

**TECHNICAL EFFICIENCY OF SMALLHOLDER WHEAT
PRODUCTION IN SORO DISTRICT OF HADIYA ZONE, SOUTHERN
ETHIOPIA**

MSc THESIS

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**Technical Efficiency of Smallholder Wheat Production in Soro District of
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DEDICATION

This thesis manuscript is dedicated to my parents!

STATEMENT OF THE AUTHOR

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ACRONYMS AND ABBREVIATIONS

ADLI	Agricultural Development Led-Industrialization Strategy
AE	Allocative Efficiency
BERCEA	Building Ethiopia's Research Capacity in Economics and Agribusiness
CSA	Central Statistics Agency of Ethiopia
DEA	Data Envelopment Analysis
EE	Economic Efficiency
EEA	Ethiopian Economics Association
ETB	Ethiopian Birr
FAO	Food and Agriculture Organization of the United Nation
GDN	Global Development Network
GDP	Gross Domestic Product
MoFED	Ministry of Finance and Economic Development
MD	Man Days
PASDEP	Plan for Accelerated and Sustained Development to End Poverty
PPS	Probability Proportional to Size
SFP	Stochastic Frontier Production
SNNPR	Southern Nation, Nationalities and Peoples Region
TE	Technical Efficiency
TLU	Tropical Livestock Unit
SWADO	Soro Woreda Agricultural Development Office
SWFEDO	Soro Woreda Finance and Economic Development Office
WFP	World Food Program

BIOGRAPHICAL SKETCH

The author was born from his parents Ayele Anaye and Amarech Gichamo on September 30, 1991 in Sengiye rural *kebele* in Duna district of Hadiya zone, southern Ethiopia. He attended his elementary education at Otorro Primary and Junior Secondary School and comprehensive Secondary school education at Gimbichu. After successful completion of his high school education, he joined Hawassa University in October 2008/09 and graduated with *Bachelor of Science Degree in Agricultural Resource Economics and Management* in July 2011/2012. Since his graduation he has served as food security expert in the Office of Agriculture and Development at Soro district Hadiya zone for two years, till he joined the School of Graduate Studies of Haramaya University to attend his *MSc degree studies in Agricultural Economics* in October 2014/15.

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Technical Efficiency of Smallholder Wheat Production in Soro District of Hadiya Zone, Southern Ethiopia

ABSTRACT

This study was conducted to estimate the technical efficiency of smallholder wheat producers and identify its determinants in Soro district of Hadiya zone, southern Ethiopia. Cross sectional data from a random sample of 125 wheat producing farmers collected during 2015/16 production season were used for the analysis. The estimated results of the Cobb-Douglas frontier model with inefficiency variables shows that the mean technical efficiency of the farmers in the production of wheat is 72 percent. This reveals that there exists a possibility to increase the level of wheat output by about 28 percent through exploiting the existing local practices and technical knowledge of the relatively efficient farmers or reduce current level of input application by 28 percent and produce the same output given the existing technological level. The discrepancy ratio gamma (γ), which measures the relative deviation of output from the frontier level due to inefficiency, was about 63 percent. This implies that about 63 percent of the variation in wheat production among the sample farmers was attributed to technical inefficiency effect. The maximum likelihood parameter estimates showed that wheat output was positively and significantly influenced by the amount of DAP and Urea fertilizers, oxen day, expenditure on herbicide and area of wheat plot. The estimated SPF model together with the inefficiency parameters shows that age, education level, land ownership, fertility status of the wheat plots and extension contact negatively and significantly affected technical inefficiency of wheat production implying that improvement in these variables improves technical efficiency. However, land fragmentation positively and significantly affected technical inefficiency showing that this variable has negative influence on technical efficiency. Hence, emphasis should be given to improve the efficiency level of those less efficient farmers by adopting the practices of relatively efficient farmers in the area. Beside this, policies and strategies of the government should be directed towards the above mentioned determinants.

Keywords: Stochastic frontier analysis; Cobb-Douglas; Technical efficiency; Wheat; Soro.

1. INTRODUCTION

1.1. Background

Ethiopian economy is predominantly an agrarian economy. However, the agricultural sector in the country is largely small-scale, subsistence oriented and heavily dependent on rainfall, which is highly variable spatially and temporally, agriculture contributes about 41% of the country's GDP, employs 83% of total labour force, and contributes 90% of exports (EEA, 2012).

The performance of the agricultural sector largely determines the performance of the entire economy of the country. In addition, following the Agricultural Development Led-Industrialization strategy (ADLI) and building on PASDEP achievements, the country's five-year (2010-2015) Growth and Transformation Plan (GTP) gives special emphasis to the role of agriculture as a major source of economic development. This means that the rate at which the agricultural sector attains its growth and sustainability makes the sector to play a critical role in the country's important macroeconomic performance. According to the plan, smallholder farmers are among the major target groups where increased agricultural productivity is believed to be achieved (ATA, 2014). Agricultural production and productivity can be enhanced through increased use of input or improvement in technology given some level of input. The other way of improving productivity is to enhance the efficiency of producers. In countries like Ethiopia with capital constraint, it is worthwhile to benefit from increasing productivity through improving efficiency in use of resources available.

Agriculture in Ethiopia is explained by low productivity, caused by a combination of agro climatic, demographic, economic and institutional constraints and shocks (WFP, 2010). The smallholder farmers, who are providing the major share of the agricultural output in the country, commonly employ traditional production technology and limited modern inputs (World Bank, 2007). Hence, being an agriculturally dependent country with a food deficit gap, increasing crop production and productivity is not a matter of choice rather a must to attain food self-sufficiency.

The major grain crops grown in the country are *teff*, wheat, maize, barley, sorghum, and millet. Out of the total grain production, cereals account for roughly 60 percent of rural employment and 80 percent of total cultivated land (Abu and Quintin, 2013). Yield of cereals has been consistently well below world average and even of least developing countries average yield, indicating poor productivity of the crops in the country. According to FAO (2011) the average cereal yield for the world and least developing countries were 37.08 qt/ha and 20.19 qt/ha, respectively, while, the average cereal yield in Ethiopia was limited to 17.60 qt/ha.

Ethiopia is the largest wheat producer in Sub-Saharan Africa and has a favorable wheat growing climatic environment. It is the fourth important cereal crop in the country and predominantly grown by subsistence farmers under rain-fed conditions. Although Ethiopia is the largest wheat producer in Sub-Saharan Africa, it is reliant on foreign wheat imports to satisfy its annual domestic demand (FAO, 2014). Wheat is cultivated in the highlands of Ethiopia, mainly in Oromia, Amhara, Southern Nations and Nationalities Peoples (SNNP) and Tigray regions and it is the first most important cereal crop in Hadiya zone, especially Soro district.

According to the report of Central Statistical Agency, for the crop year of 2015/2016, from the total land allocated for cereal crops, wheat stands in fourth by covering 13.33% of the total areas preceded by *teff*, maize, and sorghum. In the production year, the total area covered by wheat was 1.66 million hectares with a production of 42.19 million quintals and yield of 25.35 qt/ha from 4.78 million holders.

In SNNP Region, the total area covered by wheat was 133,419.8 hectare by 677,054 private peasant holders; and the total production in quintals in the same year was 3.35 million, and its average productivity in quintals per hectare was 25.08. The total production of wheat in Hadiya zone for the year 2015/16 was 550,257.63 quintals produced by 178,811 private peasant holders who were engaged in wheat cultivation on 37,149.1 hectare. The average productivity in quintals per hectare was registered as 27.5 qt/ha (CSA, 2015/16).

The Soro WADO (2015/16) report showed that about 29,671.5 hectares of land was covered by cereal crops. Of these, area covered with wheat was 9,890 hectares with production of

207,832 quintals and its average productivity in quintals per hectare was 28.2. Even though cereals especially wheat, are the most predominant in the cropping system of Soro district in which this study was carried-out, there is no empirical study that showed whether the existing scarce resources and technologies are utilized efficiently or not in the production of wheat. Therefore, this study was intended to measure the technical efficiency of wheat producers and identify its determinants in the study area.

1.2. Statement of the Problem

It has been said time and again that agriculture is the backbone of the Ethiopian economy not just because it constitutes almost half of the GDP but also because more than 85 percent of the population still depends on it for their livelihood. In Ethiopia agricultural production and productivity is very low and the growth in agricultural output has barely kept pace with the growth in population. The high potential areas of Ethiopia can produce enough grains to meet the needs of the people in the deficit areas. However, the inefficient agricultural systems and differences in efficiency of production discourage farmers to produce more (Knife *et al.*, 2012).

According to previous researches in Ethiopia, there also exists a wide cereal yield gap among the farmers that might be attributed to many factors such as lack of knowledge and information on how to use new crop technologies, poor management, biotic, climate factors and more others (Sisay *et al.*, 2015; Ahmed *et al.*, 2013; Mesay *et al.*, 2013).

Despite the importance of wheat as a food and industrial crop and the efforts made so far to generate and disseminate improved production technologies, its productivity remains far below its potential. The average wheat yield was about 2.1 tons per hectare, in 2012/2013 cropping season (CSA, 2013a).

If the existing production system is not efficient, introduction of new technology could not bring the expected improvements in the productivity of wheat and other crops. Given the existing technology, improvements in the technical efficiency will enable farmers to produce the maximum possible output from a given level of inputs. Hence, improvements in the level of technical efficiency will increase productivity.

Theoretically, introducing modern technologies can increase agricultural output. However, in the areas where there is inefficiency, trying to increase the use of a new technology may not have the expected impact and “there is a danger of trying to rediscover the wheel” if the existing knowledge is not efficient (Tarkamani and Hardarker, 1996, cited in Jema, 2008).

Yet empirical works on the farm level technical efficiency is limited and knowledge of farmers’ production situations remain inadequate particularly in Sub-Saharan Africa. Hence, given the case that developing countries have scarce resources to undertake new investments on modern agricultural technologies, improving the technical efficiency of farmers is indispensable i.e. there is a wide room for increasing agricultural productivity and production in these areas by improving technical efficiency of farmers at the existing resources.

Therefore, from the perspective of formulating effective agricultural policies, undertaking empirical works on farm level technical efficiency has a paramount importance in providing valuable information to policy makers which will be used to enhance agricultural productivity. Equally important is to examine the principal factors that affect technical efficiency of farmers, since these factors can be influenced by public policies. In the study area, there is lack of pertinent research on technical efficiency of the smallholder farmers and the determinants of the variability in the efficiency levels among farmers. This study intends towards analyzing the technical efficiency of the farmers in the study area and aims to bridge the prevailing information gap on sources contributing to efficiency differences in the production of wheat.

Moreover, some research questions should be answered. These include: What is the level of technical efficiency of wheat producing farmers in the study area? Is there any major difference in technical efficiency in wheat production among farmers of the study area? What are the factors that cause efficiency variations of wheat farmers in Soro district? And is there an opportunity to increase output of wheat by improving the level of technical efficiency?

1.3. Objectives of the study

The overall objective of this study was to assess the technical efficiency of wheat production of smallholder farmers in Soro district of Hadiya zone.

The specific objectives were:

1. To measure the level of technical efficiency in the production of wheat; and
2. To identify the sources of differences in technical efficiency of smallholder farmers in the Soro district.

1.4. Scope and Limitations of the Study

Farmers in the study area mainly produce cereal crops. Wheat is the most important crop grown in terms of area coverage and total quantity produced. This study focuses on technical efficiency measurement of wheat production during the *meher* (main rainy season) in the district. The study used a cross-sectional data to analyse the technical efficiency levels and identify the sources of differences in technical efficiency among the farmers during the 2015/16 production year. This may be affected by the specific climate of the year as agriculture in the country in general and in the study area in particular is dependent on weather. Moreover, the results of cross-sectional data do not show the change over time that is important for a follow up development strategy.

The efficiency scores of the frontier method are only relative to the best firms in the sample and hence the inclusion of extra firms (say from overseas or other efficient firms in the country) may reduce the efficiency scores (Coelli *et al.*, 1998). Thus, the efficiency scores in this study are relative values of the best farmers in the study area. This efficiency score might be reduced if more efficient farmers from other area were included in the study. Likewise, it could be increased if less efficient farmers were included.

Moreover, due to time, personnel and budget constraints the geographical scope of the study is limited to a single district and only to the analysis of technical efficiency of wheat production. allocative and economic efficiencies are not considered in this study.

1.5. Significance of the Study

The efficiency measurement is very important in any area of production because it is a factor for productivity growth. It may help to indicate a possibility of increasing production without increasing the consumption of inputs or decreasing the level of inputs and hence reduce total production cost without decreasing the level of output. Such studies help the economy by

determining the extent to which it is possible to raise productivity by improving the neglected source, i.e. efficiency, with the existing resource base and available technology.

A technical efficiency study plays a significant role in providing useful information regarding technical inefficiencies in production and helps to identify those factors, which are associated with inefficiencies that may exist. The study result indicates an entry point for further policy interventions to improve resource use efficiency of smallholder farmers. Moreover, it helps extension workers of the area to come with some important idea of efficient utilization of available production input for those who are inefficient. They can play an important role in informing inefficient farmers to derive lessons about better production practices from more efficient farmers operating in the same environment and level of technology.

Therefore, this study can show the differences in efficiency level among farmers in the study area in the production of wheat. Based on the efficiency levels, the determinants of inefficiency were identified. Identification of determinants of inefficiency is important for various planning and policy purposes. In addition, empirical findings on the analysis of technical efficiency of wheat are also useful for other grain crops that usually have similar production processes. Finally, the findings of this study can contribute to the growing body of literature and can also be used as a reference material for future researchers on the area.

1.6. Organization of the Thesis

Chapter one discussed the general background, the problem of the study, objectives of the study, significance of the study and scope and limitations of the study. In chapter two, concepts of efficiency in general and various methodological aspects pertaining to efficiency measurements are reviewed. Chapter three is devoted to methodology used in the study. It describes the study area, type, sources and methods of data collection, the sampling design and methods of data analysis. Chapter four is concerned with the results and discussions. It includes inputs and inefficiency variables that are used in the empirical estimation. Further, this section discusses the results of determinants of inefficiency variables. Chapter five presents summary, conclusion and recommendations. It briefly summarizes the main results of the study and also draw recommendations to improve the efficiency of farmers in the study area.

2. REVIEW OF LITERATURE

In this chapter, concept of efficiency, productivity, theoretical framework, approaches of efficiency measurement, models for efficiency analysis, empirical studies on efficiency and conceptual framework are discussed briefly.

2.1. Concepts of Efficiency and Productivity

Efficiency is an important economic concept and is used to measure the economic performance of a production unit. Efficiency in production is usually referred as economic or productive efficiency of a firm which means it is successful in producing as much output as possible from a given set of inputs. Production efficiency is concerned with the relative performance of the process used in transforming inputs into outputs (Coelli, 1995).

Efficiency and productivity, anyway, are two cooperating concepts. The measures of efficiency are more accurate than those of productivity in the sense that they involve a comparison with the most efficient frontier, and for that they can complete those of productivity, based on the ratio of outputs on inputs. Efficiency of a production unit is in terms of a comparison between observed and optimal values of its output and input. The comparison can take the form of the ratio of observed to maximum potential output obtainable from the given input, or the ratio of minimum potential to observed input required to produce the given output. In these two comparisons the optimum is defined in terms of production possibilities, and efficiency is technical. In a simple term, productivity is the quantity of a given output of a firm (e.g. a farmer) per unit of input.

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

Technical efficiency (that part of efficiency which explains the physical performance of a firm) measures the relative ability of a farmer to get the maximum possible output at a given input or set of inputs (Lovell, 1993).

According to Coelli *et al.* (1998) technically efficient farmers are those farmers that are operating on the production frontier that represents the maximum output attainable from each input level. All feasible points below the frontier are considered technically inefficient points.

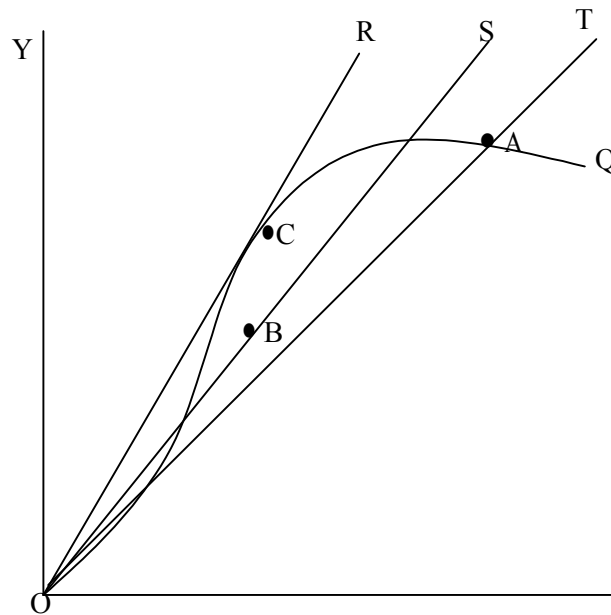


Figure 1: Productivity and efficiency

Source: Adopted from Coelli *et al.* (1998)

Productivity on the other hand shows the ability of the farmer to produce a given output (it may not be maximum possible output) at a given level of input. Hence, productivity does not show the relative performance of farmer in getting the maximum possible output given input level. Figure 1 illustrates the difference between efficiency and productivity using input- output relationships. The line OQ represents the production frontier. It shows a set of points of maximum levels of outputs that can be obtained when input X is used efficiently. Points below this line are all inefficient points. The slope of the line OR, OS and OT represent the set of points of the ratio of output Y to input X and hence represent productivity level. Farmer A is more efficient than farmer B yet farmer B is at a higher productivity level than farmer A.

In terms of productivity, farmer B is more productive than farmer A because he is getting higher output Y per unit of input X. However, if we evaluate from the point of view of efficiency, farmer A is more efficient than farmer B as he is operating on the frontier. Yet, farmer A who is efficient (operating on the frontier) can still improve its productivity by moving to point C using its economies of scale.

Technical efficiency may be defined as the ability of a firm to produce as much output as possible with a specified level of inputs, given the existing technology. In other words, technical efficiency measures are calculated relative to the production function of the fully efficient farm or unit, which is represented by a frontier function. Technical inefficiency on the other hand refers to failure to operate on the production frontier and is generally assumed to reflect inefficiencies caused by timing and method of application of production inputs (Lieweyn and Wiliams, 1996).

Technical and allocative efficiency (price efficiency) in production, which together comprises the economic efficiency are distinguished by Farrell (1957) through the use of frontier production function. While technical efficiency relates the physical input with the optimum level of output that can be produced at a given level of technology, allocative efficiency reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices and the production technology. Technical efficiency and allocative efficiency are then combined to give economic efficiency, which is sometimes referred to as overall efficiency (Coelli *et al.*, 1998).

2.2. Theoretical Framework

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

The mathematical relationship between input and output as $p = f(x_1, x_2, x_3 \dots, x_n)$ the theory of production function has been used as an important tool of economic analysis in the neoclassical tradition (Humphrey, 1997).

Generally, a production function is defined by the following equation

$$Y = f(x_1, x_2, x_3 \dots, x_n) \quad (1)$$

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

$$Y = f(x_1, x_2, x_3 \dots, x_n) + \mu \quad (2)$$

When the nature of relation is between one factor of production and one product output, the analysis is termed as input-output analysis or factor-product analysis. It generally concern itself with nature of changes in output as the level of single factor of production changes, relative to others variables are kept constant. The factor that varies with the level of output is known as variable factor or variable input.

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

Average productivity is given by dividing total output produced by the input level. It gives the information about the average output per unit of input applied, over the entire range of input applied (Palanisami *et al.*, 2002). Marginal productivity is the slope of the given production function. It gives information about the response of total output to additional input change at the margin i.e. it measures the change in total output that result from a very small change in one of the factor of production, keeping all other factors constant.

Apart from the above two concepts, the relationship between input and output can be expressed by the production elasticities. The production elasticity expresses the relative change in production through a relative change in the addition of input (Rasmussen, 2011).

2.3. Approaches to Efficiency Measurement

Following Lovell (1993), the productivity of a production unit can be measured by the ratio of its output to its input. However, productivity varies according to differences in production technology production process and differences in the environment in which production occurs. The main interest here is in isolating the efficiency component in order to measure its contribution to productivity. Producers are efficient if they have produced as much as possible with the inputs they have actually employed and if they have produced that output at minimum cost. It is important, however, to be aware that efficiency is only one part of the overall performance.

2.3.1. Input-oriented measurement

The input oriented measure of efficiency addresses the question “by how much can input quantities be proportionally reduced without changing the output quantities produced?” (Coelli *et al.*, 1998). A farm can be on or above the unit iso-quant on the input per unit of output space and cannot be below or to the left to it. A departure from the unit iso-quant indicates technical inefficiency and the more a farm is far from the unit iso-quant the more it is inefficient.

The concept of input-oriented measures of efficiency of a firm which uses two inputs x_1 and x_2 to produce a single output y , under the assumption of constant return to scale can be illustrated in Figure 2. Two inputs x_1 and x_2 are represented on horizontal and vertical axes respectively. EE^* represents an iso-quant of a fully efficient firm. All points on this iso-quant represent technically efficient production.

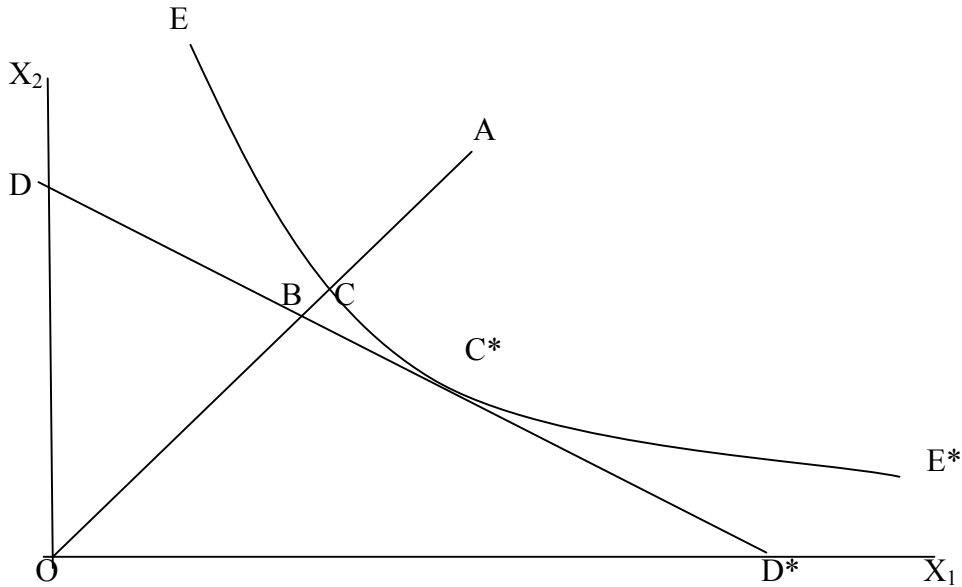


Figure 2: Input-oriented measures for technical efficiency

Source: Reproduced from Coelli *et al.* (1998).

Assume a firm is producing at point A as shown in Figure 2; this firm produces the same level of output as is produced by the fully efficient firm. To define the technical efficiency (TE) of this firm, a line is drawn from the origin to the point A. This line crosses the iso-quant at point C. In the case of a fully efficient firm, y^* amount of output (y) is produced using inputs(x_1 and x_2) at point C whereas in case of the observed firm, operating at A, additional inputs are used to produce y^* amount of output (y). Therefore, observed firm, operating at A, does not use inputs efficiently.

The technical efficiency of the observed firm can be defined as the ratio of the distance from the point C to the origin over the distance of the point A from the origin:

$$TE = \frac{OC}{OA} \quad (3)$$

The distance CA represents the technical inefficiency of the observed firm, which is the amount by which all inputs could be proportionally reduced without reduction in output. The value of TE lies between 0 and 1. A firm is technically efficient if it has TE equal to 1. If the value of TE is less than 1, the firm is technically inefficient.

2.3.2. Output-oriented measurement

Efficiency measure can also be expressed by using the output-oriented approach. “By how much can output be increased without increasing the amount of input use?” (Coelli *et al.*, 1998). Such a question can be answered by using the output-oriented measure of efficiency. Farrell (1957) used an input-oriented approach to illustrate the measurement of efficiency. He used a simple example involving firms, which use two inputs, x_1 and x_2 , to produce a single output y , under the assumption of constant returns to scale. The constant returns to scale assumption allow to represent the technology using a unit iso-quant.

The concept of output-oriented measures of efficiency of a firm producing two outputs (y_1 and y_2) with one input can be illustrated using Figure 3. Two outputs y_1 and y_2 are represented on horizontal and vertical axes respectively. AA^* is a production possibility curve showing different combinations of two outputs (y_1 and y_2) produced using a given level of input (x_1). AA^* production possibility curve represents a technically efficient practice. Any firm that is producing at this curve is said to be a technical efficient firm. A firm that is producing at point B is technically inefficient firm because it lies below the production possibility curve AA^* that represents the upper bound of production possibilities.

To define the technical efficiency of the observed firm producing at point B, a line is drawn from the origin to the point B. This line crosses the production possibility curve at point C. The observed firm uses the same input level as is used by the fully efficient firm, operating at point C. The technical efficiency of the observed firm is defined by the ratio of the distance of the point B to the origin over the distance from the point C to the origin. $TE = OB/OC$. The distance BC represents the level of technical inefficiency. It is the amount by which outputs could be increased without requiring extra inputs.

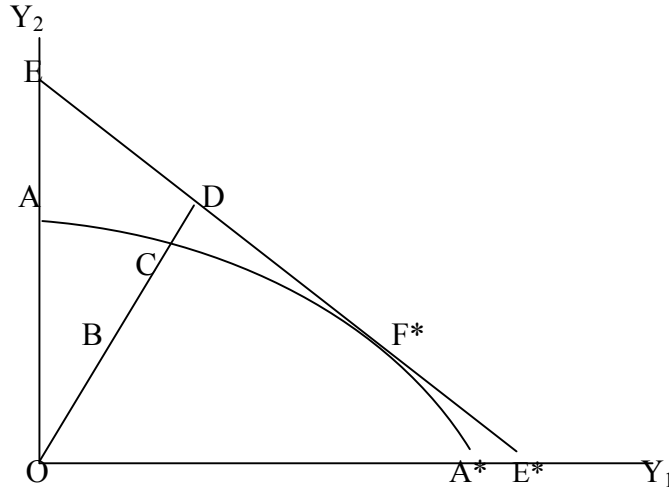


Figure 3: Output-oriented measures for technical efficiency

Source: Reproduced from Coelli *et al.* (1998).

In a poorly developed market economy, prices do not reflect the actual scarcity and values of resources due to market failure. In such cases empirical production analysis of physical quantities can explain the performance of traditional agricultural production more adequately. Given that we are considering developing country settings input quantities appear to be decision variables (Jema, 2008). Hence, for this study preference is made to the use of input oriented/primal approach.

2.4. Models for Efficiency Measurement

Efficiency measurements are usually done using frontier methodologies, which shift the average response functions to the maximum output or to the efficient firm. These methodologies are broadly categorized under two frontier models; namely parametric and non-parametric. The parametric models are basically estimated based on econometric methods and the non-parametric model, often referred to as Data Envelopment Analysis (DEA), involves the use of linear programming method to construct a non-parametric 'piece-wise' surface (or frontier) over the data (Coelli *et al.*, 1998).

2.4.1. Non-parametric model

Non-parametric analysis according to Charnes *et al.* (1978) does not require the specification of any particular functional form to describe the efficient frontier or envelopment surface. The

principal and most commonly used model in the analysis of efficiency is data envelopment analysis (DEA). Consequently, DEA model doesn't require any distributional assumption as parametric (deterministic and stochastic) frontier models do. 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 it 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. This 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).

However, the main criticism of DEA is that it assumes all deviations from the frontier are due to inefficiency and because of this, non-parametric frontier methodology may overstate inefficiencies and hence outliers may have profound effect on the magnitude of inefficiency (Licwelgn and Williams, 1996). In addition, in DEA no account is taken of the possible influence of measurement errors and other noise upon the frontier. All deviations from the frontier are assumed to be the result of technical inefficiency. An alternative method or approach to the solution of the noise problem has, however, been widely adopted.

Generally most researchers, among others Coelli *et al.* (1998), Mohammad and Premachandra (2003), Thiam *et al.* (2001), Parikh and Shan (1996) and others agree that stochastic frontiers are likely to be more appropriate than DEA in agricultural applications of efficiency analysis. Therefore, the next section reviews various issues pertaining to parametric frontiers that are classified as deterministic and stochastic frontier methodologies.

2.4.2. Parametric model

The parametric approach is naturally subdivided into deterministic and stochastic models. Deterministic models envelope all the observations, identifying the distance between the observed production and the maximum production, defined by the frontier and the available technology, as technical inefficiency. On the other hand, stochastic approaches permit one to distinguish between technical efficiency and statistical noise.

2.4.2.1. Deterministic frontier model

The first parametric deterministic frontier production function was estimated by Aigner and Chu (1968) assuming a Cobb Douglas functional form. The deterministic frontier model for cross-sectional data is defined as:

$$\ln(y_i) = x_i\beta - \mu_i \quad , i = 1, 2, \dots N \quad (4)$$

Where i - is the number of firms in the study

$\ln(y_i)$ - is the natural log of (scalar) output of the i^{th} firm;

x_i - is a $(K+1)$ row vector whose first element is "1" and the remaining elements are the logarithms of the K -input quantities used by the i^{th} firm;

$\beta = (\beta_0, \beta_1, \beta_2, \dots, \beta_k)'$ is a $(K+1)$ – column vector of unknown parameters to be estimated; and μ_i - is a non-negative random variable associated with technical inefficiency in production of firms in the industry involved.

The technical efficiency of the i^{th} firm is indicated by the factor by which the actual (observed) production deviates from the frontier (potential) output. Hence, the ratio of the observed output for the i^{th} firm, relative to the potential output, defined by the frontier function, given the input vector, x_i , is used to define:

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

The limitation of this model is that, it treats random components (like measurement error, bad weather, chance etc.) as part of inefficiency. Hence when there is high random error on the data or where there are few outliers, the inefficiency estimates will be exaggerated as compared to other models, which take into account random errors. Coelli *et al.* (1998) argues that one of the criticisms of the deterministic approach is that no account is taken of the possible influences of measurement errors and other noises up on the shape and positioning of the estimated frontier.

2.4.2.2. Stochastic frontier production model

The stochastic frontier production function was independently proposed by (Aigner *et al.*, 1977; Meuse and Von den Broeck, 1977). The original specification involved a production

function specified for cross-sectional data which had an error term with two components, one to account for random effects and another to account for technical inefficiency. This model can be expressed in the following form:

$$\ln(y_i) = x_i\beta + v_i - \mu_i \quad , i = 1, 2, \dots N \quad (6)$$

Where, i - is the number of firms in the study;

$\ln(y_i)$ - is the natural log of (scalar) output of the i^{th} firm;

x_i - is a $(k+1)$ - row vector whose first element is "1" and the remaining elements are the logarithms of the K -input quantities used by the i^{th} firm;

$\beta = (\beta_0, \beta_1, \beta_2, \dots, \beta_k)'$ is a $(k+1)$ - column vector of unknown parameters to be estimated; and

$v_i - \mu_i$ is a composed error term where v_i - is random error term of the model

μ_i - is a non-negative random variable associated with technical inefficiency in production of firms in the industry involved.

In the prediction of firm level technical efficiency, Battese and Coelli (1995) pointed out that the best predictor of $\exp(-\mu_i)$ is obtained by:

$$E\left[\frac{\exp(-\mu_i)}{e_i}\right] = \frac{1 - \phi\left(\sigma_A + \gamma \frac{e_i}{\sigma_A}\right)}{1 - \phi\left(\frac{\gamma e_i}{\sigma_A}\right)} \exp(\gamma e_i + \sigma^2 / 2) \quad (7)$$

Where, $\sigma_A = \sqrt{\gamma(1 - \gamma)\sigma_s^2}$; $e_i = \ln(y_i) - x_i\beta$; $(\cdot)$ is the density function of a standard normal random variables which can be estimated by maximum likelihood once the density function for μ_i is specified.

Agricultural production is inherent to variability due to random shocks such as drought, weather, pest infection, fires, diseases (rusts), etc. Furthermore, because many farmers are smallholders whose farm operations are managed by family members, therefore keeping of accurate records is not always a priority. Thus, much available on production are likely to be subject to measurement errors (Tim and George, 1996). Due to this nature of agriculture in developing countries, most empirical studies are highly focused on SFP model. The main advantage of this model is the ability to separate disturbance term with two components; the error component (v) and the stochastic noise (u). The other merit of the SFP function over the

former (deterministic) is that the estimation of standard errors and tests of hypothesis is possible, which the deterministic model fails to fulfill because of the violation of the maximum likelihood regularity conditions (Coelli, 1995). As a result of above argument, this study employs a stochastic frontier approach.

There are different production functions such as Cobb-Douglas, Translog, Transcendental and Quadratic, etc. used in stochastic frontier. The Translog and Cobb-Douglas specifications are the most commonly used functional forms to measure technical efficiency. Each has their own merits and demerits. Due to its simplicity and very attractive feature, the Cobb-Douglas function form has been commonly used in the empirical estimation of frontier models. However, this simplicity is associated with a number of restrictive features like constant elasticities, constant return to scale for all firms and elasticities of substitution are equal to one. Translog functional form imposes no restriction upon returns to scale; however, it is very susceptible to multicollinearity and high degree of freedom (Coelli *et al.*, 1998). Hence, in this study Cobb-Douglas production function was estimated and computed the production function using parametric approach.

The literature suggests two methodological approaches of analyzing the sources of technical efficiency based on stochastic production functions. The first approach is the two-stage estimation procedure in which first the stochastic production function is estimated, from which efficiency scores are derived, then in the second stage the derived efficiency scores are regressed on explanatory variables using ordinary least square methods or Tobit regression. This approach has been criticized on grounds that the firm's knowledge of its level of technical inefficiency affects its input choices; hence inefficiency may be dependent of the explanatory variables. The inefficiency effects would only be identically distributed if the coefficients of the farm specific factors are simultaneously equal to zero. It is possible to overcome this problem by the use of a single stage maximum likelihood approach (Battese and Coelli, 1995). The one-stage estimation procedure of the inefficiency effects model together with the production frontier function would be used in the study.

2.5. Empirical Studies on Technical Efficiency

Fekadu (2004) used the SPF model together with the inefficiency parameters to identify factors affecting level of technical efficiency in wheat production of Machakal district of Ethiopia. The study revealed fertility status of the plot, age, age square, land ownership status, training, number of plots (fragmentation), family size and livestock significantly determined the efficiency level of farmers in wheat production. Fertility status of the plot, age, land ownership, training and extension service affected efficiency of farmers positively and significantly, while the increments of age square, family size, fragmentation and livestock increased inefficiency.

Gemeda (2011) used stochastic Cobb-Douglas production functional form to analyze the wheat production efficiency in case of small-scale farmers in Gebebe-Hasasa, west Arsi zone of Oromia regional state. Analysis of the specific inefficiency variables showed that off/non-farm, income, livestock ownership, proximity and market distance were statistically significant determinants of TE.

The empirical evidence obtained from small-scale wheat seed producer farmers in Ethiopia prevails that, on average, the total wheat seed production can be enhanced by nearly 20 percent, keeping inputs and current production technology constant (Solomon, 2012). Alternatively, the mean TE of sampled households was 79.9 percent. He used Cobb Douglas production function, to determine elasticity of inputs and the level of efficiency of each producer. He applied a two-stage estimation method. He used the estimated level of efficiency as dependent variable in the Tobit model which was used to determine factors that affect efficiency. Accordingly, interest in wheat seed business (dummy) and total income positively and significantly affected TE while total expenditure has a negative and significant effect.

A study undertaken in southern Ethiopia with the objective of assessing productivity and technical efficiency of smallholder farmers, based on the data collected from 385 randomly selected farmers, indicated as there was significant level of inefficiency among maize producing farmers (Endrias *et al.*, 2013). They used a two stage estimation technique, translog production function to determine the levels of TE followed by Tobit regression model to identify factors influencing TE. The model result depicted that productivity of maize was significantly influenced by the use of labor, fertilizer, and oxen power. The mean TE was

found to be 40 percent and important factors that significantly affected the TE were agro ecology, oxen holding, farm size and use of high yielding maize varieties.

A study done by Solomon (2014) on the technical efficiency of major crops production and its determinants in Ethiopia. He used stochastic frontier production function which incorporates a model of inefficiency effects. According to his study, the inefficiency effect analysis for major crop production shown that education, participation in soil and water conservation activities, poverty status and adoption of improved seed are the major determinants. Off-farm income of the household head was found to affect technical inefficiency in *teff* production positively, contrary to this age of household head, slope and TLU were found to affect negatively. The inefficiency in wheat production is mainly explained by participation in soil and water conservation activities, extension contact, education, fertility, TLU and knowledge about land policy. As far as the technical inefficiency of maize production is concerned, frequency of extension contact was found to have positive and significant effect.

Wudineh Getahun and Endrias Geta (2015) analyzed technical efficiency of smallholder farmers in wheat production of Welmera district, central Oromia, Ethiopia. Among the farm specific, socioeconomic and institutional factors hypothesized to affect level of technical efficiency, sex, age and education level of the household head, livestock holding, group membership, farm size, fragmentation, tenure status and investment in inorganic fertilizers and distance to all weather roads were found to be important determinants of technical efficiency.

Hassen (2016) estimated the technical efficiency and identify its determinants in wheat production for smallholder farmers in south Wollo zone using Cobb-Douglas stochastic production frontier model. The average technical efficiency was 78%. The socio-economic variables that exercised important role for variations in technical efficiency were age, education, farm size, and livestock holding in Tropical Livestock Unit, number of oxen holding, access to irrigation and access to credit. The model results showed that factors such as age, education, access to credit, and oxen number were negatively related with inefficiency while number of livestock and distance to market were positively related with inefficiency

The above empirical studies which were conducted in different parts of Ethiopia in different agro-climatic and socio-economic conditions indicated the existence of efficiency differentials

among small-scale farmers. Moreover, these studies also showed that considerable variation of factors of inefficiency which are responsible for efficiency differentials. However, in Soro district such type of research work has not been conducted to determine the level of technical efficiency of small-scale farmers particularly with respect to wheat production.

Researches on technical efficiency of smallholder agriculture are not extensive, and the findings or conclusion of some of them are not consistent with one another. Therefore, policy implications drawn from some of the above empirical works may not allow in designing area specific policies to be compatible with its socio-economic as well as agro-ecologic conditions. Therefore, this study intends to fill these gaps.

2.6. Conceptual Framework

Production process involves a transformation of inputs into outputs. Inputs as well as outputs vary from one type of production to another. In crop production, inputs include land, seeds, labour, fertilizer and herbicide, which are all combined in different ratios to produce outputs. The effectiveness with which the inputs are transformed into outputs does not only depend on inputs used but also on the managerial practices that the farmer uses to combine these inputs.

Agricultural productivity in general may be increased in different ways. First, agricultural productivity may be increased through increased use of inputs, usually referred as horizontal expansion. Increasing agricultural productivity using this method requires raising the quantity of inputs used in the production. Though such activities have the potential for productivity enhancement, the method has little application in Ethiopia and other developing countries because of limited resources and restricted access to credit to increase the quantity of inputs. The second method of increasing agricultural productivity is through improving efficiency of resource utilization. Such technique increases productivity by improving the overall efficiency of farmers using the current levels, quality of inputs and existing technology. In this method, efficiency of production could be obtained through the utilization of better farm management practices and removing some existing production constraints and improvement of farm technology. The third method of increasing agricultural productivity through improvement in agricultural technologies, which includes the use of technology packages, such as use of HYV, use of fertilizers, and the use of agro-chemicals such as herbicides and pesticides. Such

technique is termed as transformation method, which is characterized by a shift of production frontier upward (Arega, 2003; Jema, 2006; Walter and Hezron, 2003; Headey *et al.*, 2010; Saweda and Liverpool, 2011).

Raising agricultural productivity depends critically on improvement of efficiency in production, development and dissemination of cost effective productivity-enhancing technologies, which leads to directly by raising production levels and indirectly by, for example, reducing poverty through raising incomes of farm households, raising employment, lowering the price of food and thereby affecting the food security and wellbeing status of rural households (De janvry and Sadoulet, 2001). Moreover, increasing agricultural productivity also has a number of advantages. First, facilitates the flow of resources from one sector to another and contributes to economic growth. Second, a higher level of agricultural productivity results in lower food prices for consumers and a rise in income of producers that increases the welfare of the society and thereby enhancing the economic growth of the country. Third, agricultural productivity growth also improves the competitive position of the sector (Jema, 2006).

Studies by Jema (2008) showed that efficiency of production was determined by the host of socio-economic, demographic and institutional factors. These factors directly/indirectly affect the quality of management of the farm's operator and, therefore, are believed to have impact on the level of technical efficiency. According to Bakhsh (2007), a range of factors like distinctiveness of farms, management, physical, institutional and environmental aspects could be the cause of inefficiencies in the production process of the farmers.

Technical efficiency of smallholder wheat production is assumed to be affected by a wide range of factors. From the extensive reviews, the various factors can be grouped as: (1) demographic characteristic (2) socioeconomic characteristics (3) farm characteristics and (4) institutional factors. The factors related to demographic characteristics include age, sex and family size. The factors related to the socioeconomic characteristics include livestock holding and education level of the household. The factors related to farm characteristics include total cultivated land, land fragmentation, land ownership, slope and soil fertility. The institutional factors include use of credit and extension service.

Managerial practices are influenced by socio-economic, demographic, farm characteristics and institutional factors, which together with the inputs determine the quality and quantity of outputs produced. Households are the decision making units where all decisions on types and amounts of inputs to be used in production process and managerial practices to be done are made. The decisions made in turn influence how inputs are efficiently transformed into outputs i.e. technical efficiency. This scenario is represented in a pictorial form as a conceptual framework (Figure 4) to guide this research study.

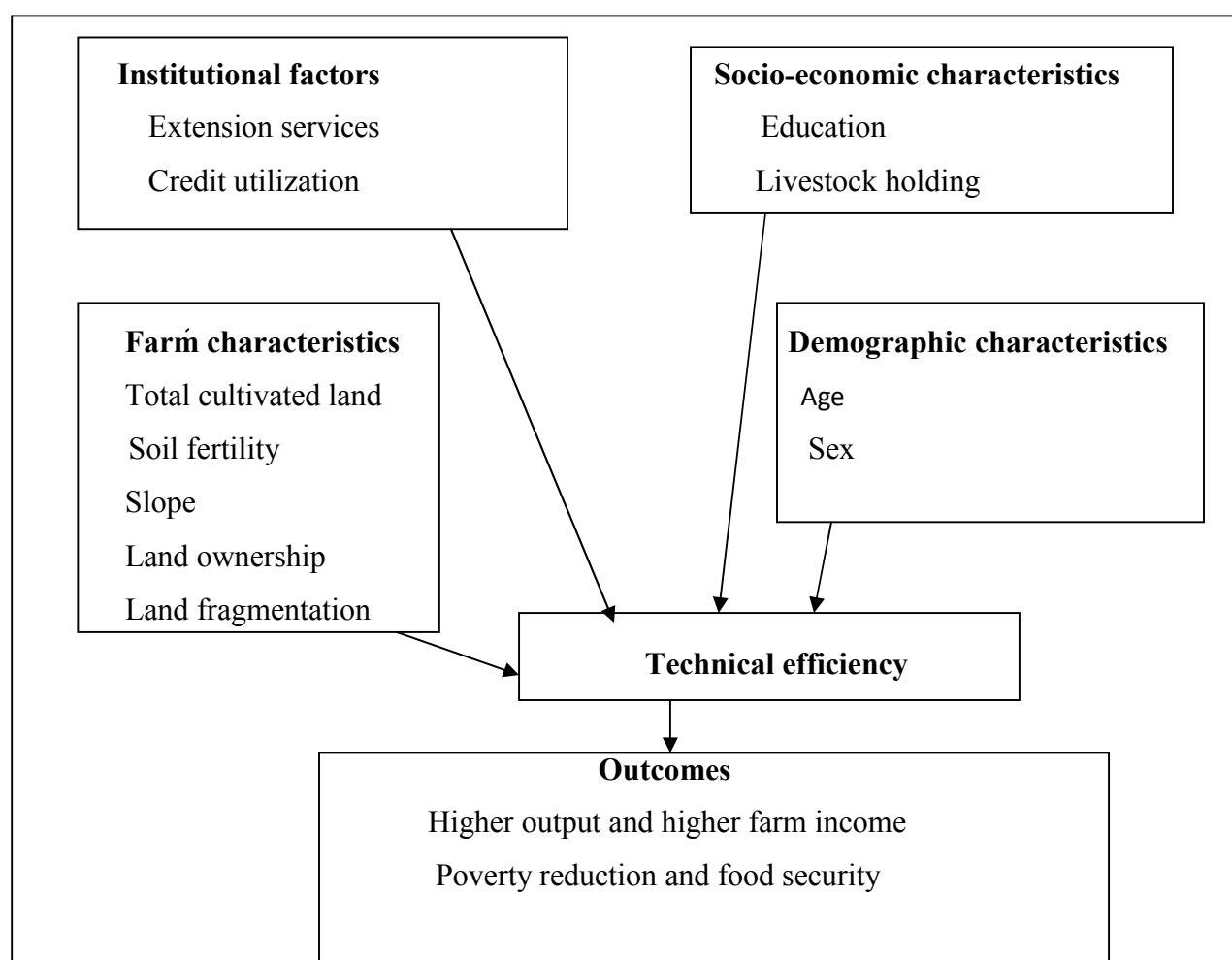


Figure 4: Conceptual framework of technical efficiency in wheat production

Source: Adopted from Arega (2003), Walter and Hezron (2003), Jema (2006), Headey *et al.* (2010) and Saweda and Liverpool (2011) with modification

3. RESEARCH METHODOLOGY

In this chapter, description of the study area, data types, sources and methods of data collection, sampling technique and sample size determination and methods of data analysis are presented.

3.1. Description of the Study Area

The study was conducted in Soro district. It is located in Hadiya administrative zone in southern Ethiopia and is lying between 7°23'00" and 7° 46'00" North Latitudes and 37°18'00" and 37°23'00" East Longitudes. The district has an altitude that ranges from 840-2850 meters above sea level. Gimbichu, capital of the district is about 260 km away from Addis Ababa and 32 km south west from Hosanna. The district is bordered by Gombora district in the north; Oromiya region and Yem special woreda in the west; Kambeta Timbaro zone and Duna district in south and southeast; Lemo district and again Kambeta Timbaro zone in the northeast and east (SWFEDO, 2014).

The district comprises 46 rural *kebeles* and three rural towns and has total human population of 229,617 of which 114,489 (49.86%) are male and 115,128 (50.14%) are female. Out of the total population, 14 % are urban dwellers (CSA, 2013b). The district has a population density of 222 persons per square kilometer, and average landholding per farm family is 0.4 hectare and has a total area of 58,061 hectare. With regard to land use pattern of the district, cultivable land comprises the highest (73.5%), pasture (4.45%), forest (8.42%) and remaining (13.53%) is considered as mountainous, swampy and otherwise unusable (SWADO, 2015/16).

According to SWADO report, (2015/16) the district has three basic agro-climatic conditions, namely *Dega* (14.2%), *Woyinadega* (53.1%) and *Kola* (32.7%). The mean annual rainfall of 1260 mm and average temperature is 19°C. Accordingly, it has two rainy seasons, *Belg* and *Kiremt*. *Belg* is the short rainy season and lasts between March and May. The *Kiremt* season, which is the longest rainy season, lasts between June and September. More than 75% of the total rain falls during this season and the highest rainfall occurs in July and August. Rain that occurs during the *Kiremt* season is very intensive (Behailu, 2009 cited in Kibamo, 2011).

Farming system of Soro is mixed crop-livestock farming. The main types of crops grown are wheat, *teff*, barley, maize, sorghum, etc. with area coverage of 9890, 7264.5, 1185.5, 8116.5 and 3215 hectares, respectively and with a production of 278,832, 131904, 468330 and 86805 quintals respectively (SWADO, 2015/16). Wheat is the most important crop grown in terms of area coverage and the volume of production in the district. Wheat being, one of the major crops grown in the study area, it is mostly used as staple food and as a source of income. Cattle, goats, sheep and equines are also important tame animals kept by the smallholder farmers integrated with crops production. Thus, both crops and livestock contribute their share to the farmers' agricultural income. Hence, assessing technical efficiency of smallholders farmers in wheat production can help to improve its productivity. Soro district is one of the main surplus grain producing areas of the Hadiya zone and wheat and *teff* are main cash crops too.

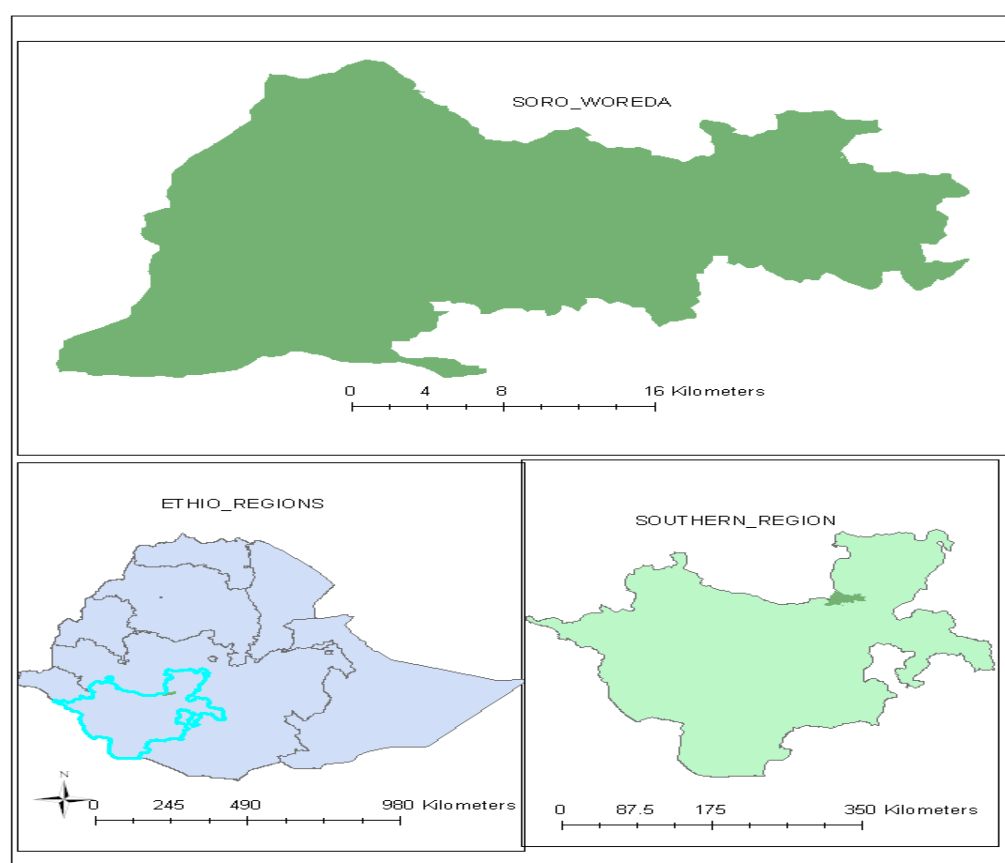


Figure 5: Map of the study area.

Source: Soro Woreda Finance and Economic Office (2014)

3.2. Data Types, Sources and Methods of Data Collection

In this study both primary and secondary data were used. The data set contained detailed information on households' socioeconomic and demographic characteristics, farm characteristics, input utilization, output produced and institutional related variables. The primary data were collected from randomly selected sample respondents using a structured questionnaire. In order to support primary data, secondary data were also collected from different published and unpublished documents about the study area from the district's agricultural development offices, governmental and non-governmental agencies and websites. Informal methods such as focus group discussion and key informants interviews were made with farmers, development agents, concerned agricultural professionals and administration offices at all levels by the researcher was also used to compliment the formal method.

3.3. Sampling Technique and Sample Size Determination

Purposive and two-stage random sampling techniques were employed for this study. The study district was purposively selected based on the extent of wheat production. In the first stage, out of 28 major wheat producer *kebeles*, three *kebeles* namely, Kecha, Bure and Sundusa were selected randomly. In the second stage, the lists of wheat producer farmers in the production year 2015/16 in the selected *kebeles* were identified in collaboration with Woreda Agricultural and Development Office experts. Finally, 125 sample farm households were selected by simple random sampling technique based on Probability Proportional to Size (PPS). The sample size for the study was determined based on Becker (1997) that forwarded the procedure of drawing an adequate sample size from a given population at 5 percent error and 95 percent confidence level. This is given by:

$$\text{Maximum Error of Margin at 5 percent} = Z\sqrt{(p * (1 - p *))/n} \quad (8)$$

Where n is the minimum sample size to be drawn, Z is the value corresponding to 95 percent level of confidence, and p* is the proportion that belongs to the target population out of total population.

The population of wheat producing farmers in the 28 *kebeles* of the district is about 24,388 in which the size of wheat farmers in the three sample *kebeles* is about 8.95 percent and Z-score that corresponds to the 95 percent level of confidence is 1.96.

Table 1 summarizes the names of the sample *kebeles*, total number of wheat producer farmers and sample size drawn. Here the proportion of sample size out of the total wheat producer farmers in the sample *kebeles* was calculated to be 4.58 percent. Thus, the 4.58 percent factor of sample selection was uniformly applied to all *kebeles* in order to draw the predetermined sample size for this study. Thus, the total sample size of 125 is the sum of samples drawn from each sample *kebeles*.

Table 1. Sample from the randomly drawn *kebeles* using PPS

No	<i>Name of kebele</i>	No. of wheat farmers	Sample size
1	<i>Kecha</i>	1015	46
2	<i>Bure</i>	820	38
3	<i>Sundusa</i>	890	41
Total	3	2,725	125

Source: SWADO, 2015

3.4. Methods of Data Analysis

To achieve the objectives of the study, both descriptive and econometric methods were employed. Accordingly, in the descriptive part, simple measures of central tendency, frequency and percentages are used to describe the socio-economic, demographic and institutional characteristics of the sample wheat farmers. An econometric estimation method was done first by specifying production frontier using Cobb-Douglas stochastic model which was developed independently by Aigner *et al.* (1977) and Meeusen and ven den Broeck(1977). The model was used to estimate parameters of production frontier, level of efficiency, and significance level of the different variables in the determination of inefficiency of farmers.

3.4.1. Descriptive analysis

This method was used to summarize and analyze the sample households input use, output levels and their socio-economic, demographic and institutional characteristics, used in the frontier production and in the efficiency model respectively.

3.4.2. Econometric analysis

Agricultural production is inherent to variability due to random shocks such as drought, weather, pest infection, fires, diseases, etc. Furthermore, because many farmers are smallholders whose farm operations are managed by family members, therefore keeping of accurate records is not always a priority. Thus much data available on production are likely to be subject to measurement errors (Tim and George, 1996). Due to these errors and random shocks which makes variation in output the stochastic production frontier will be used for its key features that the disturbance term is composed of two parts, a symmetric and a one sided component. The symmetric component captures the random effect outside of the control of the decision maker including the statistical noise contained in every empirical relationship particularly those based on cross-sectional household survey data. The one sided component captures deviations from the frontier due to inefficiency.

Therefore, the general stochastic frontier model developed independently by Aigner *et al.* (1977) and Meuse and ven den Broeck (1977) in which an additional random error, v_i , is added to the non-negative random variable, μ_i , is specified as follows:

$$\ln(y) = x_i\beta + v_i - \mu_i, \quad i = 1, 2, \dots, N \quad (9)$$

There are different functional forms to represent the production frontier. The two commonly used functional forms are Cobb-Douglas and Translog, each having their merits and demerits. Both models overwhelmingly dominate the applications literature in stochastic frontier and econometric inefficiency estimation (Coeil *et al.*, 2005). However, the work by Kopp and Smith (1980) confirmed that if the interest lies in measuring technical efficiency and not in the analysis of general structure of the production function, the functional form will have insignificant impact on measurement of efficiency. Cobb-Douglas is selected because the

number of parameters involved would be so high if translog is specified. Thus Cobb-Douglas frontier function is specified as follows:

$$\ln(OUTP) = \beta_0 + \beta_1 \ln(AREA) + \beta_2 \ln(LAB) + \beta_3 \ln(SEED) + \beta_4 \ln DAP + \beta_5 \ln(UREA) + \beta_6 \ln(OXPW) + \beta_7 \ln(HERB) + v_i - u_i \quad (10)$$

Where: OUTP - is the total output of wheat produced in quintal by the i^{th} household;

AREA - is the total area covered by wheat in hectares of the i^{th} household;

LAB - the total labor force used for plowing, planting, weeding and cultivation which are all measured in terms of man-day;

SEED - is the total quantity of wheat seed used by the i^{th} household measured in kilogram;

UREA/DAP - is the total amount of UREA/DAP fertilizer in kilogram applied by the i^{th} household for wheat production;

OXPW - the amount of draught power used for different farming activities for wheat production is measured in oxen day.

HERB - This is the total expenditure the farmer on herbicide purchase for wheat production and measured in Birr.

v_i - is the disturbance error term, independently and identically distributed as $N(0, \sigma_v^2)$ intended to capture events beyond the control of farmers; and

μ_i - is a non-negative random variable, independently and identically distributed as $N(\mu, \sigma_\mu^2)$ intended to capture technical inefficiency effects in the production of wheat measured as the ratio of observed output to maximum feasible output of the i^{th} household

μ_i - is assumed to follow half-normal distribution with mean μ_i and σ_μ^2 , such that

$$\mu_i = \delta_0 + \delta_1 Educ + \delta_2 Age + \delta_3 Sex + \delta_4 Fams + \delta_5 Totcultlnd + \delta_6 Ferty + \delta_7 Lives + \delta_8 Exten + \delta_9 Slop + \delta_{10} Credit + \delta_{11} Frag + \delta_{12} Ownl + w_i \quad (11)$$

Where the variables used in the above inefficiency model are defined as follows:

μ_i - is the inefficiency score of the i^{th} household;

δ_i - is a vector of parameter to be estimated;

w_i - is error term;

Educ - is the education level of the household farmer measured in continuous years of formal schooling;

Age - age is defined as the age of the household head in years;

Sex - is a dummy variable that takes a value of 1 if the household head is male and zero, otherwise;

Fams -This represents the total number of household members working on farm.

Totcultlnd- is the total land size operated by the farmer during the production year including his owned land, sharecropped lands and rented lands;

Ferty - is the fertility status of the soil defined as a dummy that would take a value 1 if the land is perceived fertile and 0 otherwise;

Lives - This is the total number of livestock in terms of Tropical Livestock Unit (TLU);

Exten - is measured in terms of the frequency of visit of the extension agent to the farmer during 2015/16 production season;

Slop - it a slope of the land as a dummy variable which would take a value of 1 if the land is perceived plain and 0 otherwise;

Credit - is a dummy variable which represents whether the farmer has obtained formal credit or not during production season;

Frag - is the number of plots of all annual crops the farmer managed during the production year including his own, hired and sharecropped;

Ownl- it is considered as a dummy variable, which would take a value of 1 if the land is his own or rented and 0 if the land is sharecropped.

The above production and inefficiency variables are defined and hypothesized in the next section.

The one-stage estimation procedure of the inefficiency effects model together with the production frontier function was used in the study. The two-stage procedure produces inconsistency in the assumption (Coelli *et al.*, 1998). Moreover, one-stage procedure is the most commonly used method in the analysis of technical efficiency. Thus one-stage procedure was selected for this study.

The maximum likelihood estimates of the parameters of the frontier model are estimated, such that the variance parameters are expressed in terms of the parameterization

$$\sigma_s^2 = \sigma^2 + \sigma_v^2 \quad \text{and} \quad \gamma = \frac{\sigma^2}{\sigma_s^2} = \frac{\sigma^2}{\sigma_s^2 + \sigma^2} \quad (12)$$

Where the γ parameter has a value between 0 and 1. A value of γ of zero indicates that the deviations from the frontier are entirely due to noise, while a value of one would indicate that all deviations are due to technical inefficiency.

σ^2 - is the variance parameter that denotes deviation from the frontier due to inefficiency;
 σ_v^2 - is the variance parameter that denotes deviation from the frontier due to noise
 σ_s^2 - is the variance parameter that denotes the total deviation from the frontier.
 In the prediction of firm level technical efficiencies, Battese and Coelli (1995) pointed out that the best predictor of $\exp(-\mu_i)$ is obtained by:

$$E[\exp(-\mu_i)/e_i] = \frac{1-\phi(\sigma_A + \gamma e_i/\sigma_A)}{1-\phi(\gamma e_i/\sigma_A)} \exp(\gamma e_i + \sigma^2/2) \quad (13)$$

Where $\sigma_A = \sqrt{\gamma(1-\gamma)\sigma_s^2}$; $e_i = \ln(y_i) - x_i\beta$; $\phi(\cdot)$ is the density function of a standard normal random variables.

The above Battese and Coelli (1995) models, presented in Equation (10) to (13), were estimated using the computer program, FRONTIER version 4.1, written by Coelli (1996). FRONTIER 4.1 is a single purpose package specifically designed for the estimation of stochastic production frontiers and has the advantage of specifying distributional assumption for the estimation of the inefficiency terms. In addition, FRONTIER is able to accommodate a wider range of assumptions about the error distribution term such as half-normal and truncated normal distributions. The estimation of inefficiency terms are carried out at one-step process and this avoids inconsistency that may be generated in two-step estimation (Herrero and Pascoe, 2001). The technical efficiency predictor implemented in the program is obtained by replacing the unknown parameters in Equation (13) with their maximum likelihood estimates.

According to Green (2003), in SPF hypothesis tests can be made using ML ratio test that are not possible in non-parametric models. A number of tests were made in this study using the Likelihood Ratio (LR) test given by Equation (14).

$$LR = \lambda = -2 \ln [L(H0) / L(H1)] \quad (14)$$

$$\lambda = -2[\ln L(H0) - \ln L(H1)]$$

Where, λ is the likelihood ratio (LR),

$L(H_0)$ = the log likelihood value of the null-hypothesis;

$L(H_1)$ = the log likelihood value of the alternative hypothesis; and

$\ln$ is the natural logarithms.

This test statistics is asymptotically distributed as a Chi-square (or mixed Chi-square) random variable with degree of freedom equal to the number of restrictions involved (Coelli *et al.*, 1998).

3.4.3. Variables definition and hypotheses

This study addressed both production and inefficiency variables. The identification of important variables used for the estimation of frontier model were selected based on observing the characteristics of wheat production of the areas and through review from previous works on wheat efficiency studies.

3.4.2.1. Production function variables

Output (OUTP): This is dependent variable of the production function. It is defined as the actual quantity of wheat produced by each sample household and measured in quintals during the 2015/16 production year.

Land area (AREA): The amount of land used for wheat production during 2015/16 production season by the sample household farmer measured in hectares. It belongs to the farmer's own land or land obtained by means of renting or through share cropping arrangements.

Labor (LAB): This input captures family, exchange and hired labor used for different agronomic practices of wheat production in the 2015/16 production season. But the differences in sex and age among labor would be expected. Hence, to make a homogeneous group of labor to be added, the individual labor was changed in to Man Days (MDs) using the standard developed by Storck *et al.* (1991). Therefore, the human labor input was measured in terms of total MDs employed.

Seed: It refers to the quantity of wheat seed used in kilogram (kg) by each household. Farmers mainly used improved wheat seed in the production.

Urea and DAP fertilizers (UREA/DAP): Fertilizer is a key input and its application along with other technologies could have a great potential to increase crop productivity. Urea is applied on the farm land once or using split application, but DAP is usually applied during planting time only. As input variables, the total amount of Urea and DAP used in Kg for the wheat production in 2015/16 production year.

Oxen power (OXPW): The amount of draught power used for different farming activities for wheat production is measured in oxen day. Hence, oxen power was measured using the total amount of oxen days allocated for different activities of wheat production in 2015/16 production season.

Herbicide (HERB): This is the total expenditure of the farmer on herbicide purchase for wheat production and it is measured in Birr.

3.4.2.2. Inefficiency variables

Based on the review of literature, the following variables were expected to determine wheat technical inefficiency in the study area.

Education of household head (Educ): Farmers are expected to acquire the ability of better management through education and can be used as a proxy variable for managerial ability. Farmers with ability to read and write tend to be more efficient, presumably due to their enhanced ability to acquire technical knowledge, which makes them closer to the frontier. A lot of empirical studies showed that education is one of the most recognized factors in determining the efficiency level of the farmers in the world and resulted that education determined efficiency positively and significantly (Jema, 2006; Al-hassan, 2012). Therefore, in this study, it is hypothesized that education is expected to have positive effect on technical efficiency.

Age of the household head (Age): This refers to age of the household head measured in years. It is continuous variable and hypothesized to reflect the experience of the farmer. However, as the farmer gets older, his managerial ability is expected to decrease. The findings of Haileslasie (2005) and Mesay *et al.*, (2013) indicate age have negative effect on efficiency. Hence, it was hypothesized indeterminate effect on efficiency.

Sex of the household head (Sex): This is a dummy variable that is measured as 1 if the household head is male and 0, otherwise. The findings of Zenebe *et al.* (2004) indicate that sex of the farmer has a significant impact on efficiency of farmers' production. It was hypothesized that male farmers are less inefficient than female farmers.

Family size (Fams): This represents the total number of household members working on farm. Family is an important source of labor supply in rural areas. It is expected that households with large family members have better advantage of being able to use labor resources at the right time, particularly during peak cultivation periods. But family size could have positive effect in raising the farmers' production efficiency, if actually the members are in the working force. Thus, it is hypothesized that the more the economically active family members (labor force) in a given household, the more efficient is the farm household. It was found to relate positively to technical efficiency (Haileselasie, 2005)

Total cultivated land (Totcultlnd): This refers to the size of own, shared or rented in land the household managed during 2015/16 production season. Farmers with larger area of cultivated land have the capacity to use compatible technologies that could increase the efficiency of the farmer, enjoy economies of scale. According to Andreu (2007) larger farms are relatively better efficient than small size farms. However, Jema (2008) obtained negative relationship between farm size and efficiency. Hence, it was hypothesized to have indeterminate effect on efficiency.

Fertility status of plot (Ferty): It is treated as dummy that takes a value of 1 if a household head perceives his land as fertile area and 0, otherwise. Farmers asked to categorize their land as fertile or infertile land as they are expected to approximately know the fertility status of their land. A farmer endowed with fertile land will be more technically efficient than infertile lands (Chirwa, 2007). Therefore, it was hypothesized that a farmer with a fertile land are technically more efficient than the farmer with less fertile land.

Livestock holding (Lives): This is the total number of livestock in terms of Tropical Livestock Unit (TLU). Livestock could support crop production in many ways; they can be source of cash, draft power and manure that will be used to maintain soil fertility. It also serves as shock absorber to an unexpected hazard in crop failure and the main sources of animal labor in crop

production. In addition, it indicates the wealth status of household. The number and value of livestock holding was found to be related to technical efficiency positively (Fekadu, 2004; Aynalem, 2006). Therefore, in this study the effect of livestock on efficiency was hypothesized to be positive.

Frequency of extension contact (Exten): This is a continuous variable, which is measured in terms of the frequency of visit of the extension agent to the farmer during 2015/16 production season. Access to extension services as a medium for diffusion of new technologies and information is expected to reduce inefficiency level. Hence, it may have a positive impact on efficiency levels of wheat producers through improvement of their managerial ability and general agronomic practices (Abba, 2012). Thus, it was expected to have negative effect on technical inefficiency.

Slope of plot (Slop): It is a slope of the land as a dummy variable that takes a value of 1 if the slope of the plot is flat plain and 0, otherwise. Sloppy lands are vulnerable to erosion damages and their fertility is likely to be poor due to high run-off if the soil conservation measures are not taken (Fekadu, 2004). Thus, it was hypothesized to determine technical efficiency positively.

Credit: This is a dummy variable that represents the use of credit services for wheat production activities by farmers. If the farmer has taken credit, the variable takes a value of 1 and 0 otherwise. Since credit utilization is an important source of financing the agricultural activities of smallholder farmers (Biforin *et al.*, 2010), it was hypothesized that farmers who have utilized credit are less inefficient.

Land fragmentation (Frag): This refers to total number of plots that the farmer has managed during the 2015/16 production season. Plots in the area are highly fragmented and scattered over many places that would make difficult to perform farming activities on time and effectively. Increased land fragmentation leads to inefficiency by creating shortage of family labor, costing time and other resources that should have been available at the same time (Wondimu, 2010). Hence, this study hypothesized a negative association between fragmentation and efficiency.

Land ownership (Ownl): This is a dummy variable, which takes a value of 1 if the land is his/her own or rented and 0 if the land is sharecropped. An empirical study by Fikadu (2004) revealed that sharecropping determine efficiency negatively and significantly. It was hypothesized that farmers tend to be more efficient in managing those lands that are owned and rented than sharecropped lands.

4. RESULTS AND DISCUSSIONS

This chapter has two major sections. The first section presents results of the descriptive statistics. The second section deals with econometric results of the technical efficiency analysis and provides variables that explain technical inefficiency in wheat production in Soro district.

4.1. Descriptive Statistics Results

4.1.1. Demographic and socio-economic characteristics of sample households

Studies by Coelli and Battese (1996) show that demographic factors affect the quality of the management of the farmer directly or indirectly and hence are believed to have impact on efficiency of production. However, before embarking on analyzing effects on efficiency, their descriptive statistics is discussed as follows.

Age and family size of the sample households: Age is one of the important factors which determine management experience of the farmers. Therefore, it is important to discuss age of farmers within the sample. Average age of sample household heads was 44.1 years with a range of 25 to 72 years. This implies that most of the household heads were within their productive age. The average family size of the sampled household heads was 5.2 with the minimum of 2 and maximum of 9. This large family size coupled with small land size and backward production system created difficulty for the farmer to sustain their family. It would be difficult to send his/her children to school and afford health expenses (Table 2).

Table 2. Demographic characteristics of the sample households

Variable description	Minimum	Maximum	Mean	Std. Deviation
Age	25	72	44.1	10.46
Family size	2	9	5.18	1.58
Education	0	12	3.33	3.68

Source: Own computation (2016)

Education status: Education enhances the acquisition and utilization of information on improved technologies by farmers as well as their innovativeness. Education together with increased experience could guide farmers to better manage their farm activities. The

educational level of the household head, on average, was 3.33 years with the minimum of zero and maximum of 12 (Table 2).

Sex and marital status: With regard to the respondents, about 84.8% of the sample farmers were male headed. Among the sample farmers considered, about 91.2% of them are married, 0.8% single, 4% widowed and 4% were divorced.

Table 3. Sex and marital status of the sample household heads

Sex and marital status	Category	N	Percent
Sex	Male	106	84.8
	Female	19	15.2
Marital status	Married	114	91.2
	Single	1	0.8
	Widowed	5	4
	Divorced	5	4

Source: Own computation (2016)

4.1.2. Resource base

Land: Land is scarce and a basic factor of production. According to the survey result, the average land holding of the sample households in the district was 0.93 ha with a standard deviation of 0.66 and ranging from 0.25 ha to 3.5 ha. This average land holding of the sample households is less than the district average, which is 1ha as indicated in SWADO (2015/16). From the total of about 146.5 hectares of land cropped during 2015/16 cropping season by sample farmers, most of the sample household (60.8 %) operated on their own land. Other than own land in the study area, farmers have other sources of land mainly through two informal arrangements, sharecropping and renting. During the production year (2015/16), 23.2% was contracted through sharecropping arrangement and 16% was acquired through renting. Annual crops are sown in different plots and are fragmented and scattered over different places. A farmer on average has 2.25 plots with the number of plots varying from one to five (Table 7).

Livestock holding: Livestock are an important component of the farming system, which is managed by farmers, and it is an important asset for rural households in and serves multiple

purposes. It contributes as draught power, manure, basic sources of cash income and consumption for the household. In general, the livestock holding was measured in terms of TLU. As Table 7 shows sample farmers on average own livestock of 3.74 TLU and it ranges from 1 to 18.2 TLU with a standard deviation of 2.63. This shows high variability in terms of livestock ownership among sample smallholder farmers.

4.1.3. Crop production

The dominant farming system of the study area is mixed farming where crop plays the major role in the farmers' livelihood. The major crops grown in the area are wheat, *teff*, maize and barley which covered 82.2% of the total area covered with annual crops and the sample households, on average, allocated 0.59 ha, 0.30 ha, 0.21 ha and 0.18 ha of land, respectively in 2015/16 production year (Table 4). Among cereals, wheat was the dominant crop in terms of area and number of growers. It accounted for 52.59% of total cultivated land. The dominance of wheat in the district was one of the reasons for taking wheat as the study case.

Table 4. Sample households' farm land allocation for different crops (ha)

Crop type	Mean	St. Deviation
Wheat	0.59	0.32
<i>Teff</i>	0.30	0.26
Maize	0.21	0.09
Barley	0.18	0.13
Others	0.20	0.21

Source: Own computation (2016)

4.1.4. Income sources

The income sources were broadly categorized into two; on-farm and off/non-farm income. The basic source of income for households' income in the surveyed area is earned from agriculture. The large share of farm income was obtained from production of wheat followed by *teff*. However, there are also other sources of income for the households to support their livelihood though it is limited. The main off/non-farm income source in the study area is remittance.

4.1.5. Institutional factors

Extension service: In order to give effective extension service to the farmers, there are three up to five DAs in each *kebele*. The DAs are graduates of different colleges specializing in three agricultural streams such as crop production, animal husbandry and natural resource management. The extension workers visit farmers on different intervals. The survey result indicated that the average frequency of extension contacts during the production season in relation with wheat production was about 3.19 times with standard deviation of 1.66 (Table 7)

Credit Service: There exist both formal and informal lending institutions that provide credit to farmers. The formal sources of credit in the study area are Omo micro-finance, Vision fund micro-finance and local cooperative, whereas local lenders like friends, relatives, traders, etc. are informal sources from which farmers could get credit. As far as access to credit is concerned, about 99 percent of the farmers reported that they could obtain credit from either source when they are in need of it provided that they fulfill the requirements set by the lending institutions (be it formal or informal). In the production year, about 63.2% of the sample households used credit from either sources. Most of the time majorities of the farmers get credit from Omo micro-finance and local lenders (Table 7).

4.1.6. Production constraints

In the study area, the sample farmers reported that they faced many production constraints. It is worth noting that there are multitude of problems related to weeds, pests, and diseases coupled with shortage of rainfall. Late rains and early cessation during sowing time and unexpected rains during harvesting time are rainfall related problems, which negatively affect crop production in the woreda. Sample respondents were asked to single out the most severe wheat production problem in their locality. Depending on the number of total responses, the major problems affecting wheat production in the study area were ranked as weed, disease and pest (38%), shortage of rainfall (36%) and low fertility status of the soil due to nutrients depletion (14%) in the area.

Table 5. Major problems of wheat production in the study area

Problems of wheat production	N	Percent
Weed, disease and pest	48	38
Shortage of rainfall	45	36
Low fertility status of the soil	17	14
Others (lack of improved varieties, high fertilizers cost, etc)	15	12

Source: Own computation (2016)

4.1.7. Variables used to estimate production function

The production function for this study was estimated using seven input variables. Table (6) presents summary statistics of input variables used to estimate the production function.

The dependent variable in estimation of the production function is output, measured in quintal. According to Table (6), the average wheat output produced in the study area was 13.15 qt, which ranges from 2 qt to 45 qt with standard deviation of 9.86 among the sample farmers in 2015/16 production year. The land allocated for wheat production, by sampled farmers during the survey period was on average of 0.59 ha with standard deviation of 0.32. The other very important variable is seed. The amount of seed that sample households used was on average 54.88 Kg with standard deviation of 30.22.

Regarding fertilizer type, the most commonly and intensively used chemical fertilizer for the production of major cereal crops are DAP and Urea. Chemical fertilizers are known for their responsiveness in increasing productivity. The survey results revealed that all sample farmers used DAP and Urea for wheat production during the production year. The sample farmers on average applied 49.69kg of DAP and 46.60kg of Urea.

Like other inputs, human and animal labor inputs were also decisive, given a farming system in the study area. Sampled households, on average, used 28.68 man days and 12.24 oxen days for the production of wheat during 2015/16 production season. Moreover, another essential input was herbicide, in which the average expenditure was Birr 154.07 with a standard deviation of 55.51 (Table 6).

Table 6. Descriptive statistics of both input and output variables

Variable description	Minimum	Maximum	Mean	St. Deviation
Output (Qt)	2	45	13.15	9.86
Seed (Kg)	20	135	54.88	30.22
DAP (Kg)	15	130	49.69	29.90
Urea (Kg)	10	125	46.60	29.00
Area(ha)	0.13	1.5	0.59	0.32
Human labor(MDs)	15	62.50	28.68	11.82
Oxen(OXDs)	2.50	31.63	12.24	7.29
Herbicide(Birr)	27	300	112.16	58.88

Source: Own computation (2016)

4.1.8. Inefficiency variables

This part presents the descriptive summary statistics of the explanatory variables that were supposed to cause technical efficiency variation among wheat producers in the study area. A total of 12 variables were hypothesized to affect efficiency of wheat producers, out of which five of them were dummy variables and the remaining seven variables were continuous.

Table 7. Descriptive summary statistics of technical inefficiency variables

Variable	Statistical measure			
Continuous variables	Minimum	Maximum	Mean	St. Deviation
Age (years)	25	72	44.12	10.46
Education (years of schooling)	0	12	3.33	3.68
Total cultivated land (ha)	0.25	3.5	0.93	0.66
Fragmentation(number of plots)	1	5	2.25	0.97
Livestock (TLU)	1	18.1	3.74	2.64
Family size (number)	2	9	5.18	1.58
Extension (frequency)	0	7	3.19	1.66
Dummy variables	Responses		percentage	
Sex	Male(1)		84.8	
	Female(0)		15.2	
Land ownership	Owned or rented(1)		76.8	
	Otherwise(0)		23.2	
Fertility perception	Fertile(1)		53.6	
	Otherwise(0)		46.4	
Slope	Plain(1)		51.2	
	Otherwise(0)		48.8	
Credit	Used(1)		63.2	
	Not used(0)		36.8	

Source: Own computation (2016)

4.2. Econometric Results

This section presents the econometric model outputs of the study. In this section, the production function, efficiency scores and determinants of efficiency are discussed.

4.2.1. Hypotheses testing

One attractive feature of SPF method is that it is possible to test various hypotheses using maximum likelihood test ratio. Therefore, before presenting and discussing about parameter estimates of production frontier function and the inefficiency effects, it is advisable to run hypotheses tests in order to choose an appropriate model for further analysis and interpretation. Tests of hypothesis for the parameters of the frontier model are conducted using the generalized likelihood ratio statistics, λ , defined as:

$$\lambda = -2[\log L (H_0) - \log L (H_1)] \quad (15)$$

Where, $L (H_0)$ and $L (H_1)$ are the values of the log-likelihood function under the null and alternative hypotheses, H_0 and H_1 , respectively. Tests of hypotheses for the parameters of the frontier model were conducted using the generalized likelihood ratio statistics, λ , defined by equation (15). Accordingly, the following hypotheses were tested, namely to select the correct functional form for the given data set, for the existence of inefficiency and finally for variables that explain the difference in efficiency.

Table 8. Generalized likelihood ratio tests of hypothesis for the parameters of the SPF

Null hypothesis	DF	LH ₀	LH ₁	Calculated χ^2 (LR) value	Critical value ($\chi^2_{0.01}$)	Decision
H ₀ : $\gamma = 0$	1	-7.47	35.15	42.62	6.63	Reject
H ₀ : $\beta_8 = \beta_9 = \dots = \beta_{35} = 0$	28	35.15	57.47	44.64	48.27	Not reject
H ₀ : $u_i = \delta_1 = \delta_2 = \dots = \delta_{12} = 0$	12	-6.17	35.15	82.64	26.21	Reject

Source: Own computation (2016)

The first null hypothesis was $H_0: \gamma = 0$, which specifies that the inefficiency effects in the SPF were not stochastic. The generalized likelihood ratio statistics, $\lambda = 42.62$, presented in Table 8 is found to be greater than the critical value of 6.63. Hence, we reject null hypothesis (H_0) at 1% level of significance showing that the average response function is not an adequate

representation of the data. Consequently, the null hypothesis that wheat farmers in the area are fully efficient is rejected.

Similarly, the second test was the null hypothesis that identifies an appropriate functional form between restrictive Cobb-Douglas and the non restrictive Translog production function which specifies that square and cross terms. The test result show that the calculated value of $\lambda = 44.64$ is less than the critical value of 48.27, thus the null hypothesis is not rejected at 1% level of significance implying that Cobb-Douglas functional form best fit the data set.

The next hypothesis is that the null hypothesis that the explanatory variables associated with technical inefficiency effects model are all zero, ($H_0: U_i = \delta_0 = \delta_1 = \delta_2 - - - \delta_{12} = 0$). To test this hypothesis likewise, λ was calculated using the value of the log likelihood function under the stochastic frontier model (a model without explanatory variables of inefficiency effects, H_0) and the full frontier model (a model with variables that are presumed to determine inefficiency of each farmer, H_1). The calculated value of $\lambda = 82.64$ is greater than the critical value of 26.21, thus the null hypothesis that variables in the inefficiency effects model are simultaneously equal to zero is rejected at 1% level of significance. Hence, these variables explain the difference in inefficiency among farmers.

4.2.2. Parameter estimates of the SPF model

The SPF model was specified and estimated using the maximum likelihood method to analyze the technical efficiency of sample households in the production of wheat in Soro district. A single estimation procedure was used. The model comprises of twenty one parameters, seven of them were the explanatory variables of the stochastic frontier function while twelve of which were the explanatory variables that are hypothesized to influence the technical efficiency scores and the remaining two being the parameters associated with the distribution of v_i and μ_i .

Technical efficiency was estimated using the Cobb-Douglas functional form. The computer program FRONTIER version 4.1 gives the value of the parameter estimates for the frontier model, the value of δ^2 and the value of log-likelihood function for both OLS estimations and the stochastic production function. Moreover, the maximum likelihood estimation of the SPF with inefficiency model gives the individual and mean level of technical efficiency. The value

of the parameter estimates of the inefficiency effects variables (μ_i) and the value of gamma (γ). The maximum likelihood estimates of the parameter of SPF functions together with the inefficiency effects model are presented in Table 9.

Table 9. Maximum-likelihood estimates of the Cobb-Douglas SPF with inefficiency model

Variables	Coefficient	Standard-error	t-ratio
Constant	5.09***	0.62	8.16
lnSeed	-0.08	0.09	-0.82
lnDAP	0.13***	0.05	2.57
lnUREA	0.17***	0.05	3.31
lnLabor	0.11	0.09	1.19
lnOxen	0.29***	0.09	2.99
lnHerbicide	0.12**	0.05	2.20
lnArea	0.48***	0.13	3.52
Inefficiency effect model			
Sigma-squared (σ^2)	0.06***	0.08	4.86
Gamma (γ)	0.63*	0.32	1.94
Log likelihood Function	35.15		

Source: Own computation (2016)

Note: *, ** and *** significant at 10%, 5% and 1% significance level, respectively.

The diagnostic statistics of inefficiency component reveals that sigma squared (σ^2) was statistically significant which indicates goodness of fit, and the correctness of the distributional form assumed for the composite error term. The estimated value of Gamma (γ) is 0.63 which indicates that 63% of total variation in wheat output among sample farmers is due to technical inefficiency.

As the Table 9 depicts that the estimated coefficients for DAP, UREA, oxen power, herbicide and area are all positive and significant which confirm that, these inputs significantly increase output. The MLE values of the coefficients can be interpreted as elasticity of production. The coefficients of inputs indicate that on average a 1% increase in DAP, UREA, oxen power, herbicide and area increases the output of wheat by 0.13%, 0.17%, 0.29%, 0.12% and 0.48%, respectively.

4.2.3. Technical efficiency scores

The mean TE of the sampled wheat producer households in 2015/16 production year was 72%, with minimum and maximum efficiency levels of about 37% and 96% with a standard

deviation of 17, respectively. This shows that there is a wide disparity among wheat producer farmers in their level of technical efficiency which in turn indicates that, there exists a room for improving the existing level of wheat production through enhancing the level of farmers' technical efficiency. The mean level of technical efficiency further tells us that the level of wheat output of the sample respondents can be increased on average by about 28% if appropriate measures are taken to improve the level of efficiency of wheat growing farmers. In other words, there is a possibility to increase yield of wheat by about 28% using the resources at their disposal in an efficient manner without introducing any other improved (external) inputs and practices.

Table 10. Estimated technical efficiency scores of the sample farmers

Descriptive statistics	Technical efficiency scores
Mean	0.72
Maximum	0.96
Minimum	0.37
Standard Deviation	0.17

Source: Own computation (2016)

4.2.4. Determinants of technical inefficiency

The main interest behind measuring technical efficiency level is to know the factors that determine the technical efficiency level of individual farmers. The parameters of the various hypothesized variables in the technical inefficiency effect model that were expected to determine efficiency differences among farmers were estimated through MLE method using one-stage estimation procedure. The determinants of technical inefficiency/efficiency in a given period vary considerably depending on the socio-economic conditions of the study area particularly pertaining to managerial characteristics and other related factors.

Table 11 illustrates the socio-economic, demographic, farm characteristics and institutional factors that affect efficiency in wheat production. Out of the twelve variables used, six variables (age, education, land fragmentation, land ownership, fertility status of the plot and extension contact) were found to affect significantly the efficiency of wheat farmers.

Before discussing the significant determinants of efficiency in wheat production it is important to see how efficiency and inefficiency are interpreted. The result can be presented in terms of

efficiency or in terms of inefficiency. The result in Table 11 is presented in terms of inefficiency and hence the negative sign shows the increase in the value of the variable attached to the coefficient means the variable negatively contribute to inefficiency level or conversely it contributes positively to efficiency levels. Thus, any negative coefficient happens to reduce inefficiency which implies its positive effect in increasing or improving the efficiency of the firm and vice versa.

Table 11. Maximum likelihood estimates of the factors determining technical inefficiency

Variables	Coefficient	Standard-error	t-ratio
Constant	0.90***	0.18	4.84
Age	-0.05*	0.02	-1.91
Sex	-0.06	0.07	-0.90
Education	-0.02*	0.09	-1.84
Total cultivated land	0.02	0.04	0.55
Land fragmentation	0.07***	0.03	2.87
Land ownership	-0.13***	0.05	-2.35
Fertility	-0.18*	0.07	-2.69
Slope	-0.02	0.05	-0.44
Livestock	-0.02	0.01	-0.18
Family size	-0.01	0.02	-0.85
Credit	-0.04	0.05	-0.90
Frequency extension contact	-0.04**	0.02	-2.17
Sigma-squared (σ^2)	0.04***	0.08	4.86
Gamma (γ)	0.63*	0.32	1.94
Log likelihood Function	35.15		

Source: Own computation (2016)

Note: *, ** and *** significant at 10%, 5% and 1% significance level, respectively.

Age: The age of respondents has a significant negative effect on inefficiency of wheat producing farmers at 10% level of significance. This indicates that as the age of farmers increases their inefficiency reduces which leads to improvement in the level of technical efficiency. This may be due to the fact that age can serve as a proxy variable of farming experience, in which farmers with more years of experience are expected to be less inefficient. The result is in conformity with the results of Endalkachew (2012) and Shumet (2012) and in contradiction with the study by Mesay *et al.* (2013).

Education: In this study, education was measured in years of formal schooling. As expected, the sign of education was negative and significant at 10% level of significance implying that

less educated farmers are not technically efficient than those that are relatively better educated. Hence, education can be a proxy variable for managerial ability of the farmer and improves the ability of the household to make informed decision about production inputs. Educated farmers more often have better access to agricultural information and higher tendency to adopt and utilize improved inputs (like fertilizers and crop varieties) more optimally and efficiently. This result is in line with results of the studies by Endrias *et al.* (2013) and Mesay *et al.* (2013).

Land Fragmentation: It was hypothesized that plots in the area are highly fragmented and scattered over many places that would make difficult to perform farming activities on time and efficiently. The positive and significant value of the coefficient of fragmentation in Table 11 at 1% level of significance is consistent with the previous expectation. This may be because if the number of plots operated by the farmer increases; it may be difficult to manage these plots. Thus farmers that have large number of plots may waste time in moving between plots. This finding is in line with empirical findings of Fekadu (2004) and Wondimu (2010).

Land ownership: It was hypothesized that lands owned by the operator farmers or rented in will be utilized more efficiently than the lands owed through sharecropping. In other words, farmers will be more efficient in managing their owned and hired plots than otherwise operating sharecropped lands. The result in Table 11 shows ownership measured in terms of dummy is found to determine the efficiency level of farmers in producing wheat positively and significantly at 1% of significance. Farmers who used their own land or hired land for wheat production are more efficient than farmers who manage sharecropped land. This may be due to the fact that operator farmers might not perform each farming activity on time especially during peak periods. In addition, the sharecropping arrangement will not encourage the operator farmer to take risk as the risk on loss of returns on inputs solely taken by the operator farmer. The result is consistent with the results obtained by Fekadu (2004).

Fertility: As can be seen from Table 11, perceived soil fertility had a significant and positive impact on technical efficiencies at 10% level of significance, as expected. This implies that farmers having fertile land were more efficient than those who have less fertile land. This may be associated with those fertile lands require less commercial fertilizer application which leads to reduction in cost and time and again leads to reduction in the inefficiency of farmers. This

result is similar with the studies by Shumet (2012), Hassen *et al.* (2014) and Hailemaraim (2015).

Frequency of extension contact: Finally, the result shows that extension contact determined the inefficiency level of farmers negatively and significantly at 5% level of significance. This is consistent with the priori expectation that the more the farmer has extension visit, the less he/she will become inefficient. The improvement in the production system of wheat in the study area is one of the major focuses of extension. In the study area, the contact those farmers have with extension workers play a significant role in improving the level of technical efficiency. The findings are consistent with earlier results of Berhan (2013).

The result obtained reveals that, given the existing technology at hand, providing farmers' extension service and rendering them the necessary advisory service in every aspect of the agronomic practices can help farmers increase their level of technical efficiency in wheat production. This implies that the ongoing extension advisory services (mainly focused on methods of land preparation, time and method of sowing, application of fertilizers and soil and water conservation techniques as well as disease control) are bringing positive changes.

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary and Conclusion

The study analyses the technical efficiency of farmers in production of wheat in Soro district. Stochastic frontier model with inefficiency effects was used for analyzing cross sectional data obtained from 125 sample farmers in 2015/16 production year. The Cobb-Douglas stochastic production frontier model with inefficiency effects was used to analyze the level of technical efficiency of the farmers with respect to wheat production and the causes of technical efficiency differentials among the farmers. On the other hand, various farm and farmer specific socio-economic and institutional variables that are expected to determine the technical inefficiency of farmers were estimated simultaneously with the stochastic frontier model (one stage estimation procedure).

The estimated stochastic frontier Cobb-Douglas production function indicates that the amount of DAP, UREA fertilizers, oxen power, herbicide and land allocated for wheat as positively and significantly determine production level of wheat. The positive coefficient of these parameters indicated that increased use of these inputs up to the recommended level increases the production level. Hence, given that these inputs are used to their maximum potential, introduction and dissemination of these inputs will increase the production level of wheat in the study area. Therefore, timely supply and applying the recommended rate of fertilizer increases the production level.

The test result indicates that the traditional average response function is not an adequate representation of production frontier. This indicates that significant proportion of the variation in the stochastic frontier production function being due to technical inefficiency. This implies that there is a room for improvement in output through improving the inefficiency of farmers. The mean technical efficiency level of 72 percent indicates that production can be increased by 28 percent. Hence, if inputs are used to their maximum potential, there will be considerable gain from improvement in technical efficiency.

The generalized likelihood-ratio test proved that variables considered in the inefficiency effects model simultaneously explained the existing technical efficiency differences among farmers.

Hence, identifying factors that determine the technical inefficiency level of farmers in wheat production helps to improve the technical efficiency of farmers. The estimated SPF model together with the inefficiency parameters show that age of farmers, education level, land ownership, soil fertility, and frequency of extension contact have negative and land fragmentation has positive and significant influence on the inefficiency of farmers. These factors have important policy implications to mitigate the existing level of inefficiency of farmers in the production of wheat and other crops, and hence, development programs should act upon these variables.

5.2. Recommendations

The following policy recommendations have been drawn based on the results of the study.

First, age of household head has a significant positive effect on technical efficiency of wheat production. The local government should arrange field days, cross-visits, creating forum for experience sharing elder households and provision of short-term training programs so as to share the knowledge of elder households to young farmers. Using best practices of the efficient farmers as a point of reference would help setting targets in improving efficiency levels and finding the feebleness of the present farm practices. The relatively efficient farms can also improve their efficiency more through learning the best resource allocation decision from others.

Second, education was important determining factor that has positive significant effect on farm household technical efficiency of wheat production in the study area. Thus government has to give due attention for strengthening and establishing both formal, informal type of farmers' education by using the available human and infrastructural facilities like extension agents and Farmers Training Centers.

Third, perception of fertility status of wheat farm affected technical efficiency of farmers positively. Therefore, development programs need to strengthen improved land management practices to improve and maintain the fertility of farm land to increase efficiency of farmers. The result reveals that there is land shortage in the study area as a result of high population

pressure. Hence, serious intervention is required for intensive and efficient use of farming practice by improving the fertility of land.

Fourth, the result of the study reveals that farmers who have more frequency of extension contact were more efficient than farmers with less contact. So farmers with less extension contact can improve their performance level at least to be as technically efficient as those who more have contact with extension workers. Hence, given the existing technology at hand, bringing farmers under extension contact and rendering them the necessary advisory service can help farmers increase their level of technical efficiency of wheat production.

Fifth, compared to share cropping arrangements, farmers who produce wheat on their own land or rented land were technically more efficient. Having in mind the problem that may arise from inequitable distribution of land, it is straight forward that increase ownership right of farmers on land is necessary. Moreover, land policy that would increase the ownership right of farmers on land would not only increase the efficiency of farmers but also it would increase the use of improved technologies as it would minimize the risk aversion behavior of farmers to invest on technologies.

Finally, farmers that operated larger number of plots are less efficient than others. This implies that land policy that favor consolidated land holding increase the efficiency of farmers.

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7. APPENDICES

Appendix 1. Conversion factor used to calculate man equivalent

Age group (years)	Man Days (MD)	
	Male	Female
<10	0	0
11-13	0.2	0.2
14-16	0.5	0.4
17-50	1.00	0.8
>50	0.7	0.5

Source: Storck, *et al.* (1991 as cited in Arega and Rashid, 2005).

Appendix 2. Conversion factors used to estimate Tropical Livestock Unit equivalents

Animal Category	TLU
Calf	0.25
Donkey (Young)	0.35
Donkey (adult)	0.70
Weaned Calf	0.34
Camel	1.25
Heifer	0.75
Sheep and Goat (young)	0.06
Sheep and Goat (adult)	0.13
Cow and Ox	1.00
Horse	1.10
Chicken	0.013

Source: Storck *et al.* (1991 as cited in Arega and Rashid, (2005).

Appendix 3. Estimated level of individual technical efficiency

Firm	TE	Firm	TE	Firm	TE	Firm	TE	Firm	TE
1	0.78	26	0.87	51	0.59	76	0.83	101	0.92
2	0.53	27	0.82	52	0.52	77	0.93	102	0.93
3	0.62	28	0.44	53	0.57	78	0.43	103	0.88
4	0.41	29	0.51	54	0.88	79	0.81	104	0.95
5	0.92	30	0.54	55	0.58	80	0.85	105	0.47
6	0.65	31	0.79	56	0.74	81	0.62	106	0.76
7	0.55	32	0.76	57	0.46	82	0.62	107	0.84
8	0.94	33	0.42	58	0.62	83	0.88	108	0.79
9	0.75	34	0.61	59	0.66	84	0.56	109	0.66
10	0.48	35	0.53	60	0.96	85	0.49	110	0.78
11	0.75	36	0.71	61	0.66	86	0.68	111	0.91
12	0.91	37	0.84	62	0.88	87	0.88	112	0.94
13	0.66	38	0.47	63	0.47	88	0.84	113	0.92
14	0.46	39	0.86	64	0.95	89	0.89	114	0.37
15	0.93	40	0.54	65	0.85	90	0.84	115	0.41
16	0.82	41	0.76	66	0.76	91	0.92	116	0.44
17	0.66	42	0.69	67	0.81	92	0.48	117	0.73
18	0.41	43	0.78	68	0.79	93	0.91	118	0.82
19	0.5	44	0.64	69	0.51	94	0.42	119	0.93
20	0.76	45	0.74	70	0.63	95	0.76	120	0.81
21	0.65	46	0.77	71	0.87	96	0.91	121	0.74
22	0.48	47	0.9	72	0.71	97	0.88	122	0.79
23	0.74	48	0.83	73	0.89	98	0.83	123	0.58
24	0.95	49	0.66	74	0.88	99	0.42	124	0.92
25	0.68	50	0.84	75	0.95	100	0.88	125	0.79

Source: Own computation (2016)

Questionnaire used for the study

Forms and Questionnaire developed for analysis of Technical Efficiency of wheat Production in Soro District

Name of the enumerator.....

Signature date.....

General socio-economic information

1. Household number (code).....

1.1. Name of household head..... Age.....

1.1.1. Sex: 1 Male 0. Female

1.1.2. Rural Keble Administration (KA)..... Locality (Gote).....

1.1.3. Marital status: 1. Married 2. Single 3. Divorce 4. Widowed

1.1.4. If married, do you have more than one spouse? 1. Yes 0. No

1.1.5. If yes, how many? -----

1.1.6. Education level: 1. Illiterate 2. Literate read and write 3. Educational level in grade.....

1.1.7. Religion: 1. Orthodox 2. Protestant 3. Muslim 4. Catholic 5. Other specify.....

1.1.8. Farming experience..... years

1.1.9. House types 1. Iron roof 2. Grass roof

1.2. Land holding

1.2.1. Own land holdings (timad).....

1.2.2. Rented in land (timad).....

1.2.3. Rented out land (timad).....

1.2.4. Land owed by means of sharecropping (timad).....

1.2.5. No of plots owned.....

1.2.6. Number of plots planted with wheat.....

1.2.7. Total size of own land covered by annual crops in 2015/16.....Timad

1.2.8. Total size of own land left for grazing in 2015/16 -----Timad

1.2.9. Total size of own land left uncultivated in 2015/16 -----Timad

1.2.10. Total size of own garden in 2015/16 ----- Timad

1.2.10. Soil type 1. Red 2.Black 3. Brown

1.2.11. Perception of fertility status of plots operated by the farmer

1. High 2. Medium 3. Low

1.2.12. Slope of the plots 1. Sloppy 2. Plain

2. Responsibility

2.1. Do you have any responsibility in the community? 1. Yes 0. No

2.2. If yes, what is your responsibility in the community?

1. Administrative 2. Social 3. Religious 4. Other specify.....

2.3. Do your responsibilities have a significant negative impact in farming activities?

1. Yes 0. No

2.4. How many days on average do you spend per week for these responsibilities?days

2.5. Who take care of the farming activities while you are doing these responsibilities?

1. Only family members

2. Hired workers and family members 4. Other specify.....

3. Number of family member's and age structure

No	Name	Sex	Age	Kinship	Education status	Occupation

Education 1) Illiterate, 2) Read & Write, 3. Grade in number.....

Kinship: 1. Head 2. Wife 3. Children 4. Labourer 5. Others specify

Occupation: 1. Full time farming 2.Part time farming 3. Student

4. Livestock Ownership

4.1. Do you have livestock? 1. Yes 0. No

If yes, fill in the following table

No_	Type of animal	Number		Approximate value in Birr	Remark
		Owned	owed		
1	oxen				

2	cow				
3	heifer				
4	calves				
5	donkey				
6	sheep				
7	goat				
8	hens				
9	horse				
10	beehives	modern			
		local			

5. Annual crops and annual income

No	Type of annual crop	Unit	Area in ha.	Annual income		
				Unit	Quantity	Value
1						
2						
3						

6. Perennial crops and annual income

No	Type of perennial crop	Unit	Area	Annual income		
				Unit	Quantity	Value
1						
2						
3						

7. Farm implements ownership in number and value

No	Farm implements	Unit	Quantity	Unit Price	Total Price
1					
2					
3					

8. Input (technologies) used in the production of wheat (2015/16)

8.1. Input technologies used in the production of wheat

Description (1)	Type/variety (2)	Unit (3)	Quantity (4)	Unit price (5)	Total cost (4*5)	Time of delivery	Area coverage (ha)
Seed							
Fertilizer	DAP basal						
	Urea –basal						
	Urea top dress						
Herbicide	Birr						
Pesticide	Liquid						
	solid						
Manure/compost							

Time of delivery: 1. on time 2. Late 3. Before (early or in time)

8.2. Human and ox labour input used in major farming activities

Date	Activities	Pair of Oxen		Human labor participated						Exchange or hireling labour	
		1	2	Children		Men		Women			
				1	2	1	2	1	2	1	2
	Ploughing (1 st)										
	Ploughing(2 nd)										
	Ploughing(3 rd)										
	Ploughing(4 th)										
	Ploughing(5 th)										
	Sowing										
	Top Dressing										
	Weeding(1 st)										
	Weeding(2 nd)										
	harvesting										
	Others										

1. Number 2. Time

9. Wealth condition & off-farm activities

9.1. What is the relative wealth position of the farmer? (Personal and peer group wealth ranking)

1. Very rich 2. Rich 3. Medium 4. Poor 5. Very poor

9.2. Type of the house 1. Grass cover 2. Corrugated iron

9.2.1. If the house is built with corrugated iron number of corrugated iron -----

9.3. Do you have horse /mule for personal transportation 1. Yes 2. No

9.4 Do you have any source of income other than farming?

1. Off/non-farm activity 2. Pension payments

3. Remittance from relatives 4. Salary/wage

5. Rent from asset or real estate 6. Other specify 7. None

9.5. If you have other source of income, how much average revenue do you get per month and per year?-----Birr Per month and Birr per year

9.6. How much is the average expenditure per year/month?Birr

9.7. If you are doing off-farm activity, what is the type of activity?

1. Clothes making 2. Tailors 3. Carpenter

4. Trading 5. Ceramic 6. Other, Specify.....

10. Credit access

10.1. Have you got credit in 2014/15? 1. Yes 2. No

10.2. How much do you borrowed in the years 2014/15 for,

1. Fertilizer----- 2. Seed----- 3. Herbicide-----

4. Pesticide----- 5. For animal package----- 6. Farm implements.....

10.3. Of the total amount you have borrowed over the last year, how much did you repay.....

10.4. If it is not totally repaid, why?.....

The amount of borrowing in 2015/16 cropping year

No	Purpose	Amount borrowed	Source	Type of disbursement	Remarks
1	Fertilizer purchase				
	DAP				

	Urea				
	Others				
2	Seed purchase				
3	fattening				
4	Livestock production				
5	Poultry improvement				
6	Beehives improvement				
7	Other productive purposes				
8	Consumption				

Source: 1.Cooperative 2.Money lenders 3.Omomicrofinance

4. Agricultural Development Office 5. Merchants 6.Vision fund 7. Others.....

10.5. How much did you borrow for wheat production?

1. Fertilizer----- 2. Seed----- -3.Herbicide.....4. Pesticides-----

10.6. Of the total amount you borrowed over the last year, how much proportion did you repay?

10.7.If it is not totally repaid, reason for that-----

10.8.What are the main problems regarding credit institutions if there are any?

11. Extension Service

11.1. Do you know about the current agricultural extension program? 1. Yes 0. No

11.2. If yes, are you participant of the current extension program? 1. Yes 0. No

11.3. Do you know the development agent in your area? 1. Yes 0. No

11.4. Frequency of contact with DA? 1. Once in a week 2. Once in a two weeks
3. Once in a month 4. Other specify

11.5. Where do you meet DA? 1. At his office 2. At your farm
3. At the church 4. At public meeting

11.6. When did you start getting extension service? -----

11.7. Have you got extension service on wheat production this year? 1. Yes 0. No

11. 8. Have you got any practical training over the last two years? 1.Yes 0.No

11.9. Have you got practical training on wheat production? 1.Yes 0.No

11.10. If yes, what type of training -----and duration-----

12. Farming practices

12.1. Land preparation 1. Good 2. Medium 3.Bad

12.2 Vegetative growth 1. Good 2. Medium 3.Bad

12.3.Weed infestation 1.High 2.Medium 3.Low

12.4. Dominant weeds 1. Grass weeds 2. Broad leaves 3.Mixed

12.5. Are there soil conservation structures built on the land 1. Yes 0. No

12.6. Type of soil conservation structures

- | | | |
|--------------|----------------------------|-----------------|
| 1. Soil bund | 2. Stone bund | 3. Cut of drain |
| 4. Check dam | 5. Agro-forestry Practices | 6. Others..... |

13. Production activities

13.1. What are major annual crops you grow?

- | | |
|----------------|------------------------|
| 1. Wheat | 3. Maize |
| 2. <i>Teff</i> | 4.Barley 5.Others..... |

13.2. How much of your land is covered by wheat crop this year?

13.3. What are the major varieties of wheat you are growing?_____

13.4. What is the earliest date of land preparation for wheat?-----Week of-----month.

13.5. What is the latest date of land preparation for wheat crop?-----Week of ---month.

13.6. At what time did you start land preparation this year?-----Week of -----month.

13.7. How many times do you plough your wheat land?-----

13.8. What is the earliest date of sowing wheat? -----Week of -----month.

13.9. What is the latest date of sowing wheat? -----Week of -----month.

13.10. At what time did you sow wheat this year?-----Week of-----month.

14. Yield, marketing and crop rotations

14.1. How much quintals of wheat did you get last year?

14.2. What amount did you sell?..... Where.....When.....

14.3. How is this year's output as compared to previous year's output?

1. Better 2. Same 3. Worst

14.4. What is the best crop rotation from your experience?

1. Wheat 2..... 3..... 4..... 5.....

14.5. Is weeding wheat crop a common practice? 1. Yes 0. No

14.6. If yes, when you start weeding wheat? -----Week of -----month

14.7. How many times do you weed? -----times.

14.8. What method do you use for weeding?

1. Hand weeding 2. Hoeing

3. I use chemical 4. Others, specify-----

14.9. Do you use improved wheat varieties this year? 1. Yes 0. No

14.10. If yes, source of the seed

1. Own source

2. Exchanged from other farmer

3. Government seed distributors

4. NGOs

5. Others.....

14.11. How many quintals of wheat yield did you received this year?-----Qt

14.12. How much did you sell it per Kg-----Birr or per quintal-----Birr

14.13. Is there any natural hazard in the production year in the production of wheat?

1. Yes

0. No

14.14. Natural and artificial hazards

1. Storm

2. Frost

3. Flood

4. Drought

5. Animal damage

6. Others.....

14.15. How much output you would have got, had there were no hazards?..... quintal

15. Problems in the production of wheat (in order of their importance)

15.1. Low fertility of the soil

15.2. Low productivity of local varieties

15.3. High weed infestation

15.4. Poor land preparation, due to shortage of oxen or other

15.5. Shortage of rain

15.6. Water logging

15.7. Flooding

15.8. High wheat disease & pest, specify the type of disease &/or pest

15.9. Others, if any.....

16. Land owed through sharecropping and hiring

16.1. If the land is rented, how much did you pay?

16.2. If sharecropping, who covered the following expenses?

- | | | |
|--------------------------------|-------|--------------|
| 1. Input (fertilizer and seed) | 1. Me | 2. The owner |
| 2. Human labour | 1. Me | 2. The owner |
| 3. Ox labour | 1. Me | 2. The owner |

16.3. Amount of output allotted to operator farmer

16.4. Who made decision regarding to the following issues

- | | | |
|------------------------------------|-------|---------------------|
| 16.4.1. Type of crop | 1. Me | 2. The owner farmer |
| 16.4.2. Type & amount of input | 1. Me | 2. The owner farmer |
| 16.4.3. Time of farming activities | 1. Me | 2. The owner farmer |