

**TECHNICAL EFFICIENCY OF SORGHUM PRODUCTION THE CASE
OF MELKA BELLO DISTRICT, EAST HARARGHE, OROMIA
NATIONAL REGIONAL STATE, ETHIOPIA**

MSC THESIS

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Hararghe, Oromia National Regional State, Ethiopia**

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ABBREVIATIONS AND ACRONYMS

AE	Allocative Efficiency
ATA	Agricultural Transformation Agency
CSA	Central Statistical Agency
DAP	Di Ammonium Phosphate
DAs	Development Agents
DEA	Data Envelopment Analysis
EE	Economic Efficiency
GTP	Growth and Transformation Plan
HID	Household Id
MD	Man-day
MLE	Maximum Likelihood Estimation
MoA	Ministry of Agriculture
MoFED	Minister of Finance and Economic Development
NBE	National Bank of Ethiopia
NPSB	Nitrous Phosphates Sulphur Boron
OD	Oxen Day
OLS	Ordinary Least Square
SFA	Stochastic Frontier Analyses
SFP	Stochastic Frontier Production
SRS	Simple Randomly Sampling
TE	Technical Efficiency
TLU	Total Livestock Unit
VIF	Variance Inflation Factor

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Technical Efficiency of Sorghum Production in Melka Bello District, East Hararghe, Oromia National Regional States, Ethiopia

ABSTRACT

In the last two decades, the smallholder crop production in Ethiopia has enjoyed relative growth in acreage, output, and number of growers, but productivity has remained low. In Ethiopia, there are different empirical studies on efficiency analysis in different agro-ecologies, the results shows that there is significant difference in technical efficiency and inefficiency variables. What is scarce in the literature is that their conclusion is not consistent with one another. Therefore, this study estimates the technical efficiency of sorghum farmers and identifies their determinants in Melka Bello District, East Hararghe, Ethiopia. The primary data collected from 138 randomly sampled sorghum-producing households during 2019/2020 production year were employed for analysis. Cobb-Douglas frontier model with inefficiency variables were estimated by maximum likelihood method. The result indicated that mean technical efficiency of the farmers in the production of sorghum is 76%. This reveals that there exists a possibility to increase the sorghum output by 24% by existing resources and technological level. The discrepancy ratio gamma (γ) was to be 89.5%, which measures the relative deviations of the sorghum output from the frontier due to individual inefficiency. This implies that about 89.5% of variations in sorghum production farmer were attributed to technical inefficiency. The maximum likelihood parameter estimates showed that the amount of seed, land, oxen day, Npsb fertilizer, and labour forces were positively and significantly influenced sorghum output. The inefficiency parameters shows that extension contact, fertility status of soil, age, education, soil and water conservation negatively affect technical inefficiency. The implication is that improvement in these variables reduces technical inefficiency. However, TLU positively and significantly affected the level technical inefficiency. Hence, local government should be provide a necessary supports to farmers such as formal as well as informal education, extension visits, soil managements and conservation.

Keywords: Cobb-Douglas, Melka Bello, Sorghum, Stochastic frontier analysis, Technical efficiency

1. INTRODUCTION

1.1. Background of the Study

Agriculture in Ethiopia is based on rain-fed, however, it plays an important role in Ethiopian political, economic, and social development which makes the sector extremely sensitive. Most of the country's population is critically dependent on agriculture for their livelihoods (FAO, 2017). It contributes a 72% to rural employments, about 90% of export earnings and supplies about 70% raw material for industries. However, over the past 15 years, the contribution of the sector to economy has fallen as compared to other sectors (WFP, 2019). For example, its contribution to Growth Domestic Product (GDP) was dropped to 33.3% in 2018/19 from 34.9% a year ago, but slightly lower than the goal of Growth and Transformation Plan II (GTP II) target of 34.4% to GDP (NBE, 2019). The lion's share of agricultural sector was crop production accounted for 64.8% to GDP.

In Ethiopia, cereal crops are the major food sources in terms of both area coverage and volume of production and were about 81.39% and 87.97% respectively in 2018/19. In the same year, total cereal crop yield increased at a rate of 3.68% (CSA, 2019). The report indicates that increasing production was due to cultivating more lands. Inversely, the Ethiopian population will be exceed 133.5 million by the year 2032 (Alemayhu and Yihunie, 2014). Cereals are predominantly produced by smallholders and are consumed as food, and the by-products are fed to livestock (FAO, 2017). There is continued governmental investment in improved seeds, fertilizers supply and mechanization support as it has been demonstrated and realized by extent extension activities to increases cereal productivity. However, still more than 22% of the population proportion living below the poverty line in 2018/19, which may be answered by raising crop productivity (NBE, 2019).

Sorghum is the single most important staple crops in drought prone areas of eastern and northwestern parts of Ethiopia (WFP, 2019). It accounts for the third largest share of total cereal crop production preceded by maize and *Teff* in terms of both area and production volumes. In past ten year, the area under sorghum crops was increased by 19.6%, which is below national demands. Consequently, the average productivity was increased from 17.38 to

27.45 qt/ha, which is relatively low as compared with the target of 35 qt/ha in 2020. Evidences indicate that sorghum productivity has been driven by increasing in cultivated area (CSA, 2019). Despite its notable growth in production of sorghum, the drivers of this growth are not well-understood (Dawit *et al.*, 2017).

In Oromia National Regional State, among cereal crops sorghum production is most important crops that leads its contribution to country in both area and production volumes of 39 and 40.9% respectively. Out of total land allocated for cereal crops in the region of 4.85 million ha, the sorghum positioned in fourth by covering 14.8% of the total area (CSA, 2019). The region's sorghum productivity was 28.56 qts/ha, which is higher than the national average of 27.36 qts/ha. Even though the region is performing many extension services to smallholders, its productivity was not reached to its maximum potential. There is zonal disparity in sorghum productivity within the region Agricultural Transformation Agency (ATA, 2017/18).

East Hararghe Zone has been known for many years as the production deficit area. According to CSA (2019) reports, sorghum is the most grown crop production among cereal crops followed by maize and wheat and by covering 0.142 million ha of lands, sorghum positioned in first by covering 65.21% of the total areas followed by maize, and wheat. In 2018/19 production year, the production of 4.19 million qt and average productivity of 29.43 qts/ha from 0.52 million private peasant holdings in *meher* season which is high as compared to 28.56 qts/ha regional and 27.36 qts/ha national level of productivity (EHZOA, 2019).

In the study area, there is potential of resources for sorghum production to feed the population. In this area depending on the rainfall, several hectares are grown annually. However, sorghum productivity and their determinants are not well understood. The total sorghum production of the 2017/18 production year was 118,540 qts while in the 2018/19, it was 120,133 qt and the land allocated for sorghum was increased from 9,241 to 11,183 ha respectively, which is below the level to feed the whole people in study area. This is low as compared with the national and regional mean yield figures of 27.36 and 28.56 qt/ha respectively as 16.63% proportion of district's household under food insecurity (DODRM, 2019).

1.2. Statement of the Problem

In Ethiopia agricultural output 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).

Sorghum crop is grown mainly under conditions of low moisture stress, which affects its efficiency of fertilizer uptake. Moreover, the dry areas increase the risk of crop failure and, because of this; Ethiopian farmers are unwilling to apply fertilizer to sorghum (Mitaru *et al.*, 2012). Farmers are utilizing inorganic fertilizer in the eastern Ethiopia even though the level of utilization is different between households, which results in variation of crop productivity along with other factors (Muhammed, 2020). Low rate of inorganic fertilizer application contributed to low productivity of sorghum (Nebyou and Muluneh, 2016).

Sorghum accounts for an average 10% of daily caloric intake of households living in the eastern and northwest areas of Ethiopia. Total production was produced 54.24 million qt comprising about 18% of the total cereal production (NBE, 2019). Even though, average yield has been rising from 25.25 qts/ha in 2016/17 to 27.36 qts/ha in 2018/19 which is far below the potential yield of the crop (CSA, 2019). This is a low-yield as compared to global average productivity of 32 qts/ha (Hailegebrial and Adane, 2018). Despite the significant growth in sorghum productivity, there is still low productivity of farmers as a use of modern technologies and traditional farming system constraints in producing more yields (Kifle *et al.*, 2020). This low yield has made smallholder farmers unable to meet the high food demand. This makes the country as net importer of sorghum beside resources (Rashid and Negassa, 2011).

The study area was known by production of many cereal crops. Sorghum dominates most of the cultivated land and chooses by the farmers due to it's the potential to many climatic changes. However, the farmer level of resource utilization and its determinants not researched. Crop output gap among the farmers that might be attributed to many factors such as lack of

knowledge and information on technologies and recently reduced supports from extension services coupled with poor management, biotic, climate factors and more others (Beyan *et al.*, 2013). Similar to these, the study area is stick to farming, without access to off-farm activities for generating additional income, improved technology and employment opportunities to cope up with dynamic environments attributed to variation of productivity between farmers (DOA, 2019).

The major emphasis of the governments of Ethiopia is chooses introducing new technologies as prior method to increase production and productivity (Endrias *et al.*, 2013). Farmers were forced to sell their fixed assets including their livestock, and even tortured by their leaders including extension agents in behaves of buying of modern inputs. The distribution of modern inputs such as fertilizers and improved seeds are limited to rationing among farmers based on cash on their hands. This approach discourages farmers to use efficiently modern technology and wastes productivity potential of their farmlands to produce more, even if it is assumed as increases productivity as recommended so far (Alemayehu *et al.*, 2011).

The study of Danso-Abbeam *et al.* (2012) indicated that farmers in different agro-ecologies have different socio-economic backgrounds and resource endowment, which might affect their resource use efficiency differently. In Ethiopia, there are different empirical studies on efficiency analysis in different agro-ecologies, the results shows that there is significant difference in technical efficiency and inefficiency variables. What is scarce in the literature is that their conclusion is not consistent with one another. Therefore, policy implications drawn from those empirical works also may not allow in designing area specific policies to be compatible with its socio-economic as well as agro-ecologic conditions. Thus, this study has attempted to generate information for policy implication by identifying factors that are associated with technical efficiency in sorghum production, which is lacking in the study area. Therefore, the study filled this information and knowledge gaps.

Moreover, some research questions should be answered. These include: What is the level of technical efficiency of sorghum producing farmers in the study area? Is there any major difference in technical efficiency in sorghum production among farmers of the study area? What are the factors that cause efficiency variations of sorghum farmers in Melka Bello

district? And is there an opportunity to increase output of sorghum by improving the level of technical efficiency?

1.3. Objectives of the Study

The general objective of this study is to analyze the level of technical efficiency of stallholder sorghum producer in the Melka Bello District.

The specific objectives of the study were:

1. To determine the level of technical efficiency of sorghum production, in Melka Bello District
2. To analyses the factors that affect technical efficiency level of sorghum producers in Melka Bello District

1.4. Scope and Limitation of the Study

This study focused on technical efficiency in sorghum production during *meher* season in Melka Bello district, using cross sectional data of the 2018/19 production year collected from 138 smallholder farmers producing sorghum. Technical efficiency obtained using the frontier method is the relative efficiency of sampled households to the best practices employed cross-sectional data of the study area. The study was limited to the analysis of technical efficiency of sorghum production without regard to allocative and economic efficiency. In addition, the study determined the factors affecting technical efficiency of the above mentioned farmers. Since it was used cross-section data at point in time, the study does not show any inter temporal differences in technical efficiency level of sorghum producer.

Furthermore, this study was limited to Melka Bello district, which is found in East Hararghe Zone of Oromia National Regional State. The efficiency scored of the frontier is only comparative to the best farmers of the sampled household was used as best practices for studied area only. Since technical efficiency is the function of geographical location, the sampled households was selected from only the study area otherwise may be biased the results.

1.5. Significance of the Study

This study to analyze of technical efficiency of sorghum producers and examines the factors that determine the variation of technical efficiency between farmers. It can play a significant role in providing useful information concerning technical efficiencies in production and by identifying those factors which were associated with efficiencies that may exist. It can also indicate an entry point for further policy interventions to technical efficiency of smallholder farmers. The view of the above-narrated importance of identifying the factors of inefficiency of production, the important of the study described as follows; first, the result will provide useful information for the government and policy makers regarding the key factors affecting production. Secondly, the study will also contribute to useful information for other grain crops that usually have similar production processes for farm households and helps in designing sorghum effective extension services in the context of the zone and region in addition to the study area. Thus, it will contribute to designing appropriate policies and strategies to increase sorghum production and productivity. Finally, it will serve as source for future empirical literature for scholars and students interested in the area of technical efficiency analyses.

1.6. Organization of the Thesis

The subsequent sections of the thesis are organized in five major chapters. Chapter one covers the background and justification of research, statement of the problem and research questions and, objectives of the study, significance of the study, scope and limitation of the study. The second chapter presents literature review of title of the study includes definition of concepts, theoretical framework, analytical framework of the study concerning the study addressed and followed by empirical reviews on technical efficiency, and conceptual framework of the study presented in this chapter. Chapter three presents the methodology used in the study. It gives description of the study area, methods of data collection, sources of data, sampling technique, and sample size determination, methods of data analysis and variable definitions with their hypothesis are briefly addressed. Chapter four is devoted to the presentation and discussion of the study results. The last chapter five winds up this study by drawing summary, conclusion, and recommendations based on the findings of the study.

2. REVIEW LITERATURE

In this chapter, three critical issues are stipulated. First, definition of key terminologies and working concepts was discussed. Secondly, theoretical, methodological/analytical, and conceptual frameworks of the study were carefully articulated. Finally, a through empirical review of literature and conceptual framework of the study are presented.

2.1. Definition and Concept Notes

Ethiopian farms have two major group of farmers: smallholder farmers and large commercial farmers. Smallholders and larger farms are defined as those that cultivate less and more than 25.2 ha respectively. The majority of farmers in Ethiopia are smallholder farmers. Sixty percent of smallholders in Ethiopia cultivate less than 0.90 ha of land (Alemayehu *et al.*, 2011). However, there is no unique and unambiguous definition of a smallholder. Often scale, measured in terms of the farm size is used to classify farmers into small and large. Smallholder families live in farms, which in many countries are significantly smaller than two hectares. For example, the average size of a smallholder farm in Bangladesh and Viet Nam is 0.24 and 0.32 ha respectively. In sub Sahra African countries, the smallholder farms can be relatively larger, but only marginally. For example, Kenyan smallholders farm on average holds 0.47 ha per households and in Ethiopia the average small farm size is 0.9 ha (FAO, 2015).

In microeconomic theory a production function is defined in terms of the maximum output that can be produced from a specified set of inputs, given the existing technology available to the firms involved (Battese, 1992). The production function of firms are conceptually a frontier of potential attainment for given level of input combination (Farrel, 1957). Production is basically process of transformation a set of inputs into a set of outputs. In other cases, the term production also defined as the the art of organized activity and transforming resources into finished products in the form of goods and services for the end consumption (Fried *et al.*, 2008).

The term efficiency is defined in terms of a comparison of two components (inputs and outputs), the highest productivity level from each input level is recognised as the efficient

situation. Similarly the term efficiency is described as the ability of firm's production to attain the optimum level of output from a given bundle of inputs (Farrell, 1957). Coelli *et al.* (1998) further suggest that efficiency reflects the ability of a firm to obtain maximum output from a given set of inputs. In short, the current state of technology in an industry represented by production frontier, the firms in that industry would be operating either on that frontier, if they are fully efficient or beneath the frontier if the firms are not efficient. Hence, technically efficient firms are those firms that are operating on the production frontier that represents the maximum output attainable from each input level (Coelli, 1995).

Farrell (1957) stretched on the effort of Debreu (1951) by suggesting that economic efficiency (EE) is made up of two components that are a technical efficiency and allocative efficiency or price efficiency (AE). The concepts of technical efficiency of firms in the production relate the observed level of output to ideal or potential level of output. In other words, it measures the maximum attainable level of output that can be resulted from best practice and optimal combinations of inputs (Battese, 1992). In principle, technical efficiency implies maximizing level of output produced with given the cost production. In other words, AE shows producer's success in choosing optimal set of inputs consistent with relative factor prices prevailing in the market. When a firm fails to choose an optimal combination of inputs at a given level of prices, it is said to be allocatively inefficient, though it may be technically efficient (Coelli *et al.*, 1998). To maximize the profit of output production, farmers have to choose the best combination of inputs given the prices of inputs and output. Finally, economic efficiency of firm is the multiplicative product of technical and allocative efficiencies (Fried *et al.*, 2008).

The concepts of productivity and efficiency have received a great deal of attention in many countries, since growth of productivity and efficiency affects national income and inflation, thereby affecting quality of life of individuals and closely related with that of efficiency (Battese, 1992). Hence, many governments, economists and professional researchers are concerned with defining and measuring concepts of productivity and efficiency. According to Coelli *et al.* (1998), the concepts of productivity explained as the relationship between the amount of input and output in a given production process. It does not merely define the volume of output, but output obtained in relation to input utilized in production. Conversely, the concept of efficiency shows the quality of achieving something without resource waste. As

illustrated in Figure 1, the concepts of production frontier and technical efficiency of firms are described as a simple production process involving a single output (Y) and a single factor of production X) (Coelli *et al.*, 1998).

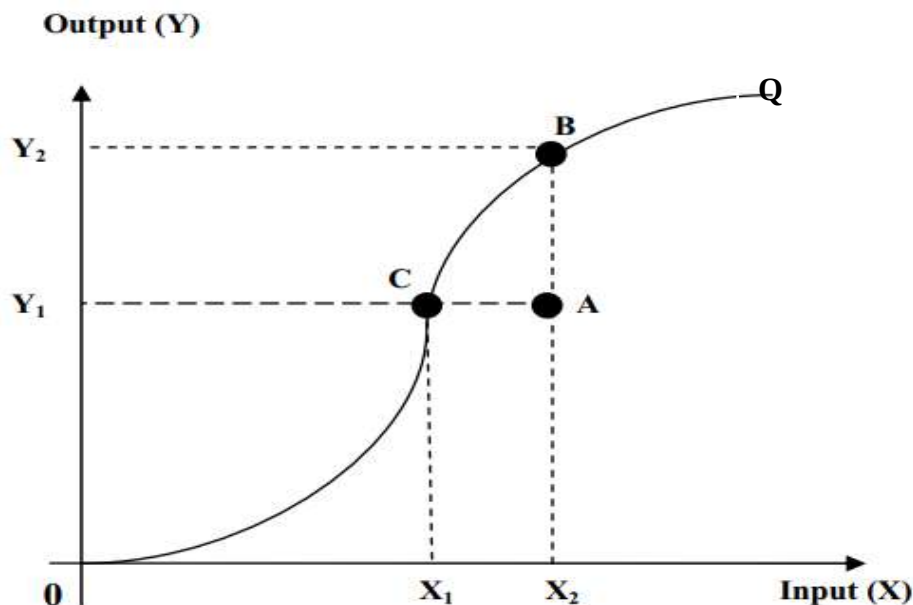


Figure : Relationship between production frontier and technical efficiency

As shown in Figure 1, OQ is the production frontier as defined earlier to measure technical efficiency. If the firm operating at point A was to move to efficient point B, which is a technically efficient point, there would be higher productivity. However, if the firm could reach point C, which is at a tangent to the production frontier, it would be at maximum possible productivity; C indicates the point of optimal scale of productivity. A technically efficient farmer is that who produce outputs on the production frontier are operating at maximum possible productivity while those who produce below OQ are considered technically inefficient (Farrell, 1957).

The existence of technical inefficiency of firms that engaged in production has been a subject of considerable debate in neo-classical economics. Thus, firms that operate at point B and C are considered technically efficient firms since they produce on frontier implies that the resources were efficiently utilized. The farmer operating at points C and A both are produces the same output level Y_1 by using different amount of input (X_1). This means having equal

resources their production variability across farmers. Any deviation from this maximal output is considered as technical inefficiency (Coelli *et al.* 2005). Farrell (1957) suggested that one could usefully analyze technical efficiency in terms of realized deviations from an idealized frontier isoquant. Inefficiency is the fundamental economic concept that the existence of a frontier functions in which the distance below production frontier or best practices represents the inefficiency of the economic agents. Inefficiency occurs when a given set of inputs produces less output than what is possible given the available production technology. Inefficient producer could produce the same outputs with less of at least one input, or could use the same inputs to produce more of at least one output (Koopmans, 1951; Fried *et al.*, 2008). This approach falls naturally into an econometric approach in which inefficiency is identified with disturbances in a regression model.

2.2. Theoretical Framework of the Study

Theory of production function is the most widely used concept in the mainstream subject economics. 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.

Theoretical work measurements in production efficiency was began in the 1950s. Koopmans (1951) provided a definition and concepts of technical efficiency. In neoclassical economics theory, it assumes that any producers in an economy always operate in efficiently ways, however in real terms producers are not always fully efficient, there is variation of production in different environments. This difference may be explained both in terms of efficiency of each producer, as well as in terms of unforeseen exogenous shocks/ noise outside the producer control (Kokkinou, 2010). Due to this fact, a theoretical framework of Farrell (1957) was guided the analysis in this paper.

The stochastic frontier production (SFP) model is motivated by the theoretical base idea that no any economic agent can exceed the ideal “frontier” production level, and deviations from

this extreme potential represent both individual inefficiencies in production and symmetric error terms. Standing from the statistical point of this view, in this study, the idea has been implemented by specifying a regression model that characterized by two composite error terms. The classical idiosyncratic disturbance, aiming at capturing measurement error and any other classical noise, the other part is included with a one-sided disturbance that represents inefficiency of producer, which is not possible in non-stochastic model (Battese and Coelli, 1995). This is why the main techniques employed in the paper were stochastic frontier model.

The framework to this paper lies in the fact of obtaining optimal estimates of the technical efficiency for the sorghum farmers in Melka Bello District, Eastern Ethiopia. The technical efficiency of producer can be obtained through different ways of measurement. To be able to use this approach, one has to estimate the given output quantities, which has historically been obtained by setting up a production function. The production function is given the input vector x_i for a producer i^{th} , the production function maximum $(x_i; \beta)$ is the technical maximum (potential) outputs. When the farm produces at the best production frontier, it is efficient. Not all farmers produce maximum output even if they have the same inputs or they may produce less than or equal to maximum $(x_i; \beta)$ and ratio of individual output y_i to maximum output $(x_i; \beta) = \text{one}$ which is defined as technical efficiency.

The two commonly used functional forms of the stochastic production function are the Cobb-Douglas and the translog widely was used in the recent topics literatures. The Cobb-Douglas production function is still today representing the unique form in many theoretical and empirical analyses of growth and productivity of different sectors since it is the model relative to the less restrictive functional form. The Cobb-Douglas production function in logarithmic form is linear in the parameters and this makes it the general framework of linear statistical analysis, as is quite familiar (Afriat, 1972). Coelli *et al.* (1998) suggested that translog functional form may imposes no restriction upon returns to scale; however, it is very vulnerable to multi-collinearity and high degree of freedom. It is noted that the Cobb-Douglas is nested within the translog form if all the square and interaction terms in translog turn out to be equal to zero. Therefore, Cobb-Douglas production function was estimated the production function in this study using parametric method. However, Koop and Smith (1980) were

indicated that functional forms have a distinct but rather small impact on estimated technical efficiency.

The literature suggests two methodological approaches for analyzing determinants of technical efficiency based on stochastic production functions. The first approach is the sources of the two-stage estimation procedure in which first the stochastic production function is estimated, from which technical efficiency scores are derived. In the second stage, the derived technical efficiency scores are regressed on explanatory variables using ordinary least square methods or Tobit regression, which contradicts the assumption of identically, distributed inefficiency effects in the stochastic frontier. 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 on the explanatory variables under the assumption that these inefficiency effects are identically distributed. The second approach advocates a one-stage simultaneous estimation approach as in Battese and Coelli (1995), in which the inefficiency effects are expressed as an explicit function of a vector of farm-specific variables. Therefore, in this study a single-stage maximum likelihood estimation (MLE) procedure was specified in obtaining both the parameter of production function and inefficiency effect model.

2.3. Analytical Framework of the Study

Since Farrell (1957) seminal paper, there has been a rising of interest of many researchers in methodologies and their applications to efficiency measurement for firms. While early methodological application is based on deterministic models, which revealed that attribute all deviations from the maximum/potential production to inefficiency of producer. However, recently many advances have made that it possible to separate account for factors beyond farmers and within the control of firms such that only the latter will cause inefficiency of the firms. Aigner *et al.* (1977), and Meeusen and van den Broeck (1977) independently proposed the stochastic frontier production function to account for the existence the individual measurement errors in processes and other noise in the data measurements, which are beyond the control of firms.

The variation of actual output from the frontier due to inefficiency and random shocks can be captured through stochastic frontier approach. The existence of inefficiency in crop production comes from inefficient use of scarce resources. There exist two main competing methods for analyzing technical efficiency and its principal determinants: the parametric frontier, stochastic frontier approaches (SFA) and the non-parametric frontier Data Envelopment Analysis (DEA). Non-parametric frontier suffers from the criticism that it takes no account of the possible influence of random shocks like measurement errors and other noises in the data (Coelli, 1995). Therefore, this study reasonably specified the last model that constitutes both one-sided error term and factors beyond farmers.

2.3.1. Non-parametric (DEA) models

Non-parametric efficiency model also referred to as DEA. The non-parametric/mathematical programming model estimation will be applied in different sectors such as agricultural productions as one measure of technical efficiency. Linear-programming-based measures of efficiency that first developed by Farrell (1957) and more expanded by Charnes, Cooper and Rhodes (1978) is called DEA. It is called non-parametric, as it does not require an explicit functional form as a case of parametric model and it constructs the frontier from the observed input-output ratios by applying linear programming techniques. Another characteristic of this model is that it has potential sensitivity analysis for technical efficiency scores to every the observation. In non-parametric frontier model, technical efficiency is defined as minimum input for any particular combination of output produced. Similarly, DEA methods could be used to obtain estimates in the case of multi-input, multi-output production technology simultaneously (Coelli and Walding, 2005).

Coelli *et al.* (1998) stated that in agricultural production especially in developed countries, in which controlled production environments and where the quality of inputs and outputs does not vary from firm to firm level, in that case DEA estimation would be the preferred method of estimation than parametric methods. In developed agriculture in which record keeping might be accurate, and while many outputs and factors of production are often homogenous specially in broad acre agriculture, the uncontrollable impact of weather condition on outputs and resource quality on production is possible to contribute to the statistical noise in the data.

However, the main criticism of this model is that it attributes all deviations from the frontier to inefficiency (Coelli, 1995). Therefore it not applied in this study due to discussed difficulties.

This non-parametric model enables to estimate frontier production with the use of non-parametric programming model leading to a ranking of all unit observations based on efficiency scores. The focus is not on the estimation of an average technology production function was used by all units analyzed but to identify the best practicing units. Coelli *et al.* (2005) expressed as a decision-making units that employs less input than another to produce the same amount of output be considered as more efficient. The efficiency frontier is constructed by linear segment that join up those observations with the highest ratio of output to input. The econometric results suggest that stochastic frontier models generate lower mean TE estimates than non-parametric deterministic models, while parametric deterministic frontier models yield lower estimates than the stochastic approach (Bravo-Ureta *et al.*, 2007). However, Resti (2000) concluded that there is no clear advantage of one method over the other.

2.3.2. Parametric model

The parametric methods involve econometric modeling of the production process and it requires a priori assumptions on the functional form of the production function and distribution of the inefficiency components. The common functional forms of the production function based on current literature are the Cobb-Douglas and Translog functional forms are well known. The distribution assumption of the non-negative components includes half-normal, exponential, truncated normal and gamma distribution. The main criticism against using these distributions for decomposing the residual is that there is often not any priori theoretical justification for selecting any of these distributions. Aigner *et al.* (1977), Meeusen and van den Broeck (1977) independently proposed the stochastic frontier production function to account for the presence of measurement errors and other noise in the data, which are beyond the control of firms.

In the agricultural production, the stochastic frontier approach has widely preferred methods, of efficiency measurements. This is probably associated with a number of factors. The assumption that all deviations from the best practices are associated with inefficiency, as

assumed in DEA, is difficult to accept the assumption, given the inherent variability of agricultural production, due to existence of factors beyond a farmer, especially in developing countries. Thus, much available data on production are likely to be subject to measurement errors (Coelli and Battese, 1996). Apparently all functions used in the parametric technique have the classical convexity and monotonicity properties so the classical production function appears to be the basic model, regardless of the further restrictive properties encountered. The advantage of Battese and Coelli (1995) model is that it allows estimation of the farm specific efficiency and the factors explaining efficiency differentials among farmers in a single-stage estimation procedure. The present paper utilizes this model. Parametric estimation approaches divided into deterministic and stochastic models.

2.3.2.1. Deterministic frontier model

Deterministic frontiers are regression based and attribute all deviations from potential production to inefficiency without considering random error in the model. Deterministic frontiers may be estimated using Corrected Ordinary Least Squares (COLS). Unbiased estimates of the slope parameters in both estimation procedures are obtained using OLS followed by a correction of the intercept. The deterministic model expressed as follows:

$$Y_i = f(X_i; \beta) \exp(-\mu_i) \quad i=1, 2, \dots, N \quad (1)$$

Where:

i - is the number of sample farmer in the study, Y_i - represents the possible production level of i^{th} farmer, X_i is vector of input quantities used by farmers, β_i is vector of unknown parameters to be estimated, $f(X_i, \beta)$ is appropriate functional form Cobb-Douglas or Translog vector. Where μ_i is non-negative random variable associated with technical inefficiency added to the model and N represents the number of firms involved in a cross-sectional survey of the industry. The presence of the non-negative random variable, U_i in model (3), is associated with the technical inefficiency of the firm and it implies that the random variable, $\exp(-u)$, has values between zero and one. Thus it follows that the possible production, Y_i , is bounded above by the non-stochastic (i.e., deterministic) quantity, $f(X_i, \beta_i)$. Hence, the model (1) is

referred to as a deterministic frontier production function, which was first specified by (Aigner and Chu, 1968). There relationships are given as:

$$(Y_i) \leq f(X_i, \beta) \quad i=1, 2, \dots, N \quad (2)$$

The econometric model suggest that stochastic frontier models generate lower mean technical efficiency estimates than non-parametric deterministic models, while parametric deterministic frontier models yield lower estimates than the stochastic approach. In addition, frontier models based on cross-sectional data produce lower estimates than those based on panel data whereas production level to the frontier output for the i^{th} firm is Y_i^* in deterministic model.

$$TE = \frac{Y_i}{Y_i^*} = \frac{Y_i}{\exp(X_i \beta_i)} = \frac{\exp(X_i \beta_i - \mu_i)}{\exp(X_i \beta)} = \exp(-\mu_i) \quad (3)$$

According to Coelli *et al.* (1998) the weakness of this model is that, it takes random components as part of inefficiency. Therefore, a fundamental problem with deterministic frontiers is that any measurement error, and any other source of stochastic variation in the dependent variable, is embedded in the one-sided component. Therefore, outliers can have profound effects on the estimates and any shortcoming in the specification of the model could translate into increased inefficiency measures (Greene, 1993). Therefore, in this study it is not researcher choices.

2.3.2.2. Stochastic frontier model

Following the inadequacies of deterministic frontier estimation due to imposing particular functional form on underlying technologies, the most popular stochastic frontier analysis technique was independently proposed Aigner *et al.* (1977), Meeusen, and van den Broeck (1977). The stochastic frontier approach, as its name suggests, can cope with statistical noise, which may be present in the data because of measurement errors, missing variables, and variation in weather conditions in addition to inefficiency components. Hence, stochastic frontier models address the noise problem that characterized early deterministic frontiers.

Stochastic frontier approaches allows the one-side error term to be statistically insignificant, if the data might suggest so, thus encompassing the classical approach with a naïve assumption of full efficiency as a special case and, importantly, allowing this assumption to be tested. Moreover, the SFA approach also contains the other extreme where one assumes no statistical noise with all the deviations treated as inefficiency to the frontier. Thus, follow the SFA is a natural compromise between approaches that make two extreme assumptions, yet also encompassing them as special cases, which can still if the data and the statistical tests from SFA would not recommend otherwise (Kumbhaker *et al.*, 2018). The original stochastic model can be shown by following formula:

$$\ln(Y_i) = X_i \beta_i + v_i - u_i \quad i = 1, 2, \dots, N \quad (4)$$

Where:

$\ln(Y_i)$ -is natural log of output of i^{th} farmer;
 X_i - is input quantities used by the i^{th} farmer;
 β_i -is an unknown parameter to be estimated;
 v_i - is a symmetric component and permits a random variation in output due to factors beyond the control of farmers and assumed to be independently and identically distributed $N(0, \delta_v^2)$.
 u_i - intended to capture inefficiency effects in the production of sorghum measured as the ratio of observed output to maximum feasible output of the i^{th} farm. It is assumed to be independently, and identically distributed as half-normal (u_i, δ_u^2) . The individual technical efficiency level calculated as the following formula:

$$TE_i = \frac{Y_i}{Y^*} = \frac{f(X_{ij}; \beta) + V_i - \mu_i}{f(X_{ij}; \beta) + V_i} = \exp(\mu_i) \quad (5)$$

Where:

Y_i =is the observed sorghum yields for i^{th} farmers;
 Y^* is maximum/ potential output of sorghum yield for i^{th} farmer in survey, $i=1, 2, \dots, 138$.

According to Coelli (1995), stochastic frontier model has many advantages such as accounts the problems of noise; it estimates standard errors, which is used for test of hypothesis. In agriculture, there many factors that hinders farmer's efficiency that beyond control of farmers,

in this case, estimating the efficiency analysis using the non-parametric approach shows difference results when compared with the parametric approaches (Coelli *et al.*, 1998). They justified reasoning because the parametric approach accounts random variables that are uncontrollable factors in addition to measurement errors, which is inherent in agriculture production. Because of above argument, this study was employed a parametric stochastic Frontier introduced by (Aigner *et al.*, 1977) and (Meeusen and van den Broeck, 1997).

The parametric frontier uses econometrics method to estimate the parameters of both stochastic frontier production function and inefficiency effect model. The biggest advantage of stochastic frontier approach is the introduction of stochastic random noises that are beyond the control of the farmers in addition to the inefficiency effects. The difficulties with this approach are that it imposes explicit restriction on functional forms and distributional assumption for inefficiency error term (Battese and Coelli, 1995).

Another issue surrounding parametric frontiers relates to the choice of functional form. Trans log and Cobb-Douglas specifications are the most commonly used functional forms to measure technical efficiency. Each model have their own advantages and disadvantages, the Cobb-Douglas function form commonly used in the empirical estimation of frontier models due to its simplicity and very attractive feature. It characterized by constant elasticity's inputs, constant return to scale for all firms and elasticity's of substitution are equal to one. Translog functional form imposes no restriction upon returns to scale; however, it is very susceptible to multi-collinearity problems and high degree of freedom (Coelli *et al.*, 1998).

Several studies from both developing and developed countries have used the Cobb-Douglas functional form to analyze farm efficiency despite its well-known limitations (Battese, 1992; Bravo-Ureta and Pinheiro, 1993). According to Koop and Smith (1980), the functional form has a discernible but rather small impact on estimated parameters. Therefore, in this study, Cobb-Douglas production function was fit to estimate and compute the production function.

2.4. Approaches to Efficiency Measurement

The farmers output can be increased through increased inputs, increasing productivity of inputs or efficiency and the combination of the two. Hence, efficiency is a central issue in

production economics helping as a guide for allocation of resources (Farrell, 1957). Much empirical evidence indicates that, the productivity improvements can be achieved in two ways. The first, one can improve the state of the technology by inventing new technology that leads to an upward shift in the production frontier. The second methods, alternatively one can improve efficiency of the farmers to use the existing technology more efficiently that favorable for developing countries. Therefore, it is evident that increase in productivity achieved through either technological progress or efficiency improvement so that the policies required to address these two issues are likely to be quite different (Coelli, 1995).

Input oriented and outputs oriented are two approaches in measuring efficiency of the firms.

The output-oriented approach deals with the question “by how much output could be expanded from a given level of inputs? Alternatively, one could ask, “by how much can input of quantities be proportionally reduced without changing the output quantity produced?” This is an input oriented measure of efficiency. However, both measures will coincide when the technology exhibits constant returns to scale, but are likely to vary otherwise (Coelli and Battese, 2005).

2.4.1. Input-oriented efficiency measurement

Input oriented efficiency measurement addresses the question of ‘by how much can input quantities be proportionately reduced without changing the output quantities produced (Farrell, 1957; 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 are 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 illustrated in Figure 2. Two inputs x_1 and x_2 are represented on horizontal and vertical axes respectively. KK^* represents an iso-quant of a fully efficient firm. All points on this iso-quant represent technically efficient production. MM^* represents a budget line of firms engaged in production. Those firms who produce at point B^* , tangency point were economically efficient.

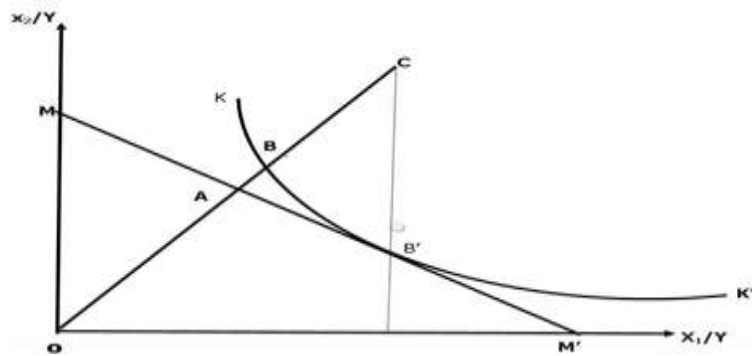


Figure : Input-oriented illustration of technical efficiency measurements

Assume a firm is producing at point C 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 C. This line crosses the iso-quant at point B. 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 C, does not use inputs efficiently. The technical inefficiency of the observed firm is represented by the distance BC, which is the quantity off all inputs, could be proportionally reduced without reduction in output. 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.

$$TE = \frac{OC}{OB} \quad (6)$$

The value of technical efficiency always lies between zero and one. A firm is technically efficient if it has technically efficiency equal to one, it means that production on frontier. If the value of technically efficient is less than one, the firm is technically inefficient.

2.4.2. Output-oriented efficiency measurement

The output-oriented measures of efficiency focuses on the changes in output of a firm that may achieved when using the same quantity of inputs. 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 4, 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 a given technology. 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 EE^* 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 from point B to the origin over the distance from the point C to the origin.

$$TE = \frac{OB}{OC} \quad (7)$$

The distance BC represents the level of technical inefficiency. It is the amount by which outputs could be increased without requiring extra inputs.

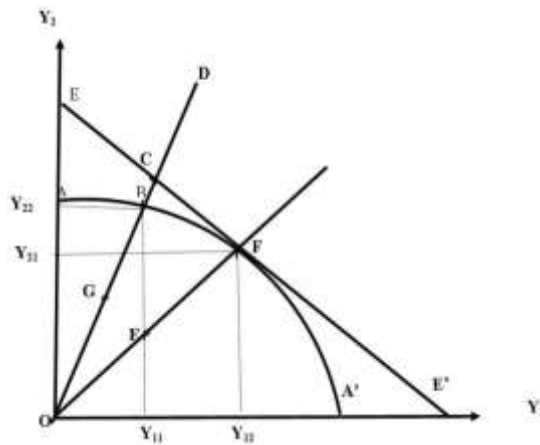


Figure : Output-oriented illustration of technical efficiency

Given the production possibility curve, a producing unit can then be located either exactly on the production possibility curve or below it. All producers on the curve have attained the maximum combination of Y_1 and Y_2 that can be produced given the input level and state of

technology. However, firms located below the curve are said to be inefficient. For instance, given the fixed amount of input and level of technology under constant return to scale firm G is producing lesser amount of both outputs than A. There is a possibility for firm G to increase the level of outputs Y_1 and Y_2 from Y_{11} to Y_{12} and from Y_{21} to Y_{22} , respectively, without requiring extra inputs. This proportion $(Y_{22} - Y_{21})/Y_{22}$, which is equal to $(Y_{12} - Y_{11})/Y_{12}$ is the level of technical inefficiency of firm, and thus technical efficiency is given by the following:

$$TE_D = \frac{OD}{OA} = \left(1 - \frac{Y_{12} - Y_{11}}{Y_{12}}\right) \quad (8)$$

2.5. Empirical Studies on Technical Efficiency

Abba (2012) analysed technical efficiency of sorghum production and its determinants in Hong local government area of Adamawa state. The estimated stochastic frontier production function shows that land, seed, and fertilizer were the important factors that affect sorghum output level. The estimated average technical efficiency is 72.62%. Farm specific variables such as education, household size and extension contact was positive and significantly associated with technical efficiency of farmers. It implies that farmers could increase output through intensive use of land, seed and fertilizer inputs given by the prevailing state of technology. Increasing variables education and extension services increases efficiency of farmers. It recommended policy interventions by the government in terms of better access to land, improved seed and fertilizer. The inefficiency effect also shows that improved farmer's educational levels through better education and literacy campaigns would help tremendously to increase efficiency.

Chepng'etich (2014) analyzed the technical efficiency of sorghum production in Kenya, using DEA model. Inputs such as seeds, fertilizer, pesticides, and labor increases output level. The overall average technical efficiency was 41% which is very low; the means for each district were about 43% and 48% for Machakos and Makindu districts, respectively. The study implies that farmers in these regions were not optimizing on their sorghum outputs mainly due to the fact that most of the inputs used for sorghum production were underutilized. Labour was the most underutilized resource compared with the other inputs used.

Zalkuwi *et al.* (2014) examined technical efficiency of sorghum production in Adamawa State, Nigeria, using cobb-douglas stochastic frontier production model. The estimated shows that farm size, family labor, seed and fertilizer were positive and significant at 1%, 5% and 10% levels while fertilizer was not significant. The estimated mean of technical efficiency was 68%; age, literacy level, gender and credit were positively, and significant affect the level of TE. Which implies that increasing significant variables by one unit increases farmers efficiency.

Musaba and Bwacha (2014) analyzed technical efficiency using Cobb-Douglas function in maize production in Masaiti District, Zambia. Land size and fertilizer were the significant factors that affected maize production. The estimated mean of technically efficient was 79.6%; age of farmer, cooperative membership, and farm size, have significant positive effects of technical efficiency. The seed types used, rotation practices, and education level of the farmer had negative effects on technical efficiency. The study implications are that to improve farm efficiency efforts should focus on access to improved inputs such as certified seed and fertilizer), information on agronomic practices, and farmer's education. Education has a positive relationship with technical inefficiency. The study recommended that an increase in the level of education would increase inefficiency or decrease efficiency.

A study of Mango *et al.* (2015) used SFA to analysis of technical efficiency in smallholder maize production in Zimbabwe. Maize output responds positively to increases in inorganic fertilisers, seed quantity, the use of labour and the area planted. The estimated mean technical efficiency was 65%; explanatory variables male household head, the frequency of extension services, and region of the faermer are positively associated with technical efficiency while household size negative associated with technical efficiency. The government could assist in improving the technical efcieny of the smallholder maize producers, who contribute more than 70% of national output, by ensuring better and more reliable support from extension services and empowering women farmers is essential.

Beyan *et al.* (2013) done the study analysis on technical efficiency of smallholder farmers in Girawa District of Ethiopia; Cobb-Douglas production function was fitted using SFA to estimate efficiency and identify sources of efficiency. Estimated Cobb-Douglas shows that

inputs labor, fertilizer, and organic fertilize positively and significantly affect output level while oxen and sedd negatively affect output level. The mean technical efficiency was 81.5%. The discrepancy ratio (γ), which measures the relative deviation of output from the frontier level due to inefficiency, implied that about 75% of the variation in output production was attributed to technical inefficiency effects; inefficiency model shows explanatory variables education, farm size, farmers' training, extension contacts, livestock holdings, and participation in irrigation were factors affecting efficiency. Social status has negative associated with technical efficiency. The study implication government should work on strengnting elder's education and increasing extension services to increase the efficiency of farmers. Improving training services also increases farmers education.

Endrias *et al.* (2013) by applying DEA model that the average technical efficiency of maize production in Wolaita and Gamo Gofa zones of Southern Ethiopia was found to be about 0.40. This indicates that there was a substantial amount of technical inefficiency in maize production. However, about 7.26% of the DMUs operated at greater than 90% technical efficiency level in maize production and they also investigated by applying tobit model to show that farm size and oxen holding were highly significant at affecting the technical efficiency of smallholder maize producers.

A study of Getahun (2014) assesed off-farm income and technical efficiency of smallholder farmers in Ethiopia using SFA. The average technical efficiency of farmers was 53%, implying the existence of wider scope for improvement of their efficiency. Results confirm the appropriateness of the Cobb-Douglas functional form of the production function over the translog and stochastic frontier analysis over the ordinary least squares. The estimation result indicates that variables household size, education of household head, soil conservation, extension services and off-farm income are major factors for differences in technical efficiency among farmers.

Wondimu and Hassen (2014) undertook a study on technical efficiency in maize production of smallholder farmers in Dhidhessa Woreda, Illubabor, Ethiopia. The estimated gamma parameters indicated that 73% of the total variation in maize output was due to technical inefficiency. The average technical efficiency was 86% while return to scale was 0.96%. Age,

education, improved seed, training on maize production and labor availability in the household negatively affect inefficiency while a number of livestock, market distance, and interaction of education and off farm income of livestock, market distance, and interaction of education and off farm income were affect negative and significant positive and significantly affect inefficiency .

A study of Musa *et al.* (2014) on technical efficiency of maize producing farmers in Arsi Negelle, Ethiopia using SFA. The estimated production frontier shows that DAP fertilizer, land, labor, seed and oxen are significant determinants of maize production level. The average technical efficiency of the individual farmers in the production of maize estimated to be 88%; inefficiency model results revealed that number of weeding, access to credit and frequency of extension contact positively affect the technical efficiency level while home distance to market and family size negatively affect technical efficiency level of the farmers in maize production.

A study conducted by Getachew and Bamlak (2014) in Horo Guduru Wollega, Ethiopia, to examine the level of technical efficiency of smallholder maize producers and identify its determinants in using Cobb-Douglas stochastic production function. Accordingly, the estimated production function shows that farm size, fertilizer (DAP) and seed are the major factors that are associated with changes in the maize output. The mean technical efficiency of households were to be 66%. The ages, education, extension contacts, off-farm activities, number of plots/ land fragmentation positively and significantly affect technical efficiency.

Hailemaraim (2015) estimated the technical efficiency of *teff* production in Bereh District, Oromia National Regional State using a Cobb-Douglas stochastic production frontier model. The mean level of technical efficiency of *teff* producers was about 72%. The variables fertility status of the farm, off-farm occupation, education level, credit service, and extension contact were found to increase technical efficiency significantly. However, the explanatory variables age, family size, number of farm plot, and total farm size were found to reduce farmers' technical efficiency.

The study of Hassen (2016) was assessed the level of technical efficiency and identify its determinants in wheat crop for smallholder farmers in south Wollo Zone; Ethiopia. A multi-stage sampling technique was employed to select 68 wheat growing sample households. The

average TE was 78%. The variables age of household heads, education level, access to credit, and oxen number were positively significant affect technical efficiency while off-farm income, number of livestock and distance to market were negatively.

Wudineh and Endrias (2016) also analyzed the technical efficiency and factors affecting efficiency of wheat production in Welmera district of Oromia region, Ethiopia. The stochastic frontier and translog functional form with a one-step approach were employed to analyses efficiency and factors affecting efficiency in wheat production. The results pointed out that the average technical efficiency was found to be 57%. The explanatoy variables sex of respondents, age and education level of household head, livestock holding, group membership, farm size, land fragmentation, tenure status, and investment in inorganic fertilizers affect efficiency positively and distance to all weather roads negatively affects technical efficiency.

According to the work of Tads' *et al.* (2017) carried out analysis technical efficiency of rice production in Fog era district, Ethiopia. The result shows that land, fertilizer, oxen, seed, and labor inputs were positive and significantly related to rice production. The mean score of technically efficient was 77.2% implying that there was opportunity for output increment by improving the resource use efficiency of households. The explanatory variables extension services, training, experience, agrochemicals, and education level positively and significantly determine technical efficiency and family size negatively and significantly to technical efficiency was reported.

Musa *et al.* (2018) evaluated the technical efficiency, EE, and AE of maize production in eastern Ethiopia. The stochastic production function, fitted using the Cobb-Douglas production function, indicated that the amount of seed, land and DAP are highly significant in determining maize production in the study area while urea fertilizer not significant associated with maize output. Mean technical efficiency was to be 82.24; inefficiency model shows variables such as off-farm activities, extension contact, being member of cooperative and using improved seed affect negatively affect the level of technical efficiency. While distance market found to be positively and significantly in influence the level of technical inefficiency.

A study of Kussie *et al.* (2019) in southern region, Konso district analyzed technical efficiency of smallholder sorghum producers. Land size, fertilizer, human labor, oxen power, and agro-

chemicals significantly increase outputs level. The mean technical efficiency was 68.75%, which indicates the existence of an option to increase the level of sorghum by about 31.25%. Inefficiency model shows education level, family size, off-farm activities, extension contact, and soil fertility status affect positively affect the level of technical efficiency while variable such as age, livestock holding, and plots distance found to be negatively and significant in influence the level of technical efficiency.

The conclusion from the above studies employed in different parts of Ethiopia region that charecteized by different agro-climatic conditions, farm-specific charecteristics, socio-economic conditions indicated that there is efficiency level variation among smallholder farmers. The study also showed that there is significant variation in inefficiency factors which are accountable for efficiency differential among the smallholders. However, in Melka Bello district, there is not any research work has been conducted to determine the level of technical efficiency and determinents of inefficiency among smallholders. From the above conclusion, policy formulation for the selected site not valuable which have its own agro-ecology difference from the other. This is one of the research gaps.

Studies on technical efficiency of smallholder agriculture are not general types, and the findings 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 this gap. Technical efficiency is assumed to be a function of farm household and location specific variables, though production efficiency of different crops has been investigated in Ethiopia, production efficiency of sorghum in the study area has not been addressed to the best of this author's knowledge.

2.6. Conceptual Framework of the Study

Based on review of empirical studies of different works presented in above literature review, a conceptual framework has been formulated by taking into consideration different demographic characteristics, socio-economic factors, institutional factors, and farm characteristics affect technical efficiency of sorghum crop production in the study area. The following Figure 4

summarizes the interaction between various factors that were considered to have a various degree and direction of effect on the level of technical efficiency of sorghum production. The double arrow in the diagram indicates that there is an interaction between the each concept, in both directions relationships. The single arrows indicate that the interaction of concept was unidirectional.

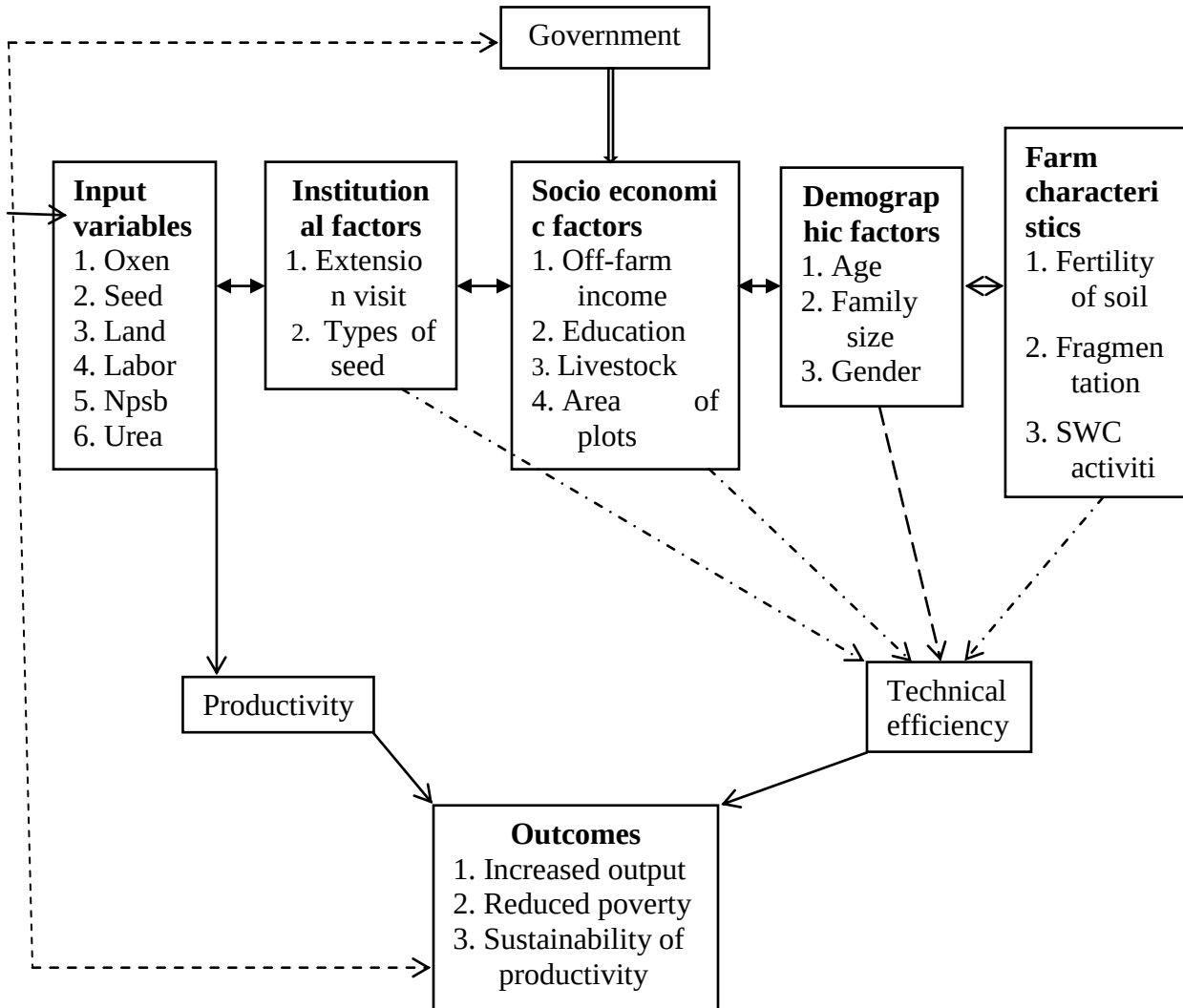


Figure : Illustration of conceptual framework of the study
Source: Own design, 2020

3. ESEARCH METHODOLOGY

Under this chapter the methods and approaches in which the research assessed and conducted was discussed. It deals about how the study is applied. It explains the description of the study area, data types, and sources, and methods of data collection, sampling technique, and sample size determination and methods of data processing and analysis were presented below.

3.1. Description of the Study Area

Melka Bello is one of the Oromia region districts located in East Hararghe Zone, Ethiopia. Jaja is the capital of the district that is about 487 km away from Addis Ababa. Geographically it is found between latitude $8^{\circ}30'27.14''$ N to $9^{\circ}15'.05''$ N and longitude $41^{\circ}10'2.03''$ E to $41^{\circ}31'27.95''$ E points. Deder borders Melka Belo on the north, on the southeastern by Gola Oda, on the eastern by Bedeno and on the north by Shenen Dugo. Administratively, district sub-divided into 26 *kebeles* of which four of urban *kebeles* and the rest 22 rural *kebeles*. The district's total population is 232,430 of which 118,539 (51%) are male and 113,891 (49%) are female. Out of the total population, 168,074 of which 85,475 male and 82,599 females found in rural *kebeles* while 9,342 of which 5,134 male and 4,208 females found in rural town (DHO, 2019).

The altitude of district ranges from 600 to 3138 meters above sea level; the highest point is Agudora. The types of soil resources include sandy soil that covered 20%, loam soil 20%, silt loam soil type 15%, clay loam soil 30%, and heavy clay soil 10%. Based on agro-climatic zone classification; the district has three agro-climatic zones can be distinguished namely *dega* covering 20% (annual rainfall 1776 mm), *weyna dega* (annual rainfall 944 mm) that covers 39% and *kola* covers about 41% (annual rainfall 540 mm). The mean annual temperature is ranging from 25 to 30 $^{\circ}\text{C}$. The average annual rainfall is 1086 mm accordingly; it has two major rainy seasons, which is called *Belg* and *Kiremt* (EHZAO, 2019).

The study area has been known for a years as a cereal crop production deficit area. Increasing incidence of climatic hazards and progressive land use patterns for cash crops amplify the negative trend for crop production. However, market has a sufficient supply of main staple foods for the area, originating from neighboring surplus producing areas was used as sources

food crops. The actual trend of farmer's main capital besides human labor, the arable land potential is reaching a critical stage of fragmentation between households that was forced farmers to move western Oromia regions where there was possibility of farmlands. The prevalence of an extreme land pressure has already resulted in vast natural resource deforestation and the cultivation of unsuitable land slopes in the highlands and mid-highlands causing a severe environmental degradation problem that causes unpredictable rainfall types characteristics more for years that hinders individual smallholder to produce sufficient foods (DODRDM, 2019).

The major crop production in the area includes maize, sorghum, wheat, barley, common bean, and pulses produced in different agro-ecology. Sorghum being one of the major crops grown in the study area specially in *kolla* area which found low rainfall condition. The major varieties of sorghums grown in the study area was includes local and hybrid types. Among local varieties with low productivity *Jeldi*, *Thomis* and *Bobe* are widely cultivated in June and matured in November. The favourable type *Gababe* and *Muyra* also local varieties that is lasted for five months to mature that preferred by farmers (DOA, 2019).

The livelihood of the study area depends mainly on mixed types of farming system of crop production with *khat* and livestock rearing (95% depends on agriculture 2% pastoral, dependent on non-farm activities was 3%). Cattle are important tame animals kept by the smallholder farmers integrated with crops production used as sources draft power and additional income sources. Thus, both crops and livestock contribute their share to the farmers' agricultural income sources. Crop production is the first sources food-generating activities and at the secondary stage livestock rearing. The total areas of district land mass coverage are about 114,725 ha of which 29,591 ha under cultivation. Main types of crops grown during rainy season are sorghum, maize, wheat and barley in their order of area coverage. The produced crop feeds not more than six months. Hence, for half-year food crops depend on availability of supply feed crops on markets. The district was known by coffee and *khat* producing area mainly for income sources. *Khat* is important cash crops produced by more than 70% of farmers produces spatially for Djibouti and Somalia (DODRDM, 2019).

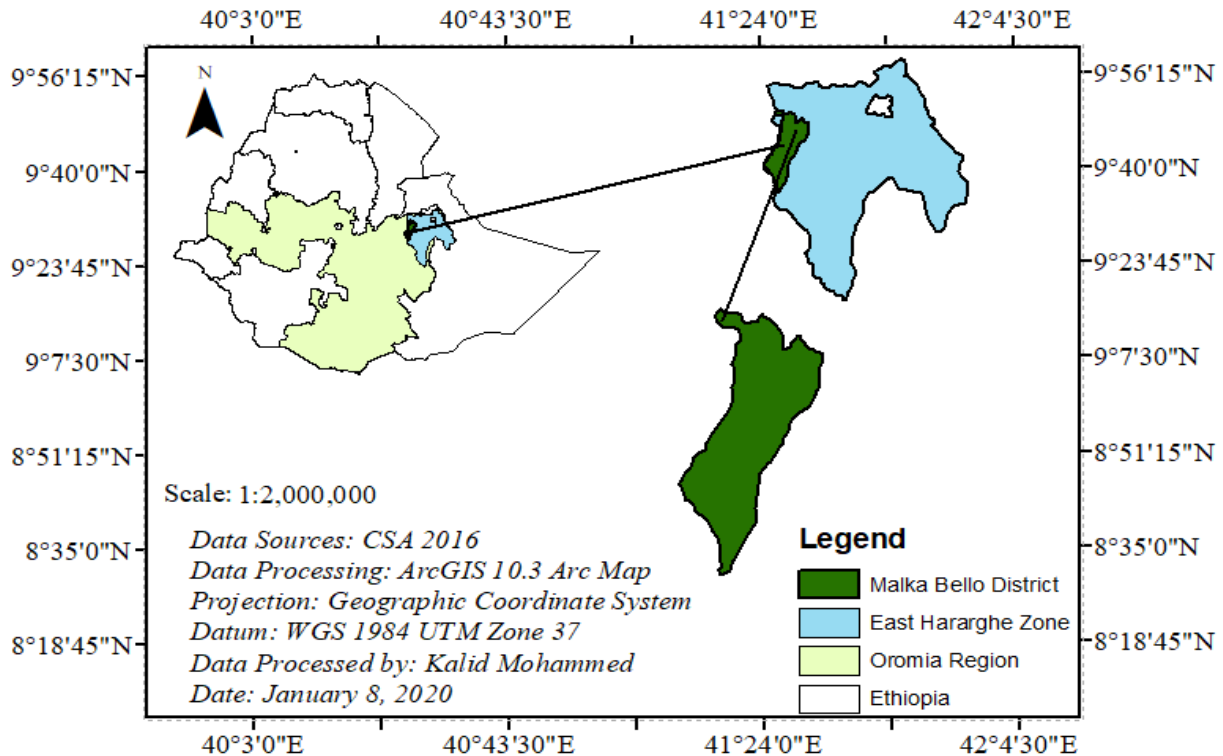


Figure : Geographical location of the study area

Source: Own sketch, 2020

3.2. Data Sources, Type and Method of Data Collection

Different sources used in order to collect qualitative and quantitative data on household farmers. In the study, both the relevant primary and secondary data were collected to attain the objectives of this paper, which includes both qualitative and quantitative types of data.

The primary data were collected from 138 randomly selected respondents using well-structured questionnaire. Enumerator and the *Kebele* Development Agents (DAs) did the primary data collection. The cross-sectional data of households sorghum producing in 2018/2019 cropping season used in the analysis. The enumerators were trained on data collection procedures. The questionnaire would be ready after making necessary corrections and pre-test before actual use in order to obtain more clear information. During interview, the researcher as well as respective enumerators as provided precise and enough information about the objectives of the study to let alone potential bias from the sample households in

responding to questions. There close supervision by the researcher during data collection so that errors were easily corrected. The data on farm features included socio-economic factor; farm characteristics and input utilization collected through interviews.

Generally more effort would be employed in each activity of the sample to assure data quality. Sufficient time was given in order to set up questionnaire very well in such way that the enumerators can easily understand it. Especial attentions was given towards simplifying clarity and logical order of questionnaire measurement tool of variable, definitions of technical terms and concepts to avoid possible bias that can emanate from it.

In order to support primary data, secondary data collected from both published and unpublished sources, which includes data on agricultural production current level of sorghum yield/ha, cultivated area, and volume of production, total farmers engaged in production, and other baseline information collected as secondary data at national and regional level.

3.3. Sampling Technique and Sample Size Determination

For this study, purposive and multiple-stage sampling techniques used to attain an accurate cross-sectional data from sample households in study area. In the first stage, out of the three agro-ecologies of the district *weyina dega* and *dega* were purposively select because of the presence of large number of sorghum producer households and its extent of production in the area.

In the second stage two *Kebeles* from *kola* agro-ecology and one *Kebele* from *dega* agro-ecology, totally three *Kebeles* as listed in (table 1) were selected by using lottery method in simple random sampling from 14 *Kebeles* which having higher area and potential under sorghum production based on access good information within district agricultural extension service officers.

In the third stage, from farmer list frame for the purpose of providing agricultural input by agricultural extension service officers 16,250 smallholder households who produce sorghum in 2018/19 production season about 138 total sample households were selected through systematic sampling techniques after obtained number of total sample size through a basic

formula provided by (Yamane, 1967). The simplified formula used to determine the sample size of the study specified as follows:

$$n = \frac{N}{1 + Ne^2} \quad (9)$$

Where: n = desired sample size, N is the total households producing sorghum (16,250) and e = (8.45%) desired level of precision. Totally, 138 sorghum growers was interviewed.

Table : Total sorghum producers households of *Kebele* and number of sample farmers

<i>Kebeles</i>	Total of sorghum households	Sample size	Percentage
To/Bilisuma	1895	62	49.27
Dire Kufa	1114	43	28.98
Makanisa	837	33	21.74
Total	3846	138	100

Source: Own sampling design, 2020

3.4. Methods of Data Analyses

To attain the objective of the study, the data obtained from field was analyzed with both descriptive statistics and econometric analysis methods.

3.4.1. Descriptive statistics methods

Descriptive statistics was applied to the basic characteristics of the sample households to assess differences or similarities among the sampled households. The descriptive statistics such as tables, percentage, minimum, maximum, and mean score were used to analyzing data collected on socio-economic, farm level and institutional characteristics of a sample. The inferential statistics like t-test and chi-square (χ^2) tests used to undertake statistical tests on different continuous and categorical variables data, respectively.

3.4.2. Econometric analysis

Following descriptive analysis, econometric method estimation done first by the specification empirical model and selection of functional form followed. In econometric analyses the first

step, the data were checked for regression model assumption including multicollinearity, heteroscedasticity, and model specification test. Finally, the data were analyzed using SFA by using single-stage estimation (Battese and Coelli, 1995).

3.4.2.1. Specification of empirical model

The original specification involved production function with composite error terms accounting for random effect as well as technical inefficiency effect both of which could cause production output deviation from frontier. Stochastic production frontier is the most appropriate method for efficiency analysis studies that have a probability of actuality affected by factors beyond control of farmers. This is because of the fact that this method was accounts for measuring inefficiency variables because of these factors and errors occurring in measurement and observations. In addition, measurement and observational errors could also occur during data collection. To capture effects of these errors, this study used stochastic frontier model that independently proposed by Aigner *et al.* (1977), Meeusen, and van der Broeck (1977).

The variation of actual output from the frontier due to inefficiency and random shocks can be captured through stochastic frontier approach. The existence of inefficiency in crop production comes from inefficient use of scarce resources (Coelli, 1995). The original stochastic frontier model described as follows:

$$\ln(Y_i) = \beta_0 + \sum \beta_i \ln X_{ij_i} + v_i - u_i \quad i = 1, 2, \dots, N \quad (10)$$

Where:

$\ln$ = denotes the natural logarithm;

i = represent the i^{th} farmer,

Y_i = is represents yield of sorghum output produced by i^{th} firm in (Qt)

X_{ij} = is input variables used by the i^{th} farmer;

β_i = is unknown parameter to be estimated;

v_i = is a symmetric component and permits a random variation in output due to factors beyond the control of farmers. It is assumed to be independently distribution as zero mean and constant variance;

u_i = is non-negative random variable intended to capture inefficiency effects which was measured as the ratio of observed output to maximum output of the i^{th} farmer. It is assumed to be independently and identically distribution as zero mean and constant variance.

Estimation by OLS yields inconsistent estimate of β_0 parameter. It is impossible to separate the technical inefficiency from the symmetric components with OLS estimation methods. The literature suggests two methodological approaches for analyzing technical efficiency based on stochastic production functions. The first approach is the sources of the two-stage estimation procedure in which first the stochastic production function was estimated, from which efficiency scores are derived. In the second stage, the derived efficiency scores are regressed on explanatory variables using OLS 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 on the explanatory variables.

The second approach advocates a one-stage simultaneous estimation approach as in Battese and Coelli (1995), in which the inefficiency effects were expressed as an explicit function of explanatory variables. Therefore, in this study a single-stage maximum likelihood estimation procedure was employed in obtaining the parameter coefficients of all β_i and α_i (14) of the inefficiency effect model. These parameters can be expressed in terms of the variance parameters of the stochastic frontier sigma squared (δ_s^2) and the inefficiency effects gamma (γ) that is the variance was given by $\delta_s^2 = \delta_u^2 + \delta_v^2$ and $\gamma = \delta_u^2 / \delta_v^2$ respectively. The δ_s^2 is the variance parameter that denotes the total deviation from the frontier. The γ is yield production deviation from frontier in countered by inefficiency of farmer's. 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. The δ_u^2 is the variance parameter that denotes deviation from the frontier due to inefficiency while δ_v^2 is the variance parameter that denotes deviation from the frontier due to noise (Battese and Corra, 1977). To summarize, the variation of actual output from the frontier due to inefficiency and random shocks can be captured through SFA.

There are different assumptions about distribution of u_i . According to by Aigner *et al.* (1977), Jondrow *et al.* (1982) one sided term may follow half normal distribution, truncated normal

distribution (Stevenson, 1980), and exponential distribution (Aigner *et al.*, 1977; Meeusen and van den Broeck, 1977). Maximum likelihood estimate of β_i and u_i a prior imposition of distributional assumptions and assume a normal distribution with mean zero and constant variance for v_i . The technical efficiency of production for the i^{th} farm is defined by:

$$TE_i = \exp(-\mu_i) = \frac{Y_i}{Y_i^*} = \frac{Y_i}{\exp(x_i\beta + v_i)} = \frac{\exp(x_i\beta + v_i - u_i)}{\exp(x_i\beta + v_i)} \quad (11)$$

Where: u_i = is represents non-negative random variables to capture inefficiency;

v_i = is symmetric components; Y_i^* = represents maximum output produced by i^{th} farmer.

3.4.2.2. Selection of functional form

Among the possible algebraic forms, Cobb-Douglas and the translog functions have been the most widely used functional forms in most empirical production analysis studies (Coeilli *et al.*, 2005). The choice of functional form for efficiency analysis should be based on convenience, meeting selection criteria premise on the value of variance-parameters and objective of the study (Umar *et al.*, 2017). However, it confirmed that if the interest in measuring TE, not in the analysis of general structure of the production function the functional form has low impact on analysis of technical efficiency level (Koop and Smith, 1980).

To summarize, the choice of this functional form is due to the fact that, first the Cobb-Douglas has been the most commonly used functional form in the specification and estimation of production frontiers in empirical studies in most efficiency especially farm efficiency studies in both developed and developing countries. In the second, because of the logarithmic nature of the production function that makes econometric estimation of the parameters a very simple matter. This study used the Cobb-Douglas stochastic frontier approaches to estimate production function and the level of technical efficiency, which requires the priori specification of the production function (Afriat, 1972). Therefore, decision to use the Cobb-Douglas form is reasonable. The Cobb-Douglas frontier production function is specified as follows:

$$\ln(OPUT) = f \left(\begin{array}{l} \beta_0 + \beta_1 \ln LAND + \beta_2 \ln OD + \beta_3 \ln SED + \beta_4 \ln LAB + \beta_5 \ln NPSB \\ + \beta_6 \ln UREA + V_i - \mu_i \end{array} \right) \quad (12)$$

$\ln(OPUT)$ - is the total amount of sorghum produced in quintal by the i^{th} farmer;

$\ln OD$ - the total number of oxen-power used for sorghum production in oxen-day by i^{th} farmer;

$\ln SED$ - is the quantity of sorghum seed in kg used in production by the i^{th} farmer;

$\ln LAND$ - is the total area of land in ha allocated for sorghum production by the i^{th} farmer;

$\ln LAB$ - is the total labor in person-day used in sorghum production by the i^{th} farmer;

$\ln NPSB$ - is the amount of Npsb fertilizer in kg used in sorghum production by the i^{th} farmer;

$\ln UREA$ - is the amount of Urea fertilizer in kg used in sorghum production by the i^{th} farmer;

v_i = is a symmetric component and permits a random variation in output due to shocks;

μ_i = is non-negative random variable intended to capture inefficiency effects;

According to Battese and Coelli (1995), the technical inefficiency effects model in which both the stochastic frontier and factors affecting inefficiency are estimated simultaneously is specified as follows:

$$\ln(OPUT) = f \left(\begin{array}{l} \beta_0 + \beta_1 \ln LAND + \beta_2 \ln OD + \beta_3 \ln SED + \beta_4 \ln LAB + \beta_5 \ln NPSB + \\ \beta_6 \ln UREA + V_i - (\alpha_0 + \alpha_1 age + \alpha_2 edu + \alpha_3 fmsz + \alpha_4 offa + \alpha_5 fev + \\ \alpha_6 tlu + \alpha_7 sfer + \alpha_8 frg + \alpha_9 swc + \alpha_{10} sex + t_{sed} + \alpha_{12} area \end{array} \right) \quad (13)$$

Where: edu – is education level (number of years of schooling);

Age - is age of the household head in years;

Offa –is off-farm income additional off farm incomes;

Fmsz – is household size (total numbers of family member who lives in one roof);

Area- is total land size operated by the farmer;

Tlu - is the total number of livestock in terms of TLU;

Fev –extension contact (the frequency of visit of the extension agent to the farmer);

Swc- soil and water conservation (A dummy variable it takes a value of 1 if yes, 0 otherwise);

Tsed- seed type (A dummy variable. takes value of 1 if improved seed and 0 otherwise);

Sex- gender (A dummy variable 1 if the household head is male and 0, otherwise);

Frg - land fragmentation (it include the number of locations of different plots);.

Area- is total size of farmlands

The validity of the models used for the analysis and hypothesis test was investigated using the general likelihood ratio test. Generalized likelihood ratio computation was expressed as;

$$LR = -2[\ln LH_0 - \ln LH_1] \quad (14)$$

Where LR= Log likelihood ratio, LH_0 =Value of log likelihood of null hypothesis, LH_1 = Value of log likelihood of alternate hypothesis. Df = degree of freedom equal to number of restrictions = number of estimated inputs and inefficiency variables in the current model (alternate hypothesis) minus number of estimated inputs and inefficiency variables in the preceding model (null hypothesis). The null hypothesis will be rejected when LR (calculated χ^2 at df > tabulated χ^2 at df. If the null hypothesis will be true, the test statistic will approximately a χ^2 distribution or mixed χ^2 distributions with degrees of freedom equal to the difference between the numbers of parameters specified in the null and alternative hypothesis.

3.5. Definition and Measurement of Study Variables

The listed variables in these topics that were used both in the stochastic production function and in the inefficiency model were selected based on the reviewed literatures, theoretical and/or empirical justification, crop production characteristics, and socio-economic condition of the study area. The outputs and all inputs variables were transformed to natural-log values in estimating the Cobb-Douglas production function.

Sorghum Output (OPUT): This is the dependent variable of the production function.

The output measured in local unit. This is the dependent variable of the production function. The output measured in local unit such as sack that obtained from market. For the analysis, it was changed to quintal (qt) which is standard unit during production year.

3.5.1. The input variables with hypothesis

Land (LAND): The amount of land measured in hectare that the sampled household allocated for sorghum production in surveyed year 2018/19. These variables measured as *qind* (0.125 ha) locally changed the standard unit of hectares (ha). The land owned by individual farmers or land obtained by means of renting or through sharecropping is considered for analysis. It is

It is hypothesized to affect positively determines production level of sorghum. The finding of Zalkiwi (2014), Hassen (2016) indicated that direct relationship between area of sorghum plot and level of sorghum output.

Oxen power (OD): Oxen are used as a source of draught power in sorghum production process in the study area. This is the total amount of draught power used by the sampled household in different activities including land preparation and sowing. The oxen power measured using the total amount of oxen days allocated for different activities of sorghum 2018/19 production year. It is hypothesized to affect positively determines production level of sorghum (Beyan *et al.*, 2013).

Seed (SED): It is the total quantity of sorghum seed used by the sampled household measured in kilograms, regardless of the type of maize seeds used on the plot. Sampled households mainly used local sorghum seed in the production season. A study of Tadie (2019) shows that direct relationship between seed and level of output. Therefore, it is hypothesized that seed affects positively determines technical efficiency of farmers in sorghum production.

Labor (LAB): It refers to total amount of labor force used in all activities from land preparation up to transportation of sorghum output to home. It measured by person-day. The source of this input includes children, man, and woman. The labor as factors of production converted in to man-equivalent. Man-equivalent computed considering ages and sex of the laborer by standard conversion factors reported by Strock *et al.* (1991). The finding of (Musa *et al.*, 2014; Mogos, 2019) shows that direct relationship between labour and level of output. It is hypothesized affect positively and significantly determines production level.

Nitrous phosphates sulphur boron fertilizers (NPSB): It is total amount of NPSB chemical fertilizer that used by the sampled households for sorghum production, which measured in kg. These inputs NPSB usually apply during planting time only. As input variables, the total amount of NPSB used in (kg) for the 2018/19 year sorghum production was considered in this study.

UREA fertilizers (UREA): This is the total amount of urea chemical fertilizer that used by the i^{th} farmer for sorghum production measured in kg. It is applied on the farmland using split

application. The finding of Kussei *et al.* (2019) shows that direct relationship between labour and level of output. Therefore, it was hypothesized that seed affect positively determine technical efficiency of farmer's production.

3.5.2. The inefficiency variables and their hypothesis

Depending on previous empirical studies, the following factors expected to explain differences in sorghum production efficiency among farmers in the study area.

Age (age): This refers to age of the household head and a continuous variable measured in number of years. It may be that older farmers are more risk averse and less likely to be flexible than younger farmers. The finding of the study of (Chepng'etich *et al.*, 2014; Tadele, 2019) was indicated that farmer's age positively influence technical inefficiency of producer. In this study, age was expected negatively influence on technical efficiency.

Education (edu): It is a continuous variable and measured in the years of formal schooling. This is used as a proxy variable for managerial ability of the household heads. Many empirical evidence shows that education is hypothesized to increase the household's ability to utilize existing technologies and attain higher efficiency levels. 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 (Hailemaraim, 2015; Hassen, 2016; Tadesse *et al.*, 2017). In this study, education expected to increase the level of technical efficiency positively.

Family size (fmsz): It is total numbers of family member who are living together in one-roof and utilizing scarce resources, and measured in adult equivalent. It is a continuous variable grouped by employing person-day per adult equivalent. Family size is input labor, labor is the one the most inputs in sorghum production among factor of production, and a farmer that has large family size can carry out important agricultural activity at timely. Empirical studies by (Abba 2012; Tadesse *et al.*, 2017) indicated that the number family size was found to have a positive and significant effect on technical efficiency of households. Therefore, in this study, family size expected to increase the level of technical efficiency positively related with sorghum production.

Off-farm income (Offa): Off/non-farm income can supplement to the agricultural activities in terms of providing cash income there by purchase necessary inputs timely. It is considered as continues variables that are the amount of off-farm income gained by farmers in the survey years. Several studies found that households who have more off-farm income more technically efficient than their counterparts (Mussa *et al.*, 2014; Hailemaraim, 2015; Musa *et al.*, 2018; Kussie *et al.* 2019). The extra income that farmers get from other sources may associate in increases their capacity to buy more agricultural inputs. Hence, in this study negative relation between off/nonfarm income and technical efficiency was expected.

Frequency extension visit (fev): It is considered as continues variables, which is used as proxy measure of access to extension services for farmers, and defined as the frequency of extension agents visited the farmer in stated production. Access to extension services as a medium for diffusion of new technologies and information is expected to reduce inefficiency level through improvement of their management skill farmer. Farmers who accessed extension services have higher level of technical efficiency than those who failed to access the services (Abba, 2012; Beyan *et al.*, 2013; Mango *et al.*, 2015; Tadesse *et al.*, 2017). It was therefore, expected to affect the level of technical efficiency positively.

Number of livestock holding (tlu): This variable stands for the number of livestock owned by the household heads in TLU. It is assumed to reflect the wealth of household. These variables considered as continues variable. Its resources that household has in terms of TLU in survey year. Many literatures confirmed that as livestock number increases technical inefficiency increases (Hassen, 2016). It is therefore, was expected to reduce the level of TE.

Land fragmentation (frg): It is a continuous variable, which is measured as the number of plots under which farmer managed during the production year. As farm plots are fragmented and scattered over many places that would make it 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. Therefore, additional plots of farmers is associated negatively associated with technical efficiency (Abba, 2012; Wudineh and Endrias, 2016; Tadie *et al.*, 2019). In this study, negative association between fragmentation and technical efficiency was expected.

Soil fertility status (sfer): It is category variable, based on farmers' perception, plots were classified based on soil erosion severity: 1 as excellent, 2 as very good, 3 as good, and 4 as poor. It is the fertility status of the plots allocated for sorghum. A difference in fertility of land could also have a bearing in the decision of the farmer whether to adopt a new technology or not. It is the nature of soil nutrient practiced by the respondent during the survey year. It is an important factor in influencing the level of production of sorghum (Hailemaraim, 2015; Kussei *et al.*, 2019). In this study, it expected to affect technical efficiency positively.

Total farm Size (area): This is continuous variable measured in total cultivated farmland that a farmer owns which is measured in hectares. As the level of farm size increases the managerial ability of farmers decreases with a given level of technology existed since some farm activities was technically efficient when it done with its own seasonal calendar. The various studies showed that farmers with larger farm sizes were less technically efficient than with smaller farms (Getachew and Bamlak, 2014; Hailemaraim, 2015; Mogos, 2019). Thus, farm size was expected to be negatively associated with the level of technical efficiency.

Soil and water conservation (swc): It is a dummy variable that assumes 1 if soil and water conservation practices at farm and 0 otherwise. Households practice different soil conservation mechanisms to sustain the productivity their farmland. The more farmers practiced soil and water conservation the less he/she being inefficient than those who practice less activities (Getahun, 2014). Thus, it expected to be positively associated with the level of technical efficiency in this study.

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 women play a substantial role in agricultural activities; however, there are still tasks that are not used by their self's. The finding of (Wudineh and Endrias, 2016) was indicated that sex of the farmer has a significant impact on efficiency of farmers'. In this study, it was hypothesized those male farmers less inefficient than female farmer will.

Types of seed (tsed): It is dummy variable, which have the value of one if the farmer used improved seed; and zero otherwise. This argues that, improved seed of sorghum is

enhancing productivity and quality of the output. Thus in this study, types of seed was expected to be positively associated with the level of technical efficiency (Tadele, 2019).

Table : Summary of definition, measurements, and hypothesis of working variables

Variable s	Description of variables	Definition	Measure ment	Expe cte d sign
Age	Age	Age of household head	Year	+
Sex	Sex	Sex of the household heads having value of 1 for male and 0 otherwise	Dummy	-/+
Edu	Education	Number of year attends formal school	Year	-
Fev	Frequency extension visit	Number of extension visits during farming season	Number	-
Sfer	Soil fertility status	Fertility status of soil such that value 1 for high, 2 for medium and 3 for low	Categori cal	-
Fmsz	Family size	The total numbers of family member who lives in one roof	Number	—
Area	Total farm Size	Total cultivated farm size	Hectare	+
Swc	Soil and water conservation	Soil and water conservation having value of 1 for male and 0 otherwise	Dummy	-
Offa	Off-farm income	It is amount of off farm income	Birr	+
Tsed	Types of seed	Types of sorghum seed having a value of 1 for improved seed and 0 otherwise	Dummy	-
Tlu	Livestock holding	Number of livestock holdings	TLU	+
Frg	Fragmentation	The total number of plots	Number	+

Sources: Own expectation, 2020

4. RESULTS AND DISCUSSIONS

This chapter presents the descriptive and econometric analyses of data collected from the sampled farmers. The chapter is divided into two main sections. The first section is descriptive statistics, which briefly discusses the results of descriptive statistics to describe difference and similarity between inputs used, the data on demographic and socio-economic characteristics of the sample households in sorghum production. The second part of this chapter presents and briefly discussed the econometric results of parameters of production function, technical efficiency, and sources of inefficiency variation between sorghum producers.

4.1. Descriptive Statistics Results

Under this sub-topic descriptive result of production function inputs and explanatory variables used in inefficiency effect model were analyzed by different statistical measures such as frequency, mean, standard deviation, percentage, minimum and maximum values of variables used in the model.

4.1.1. Summary statistics of production function and variables

The results of inputs used in analysis of stochastic frontier model were presented in this section. The average productivity of sorghum output were to be 14.91 qt/ha which ranges from 3 to 30 qts/ha with standard deviation of 6.88 among the farmers. The results is far below the regional and national level sorghum productivity of 28.56 qts/ha and 27.36 qts/ha respectively (CSA, 2019). This indicates the large variability of sorghum output among the farmers in sorghum production. This implies that most of the farmers interviewed were net food buyers. More than 90% of sampled households buying their food crop on average 2.81 qts in the year from market in addition to other commercial food items. It confirmed that one of the characteristics of subsistence farming-system in the study area. The land allocated for sorghum production by sampled farmers was ranged from 0.13 to 0.75 ha with an average of 0.342 ha holdings which is lower than 0.388 and 0.354 ha at national and Oromia region level land allocated by private small holders for sorghum crop respectively (WFP, 2019).

The amount of sorghum seed sown by sample farmer was on average 5.32 kg that varied from 1.5 to 10.5 kg. This indicates that most of the farmers sown by drilling manually. The farmers on average were used 25.75 kg/ha of Npsb chemical fertilizer and 19.34 kg/ha amount of urea fertilizer which is low when compared to the recommended fertilizer application rate of 105 kg/ha and 50 kg/ha respectively (ATA, 2017/18). In addition, only 30.44 and 21.74 % of farmers were used Npsb and Urea fertilizer to sorghum crop respectively. This indicates that, in study area, farmers those lowland areas not prefer to apply both fertilizer to their crops due to the low confidence to continue rainfall because fertilizer efficiency depends on rainfall condition. There is high variation of chemical fertilizer utilization of both Npsb and Urea in sorghum production. This low chemical fertilizer application rate attribute to their inefficiency difference in addition to inefficiency variables.

The mean annual total labor forces utilized by sample households for sorghum production found to be 36.59 person-days in different activities with minimum 10 and maximum of 71 person-day. This figure calculated based on conversion factor methods. This is as expected, since the sorghum produced by traditional technology that relies heavily on huge family labour. Proportions of women and children participated in agricultural activities are 14% and 6% respectively. According to the survey result, the mean annual oxen power utilized by sample households found to be 13.69 oxen-days in range of 1 to 14 oxen day. It was computed by assuming, as a farmer working for 8 hours by pair of oxen per day as the study area experienced by half-day working hours. About 85.5% sample households were used oxen power for ploughing their sorghum land. This is due to land slopes farmers plough their land by hand hoe even having own oxen pair.

Table : Summary statistics for output and input variables used in production function

Variables	Obs	Min	Max	Mean	Std. Dev.
Output (qt)	138	3	30	14.91	6.88
Land (ha)	138	0.13	0.75	0.342	0.16
Seed (kg)	138	1.5	10.50	5.32	5.54
Npsb (kg)	42	18.75	50	25.75	10.83
Urea (kg)	30	12.50	25	19.34	6.48
Oxen power (od)	118	1	14	13.69	9.21
Labour (Mds)	138	10	71	36.59	11.64

Source: Survey result (2020)

4.1.2. Summary statistics of demographic and socio-economic variables

4.1.2.1. Summary statistics of continuous variables

The average age of household heads was 42.99 years within a range of 22 to 70 years, which is below the average life expectancy of Ethiopian were to be 62.4 and 66.6 for male and female respectively (NBE, 2019). Based on Strock *et al.* (1991) results, the average age of farmers of this study was included in the range of the most economically active age group of 17-50 year. This implies that most of the household heads of the study area were within their productive age. The average family size of farmers were to be 6.95 person with minimum and maximum 2 and 13 members respectively which higher than family size at national level. According to HCES (2015/16), in Ethiopia the average family size was to be 4.6 while adult equivalent family size was 3.8 as reported in WFP (2019) which is lower than in study area. This indicated that the study area characterized by high family size that causes high-pressure on land productivity.

The average education level of the sample farmers was to be 4.82 years, which found in the range of 1 to 10 years, its details (Appendix 5). Land is the main resource needed by the farmers to earn their livelihoods. The average land area under farmer's operation was approximately to be 0.51 ha that ranged from 0.25 to 2.5 ha, which is below national level. The average land holding size of households in Ethiopia were estimated to be 0.95 ha mainly for subsistence farming system (WFP, 2019). This indicated that farmers in the study area were small-scale and family-managed farming-system, these results confirms that one of the characteristics of subsistence agriculture in the country (Alemayo, 2011).

In this study, on average 76% of the farmers reported that they have been receiving extension services out of which 37% received advice on sorghum production in a week. The extension workers also visit farmers on different intervals. Some farmers are being visited more frequently while others have no chance at all to be visited by extension workers due to proximity problems. The average frequency of extension contacts during the production year in sorghum production was approximately 3.82 times with minimum 1 and maximum 5 times. The average livestock holding of the sample households were to be 4.41 in area. Livestock production is also another important production activity, which serves as a means of security

during failure crop production and plays a vital role as the sources of income. The livestock subsystem is highly interrelated with the crop production, that is, it provides draught power for agricultural activities.

Table : Summary statistics of continuous variables used in efficiency model

Variables	Obs	Min	Max	Mean	Std. Dev.
Age	138	22	70	42.99	9.47
Family size	138	2	13	6.95	2.47
Education	83	1	10	4.82	2.21
Extension visit	78	1	5	3.82	1.45
Area	138	0.25	2.5	0.51	0.31
Fragmentation	138	1	5	2.12	1.05
Livestock holdings	138	0.13	28.50	4.41	3.87
Off-farm income	40	450	15000	4442.10	3329.47

Sources: Survey results, 2020

4.1.2.2. Summary statistics of dummy variables

The majority of the households were male headed. Out of the total sample household, about 83.33% were male headed and the remaining 16.67% were female-headed households and about 97.83% of them are married, 1.45% are non-married/ widowed and 0.72% of them are divorced. The result shows that there is no significant difference between male-headed and female-headed households on sorghum production. Majority of the respondents said that they do not have soil fertility problem, only 27.54% were reported that their land not fertile.

Table : Summary of dummy and categorical variables used in efficiency model

Variables	Description	Frequency	Percentage
Sex	Male (1)	115	83.33
	Female (0)	23	16.67
Soil and water activity	Yes (1)	96	69.57
	No (0)	42	30.43
Soil fertility status (Categorical)	High (1)	35	25.36
	Medium (2)	65	47.10
	Low (3)	38	27.54
Types of seed	Improved seed (1)	20	14.49
	Local seed (0)	131	5.07

Source: Survey results, 2020

4.2. Econometric Model Results

This section presents the econometric model outputs of the production function. Maximum likelihood estimates of the production function, individual efficiency scores, and the determinants of technical inefficiency of farmers are presented and discussed. Before running the econometric analysis, the data tested against different econometric problems. Accordingly, multicollinearity test for both continuous and dummy variables at the same time was done using variance inflation factor (VIF) (Appendix table 6), to check multicollinearity problem among all variables.

4.2.1. Hypothesis Testing

One attractive feature of stochastic frontiers is that it is possible to test various hypotheses, which are not possible in non-parametric model (Bravo-Ureta *et al.*, 2001). Hypotheses stated in the model specification and validity of the model, which is used for this analysis, has to be tested before estimating the parameters of the model. Accordingly, the following three hypotheses were tested, namely to select the correct functional form for the given data set, variables that determine the variation in efficiency scores and existence of efficiency in model were tested and discussed respectively.

Table : Generalized likelihood tests of hypothesis for parameters of production function

Null hypothesis	DF	LH ₀	LH ₁	Calculated χ^2 (LR)	Critical value ($\chi^2_{0.05}$)	Decision
Ho : $\delta_7 = \delta_8 = \delta_{27} = 0$	21	-20.93	-8.17	12.76	32.67	Accept
Ho: $\gamma = 0$	1	-26.71	-20.93	11.56	3.84	Reject
H ₀ : $u_i = \delta_1 = \delta_2 = \dots = \delta_{12} = 0$	12	-48.98	-20.93	56.10	21.03	Reject

Source: Own computation, 2020

The first hypothesis test identifies an appropriate functional form between restrictive Cobb-Douglas and the flexible Translog production function. This conducted by testing the null hypothesis that the coefficients of all interaction terms and square specifications in the translog functional forms are equal to zero, then Translog frontier function turns into Cobb-Douglas and using the following LR formula given by (14). The estimated LR values of the Cobb-Douglas and Translog production functions were -20.93 and -8.17 respectively. The

calculated value of LR is 12.76, which is lower than the upper 5% critical value of the 32.67. Thus, the null hypothesis that all coefficients of the square and interaction terms in translog specification are equal to zero not rejected. This implies that the Cobb-Douglas functional form adequately represents the farm level data.

The second hypothesis test was to test for adequacy of representing the data using SPF over the traditional mean response function, OLS. The null hypothesis that, $H_0: \gamma=0$, where the parameter $\gamma = \delta_u^2 / (\delta_u^2 + \delta_v^2)$, γ has mixed chi-square distributions which specifies that the inefficiency effects are absent from the model (that is all sorghum farmer are fully efficient). Whereas, the alternative hypothesis, $H_1: \gamma>0$ states that there is inefficiency in production of sorghum in the study area. The calculated value LR is equals to 11.56 while the critical LR value (χ^2) at 1 degree of freedom with 5% level of significance equals to 3.84. Hence, $H_0: \gamma = 0$, this means to all sorghum producing farms are 100% efficient and is strongly rejected. This indicates that the explanatory variables specified in the model make significant contribution in explaining the inefficiency effect associated with production.

The last hypothesis is that the explanatory variables in technical inefficiency effect model are all equal to zero, $H_0: \delta_1= \delta_2,..., \delta_{12} = 0$. To test this hypothesis log- likelihood ratio is calculated using the value of the log likelihood function under the Cobb-Douglas stochastic frontier model (a model without explanatory variables of inefficiency effect model, H_0) and the full frontier model (a model with all explanatory variables of inefficiency effect model, H_1). The calculated LR equals to 56.10 while the critical likelihood ratio (χ^2) of 5% level of significance at 12 degree of freedom equals to 21.03. Since the calculated likelihood ratio, LR value is greater than the critical value of LR , χ^2 at 12 degree of freedom with upper 5% level of significance, the null hypothesis that explanatory variables in the inefficiency effect model are simultaneously equal to zero is rejected, hence inefficiency effect model are jointly different from zero.

4.2.2. Maximum likelihood estimates of production function

As already stated above, the present study employed single-stage maximum likelihood estimation procedure, which simultaneously estimate the parameters of both SFP function and inefficiency effect model. The model comprises of nineteen parameters, six of them were the

input variables of the stochastic frontier function while twelve of them were the explanatory variables that are hypothesized to influence the technical inefficiency scores. The estimated coefficients for oxen power, seed, land, labor and Npsb are all positive and significant which confirm that, these inputs significantly increase output while the coefficient of urea fertilizer insignificant. The coefficients of inputs indicate that on average a 1% increase in oxen power, seed, land, labour, and Npsb increases the output of sorghum by 0.129%, 0.105%, 0.35%, 0.25%, and 0.03%, respectively. In other words, if all the inputs increased proportionally by 1%, output would increase by 0.862%.

Table : Maximum likelihood estimates (MLE) of stochastic frontier production function for sorghum farmers

Variables	Coefficient	Standard-error	Z-value
lnOxen	0.129**	0.054	2.38
LnSed	0.105**	0.051	2.04
lnLand	0.346***	0.091	3.80
lnLab	0.250**	0.097	2.57
lnNpsb	0.031***	0.011	2.80
lnUrea	0.001	0.001	1.58
Diagnostic parameters			
Sigma-square (δ^2)	0.301***		
Gamma (γ)	0.895***		
Lambda	2.94		
Log likelihood	-20.93		

Source: Model output, 2020

*, **, ***, Significant at 10%, 5% and 1% level of significance

The value of sigma-squared (δ^2) for production frontier was to be 0.301 and significant implying that significantly different from zero. The significant value indicates the goodness of fit of the specified assumption of the composite error term's distribution assumption. Moreover, the estimate of γ , which is the ratio of the variance of farm-specific technical efficiency, δ^2_u to the total variance of output, δ^2 , lies between 0 and 1. The value equal to 0 implying that technical inefficiency is not present and the OLS estimation would be an adequate representation and a value close or equal to 1 implying that the frontier model is appropriate. The value of $\gamma = 0.895$, its interpretation that 89.5% of total variation in output is due to one-sided error of the farmers whereas the remaining 11.5% were due to random error component outside the farmers' control. The example of such shocks are crop diseases, land

slop, weathers, damaged through careless handling and statistical data measurements errors during data collection processes (Aigner and Chu, 1968; Aigner *et al.*, 1977; Porcelli, 2009; Chen *et al.*, 2015). The returns to scale analysis coefficients calculated to be 0.862% indicating production in the study area was to be decreasing returns to scale. Furthermore, this implies increase in all inputs proportionally would increase the production by less than 1%. The model output show the relative importance of individual inputs and their aggregate significance in the production as well as being useful in predicting the level of individual TE.

4.2.3. Technical efficiency scores of sample households

A Cobb-Douglas stochastic frontier production function assumed to explain the variation in sorghum output in terms of several input variables. The parameters of the model were estimated by the method of maximum likelihood. The technical efficiency ranged from 0.24 to 0.97.

Table : Summary statistics of estimated technical efficiency of farmers

Statistics	The level of technical efficiency
Minimum	0.24
Maximum	0.97
Mean	0.76
Standard Deviation	0.16

Source: Own computation, 2020

In this survey, the result of data analysis shows that, the average technical efficiency of the farmer was to be 76%, with minimum of 24% and maximum of 97% with 16% of standard deviation. This result revealed that there is a wide difference among sorghum producer farmers in their level of technical efficiency, which in turn indicates that, there exists a room for improving the existing level of sorghum production through enhancing the level of farmers' technical efficiency. The mean level of technical efficiency further tells us that the level of sorghum output of the sample respondents can be increased on average by 24% if appropriate mitigation measures are taken to improve the level of efficiency farmers.

Table : Frequency distribution of technical efficiency of sample households

Range of TE (%)	Frequency	Percentage
<=40	5	0.04
(40-50]	14	0.10
(50-60]	16	0.12
(60-70]	14	0.10
(70-80]	27	0.20
(80-90]	44	0.32
90-100	18	0.13
Total	138	1.00

Source: Own computation, 2020

It was observed that 42.03% (58) of the sample households are operating below the mean level of technical efficiency. The majority of the sorghum-producing farmers 57.24 % were able to achieve above the overall mean level.

4.2.4. Sources of technical inefficiency of farmers

After deriving farm-specific estimates of technical inefficiency, the second specific objective of this study was to identify the major factors that cause variations of efficiency level among farmers. Accordingly, there were twelve socio-economic and institutional variables were hypothesized to influence level of technical inefficiency of sorghum producer in the study area. Out of which three of them were dummy variables, one of category variable and the remaining eight variables were continuous variables. Most of the variables were discussed in the descriptive statistic results section above. Hence, here only some of the variables in inefficiency effect model that significantly determine the technical inefficiency were discussed below.

The determinants of technical inefficiency in a given period vary considerably depending on socio-economic conditions of the study area particularly relating to managerial characteristics and other related factors. The parameters of the various hypothesized variables in the technical inefficiency effect model that are expected to determine efficiency differences among sampled households in study area were estimated through MLE method using one-stage estimation procedure. Maximum likelihood estimation procedure using the estimated technical inefficiency level, as dependent variable is makes single-stage estimation procedure easier

than second-stage produce. One important point to be considered is that the dependent variable is the inefficiency component of the total error term that estimated in simultaneously with the production frontier. Greater attention has to be given during interpretation of the signs of coefficients of technical inefficient effect. The negative sign indicates that an increase negatively determines to technical inefficiency. The parameter estimates of the relationship between technical inefficiency and farm and farmer characteristics using the MLE presented in the following table.

Table : Maximum likelihood estimates of the factors determining technical efficiency

Variables	Coefficient	Standard-error	Z-values
Constant	2.36**	1.216	1.97
Frequency extension contact	-0.408***	0.139	-2.93
Soil fertility status	-0.726***	0.294	-2.46
Age of household	-0.050**	0.023	-2.18
Sex	0.336	0.472	0.71
Family size	-0.062	0.086	-0.72
Education level	-0.206***	0.076	-2.70
Off-farm income	-0.178	0.417	-0.43
Soil and water conservation	-0.002**	0.001	-2.00
Total cultivated land	0.864	0.561	1.54
Land fragmentation	0.109	0.176	0.62
Types of seed	-0.216	0.933	-0.23
Livestock holding	0.145***	0.052	2.79
Log likelihood	-20.93		

Source: Model output, 2020

*, **, ***, Significant at 10%, 5% and 1% level of significance

The hypothesized factors which were significant in describing the variability in technical inefficiency were includes frequency of extension visits, fertility status of soil, age of household, soil and water conservation activities, level of education, and number of livestock holding which is different from zero in affecting technical inefficiency of farmers.

Frequency of extension visit: Extension contact refers to whether a sampled household has contact with DAs or not during the survey year to get agricultural extension services concerning sorghum production. The result shows that the coefficient of the extension visit was negatively and significantly affects technical inefficiency at 1% probability level. The negative sign and significant statistical relationship between extension visit and technical

inefficiency indicated that those farmers who contact with extension agent less technically inefficient as compared to their counterparts. This is due to its attribution to increases the knowledge of farmers' modern agricultural technology for input utilization, disease control, delivering plan and actual inputs on time, and enhances farmers' understanding of extension recommendations. It assumed to be the main instruments used in widening farmer knowledge regarding the use of modern technologies starting from land preparation until the harvesting time. Therefore, in the study area, the contact farmers' have with extension workers play a significant role in improving the level of technical efficiency. This result is in line with empirical findings in Ethiopia and elsewhere in the world (Beyan *et al.*, 2013; Mussa *et al.*, 2014; Mango *et al.*, 2015; Mussa *et al.*, 2018). Nevertheless, this seemingly contradictory finding has been reported in other studies (Musaba and Bwacha, 2014; Tadesse, 2017; Tadie *et al.*, 2019).

Fertility status of soil: It hypothesized that the fertility status of the land to have significant impact on the level of inefficiency in sorghum production. The output of the model shows that the coefficient of soil fertility status of plots was negatively and statistically significant at 1% level of significance influencing technical inefficiency. This implies that households who allocated land, which was relatively fertile, were lower in technical inefficiency than the others were. This may be associated with, those who allocate fertile lands can survive occurrence of drought and striga weeds problems. In addition, those fertile lands require less commercial fertilizer application, which leads to reduction in cost and repeatedly leads to reduction in the inefficiency of farmers. Therefore, soil fertility could cause for significant productivity difference between farmers. This result was also consistent with other findings of (Hailemaraim, 2015).

Soil and water conservation: The coefficient of soil and water conservation was indicated that negatively association between soil and water conservation practices and technical inefficiency. In this study, as expected practicing soil and water conservation on farm was negative effect on technical inefficiency at 5% level of significance. It implies that who conserves his plots by soil and water conservation the less he/she to be technically inefficient than their counterparts. This is due to reduction in possibility of erosion, increases moisture retention capacity, and increases the efficiency of inputs in production of conserved farms.

Soil and water conservation not only increase production and productivity of farmland, but also enhance environmental sustainability since the study area characterized by sloppy lands area. In countries such as Ethiopia with topographic complexity, crop productivity could be undermined due to high level of soil loss and low level of soil moisture making the farmers hinder to produce more. Conserving cropland by such factor is the only strategy to reduce the future stresses. This result was consistence with the work of (Getahun, 2014).

Education level household heads: Household head's education represented the level of formal schooling attended by the household headed. The coefficient of education is negative relationship with technical inefficiency, which indicates that farmers with greater years of formal schooling tend to be less technically inefficient than the other were. This was indicates that the farmers with more education respond more readily in using the new technology and produce closer to the frontier output. This is because education can increase their information acquisition and adjustment abilities, thereby increasing their decision-making capacity. In general, farmers who are more educated were able to perceive, interpret and respond to new information and adopt improved technologies such as pesticides, fertilizers, compost, and lead his farms by formal planning much faster than their counterparts do. This result was in line with the findings of (Abba, 2012; Beyan, 2013; Getachew and Bamlak, 2014; Hassen 2016; Wudeneh and Endrias, 2016). Nevertheless, this seemingly contradictory finding has been reported in other studies (Musaba and Bwacha, 2014).

Age of farm household heads: The age of the household is the proxy for the experience of the household head in farming. In this study age of farm household heads was found to have unexpected result. The result indicated that age of the household heads influenced inefficiency negatively at 5% level of significance. This suggested that older farmers were more efficient than their young counterparts were. The reason for this may probably be that the farmers become more skill full as they grow older due to cumulative farming experiences (Zalkiwi, 2014). This result was consistent with the arguments by (Evaline *et al.*, 2014, Musaba and Bawacha, 2014) indicated that, since farming as any other professions needs accumulated knowledge, skill and physical capability, it is decisive in determining efficiency. The knowledge, the skills as well as the physical capability of farmers is likely to increase as their age increases.

Livestock holding: Number of livestock the households in terms of TLU hypothesized to have positive influence in the technical inefficiency. That means households who have better livestock holding are more technically inefficient than the others were. In this study, the coefficient of TLU is positively and significantly influences technical inefficiency at 1% level of significance. The study area characterized by zero grazing system and absence of communal grazing land has apparently created severe feed shortage. Similarly, possession of large number of livestock believed as greater wealth and capacity. Those who have large number of animals are trekked to the other area during the dry season as to find livestock feed, which overlaps with cropping season, and less time allocated for crop managements. Due to this fact, farmers who owned large livestock might be more technical inefficient as compared to those who possessed less livestock. Hence, the possible policy implication here is that farmers should be advised to have an optimum size of livestock. The result in this study is in line with the findings of several other empirical works (Wondimu and Hassen, 2014; Hassen, 2016).

5. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1. Summary

Since sorghum is the main staple food in Ethiopia, high productivity and efficiency in its production are critical to food security in the country. The purpose of this study was to estimate the technical efficiency and identify variation source of technical inefficiency of sorghum farmers in Melka Bello District of Eastern Ethiopia. For this study, both primary and secondary data were used. The primary data source was gathered from 138 sample households using structured questionnaires. Secondary data related to sorghum production were collected from different sources to support primary data both at national and regional level data. Both descriptive statistics and econometric model were employed to analyze data. The Cobb-Douglas frontier functional form was found to be best fit the farm level data to estimate the level of technical efficiency by with inefficiency effects. The single-stage estimation procedures that constitute six inputs in frontier production function and twelve explanatory variables included in inefficiency model was employed.

The model results revealed that Npsb fertilizer, land, seed, labour, and oxen power were significantly determinate sorghum production while Urea fertilizer was positive relationships with outputs but insignificant. The analysis also revealed that the sum of the partial output elasticity's with the respective inputs is 0.862. This result indicates that production structure characterized by decreasing return to scale. That means a proportional increase in all the inputs leads to the smaller proportional increase in output.

The discrepancy ratio, γ , which measures the relative deviation of output from the frontier level due to inefficiency was about 89.5% the rest was attributed to noise. The mean technical efficiency level of households in sorghum production was 0.76, ranging from 0.24 to 0.97. Sorghum production can be increased by 24% through efficient use of the available resources, given the current state of technologies. Hence, smallholder households growing sorghum are not technically efficient and therefore there is allowance of efficiency improvement by addressing some important policy variables influenced households' level of technical inefficiency in the study area.

Out of twelve hypothesized variables, only six of them significantly determine technical inefficiency. The coefficient of the extension visit is negatively and significantly affects technical inefficiency at 1% significance level. The negative and statistical relationship between extension visit and inefficiency supports the notion, which implies that farmers who had more extension visits/teachings are likely to be more successful in gathering information and understanding new practices and the use of modern inputs. It enhances information exchange between development agents and farmers in using natural resources and technology that may causes technical inefficiency variation.

Education is fundamental in improving the technical efficiency of farmers. Moreover, education should be considered in increasing resource use efficiency and agricultural productivity. The coefficient of education is negative for farmers within which indicates that farmers with greater years of formal schooling tend to be more technically efficient. Therefore, the regional governments need to strengthen farmers' access to education that could be implemented through expansion of farmers training center or formal and non- formal education in the study area. Off-farm income was found to be negative and significant at 5% level significance in determining technical inefficiency. Moreover, the negative sign of the estimated coefficients had important implications of variables in technical inefficiency.

The result shows that the number of livestock owned found positive and significant at 1% level of significance in determining technical inefficiency. That means households who have better livestock holding are more technically inefficient than the others were. The coefficient of soil and water conservation was negatively associated with technical inefficiency of farmers. In this study, as expected soil and water conservation activities negatively effect on technical inefficiency at 1% level of significance. Both physical and biological conservation increase fertility and soil nutrients causes increasing productivity must consider as the last mitigation.

The negative coefficient of soil fertility status indicates that, fertility of soil has significant and negative contributes to technical inefficiency of sorghum production in the study area. This again implies that households with fertile land were technically efficient than those who have infertile land. Therefore, local government would support farmers' different activities that

increase soil fertility. Since, an additional resource to poor soil may causes increasing the extent of low productivity of the producer.

5.2. Conclusion and Recommendations

In the study areas, there were limited resources, the efforts to increasing the efficiency of smallholder farmer limited. Therefore, the result of this study summarizes information to all stakeholders, policy makers, and extension workers agents on how to increase farm level efficiency and specifying determinants of technical inefficiency must considered as one of the best strategies rather than in unneeded allocation of the resources. The argument here is that improvements in the agricultural productivity in the use of modern technologies are timely unattainable by considering economy, require relatively longer time to achieve and farmers have serious financial constraint to afford them.

In addition to this, consequently production of agricultural sector by using improved technologies will be high if it is coupled with the improvement of the existing level of inefficiency of households. Since the existence of higher inefficiency and the determinant factors that are responsible for the efficiency variation between the households have important policy implications to reduce the existing level of efficiency of households in the study area, the following policy recommendations have been drawn based on the results of the study.

First, investment in education and strengthening extension services should be considered as a central ingredient in the achievement of improving agricultural productivity. This study indicates that education of household heads improve production efficiency that brings substantial improvement on sorghum productivity. The local government should give due attention for farmer's education through establishing and strengthening informal education and extension service accesses in short terms. Finally, the existing level of inefficiency in sorghum production is high and this calls for better attention in increasing farmer's awareness on natural resource managements through soil and water conservation activities to enhance gain of the producer through removing existed level of technical inefficiency of sorghum farmers. In such circumstances, strengthening sustainability of soil and water conservation was essential policy recommendation.

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7. APPENDICES

Appendices table: Types of crops, land allocated, productivity and output obtained

Types crops		Area(ha)	Total output produced (qt)	Productivity (qt/ha)
Maize		6801	142,821	21
Sorghum		9241	120,133	13
<i>Teff</i>		909	3,272.4	3.6
Wheat		2041	31,839.6	15.6
Barley		1134	15,989.4	14.1
Peas		386	3,937.2	10.2
Soybean		68	544	8
Haricot bean	136	136	9	50
	1300	1284	4	36
Chickpeas		45	180	4
Lentil		46	138	3
Lenseed		23	55.2	2.4
Groundnut		1,248	5,990.4	4.8
Sesame		590	1770	3
Total		23966	332,940.2	60

Source: MDOA, 2019

Appendices table: The conversion factors to estimate livestock unit equivalents

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

Sources: Cited in Assefa (2016)

Appendices tables: Total number of livestock in study area in 2019/2020

Animal category	Quantity
Cow	237,908
Ox	145,000
Calf	0.25
Donkey	18,157
Heifer	0.75
Goat	228,459
Sheep	39,012
Camel	5,635
Mule	684
Horse	856
Chicken	294,250
Traditional hive	19,241
Modern hive	606
Transitional hive	174

Sources: DOA, 2019

Appendices table: Patterns of land use in study area in 2019/20

Sr no.	Description	Size in ha
1	Cultivated land (ha)	29,591
2	Coffee land (ha)	8,039
3	Chat (ha)	4654.5
4	Forest land(ha)	27,387
5	Grazing land(ha)	6,087

Sources: DOA, 2019

Appendices table : Level of education of sampled household heads

Education level	Frequency	Percentage
Illiterate	68	49.57
Grade1-4	32	23.19
Grade 5-8	35	25.36
>= grade 9	5	3.63
Total	138	100

Source: model output, 2020

Appendices table : The VIF for continuous variables used in efficiency model

Variable	1/VIF	VIF
Land fragmentation	0.851	1.17
Education	0.87	1.15
Farm size	0.862	1.16
Family size	0.67	1.48
Age of the household head	0.72	1.38
TLU	0.91	1.10
Meeting	0.92	1.08
Extension visit	0.85	1.17
Mean VIF	1.20	

Source: stata output, 2020

Appendices table : Summary of technical efficiency of sampled households

HHID	TE	HID	TE	HID	TE	HID	TE
1.	.80	35.	.72	69.	.95	103.	.77
2.	.919	36.	.96	70.	.78	104.	.84
3.	.96	37.	.817	71.	.83	105.	.90
4.	.63	38.	.8	72.	.49	106.	.92
5.	.62	39.	.39	73.	.48	107.	.78
6.	.79	40.	.82	74.	.79	108.	.63
7.	.89	41.	.64	75.	.93	109.	.79
8.	.83	42.	.88	76.	.47	110.	.48
9.	.80	43.	.49	77.	.92	111.	.85
10.	.94	44.	.39	78.	.93	112.	.62
11.	.75	45.	.82	79.	.88	113.	.67
12.	.66	46.	.73	80.	.68	114.	.90
13.	.93	47.	.89	81.	.74	115.	.55
14.	.88	48.	.94	82.	.89	116.	.82
15.	.82	49.	.90	83.	.83	117.	.63
16.	.56	50.	.75	84.	.85	118.	.91
17.	.86	51.	.84	85.	.72	119.	.54
18.	.66	52.	.83	86.	.83	120.	.40
19.	.47	53.	.83	87.	.76	121.	.37
20.	.50	54.	.88	88.	.47	122.	.89
21.	.56	55.	.85	89.	.52	123.	.32
22.	.75	56.	.91	90.	.64	124.	.85
23.	.90	57.	.88	91.	.94	125.	.63
24.	.88	58.	.85	92.	.77	126.	.35
25.	.58	59.	.84	93.	.49	127.	.47
26.	.78	60.	.95	94.	.95	128.	.52
27.	.84	61.	.85	95.	.51	129.	.51
28.	.77	62.	.58	96.	.71	130.	.56
29.	.91	63.	.83	97.	.48	131.	.58
30.	.51	64.	.95	98.	.52	132.	.80
31.	.53	65.	.60	99.	.72	133.	.43
32.	.79	66.	.83	100.	.82	134.	.50
33.	.69	67.	.88	101.	.83	135.	.54
34.	.46	68.	.80	102.	.62	136.	.86
137.	.523	138.	.86				

Sources: Stata output, 2020

Questionnaire

Forms and questionnaire developed for analysis of technical efficiency of sorghum production in Melka Bello District.

I. General Information

1. Questionnaire number _____ 2. Name of enumerator _____
 Signature _____ 3. Date _____ 4. Name of *kebele* _____
 5. Supervisor: Kalid Mohammed

II. Personal Information of the Household Head and the Family

1. Local name of the field _____
 2. Name of the household's _____
 3. Sex: 1. Male 2. Female 4. Age: _____
 5. Education level: 1. Illiterate 2. Read & Write 3. Formal education (Grade _____)
 6. Marital Status: 1 Single 2. Married 3. Divorced 4. Widow
 7. If married, do you have more than one spouse. 1. Yes 0. No
 If yes, how many? _____ 8. Farming experience _____ Years
 9. Main occupation 1. Farmer 2. Non-farming 3 Other:
 Specify _____
 10. What is the relative wealth position of the farmer? (Categorized by peer groups)
 1. Very rich 2. Rich 3. Medium 4. Poor 5. Very poor
 11. House types 1. Iron roof 2. Grass roof 13. Family size (including the head):
 Male _____ Female _____ Total _____

No	Name	Sex	Age	Kinship	Education level	Religion	Occupation	Ethnic category
1								
2								
3								
4								

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

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

Occupation: 1. Full time farming 2. Part time farming 3. Student 4. Other _____

Ethnic category: 1. Oromo 2. Amhara 3. Tigray 4. Other (specify) _____

12. Adults in the household including households

Member of Household	Sex	Age	Education level	Main occupation	No of years at work

III. Livestock Ownership

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

2. If yes, fill in the following table

No	Type of animal		Number		Approximate value in Birr	Remark
			Owed	Owed		
1	Oxen					
2	Cow					
3	Heifer					
4	Calves					
5	Donkey					
6	Sheep					
7	Goat					
8	Hens					
9	Camels					
10	Beehives	Modern				
		Local				

Iv. General description of the sorghum plot

1. Do you have own cultivated land for sorghum. 1. Yes 2. No.

2. Then what type's ownership? 1. Owned 2. Rented 3. Shared 4. None

3. What is the average cost of renting land in this Area _____birr/*timad* per year?4. Rented in land (*timad*) _____how much did you pay in birr/*timad* per year? _____5. Rented out land (*timad*) _____

6. How many quintal of sorghum you got from the crop sharing? _____qt

7. Land owned by sharecropping (*timad*) _____then who cover the following expenses?

1. Purchase of seed 2. Purchase of pesticide 3. To hire Oxen power

4. Purchase of fertilizer 5. To hire human labor

8. How many quintal of sorghum given to the owner of the land? _____

9. No of plots owned _____ and Number of plots planted with sorghum _____ *Timad*10. Total size of own land covered by annual crops in 2018/19 _____*Timad*

11. Total size of own land left for grazing in 2018/19 _____ *Timad*

12. Total size of own land left uncultivated in 2018/19 _____ *Timad*

13. Total size of own garden in 2018/19 _____ *Timad*

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

15. Fertility status 1. Excellent 2. Very good three. Good 4. Poor

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

V. Farming Practices

1. Which season(s) is the most important for your agricultural activities?

1. Meher 2. Belg 3. Belg and Meher 4. All year

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

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

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

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

6. Is there soil conservation structures built on the land? 1. Yes 2. No

7. What type of soil conservation mechanism employed on your sorghum plot?

1. Soil Bund 2. Stone Bund 3. Cut of Drain 4. Chek Dam 5. Agro-forestry practices 6. Others _____

8. Are you participating in community based watershed managements? 1. YES 0. NO

VI. Production activities

1. What are major annual crops you grow?

1. Sorghum 2. Maize 3. *Teff* 4. Barley 5. Wheat

6. Others _____

2. What are the major perennial crops you are growing? List? _____

3. How many plots do you have? _____

4. On how many plots do you plant sorghum 2017/18 (last year)? _____

5. How much of your land covered by sorghum crop last year? _____

Human and oxen labor input used in major farming activities

Date	Activities	Pair of oxen		Human labor participated						Exchange/hireling labor	
		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)										
	Sowing										
	Top Dressing										
	Weeding(1 st)										
	Weeding(2 nd)										
	Harvesting										
	Others										

1. Number 2. Time

6. Did you use fertilizer, seed, and pesticides in sorghum field? 1. Yes 2. No

7. Did you use organic fertilizer on sorghum field? 1. Yes 2. No

If yes, fill the following tables

Description (1)	Type/variety (2)	Unit (3)	Quantity (4)	Unit price (5)	Total cost (4*5)	Time of delivery	Area coverage (kg/ha)
Seed	Local						
	Improved						
Fertilizer	NPSB						
	UREA						
Pesticide							
Inorganic fertilizer	Green Manure						
	Compost						
	Animal waste						

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

8. If you do not use chemical fertilizer, why?

1. Too expensive

2. Inconvenient to transport

3. Not timely available

4. Not available

5. Not good to apply on sorghum field 6. Other _____

9. What type of sorghum seed you used this year? 1. Local varieties 2. Improved varieties
10. If improved varieties, source of the seed
 1. Own source 2. Exchanged from other farmer 3. Government seed distributors
 4. NGOs 5. Others_____
11. If you do not use organic fertilizer, why?
 1. It is bulky to transport 3. I do not have animals to prepare it
 2. Lack of awareness 4. Others, specify_____
12. Do you practice fallowing? 1. Yes 2. No
13. If yes, after how many years of harvesting do you fallow your land? _____years
14. Then for how long you fallow your land? _____years
15. Do you practice crop rotation? 1. Yes 2. No
16. How many qt of sorghum yields you get in 2018/19 year? _____qt

VII. Expenditure and income source of the farm households

1. What is the first source of income of the Household?
 1. Crop production 2. Livestock Production 3. Crop & livestock
 4. Forest products 5. Petty trade 6. Other (specify)

2. What is your off farm activity?
 1. Tailor 2. Hair making 3. Carpenter 4. Handcraft
 5. Pottery 6. Trading 7. Others, specify_____
3. How many days per month do you spent on off farm activities? _____
4. What is the secondary source of income?
 1. Crop production 2. Livestock products 3. Forest products
 4. Petty trade 5. Off-farming employment 6. Others if any_____
5. Estimates of annual income of the household from different sources

No	Income sources	Annual income in Birr	Remark
1	Crops production		
2	Sale of livestock		
3	Sale of livestock products (milk, butter, Cheese, egg, skin, honey, etc.)		
4	Sale of vegetable and fruits		
5	Sale of chat		
6	Sale of coffee		
7	Sale of forest products		
8	Off farm activities		
9	Remittance		
10	Others		
	Total		

6. What is the relative wealth position of the farmer? (Personal and peer group Ranking.

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

7. Type of the house 1. Grass cover 2. Corrugated iron 3. Other type_____

If the house built with corrugated iron, number of corrugated iron _____

8. Why some members of your family are engaged in off/non- farm activities?

1. Shortage of land 2. Excess family labor 3. Attractive income from off-farm

4. Other, specify_____

9. How much is your average expenditure per month? _____Birr per year_____Birr.

1. For food items _____Birr 2. For non-food items _____Birr.

No	Type of expenditure	Annual expenditure in Birr	Remark
1	Food		
2	Clothing		
3	Fuel		
4	Salt, sugar, oil, etc.		
5	Soap and other sanitation purposes		
	Others		

10. How many crops yield lasts for consumptions? 1. Month _____2. Year

VIII. Extension service and training

1. Do you have extension contact in 2018/19? 1. Yes 0. No

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

3. How often do the development workers visit your farm starting from land preparation until?

Harvesting of crops?

1. Daily 2. Weekly 3. Monthly 4. Quarterly
5. They didn't visit at all 6. Other, specify _____
4. Where do you meet DA?
 1. At his office 2. At your farm 3. At Mosques 4. At public meeting
5. When did you start getting extension service? _____ year
6. Did you ever received any pieces of advises regard sorghum Production? 1. Yes 2. No

If yes, for _____ days or _____ months.
7. How many days did you visited the extension agent (land preparation until harvesting of crop)? _____ Days
8. Have you ever attended training related to crop production in the last two years separately from government meeting? 1. Yes 2. No

If yes, the type of training _____ Duration _____ days
9. Have you got practical training on sorghum production? 1. Yes 0. No
10. Have you ever attended a field day or demonstration trial on sorghum? 1. Yes 2. No

If yes, on which farm _____ specify _____
11. Did you ever receive any training outside the locality? 1. Yes 2. No

If yes, the type of training _____ duration _____
12. Do you have access to any sources of credit? 1. Yes 2. No

If yes, what sources of credit do you have? 1. Formal sources 2. Informal 3. Both
13. What are the formal sources of credit institutions? 1. Commercial banks 2. Oromia micro finance Credit and Saving Institution 3. NGOs 4. Others, specify _____
14. Have you received any borrowing from the formal institutions this year? 1. Yes 2. No
15. If yes, what kind of credit does you received? 1. Short term 2. Medium term 3. Long term
16. For what purpose do you borrow? 1. Primary basic needs 2. Medicine
 3. School 4. Input purchase 5. Investment 6. To pay back other loans 7. Other, specify _____
17. How much money did you received for the current production year? _____ birr
18. What is the interest rate? _____ %
19. What collateral (security) was requested for the credit?
 1. Animals 2. Land 3. Durable goods
 4. Friends or relatives guarantee 5. Other, specify _____

20. What are the informal sources of credit? 1. Traders 2. Relatives 3. Friends 4.

Others, specify _____

21. For what purpose did you borrow from informal credit sources?

1. Primary basic needs 2. Medicine 3. School 4. Input purchase 5. Investment

6. To pay back other loans 7. Other, specify _____

22. How much money did you receive from informal sources this year? _____Birr.

23. Which period is foreseen for the credit repayment? _____months

24. How much is the interest rate per month? _____%

25. What collateral (security) was requested for the credit? 1. Animals 2. Land 3.

Durable goods 4. Friends or relatives guarantee 5. Other, specify

26. Have you received any borrowing from the institutions last year? 1. Yes 2. No

27. For what purpose did you borrow from the formal sources? _____

28. Do you have a saving habit? 1. Yes 2. No

29. How much do you save per year? _____Birr

30. Where do you save? 1. Home 2. Oromia Micro Finance Credit and Saving Institution

3. Commercial Bank 4. Oromia Cooperative Bank 5. Other, specify_____

IX. Constraints

What are the major constraints of agricultural production on your farming?

1. Shortage of fertilizer

2. Low productivity of local seed varieties

3. High weed infestation

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

5. Shortage of rain

6. Water logging

7. Flooding

8. High sorghum disease & pest, specify the type of disease &/or pest

9. Shortage of draft animal

10. Shortage of labor

11. Others, if any_____

Thank you for your cooperation