deviation from the frontier because of shocks was 19.5%.

Table 4.1: Likelihood Estimate for the Trans-log Production Function

Variables	Coefficient	Standard error	P-value
lnLAND	0.736	0.059	0.000***
lnLAB	-0.090	0.041	0.027*
lnOXN	0.109	0.036	0.002**
lnSEED	0.094	0.043	0.031*
lnFERT	0.170	0.039	0.000 ***
Sigma u	0.0031	0.176	
Sigma v	0.294	0.011	
$Sigma^2$	0.086	0.007	
Lambda	0.011	0.178	
Gamma (γ)	0.805		
Log likelihood	71.87		
TE (mean)	0.750		
Sample size	354		

***, **, * significance at the 1%, 5% and 10% levels,

Source: Survey data 2024

4.2.4. Technical Efficiency Score

The mean technical efficiency score was 75.01 percent with the minimum of 45.17 and maximum 90.30 efficiency level. The result indicates that the farmers in the study area not equally efficient and there were significant efficiency variations among farmers. The result also shows that farmers can increase their output without increasing the use of inputs and technology by increasing efficiency. The mean technical efficiency of farmers in Awabel woreda for teff production was less than the mean technical efficiency of farmers (i.e., 99.2%) in central Tigray for teff production (Hagos, 2014) , mean technical efficiency of farmers (i.e.,78%) in south Wollo district, Amhara regional state for teff production (Moges, 2017). and higher than the mean technical efficiency of farmers (i.e., 55%) in Legahida woreda south Wollo district, Amhara regional state for teff production (Argaw Y, 2017).

Table 4.2: Technical Efficiency (TE) Score

Mean TE	75.01
Min.	45.17
Max	90.30
Standard Dvn	0.09
Observation	354

Source: Survey Result 2024

The observed that a few farmers have technical efficiency score values of less than 75% and most of the farmers have above technical efficiency score values of higher than 75 %.

4.2.6 Factors Affecting Technical Efficiency

The technical efficiency of farmers is affected by socioeconomic characteristics of farmers and adoption of agricultural technology and land management practices.

Table 4.3: Factors Affecting Technical Inefficiency

Variable	Parameters	Coefficient	Standard error	P-value
Constant	δ0	1.993	0.175	0.000***
AGE	δ1	0.007	0.002	0.002 **
SEX	δ2	0.196	0.055	0.000***
EDU	δ3	-0.007	0.028	0.797
PLOT	δ4	0.124	0.026	0.000***
AGECO	δ5	-0.037	0.031	0.235
CRDT	δ6	0.112	0.054	0.016*
MANR	δ7	0.131	0.047	0.006 **
IMPS	δ8	0.258	0.055	0.000***
Total		**0.784**	**0.296**	
Observation		354		

***, **, * significance at the 1%, 5% and 10% levels, Source: Survey data 2024

Being male-headed household increases technical efficiency as expected. This is because in Ethiopia female-headed households face different socio-economic challenges and cultural influences. For example, women involved in both domestic work (i.e., cooking food for the

household, providing care for children and elderly people) and farming activities but male rarely involve in domestic tasks. Accordingly, the mean technical efficiency level of male-headed households was 2.997 and the mean of female-headed were 2.738 which indicate that male-headed farmers were more efficient than that of female-headed households. To strength this t-test result indicates that the mean technical efficiency score of males and females were statistically different from zero (t=-4.364 ,p=0.000).The finding is consistent with Getahun (2014) and Fikadu (2024) studied technical efficiency farmers for crop production in Ethiopia and found that men headed households have higher mean technical efficiency score than female-headed households.

Age was found to affect technical efficiency of teff production positively. This suggested that older farmers were more efficient than younger farmers in study area. The reason was age can serve as a proxy variable of farming experience, in which farmers with more years of experience are expected to be more efficient. To strength this t-test result indicates that the mean technical efficiency score of between ages were statistically different from zero (t=-86.36 ,p=0.000).This finding was similar with the finding of Argaw ,Y.(2017), (Fikadu,& Gebre,2024).

In assumption education increased the technical efficiency of farmers. Higher education increases farmers access to various agricultural technologies, information, and implementation of land management practices. But a one way ANOVAs test result indicates that there were insignificant difference in mean level of efficiency difference between different education groups (F=0.07 ,p=0.975). The result indicated that education is not affecting teff producer farmers in study area because the mean level of inefficiency between grade levels is almost similar with slight difference. This showed that farmers in study area are well informed and experienced about new technologies for teff production.

Table 4. 4: Mean Level of Efficiency with Education Level

Education level	Freq.	Mean.	Std. Dev
Illiterate(1)	198	2.949	0.463
1-4 (2)	106	2.938	0.494
5-8 (3)	37	2.916	0.449
>9 (4)	13	2.916	0.552

Source: Survey data 2024

At the same thing agro ecological inefficiency factor is not significant for teff production in study area because teff is well grown in all the three agro ecological zones. But there is slight different mean technical inefficiency of farmers between those agro ecological zones in study area.

Table 4. 5: Mean Level of Efficiency with Agro ecology Level

Agro Ecology	Freq.	Mean.	Std. Dev
(1) Kola	84	2.953	0.376
(2) Weynadega	170	2.987	0.526
(3) dega	100	2.853	0.441
Total		2.941	0.473

Source: Survey data 2024

Access to microcredit has a positive significant effect on efficiency as hypothesized. Access to credit removes constraints of farmers to buy agricultural inputs. The t-test performed to strength the conclusion indicates that the mean technical efficiency of the two groups significantly different from zero(t=-2.757 ,p=0.016).The result is consistent with the findings of Musa et al., (2016).

Table 4.6: Sustainable land management practices and Technical efficiency of farmers

Activities	Response	farmers	Mean TE	Standard.dv
Manure application	No	179	2.830	0.453
	Yes	175	3.054	0.466
Improved seed usage	No	263	2.855	0.451
	Yes	91	3.186	4.446

Manure application has a significant positive effect on technical efficiency. The mean technical efficiency score of farmers add manure to soil was 3.054 while the score for farmers does not add manure to soil was 2.830 this shows that farmers who apply manure on their farm were more efficient than those who did not apply. The difference in efficiency scores attributed to the fact that manure application enhances soil fertility. Additionally the t-test result supports that there was a significant mean technical efficiency difference in manure application between farmers (t =-4.578, p=0.000).The positive effect of manure also supported by a study by (Argaw Y, 2017).

The result of the study indicates that the application of improved seed have a significant and positive impact on the efficiency of farmers. The role of improved seed application emphasized more when comes directly from concerned seed supplier institutions which are liable. Practically in the survey period, farmers reflect most improved seed supplied from seed multipliers and the quality was low. As the data collected from focus group discussion and the survey questioner indicates, farmers purchased with expensive cost and the seed quality was mixed. The reason gathered from the discussion with farmers and experts indicates seed multiplier institutions distribute for selected farmers to multiply and to collect back the product for them. But the multipliers mix other teff product with the improved since there was no improvement mechanism. Then that mixed seed distributed for the farmers and the quality of seed become less and farmers attitude towards improved seed minimized.

Even though a few farmers applied quality seed and farmers' access to quality seed was low, quality seed application improves technical efficiency. The mean technical efficiency score of farmers applied improved seed was 3.190 while farmers did not apply had technical efficiency

score of 2.855.The result of t-test indicates that the mean technical efficiency of the two groups of farmers significantly different from zero (t=-6.216, p=0.000). The main types of improved seed varieties available in the area were ‘kucho’ and ‘Etsub’. Farmers used local seed and improved seed from suppliers or their own. Most of the farmers do not apply improved seed because of a shortage of supply and expensiveness. The finding of the survey related with Solomon (2014) , Muket et al., (2016) and Dessale, et al. (2017). Technical efficiency in teff production in Jamma District, South Wollo Zone .

The farmers use the credit for different activities like school expenses for their family, for the purchase of farm inputs and for weeding and other conditional activities. Access to credit used to address the problem of finance to supply agricultural inputs in production. Farmers that get credit periodically have the chance to produce efficiently when the credit is applied for agricultural activities in study area. The result showed that a 1% increase in credit usage increase farmers efficiency by 0.132% the result is related with Dessale, et al. (2017), (Argaw Y, 2017) and Mulatu, N. T. (2023).

The overall effect of sustainable land management practices on technical efficiency is promising. The result implies that effective implementation of land management practices reduces soil erosion and increase soil fertility- these reduce wastage of yield because of soil erosion and low soil fertility- and hence increases farmers technical efficiency.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study performed based on the initial purpose to estimate the technical efficiency, to estimate output elasticity and to identify the main determinant of the technical efficiency of teff producer farmers in Awabel Woreda. Random sampling procedure applied to select the sample size of the survey. The cross-sectional data collected from 354 sample farmers in 2023/24 production year used for the estimation of the technical efficiency of the farmers in the district. The study applied the necessary pre-tests in order to fulfill the minimum requirements. Depend on hypothesis tests the Trans-log production functional form and stochastic frontier production function applied. The half-normal distribution assumption and the one step maximum likelihood estimation procedure applied in order to estimate the Trans-log stochastic frontier production function and the technical inefficiency effect model simultaneously.The Data collected in the survey were analyzed by applying both descriptive statistics and econometric model with Stata 14 software.

The result conducted in SFP indicates the average technical efficiency of farmers was 75 and the variation between the farmers efficiency ranges from 45.173 to 90.31 level. According to the survey result, there are farmers with the distribution of below and above 75% mean technical efficiency level .

The value of gamma 0.805 indicates the deviation from the frontier due to the inefficiency of the farmers. Farmers were lack the potential efficiency level 80.5 percent with their inefficiency and the remaining 19.5 with external shocks out of their control.

The partial elasticity coefficients of the input variables indicate that land has the highest elasticity followed by fertilizer .oxen and seed 0.77, 0.167, 0.109 and 0.064 respectively. Labor has the lowest negative value of -0.091.

The total socio-economic variables that have an effect on the technical efficiency of the farmers were identified and analyzed. The variables in the inefficiency model which have the determinant role were sex, education, credit, manure application, improved seed. The sign of the

coefficients of the variables consistency with the initial hypothesis. The remaining variables age, agro ecology, and plot have no significant effect on teff production in the study area.

Since financial constraint was an obstacle of production efficiency, those farmers access to credit is more efficient than those not gained credit.

Application of land management activities has a great role in determining technical efficiency. From the main findings Manure applied farmers were more efficient than those not applied with 3.05 and 2.830 mean efficiency level. Even though there were supply and quality problem, those apply improved seed have 3.05 mean efficiency level which is better than those not applied with 2.830 efficiency level.

The above findings reflect the need for policy formulation and practice to increase farmers' efficiency to produce the expected amount which leads to economic development.

5.2. Recommendations

The study suggested the following main recommendations based on the findings.

- The use of fertilizer increases yield and application of quality seed improves technical efficiency of farmers. For this, the regional government and other concerning bodies need to work to increase farmers' access to sufficient fertilizer and quality seed. Farmers' application of modern input on farm fields needs to be supported by experts and extension workers to avoid poor application of these inputs by farmers.
- Standing from the great role of land management practices for increasing efficiency of farmers, building farmers understanding towards soil and water conservation practices must be taken priority. The land management system must be supported and led with research and innovation. Policymakers and all concerned bodies focus must be conserving the available resources for sustainable efficiency increased with the available state of technology. Farmers should give care for the sustainability of land management practices and maintenance mechanisms.
- Financial deficient was one of the obstacles in the production process. To solve financial problems governmental and nongovernmental organizations focus to establish and strengthening microfinance and agricultural cooperatives to fulfill the interest of credit for

farmers with balanced interest. Additionally, consider addressing agro-input markets that supply affordable and improved seed and fertilizer inputs.

- Standing form the analyzed role of education in the study area developing formal and informal education method in the rural area, building training centers and fulfilled necessary facilities establishing technical and vocational schools nearest to farmers wants priority in policy. Capacity building of females with attitude and skill also put under consideration.

  Finally, the availability of technical inefficiency in the study area shows all concerned bodies to form integrated and scientific development effort that leads to upgrading the existing level of input use and necessary measures that will decrease the existing level of inefficiency of farmers.

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APPENDICES

Appendix 1 Conversion Factor used to calculate Adult Equivalent (AE)

Age Category(Years)	Male	Female
< 10 Years	0.60	0.60
10 – 13	0.90	0.80
14 – 16	1.00	0.75
17 – 50	1.00	0.75
> 50	1.00	0.75

Source: Storck, et al., (1991)

Appendix 2 Model specification test for input variables in stochastic frontier model

regress lnOUTP lnLAND lnOXEN lnLAB lnFERT laSEED

```
      Source |       SS       df       MS      Number of obs   =       354
-------------+------------------------------   F(5, 348)       =    128.09
       Model |  51.0732404         5  10.2146481   Prob > F        =    0.0000
    Residual |  27.7516621       348  .079746156   R-squared       =    0.6479
-------------+------------------------------   Adj R-squared   =    0.6429
       Total |  78.8249025       353  .223300007   Root MSE        =    .28239
------------------------------------------------------------------------------
      lnOUTP |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     lnLAND |   .7357181   .0590384    12.46   0.000     .6196011     .851835
     lnOXEN |   .1090012   .0355151     3.07   0.002     .0391499    .1788525
      lnLAB |  -.0901492    .040613    -2.22   0.027    -.1700271   -.0102713
     lnFERT |   .1699884   .0389608     4.36   0.000     .0933601    .2466167
     laSEED |   .0937771   .0432108     2.17   0.031     .0087899    .1787643
      _cons |   2.495691    .239481    10.42   0.000     2.024679    2.966703
```

Appendix 3 VIF for the input variables

Variable	VIF	1/VIF
lnLAND	2.32	0.430829
laSEED	1.78	0.561289
lnFERT	1.55	0.644858
lnOXEN	1.21	0.823652
lnLAB	1.17	0.857529
Mean VIF	1.61	

Appendix 4 Model specification test for inefficiency variables in stochastic frontier model

. regress lnOUTP PLOT AGE SEX EDU AGECO CRDT IMPSD MANR

```
      Source |       SS           df       MS      Number of obs   =       354
-------------+----------------------------------   F(8, 345)       =     13.89
       Model |  19.2009531         8  2.40011913   Prob > F        =    0.0000
    Residual |  59.6239495       345  .172823042   R-squared       =    0.2436
-------------+----------------------------------   Adj R-squared   =    0.2260
       Total |  78.8249025       353  .223300007   Root MSE        =    .41572

------------------------------------------------------------------------------
      lnOUTP |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        PLOT |   .1240119   .0257877     4.81   0.000     .0732911    .1747327
         AGE |   .0071022   .0023276     3.05   0.002     .0025242    .0116801
         SEX |    .195453    .05454     3.58   0.000     .0881801    .3027258
         EDU |  -.0073278   .0285147    -0.26   0.797    -.0634125    .0487568
       AGECO |  -.0367889   .0309191    -1.19   0.235    -.0976025    .0240246
        CRDT |   .1314527   .0542102     2.42   0.016     .0248287    .2380767
       IMPSD |   .2581613   .0556996     4.63   0.000     .1486078    .3677148
        MANR |   .1306976   .0469097     2.79   0.006     .0384325    .2229626
       _cons |   1.992897   .1748694    11.40   0.000     1.648953    2.336841
------------------------------------------------------------------------------
```

Appendix **5** VIF for the inefficiency variables

Variable	VIF	1/VIF
IMPSD	1.21	0.823956
MANR	1.13	0.887541
EDU	1.11	0.902486
CRDT	1.10	0.910484
PLOT	1.05	0.948752
SEX	1.04	0.964281
AGE	1.02	0.980141
AGECO	1.01	0.986374
Mean VIF	1.08	

Appendix 6 Stochastic frontier Translog function result

Stoc. frontier normal/half-normal model Number of obs = 354

Wald chi2(5) = 785.94

Log likelihood = -42.624103 Prob > chi2 = 0.0000

lnOUTP	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
lnLAND	.7299544	.0579826	12.59	0.000	.6163105	.8435982
lnOXEN	.1069814	.0347693	3.08	0.002	.0388349	.1751279
lnLAB	-.0876132	.0378207	-2.32	0.021	-.1617403	-.013486
lnFERT	.2077292	.0370622	5.60	0.000	.1350886	.2803699
lnSEED	.067793	.0399447	1.70	0.090	-.0104972	.1460832
_cons	2.850358	.2316498	12.30	0.000	2.396332	3.304383
/lnsig2v	-3.523827	.3270745	-10.77	0.000	-4.164881	-2.882773
/lnsig2u	-2.025423	.2555395	-7.93	0.000	-2.526271	-1.524574
sigma_v	.1717159	.028082			.1246257	.2365995
sigma_u	.3632328	.0464102			.282766	.466598
sigma2	.1614244	.025956			.1105516	.2122973
lambda	2.115312	.0719106			1.97437	2.256254

LR test of sigma_u=0: chibar2(01) = 8.60 Prob >= chibar2 = 0.002

Debremarkos University

College of Business andEconomics

Department of Economics

Post Graduate Program in Project Planning and Management

Summer Program

MScThesis Questionnaire

Questionnaire

The questionnaire prepared to study productivity and technical efficiency of teff production in Awabel woreda, East Gojjam.

Name of the enumerator_____ Signature _____ Date_____

Name of the supervisor _____ Signature _____ Date _____

Kebele _____

1. **General information**

1.1. Age of the household head: _____ years

1.1.1. Age below 10 ___ age 10 -14____ and age 15-64___ age above 64_____

1.2. Sex of household head: 1= Male 0= Female

1.3. Can you read and write? 1= yes 0 = No

1.4. Highest grade completed: _____

1.5. Marital status of household head:1= Married 2= Single 3= Divorce 4= Widowed

1.6. Main occupations: 1= Farmer 2.= Non-farming 3= Other Specify:_____

1.7. Walking distance from home to nearest urban center (lumame): _____ minutes

2. Land and land ownership information

2.1. Total land size you have: ——————timad.

2.2. Total land size rented and share cropped:_____ timad

2.3. Total number of plots you cultivated in 2016/17 E,C_____

3. Characteristics of plots used for Teff production in 2016 E.C

Plots	Type of ownership 0 =own 1= rented	Total area used for teff production (timad)	Soil type: 1=brown 2= red 3= black	Soil fertility level: 1=fertile 2.=medium 3= poor	The slope of plot 1=steep 2= medium 3= flat	Is the teff plant attacked by pest 1= yes 0= no	agro-ecological location of the plot 1=dega 2=woynadega 3=kola	Total yield of each plot (in quintal)	Walking distance from home to plots (in min)
plot 1									
plot 2									
plot 3									
plot 4									
plot 5									

4. What is total teff yield in 2016 E.C.: _____ quintals

5. Labor hours used for teff production in 2016 E.C.

Activities	Number of labors and hours used for teff production					
			Human labor			
	Pair of oxen		age 10-14		Adult labor	
	numbe	Hou	Number	Hour	Number	Hour

	r	r				
total plowing						
Sowing						
total weeding						
Harvesting and gathering						
Threshing						

6. Do you have livestock? 1= yes 0 = no

If yes what is the no of each livestock								
	livestock	No.		Livestock	No.		Livestock	**No.**
1	Cows		5	Donkeys		9	chickens	
2	Calves		6	Mules		10	Heifer	
3	Oxen		7	Sheep				
4	Horses		8	Goats				

7. Credit access

7.1. Have you borrowed money from any microfinance? 1= yes 0= no

7.2. How much money have you borrowed: _____birr

7.3. For what Purpose, do you use credit***? 1= to buy modern input (such as quality seed, fertilizer and pesticide) 2= to start off-farm or nonfarm business 3= to buy food for households 4= others

7.4. If you have not used credit, what is the reason**?

1= high interest rate 2= lack of collateral 3= no need of credit 4= others

8. Land management practices: have you applied

Plots	Stone bounds? 1 =yes 0= no	Soil bounds? 1 =yes	Water ways? 1 =yes 0= no	Teff-legume rotation? 1 =yes	Compost/ manure use?	Improved teff seed use ln killogram	Amount of chemical	Row teff planting is applied 1 =yes

		0= no		0= no	1 =yes 0= no	? 1 =yes 0= no	fertilizer use in quintal	0= no
plot 1								
plot 2								
plot 3								
plot 4								
plot 5								

8.1. Amount of teff quality seed used: _____ kilograms

8.2. Have you made maintenance of terraces every year? 1= yes 0=no

8.3. Have you made maintenance of waterways every year? 1= yes 0=no

8.4. If you have not practiced waterways, why**? 1= lack of skill 2= neighboring farmers are not collaborating 3= the advantage is less 4=Others specify_____

8.5. If you have not used enough chemical fertilizer, what is the reason **? 1 = high price 2= fertilizer is not available 3= lack of credit to buy it 4= other

8.6. Is teff farm fertility increasing overtime? 1= yes 0=no

8.7. If you did not use improved teff varieties, what is the reason**? 1= expensive 2= not better than local seed 3= not available 4= lack of credit to buy seed 5= others

8.8. Do you plant legume crops following teff production on any plot? 1= yes 0= no

9. Off/nonfarm activity and socio economic participation

9.1. Have you or your family participated in off-farm activities? 1= yes 0= no

9.2. What are the off-farm activities you or your family practice **?

1= handcrafts 2=Trade 3=hired off-farm work 4= other

9.3. Total annual income from nonfarm activity generated by family members: _____ Birr

9.4. Are you a member of a social network (such as edir, senbete, mahber, ekub or debo)?

1= yes 0=no

** indicates for response more than one