Does Technical Efficiency Matter for Ethiopia's Sorghum Producer Farmers? A Study on its Implication for Productivity Improvement[1]

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Abstract

Efficient use of the existing resources by farm households improves their productivity and thereby increases their production and achieves the goal of food security. This study examined the technical efficiency of Smallholder Sorghum Producer households and also identifies its major determinants as the case of smallholder farm households in Southwestern Ethiopia. Purposive sampling technique was employed to draw an appropriate sample of 543 sorghum producer farm households for this cross-sectional survey study. Data analysis tools such as descriptive statistics and econometrics model (stochastic frontier model) were used in combination in this study. The stochastic frontier model shows inorganic fertilizer, labor, seed amount, and oxen power were found to be an important input variable that positively affects the production of sorghum. The results show the mean technical efficiency estimate for sorghum producers was 70 percent. This indicates that there exists a room for improving the existing level of sorghum production through enhancing the level of farm household's efficiency. The stochastic frontier model results from inefficiency estimates shows that education level, of-f-farm income, frequency of extension contact, credit amount, livestock holding, proximity to farm, and total cultivated land were significantly determined the level of technical inefficiency of sorghum production. Hence, to improve the production efficiency, level extension package efforts should give focus to those less efficient farm households. As policy implications, agricultural policy packages should direct towards those important socio- economic factors to improve the productivity of smallholder farmers.

Keywords: Efficiency, MLE, Stochastic frontier, Productivity, Smallholder, Sorghum
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Abbreviations

BSZAO: Bench Sheko Zone Agricultural Off-farm-income;
CSA: Central Statistical Agency;
GDP: Gross Domestic Production;
KZAO: Kaffa Zone Agricultural Off-farm-income;
LR: likelihood ratio;
ML: Maximum Likelihood;
FDRE: Federal Democratic Republic of Ethiopia;
SRS: Simple Random Sampling;
TE: Technical Efficiency;
UN: United Nations;
TLU: Tropical Livestock Unit;
MoARD: Ministry of Agriculture and Rural Development;
PPS: Probability Proportion to Size;
WFP: World Food Program.

1. Introduction

Sustainable Development Goal-2 (Target-2.3), states that by 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists, and fishers (UN, 2015). In Sub-Saharan Africa (SSA), agriculture-based economies are predominant and economic development planning is often tied to agricultural productivity growth. (World Bank 2007; Dejanvry and Sadoulet 2020). According to World Bank, (2014), poverty reduction and income growth can generally be achieved through agricultural growth that creates spillover effects to the remaining sectors.

However, production and productivity of the agricultural sector in SSA is low due to low technological adoption and techniques among others (Abraham et al., 2014; Gashaw *et al*., 2014 and Lulit *et al*., 2012). Smallholder farmers in low-income countries are characterized by low production and productivity (Azam *et al.*, 2012). Agriculture is the livelihood of the majority Ethiopian population that contributes 43% of Gross Domestic Product (GDP), 90% of export earnings, 96% of rural employment, and 70% provides raw materials for industries in the country (Biru *et al*., 2020). It is the primary activity in Ethiopian economy, where about 84% of the country's population engages in various agricultural activities and generates its income from household consumption to sustain its livelihood. Total agricultural output produced by smallholder farmers was about 94% and the farm land being cultivated by them was 95% (Gebre Selassie and Bekele, 2012; CSA, 2017). The demand for food has been increasing while the availability of land has been diminishing due to the rising of population pressure. Thus, the only way to raise agricultural production is to increase yield per unit area (Khan *et al.* 2014). More than 80% of Ethiopians live in rural areas, depending on rain-fed, small-scale farming in the highlands and pastoral livelihoods in lowland areas. With population growth, farm sizes become smaller and explained by low productivity (USAID, 2018; Alemayehu *et al*., 2012; WFP, 2010).

Smallholder agricultural will continue to be the base for agriculture sector development and increasing the production and productivity of major crops will continue to be priority as a source of growth and poverty reduction (FDRE, 2015). Cereals are the major food crops both in terms of volume of production obtained and area coverage which are predominantly produced by smallholders in Ethiopia (Abu, 2013). Out of the total grain crop area, 81.46% (10,478,218.03 hectares) was under cereals and contributed 88.52% (about 296,726,476.94 quintals) of the grain production. Sorghum accounts 14.21% (1,828,182.49 hectares) of the grain crop area and contributed 15.71% (52,655,800.59 quintals) of the grain production that makes it the third largest share of total cereal production (CSA, 2020). In the southern region, from the total land size of 1,148,320.13 hectares covered under grain crops, cereals accounted an area of 916,197.26 hectares with production of 27,057,812.44 quintals (CSA, 2020).

Sorghum is the major grain produced globally after maize, wheat, rice, and barley and Africa's second most important cereal (Naik *et al*., 2016; Omoro, 2013). Sorghum is a multipurpose crop mainly grown for food consumption and the rest for animal feed, and processed into various industrial products such as starch, malt and alcoholic beverages, biofuels (alcohol), sweeteners, edible oils, and other forms of traditional foods (Adebo, 2020; Nangobi and Mugonola, 2018; FAO, 2014; Hager *et al*., 2014). In the southern region of Ethiopia, from the total area covered by cereal crops, the area allotted for sorghum is 105,255.96 hectares with a production level of 2,849,141.51 quintals (CSA, 2020). In densely populated areas of south western Ethiopia, major cereal crops like sorghum are the most predominate crop but the population is growing rapidly and the pressure on land is increasing, resulting in marginal lands to be taken into production problems.

In Ethiopia today, there has been an increasing focus by policy makers on adoption of modern technologies rather than efforts targeted at improving the efficiency of inefficient farmers. It is obvious that, introducing modern technologies can increase agricultural productivity and production. Trying to introduce new technologies may not have the expected results or will not be cost effective in areas where there is inefficiency in which the existing inputs and technologies are not efficiently utilized (Asefa, 2012). As a result, the use of the existing technologies is more cost-effective than applying new technologies. It is known that, the level of farmers' technical efficiency has paramount implications for country's choice of development strategy (Zenebe *et al*., 2004; Rashid and Negassa, 2012). Thus, a technical efficiency analysis is crucial to find out if farmers are efficient in the use of the existing resources and to decide when to introduce new technologies.

Measuring efficiency level of farmers can benefit the economies by determining the extent to which it is possible to raise productivity by improving the neglected source of growth (efficiency) with the existing resource base and available technology. In this regard, there have been various empirical studies conducted to measure technical efficiency and showed wide efficiency differences among small-scale farmers in Ethiopia (such as Seyoum et al., 1998; Mohammad et al., 2000; Temesgen and Ayalneh, 2005; Shumet, 2011; Musa et al., 2014; Berhan, 2015; Getachew and Bamlak, 2014; Hassen, 2016; Tekleyohannes *et al*., 2018). Nonetheless, findings of these studies might not be applicable to the case of sorghum production in southwestern Ethiopia and such results need to be looked at within the production contexts that may be unique and more localized due to the diverse agro-ecological zone, differences in the know-how of the farmers, differences in the output produced, and differences in technology and means of production. Per knowledge of authors', there are no studies undertaken on productivity and technical efficiency of cereal crops in general, specifically on sorghum producing farmers in the study area.

Additionally, it is imperative to update the information based on the current productivity of farmers. Studies on technical efficiency of smallholder agriculture are not extensive, and the findings or conclusions of some of them are not consistent with one another. Thus, 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. Although a study that targeted production systems of smallholder farmers would provide relevant information to policymakers and key stakeholders considering the time when productivity growth level significantly in critical policy targets, there is a great demand for analysis from diverse stakeholders to develop future strategies. Thus, increasing agricultural productivity is the major step towards transforming the rural economy and ensuring food security. Additionally, considering the production potentials and its factors vary across different agro-ecologies in the country, the very low productivity of agricultural system in the study area, lacks in empirical studies on productivity, and how much farmers are efficient in sorghum production in the study area. Therefore, this study tries to measure the technical efficiency of sorghum production and aims to bridge the prevailing information gap by providing empirical evidence on smallholder resource use efficiency in southwestern Ethiopia.

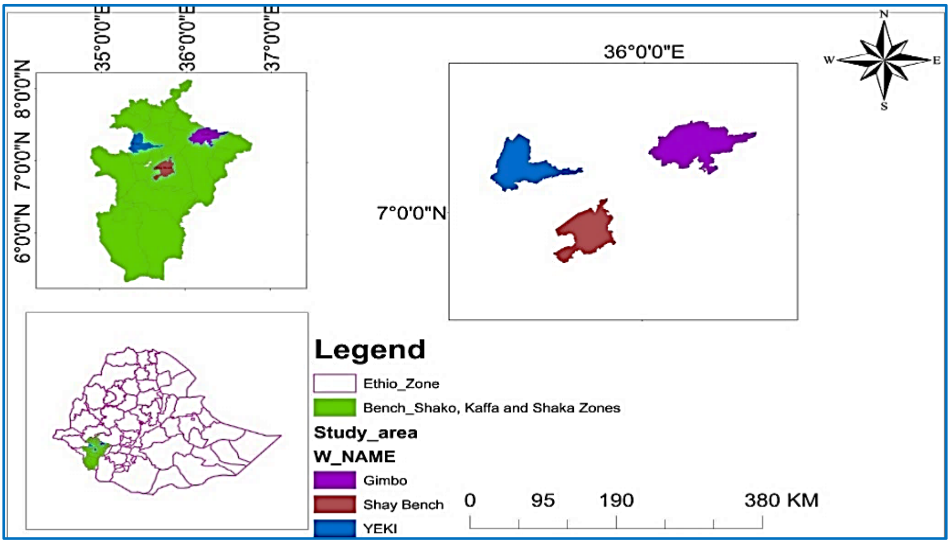
2. Materials and Methods

2.1 Study Area Description

The study was conducted in Kaffa, Sheka and Bench Sheko zones of Southern Nations Nationalities and People's Region. Kaffa Zone lies within 07°00'- 7°25'North latitude and 35°55'-36°37'East longitude. The altitude of the study sites ranges from 1600 to 1900 meters above sea level. The topography is characterized by sloping and rugged areas with very little plain land (KZAO, 2018). According to Central Statistical Agency report on population projection the total population of the zone in the year 2017 was estimated to reach 1,102,278. Out of which the total population 49.14% and 50.86% are male and female respectively (CSA, 2013).

Sheka zone lies between 7°24‟ to 7°52‟ N, 35°13‟ to 35°35‟ E, and 900 to 2700 meters above sea level. Its area coverage is 2175.25 kilometers square, out of which 47% is forest, and 56, 24, and 20% is highland, amid altitude, and lowland, respectively. The total population of the zone in the year 2017 was estimated to reach 269,243 out of which 50.30% and 49.70% are male and female respectively (CSA, 2013). Major crops that cultivated in the zone include off-farm-income, maize, sorghum, millet, beans, ginger, turmeric, ''enset'', wheat and pea (Mohammed, 2010).

Figure 1: Location of study areas



Source: ARCGIS, 2019

The total population of Bench Sheko zone in the year 2017 was estimated to reach 847,168. Out of the total population 49.31% and 50.69% are male and female respectively (CSA, 2013). The main food crops in this zone include Maize, Sorghum, Off-farm-income, Taro, and Enset. Cash crops, fruits, Spices, etc. According to report of Zones, agricultural Off-farm-income, 243522 quintals of sorghum produced from area allocated, 13529 hectare with productivity of 18 qt/ha (BSZAO, 2018).

2.2 Data Types, Sources and Data Collection Methods

For the study, relevant data were collected by two phase primary survey. First, preliminary survey was conducted to broadly understand the farming systems and the major types of crops grown in the study area. During this exploratory survey, formal and informal discussions were held with different stakeholders including farmers, DAs, farmers' association leaders, and agricultural experts/off-farm-incomers. The purpose of the survey is to facilitate characterization of the existing farming systems and livelihood strategies of the farm households in the context of their specific socio-economic and biophysical settings. It also tries to refine the study objectives, sampling methods, and the survey instrument. Once having the basic information using need assessment survey, the main survey was carried out using structured survey instrument. An interview was carried out with the selected farm households. The enumerators, who can speak the local languages and are familiar with the culture of the local people were selected. They were given training on data collection procedures and interview techniques to simplify the complexity of data collection. Thus, primary data analysis results were supported and traingulated by secondary sources like reports, books and empirical findings of different relevant published and unpublished materials.

2.3 Sampling Procedure and Sample Size Determination

The target population for this study was smallholder sorghum producer farm households. A combination of both purposive and random sampling techniques was employed to draw an appropriate sample. The data were collected from purposively selected three zones, Kaffa, Sheka and Bench Sheko. These three zones were among sorghum growing zones in southwestern Ethiopia. From these three zones, according to information obtained from the zones agricultural off-farm-income, Gimbo district (from Kaffa zone), Shay Bench district (from Bench Sheko zone) and Yeki district (from Sheka zone) have a relatively higher potential of sorghum growing than other districts have in these zones. Thus, the districts were selected purposively. First, *Kebeles*[3] in the three districts were stratified into sorghum producers and non-producers. Then, among the sorghum growing *Kebeles*, 15 (fifteen) *Kebeles* (7 *Kebeles* from Gimbo district, 5 *Kebeles* from Shay Bench district and 3 *Kebeles* form Yeki district) *were* randomly selected in order to obtain representative sample household heads**.** Finally, from the total list sorghum producer farm households of 15 *Kebels*, 543 sample farm households were selected by using a simple random sampling (SRS) technique based on probability proportional to size (PPS).

Table 1: Zone, Districts, and sample size selected from sample *Kebeles*

Zone	District	Target population	Sample size proportion	Percentage
Kaffa	Gimbo	10,522	203	37.38
Bench Sheko	Shay Bench	9,226	178	32.78
Sheka	Yeki	8,397	162	29.83
	Total	28,146	543	100.00

Source: Own sampling design

[3] *Kebele* is the lowest administrative unit of a region

2.4 Analytical Framework

Descriptive statistics like mean, percentages, frequency charts, and standard deviations were used. Inferential statistical tests like chi-square test for potential discrete (dummy) variables and t-test was used to test the significance of the mean difference of continuous variables for the sample households. Descriptive statistics often fails to predict the combined effect of explanatory variables on the dependent variable (Aldrich and Nelson, 1984). Thus, this gap is to be filled by running appropriate econometric models/ linear programming techniques. There are two analytical approaches that can be used to estimate efficiency or inefficiency level in production; the non-parametric approach and parametric approaches. A non-parametric approach is represented by Data Envelopment Analysis (DEA) while parametric approach by deterministic and stochastic frontier models. The non-parametric approach called (DEA) first developed by Charnes, Cooper and Rhodes (1978), has the power of accommodating multiple outputs and inputs in technical efficiency analysis. It is non-parametric, as it does not require an explicit functional form and constructs the frontier from the observed input-output ratios by linear programming techniques. Nonetheless, DEA fails to take into consideration the possible impact of random shock like measurement error and other types of noise in the data. Additionally, it lacks the statistical procedure for hypothesis testing (Coelli, 1995). On the other hand, the stochastic frontier does not accommodate multiple inputs and outputs and is more likely to be influenced by mis-specification issues. However, the fact that the latter incorporates stochastic components into the model increased its applicability in the analysis of technical efficiency of agricultural productions. Thus, for the study stochastic frontier production function was employed.

2.4.1 Specification of Stochastic Frontier Model

As indicated above, non-parametric approach (DEA) assumes the absence of random shocks while farmers always operate under uncertainty. Because of which, the study employed the stochastic frontier approach. The stochastic frontier model can be specified as:

$$y_i = f\left(x_i;\beta_j\right) + v_i - u_i \qquad \textbf{(1)}$$

Where: i – is the number of sorghum producing farm households, y_i – is the sorghum output measured in kilograms, x_i – is a vector of input quantities used by the i^th^ sample farm households, β_j – is a vector of unknown parameters to be estimated, $f(.)$ – is Cobb-Douglas or Translog production function, v_i – is the random error term, independently and identically distributed as $v_i \sim N(0, \delta_v^2)$ is intended to capture events beyond the control of farmers, u_i – it is a non-negative random variable as $u_i \sim N(\mu, \delta_u^2)$ is intended to capture technical inefficiency of the i^th^ farm households.

The various null hypotheses for the parameters in the frontier production function and inefficiency model were tested by using the likelihood ratio test (LR).

The first likelihood ratio (LR) test was computed from the log likelihood value obtained from the estimation of Cobb-Douglas and Translog production specifications. Thus, the computed value of likelihood ratio (LR) = 22.24 is less than the upper 5 percent critical value of 41.34. Thus, the Ho that states all square and interaction terms coefficients in Translog specification are equal to null was not rejected. Based on that, the Cobb-Douglas stochastic frontier model adequately represents the survey data and specified as;

$$LnSOUTPUT = \beta_0 + \beta_1 \ln LAND + \beta_2 \ln UREA + \beta_3 \ln DAP + \beta_4 \ln OXEN + \beta_5 \ln LABOR + \beta_6 \ln SEED + \beta_7 \ln HIP + v_i - u_i \quad \textbf{(2)}$$

Where Ln is the natural logarithm**,** i- represents the i^th^ farm household in the sample.

The model parameters in stochastic production function were analyzed by employing a single stage estimation procedure. In using the two-stage estimation procedure of efficiency level and factors determining, the efficiency index is estimated by the stochastic production function in the first stage and then regressed against a number of other farm specific and socioeconomic variables in the second stage. The one-stage estimation procedure of the inefficiency effects model together with the production frontier function would be used in the study. The two-stage procedure produces inconsistency in the assumption (Coelli *et al.*, 1998). Moreover one-stage procedure is the most commonly used method in the analysis of technical efficiency. Thus one-stage procedure is selected for this study. Additionally, the null hypothesis that the explanatory variables associated with inefficiency effects which are all zero (H_0: $\delta_1=\delta_2,\ldots=\delta_{13}=0$) was also tested. The calculated value λ_{LR} = 59.24 is greater than the critical value of 22.36 at 13 df. Thus, the null hypothesis (H_0) that the explanatory variables are simultaneously equal to zero was rejected at 5 percent significance level.

The technical efficiency model by Battese and Coelli (1995), in which both the stochastic frontier and factors affecting inefficiency (inefficiency effect model) are estimated simultaneously as the joint estimation of a stochastic frontier production function is specified as:

$$LnSOUTPUT = \beta_0 + \beta_1 \ln LAND + \beta_2 \ln UREA + \beta_3 \ln DAP + \beta_4 \ln OXEN + \beta_5 \ln LABOR + \beta_6 \ln SEED + \beta_7 \ln HIP + v_i - (\delta_0 + \delta_1 FARMEXP + \delta_2 SEX + \delta_3 EDUCLHH + \delta_4 FAMSIZE + \delta_5 COOPMEM + \delta_6 TLU + \delta_7 CULTLAND + \delta_8 OFINCOME + \delta_9 FRQEXTC + \delta_{10} DFARM + \delta_{11} CRETAM + \delta_{12} ACCTR + \delta_{13} FRGMNT + w_i) \tag{3}$$

Where δ_i = parameter vector associated with the estimated inefficiency effect and w_i = stochastic is error term.

The maximum likelihood (ML) estimates were used which require distributional assumptions for the composed error term. We considered the (Battese and Coelli, 1995) parameterization. The maximum likelihood (ML) estimates of the production function were obtained from the following log-likelihood function using one-stage estimation procedure:

$$Ln(Y_i) = \frac{-N}{2}\ln\left(\frac{\pi\delta_s^{\ 2}}{2}\right) + \sum_{i=1}^{N} \ln \Phi\left(\frac{-\varepsilon_i \lambda}{\delta_s}\right) - \frac{1}{2}\delta_s^{\ 2} \sum_{i=1}^{N} \varepsilon_i^{\ 2} \tag{4}$$

Where, $\varepsilon_i = v_i - u_i = \ln y_i - x'_i\ \beta$ and $\lambda = \sqrt{\delta^2{}_u / \delta^2{}_v}$

$\Phi(.)$= Is the distribution function of the standard normal random variable; $Ln(Y_i)$ = a logged output level for the i^{th} farm households; X'_i = logarithm of the level of input for the i^{th} farm households; β = regression coefficient; λ = a discrepancy parameter as defined above; $\sigma_s^{\ 2}$ = a variance of standard error of the composed error term and N = number of observations.

The technical efficiency of an individual farm household is defined in terms of the observed to the corresponding frontier output given the level of input. From Equation (1), Technical efficiency of the farm households can be specified as:

$$TE_i = \frac{y_i}{\exp(x'_i\beta + v_i)} = \frac{\exp(x'_i\beta + v_i - u_i)}{\exp(x'_i\beta + v_i)} = \exp(-u_i) \qquad \textbf{(5)}$$

Where y_i = denotes output of sorghum produced by the i^{th} farm household,
x'_i = is a (1×k) row vector with the first element equal to 1, of the input quantity used by the i^{th} farm household for the production of sorghum,
$\beta = (\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \ \ldots \beta_k)$ is a (1×k) column vector of unknown parameters to be estimated,
u_i = is a nonnegative random variable associated with technical inefficiency of the i^{th} farm household for sorghum production,
v_i = is the random error term of the model which captures the random error of the production of sorghum in the i^{th} farm household and i = 1, 2, …, n is the number of samples in a population.

As defined by Equation (4), the null hypothesis is that there are no technical inefficiency effects in the model is conducted by testing the null and alternative hypothesis H_0: $\gamma = 0$ versus H_1: $\gamma > 0$.

The Generalized likelihood ratio (LR) test statistic is calculated as:

$$LR = \lambda = -2\{Ln[L(H_0)/L(H_1)]\} = -2\{Ln[L(H_0) - L(H_1)]\} \quad \textbf{(6)}$$

Where: $L(H_0)$ = the log- likelihood value of the null hypothesis;
$L(H_1)$ = the log- likelihood value of the alternative hypothesis; *Ln* is the natural logarithm

Important factors need to be identified to define the problem of inefficiency by investigating for remedial measures to solve the problem if those farmers do not achieve the maximum output level with a given technology. Some of the empirical literatures that are conducted are presented hereunder in brief to support the hypothesis specified inefficiency variables. Hence the specified dependent and explanatory variables based on theoretical suggestions and previous studies are presented in (Table 2 and 3) as follows.

Table 2: Definition of variables incorporated in the stochastic production function

Variable Notation	Type	Description and measurement	Expected sign
Ln (SOUTPUT)	Continuous	Natural log of the total output of sorghum obtained from the i^{th} farm in kilogram	
Ln (LAND)	Continuous	Natural log of the total amount of land allocated for sorghum crop in hectares by the i^{th} farm household	+
Ln (UREA, DAP)	Continuous	Natural log of the total amount of Inorganic fertilizer (Urea and DAP) in kilogram applied by the i^{th} farm household	+
Ln(OXEN)	Continuous	Natural log of the total number of oxen days used by the i^{th} farm household	+
Ln (LABOR)	Continuous	Natural log of the labor force (family and hired) which is all measured in terms of man-days	+
Ln (SEED)	Continuous	Natural log of the quantity of sorghum seed used by the i^{th} household measured in terms of kilograms	+
Ln (HIP)	Continuous	Natural log of the quantity of chemicals such as herbicides, insecticides/ pesticides used as an input by the i^{th} farm household measured in Ethiopian Birr	+

Source: Own elaboration

Table 3: Definitions of the variables used in the inefficiency effect model

Variable Notation	Description and measurement	Expected sign (Hypothesis)	Theoretical suggestions and empirical literatures to support hypothesis
FARMEXP	Farming experience of the household head in sorghum production is measured in terms of years	+	Khanal and Maharjan,2013; Tadesse et al., 2017
SEX	This variable assuming a value of 1 if male headed and 0 for female household head.	+	Zenebe et al. (2005); Aynalem (2006)
EDUCLHH	Level of education attained by household heads measured in terms of years	+	Aynalem (2006); Abba, (2012); Chepng'etich *et al*., 2015; Sisay et al., 2016; Mustefa et al., 2017 and Tekleyohannes *et al*., 2018
FAMSIZE	Number of family size in terms of count	+	Aynalem (2006); Orewa and Izekor (2012)
COOPMEM	It is a dummy variable and measured as 1 if the household is involved as a member of the cooperative and, 0 otherwise	+	Abdulai et al.,2018; Khanal et al. (2018b); Wongnaa and Awunyo-Vitor, 2018
TLU	The total number of livestock owned by the household measured in terms of Tropical livestock unit (TLU)	+/-	Fekadu (2004 +[17]); Aynalem (2006+); Hassen and Wondimu, (2014-[18]); Hassen (2016-)
CULTLAND	It is the cultivated land other than sorghum that the house hold managed measured in terms of hectare.	+/-	Endrias et al. (2012+); Hailemaraim (2015-); Beyan *et al*., 2013+)

17 "+" Indicates studies found positive relationships
18 "-" Indicates Studies found negative relationships

Variable Notation	Description and measurement	Expected sign (Hypothesis)	Theoretical suggestions and empirical literatures to support hypothesis
OFINCOME	It is the amount of income obtained from offarm to none farm activities measured in Ethiopian Birr.	+/-	Haileselassie (2005-); Elibariki et al. (2008 +), Hassen and Wondimu, (2014-); Hailemaraim (2015+);
FRQEXTC	Frequency of the extension contact of the farm households measured in terms of frequency	+	Fekadu (2004); Haileselassie (2005); Hailemaraim (2015);
CREDITAM	It is the amount of money that the farm household head borrowed measured in terms of Ethiopian birr.	+	Bamlaku et al. (2007); Hailemaraim (2015); Hassen (2016); Kaleb and Workneh, 2016
DFARM	It is the average distance between the home of the farm household and the farm in walking minutes.	-	Kinde (2005); Alemayehu (2010); Kusse et al., 2018
ACCTR	It takes a value of 1 if the farm household head participated in the training and 0 otherwise.	+	Fekadu (2004); Tadesse et al., 2017
FRGMNT	It refers to the total number of farm plots that the farm household had managed during the survey period	-	Fekadu (2004); Elibariki et al. (2008); Hailemaraim (2015)

Source: Own elaboration

3. Results and Discussion

3.1 Descriptive Statistics Results

Under this section, the descriptive results of the socio-economic characteristics of sorghum producer farm households and variables used in stochastic production are presented and discussed.

3.1.1 Descriptive results on socio-economic characteristics

As presented in (Table 4), the mean age of sorghum producers was 42.081 years with minimum of 22 and maximum of 80 ages, respectively. As indicated in (Table 4), on average a household head has about 3.379 years of education level. The average family size of sorghum producers was 5.823 with the minimum of 2 and the maximum of 13. Males who headed households represented 80.8 percent of the total number of households under study. This shows proportion of household head in the sample is much lower than the one at national level (i.e. one fourth of the total rural household head is female). Thus, the gender distribution in the study area can be characterized as male dominated research. On the other hand, the average frequency extension contact for sorghum producers was 10.631 while 67.2 percent have participated in sorghum output improvement trainings. As depicted in (Table 4), 55.4 percent of sorghum producers are member of multipurpose cooperatives. Farm households own an average of 5.2 TLU with standard deviation of 2.77 as depicted in Table 4. On average, sorghum producer households' farmers earned 1023.252 Ethiopian Birr from off-farm activities as indicated in (Table 4).

Table 4: Summary statistics of the socio-economic variables

Variable description	Mean	Std.dev.	Minimum	Maximum
Age of household head (in Years)	42.081	11.438	22	80
Education Level (in Years)	3.379	2.746	0	11
Family size (Counts)	5.823	2.457	2	13
Farming Experience (in Years)	20.365	10.078	3	50
Credit Amount (in Ethiopian Birr)	1850.967	1978.775	0	6570
Livestock ownership (in TLU)	5.208	2.771	0	12.03
Extension contact (Frequency)	10.631	12.108	0	46
Off-farm-income (Ethiopian Birr)	1023.252	1849.414	340	9850
Cultivated Land under other crops (Hectare)	0.784	0.418	0.023	2.1
Proximity to farm (in walking minutes)	51.202	24.955	7	135
Number of plots (Fragmentation of land)	3.282	1.325	1	6
Gender of household head	0.808	0.394	0	1
Membership in cooperative	0.554	0.497	0	1
Access to training	0.672	0.470	0	1

Source: Survey result, 2018/19

3.1.2 Descriptive results of production function variables

In this study, seven input variables are used to estimate the stochastic production function. On average, sample farm households produced 1328.545 kilograms of sorghum with a standard deviation of 766.061 (Table 5). The productivity varied between a minimum of 400 kilograms and a maximum of 3800 kilograms per hectare, indicating a considerable scope for improving sorghum yields in the study area. In the study area, farm households used inorganic fertilizer (DAP and urea) for sorghum production during the survey period. The average amount of DAP and urea fertilizers applied for sorghum production by sample farm households were 51.243 kilogram per hectare and 45.759 kilograms per hectare, respectively during the production season.

Table 5: Summary of the variables used to estimate the stochastic production function

Variable description	Mean	St. deviation	Maximum	Minimum
Sorghum output (Kg/Ha)	1328.545	766.061	3800	400
DAP (Kg/Ha)	51.243	42.372	98	46
Urea (Kg/Ha)	45.759	42.082	95	25
Land (Ha)	0.805	0.398	2.35	0.235
Human labor (MDs/Ha)	36.761	9.604	59	17
HIP Chemicals (Eth. Birr/Ha)	42.679	51.154	250	45
Seed (Kg/Ha)	20.576	7.235	32	7
Oxen power (ODs/Ha)	12.112	4.980	30	5

Source: Survey Result, 2018/19

As presented in Table 5, the average land allocated for sorghum crop by sample farm households was 0.805 hectares. This is greater than the national average land allocated for sorghum (0.485 hectare) and less than regional size of 1.069 hectare by farm households. On average, the labor force used in the production of sorghum was 36.761 man-days per hectare with a standard deviation of 9.604. In addition, the average oxen power used by sample farm households was 12.112 oxen days per hectare with standard deviation of 4.980 (Table 5). And the amount of seed sample farm households' used was 20.576 kilograms, with a standard deviation of 7.235 in the study area. This indicates the average seed rate was 20.576 kilogram per hectare that is greater than the recommended rate of 12 kilograms per hectare. Moreover, another essential input was chemicals, on average; sample farm households applied 42.679 Ethiopian Birr (Table 5) for chemicals like weedicides, herbicides, or pesticides per hectare in the study area for the protection of sorghum farms during the production season.

3.2 Econometric Model Results

In this section, the econometric model results of the stochastic production function, individual efficiency scores of smallholder producers, and sources of differences in technical inefficiency of sorghum producer farm households are presented and discussed.

3.2.1 Stochastic frontier model estimation results

The result of the stochastic production function showed that inorganic fertilizer (UREA and DAP), oxen power (OXEN), labour force (LABOR), and the amount of seed (SEED) were positive and significant effect on the level of sorghum output at 1 percent significance level except for amount of seed that is at 5 percent level of significance (Table 6). That means these input variables are important in shifting the frontier output to the right (i.e., for each unit of these variables there is a possibility to increase the level of output). However, the land allocated for sorghum (LAND) and chemicals (HIP) such as herbicides or pesticides were insignificant. Thus, the insignificant value of land allocated for sorghum indicates sorghum output depends more on how well available land is used rather than land size allocated. Thus, the Cobb-Douglas production function revealed that the input variables labor force, oxen power, and amount of seed were the main inputs in determining the level of sorghum output in the study area. Whereas, the partial elasticity of inorganic fertilizers (UREA and DAP) was very low, implying that these have less effect in determining the output level for the best practice. The positive coefficients of input variables indicate that a 1 percent increase in inorganic fertilizer (Urea, DAP), labor force, amount of seed and oxen power yields 0.009%, 0.079%, 0.254%, 0.067%, and 0.203% increase in sorghum output, respectively. In other words, if all inputs are increased by 1 percent, the sorghum output would increase by 0.62 percent (Table 6).

The value estimated sigma square (δ^2) for frontier of sorghum output was 0.293, implying that significantly different from zero and significant at 1% level of significance. The significant value indicates the goodness of fit of the specified assumption of the composite error terms distribution. Stochastic production function result shows that the value of the important parameters of log- likelihood in the half- normal model $\lambda = \sigma u/\sigma v = 2.32$, this indicates that the estimated value is significantly different from zero. The null hypothesis that there is no inefficiency effect ($\lambda = 0$) was rejected at the 1percent level of significance, suggesting the existence of inefficiency effects. Additionally, the variance ratio parameter γ which found to be significant at 1percent level expressed that about 84.3% of sorghum output deviations are caused by differences in farm level TE as opposed to the random variability that are outside their control of the farm households. This also makes the stochastic frontier model appropriate for the study. Furthermore, the returns to scale analysis coefficients were calculated to be 0.62 percent indicating decreasing returns to scale. As a percent increase in all inputs proportionally would increase the total production by less than 1 percent (Table 6).

Table 6: Stochastic production frontier model results

Variable description	Parameters	Coefficients	Std. Err.	P>|z| value
Ln UREA	β_1	0.009***	0.002	0.000
Ln DAP	β_5	0.079***	0.028	0.004
Ln LAND	β_3	-0.006	0.004	0.172
Ln LABOR	β_4	0.254***	0.053	0.000
Ln HIP	β_2	0.002	0.002	0.529
Ln SEED	β_6	0.067**	0.032	0.037
Ln OXEN	β_7	0.203***	0.035	0.000
_cons	β_0	7.240***	0.211	0.000
Diagnostic statistics				
Sigma- square	δ^2	0.293 ***	0.033	
Lambda	λ	2.318 ***	0.063	
Gamma	γ	0.843***		
Log likelihood function		-214.457		
Returns to scale	$\sum\beta_{1-7}$	0.620		

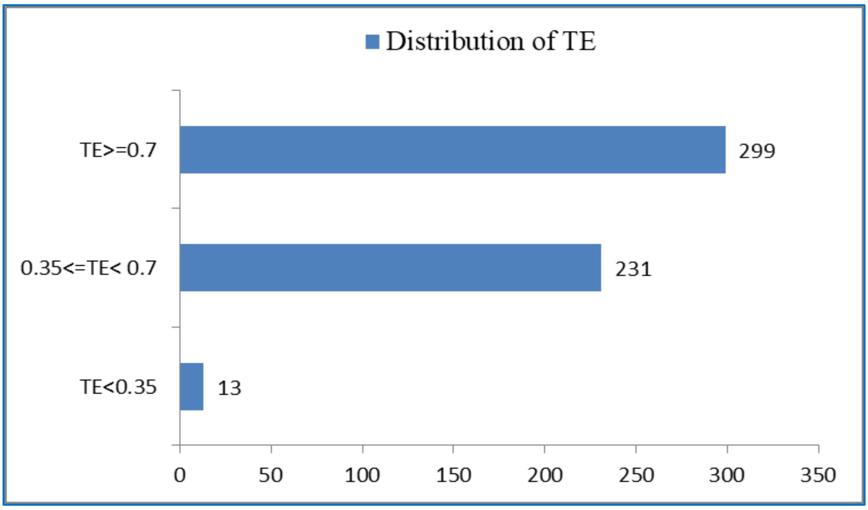
Note: "*", "**" and "***" represent the statistical significance of factors at 10, 5, and 1% levels

Source: Survey Result, 2018/19

3.2.2 Efficiency scores of sample farm households

The results of the model (Table 7) indicated that there was wide range of differences in technical efficiency scores among sorghum grower farm households in the study area. The mean technical efficiency of sample farm households during the survey period was 70.1%. The technical efficiency among households ranged from 22.3 to 93.2% (Table 7). This wide variation in household specific technical efficiency levels is consistent with the study results reported by (Ike and Inoni, 2006; Dhehibi *et al.*, 2014; Wudineh and Endrias, 2016; Wongnaa and Awunyo-Vitor, 2018); Belete, 2020). This shows the existence of room for improving the existing level of sorghum production through enhancing the farm household's technical efficiency. The distribution of efficiency (TE) indexes among smallholder sorghum producers is depicted in (Figure 2).

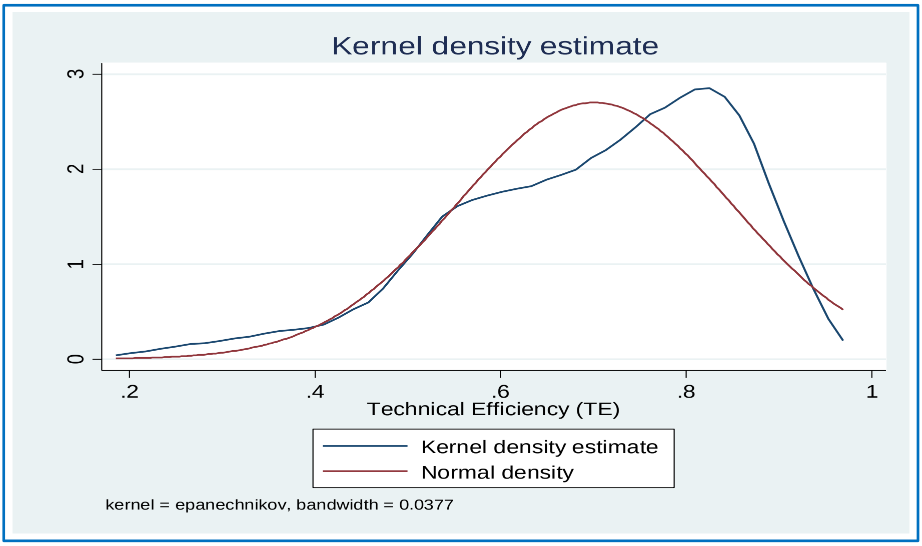
Figure 2: The distribution of efficiency (TE) indexes among smallholder sorghum producers



Source: Survey Result, 2018/19

Average level of TE further shows the level of sorghum output of the sample farm households can be increased by about 30% if appropriate measures are taken to improve the efficiency level of sorghum grower farm households. In other words, there is a possibility to increase the yield of sorghum by about 30% using the resources at their disposal in an efficient manner without introducing any other improved (external) inputs and practices. It is observed that 244 (44.93%) of the sample farm households are operating below the overall mean level of TE while 299 (55.06%) of the farm households are operating at the TE level of more than 70.12% (Figure 2). Thus, the majority (55.06%) of the sorghum growing farm households were able to attain the overall mean level of technical efficiency. In addition, a kernel density function is plotted (Figure 3) to make sure whether or not the half-normal distributional assumption is met, such as the post-estimation of stochastic frontier normal or truncated-normal model. Density function distribution closely resembles the standard half-normal inefficiency typically assumed in frontier estimation. This proves the assumption that the inefficiency effect error term u_i is nonnegatively distributed with half-normal distribution and significant at 5 percent level of significance.

Figure 3: Kernel density estimate for efficiency scores by full sample farm households



Source: Survey Result, 2018/19

3.2.3 Comparison of actual and potential output

The individual farm households' efficiency levels and their corresponding actual output enable us to determine how much yield is lost because of the inefficient use of existing resources. From the current production practice of the existing resources, it is possible to determine the potential attainable level of sorghum output. Either the farm households had used the available resources in an efficient way was calculated using the actual observed individual level sorghum output and predicted individual technical efficiency from the frontier model. Empirical literatures of (Tigabu, 2016; Abate et al., 2019; Hunde and Abera, 2019) adopted for the potential sorghum production of each individual farm household presented as follows in (Table 7).

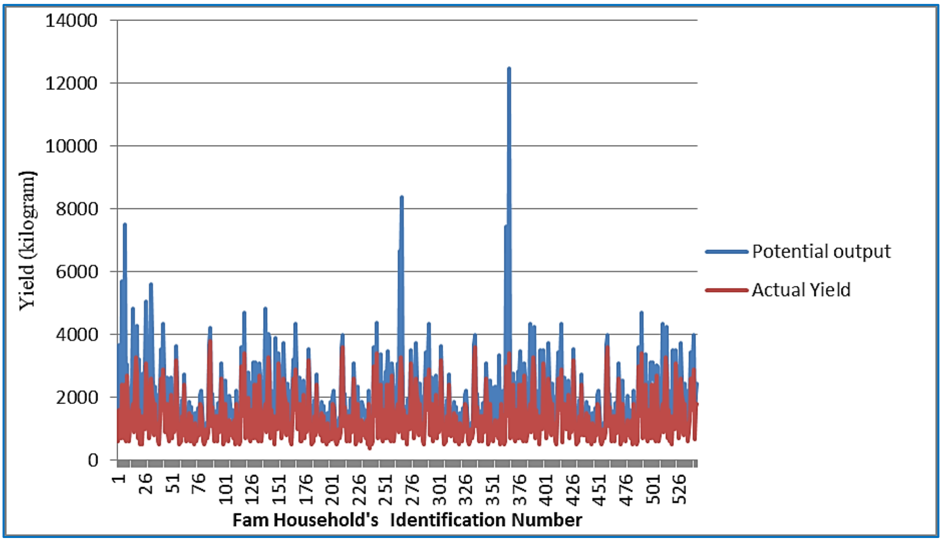
Table 7: Comparison of actual and potential output levels of the farm households

Variable description	Mean	St. deviation	Minimum	Maximum
Actual output (kilogram)	1328.545	766.061	400	3800
Mean TE	0.701	0.148	0.223	0.932
Potential output (kilogram)	1946.163	1203.204	526.890	12462.66

Source: Survey Result, 2018/19

The average level of actual and potential output during the production season was 1328.55 kilograms per hectare and 1946.16 kilograms per hectare with a standard deviation of 766.061 and 1203.204 respectively. This shows the existence of inefficiency and, if farmers use the existing agricultural inputs at the optimal proportion level, a maximum of 12462.66 kilograms of sorghum can be obtained per hectare. There is a statistical difference of the actual and potential output values at P≤0.001 significance level (Table 7).

Figure 4: Comparison of the actual and the potential level of yield



Own survey result, 2018/19

3.2.3 Determinants of technical inefficiency

The driving force behind measuring farm households' efficiency is to identify important determinants as a basis for informing agricultural policy on what needs to be done to improve smallholder agricultural productivity. Result in (Table 8) is presented in terms of inefficiency model estimates and the negative sign shows the variable negatively contributes to the inefficiency level or conversely it contributes positively to efficiency levels. One important point to be considered is that the dependent variable is the inefficiency component of the total error term estimated in combination with the production frontier.

Table 8: MLE of the stochastic frontier model with inefficiency effect

Variables	Coefficient	Std. Err	P>|z| value
FARMEXP	0.011	0.011	0.283
EDUCLHH	-0.071*	0.038	0.066
SEX	0.043	0.278	0.878
FAMSIZE	-0.042	0.046	0.360
COOPMEM	0.330	0.215	0.126
OFINCOME	-0.151***	0.029	0.000
FRQEXTC	-0.684***	0.221	0.002
DFARM	0.192*	0.110	0.082
CREDITAM	-0.101***	0.029	0.001
TLU	0.083**	0.038	0.030
TCULLAND	-0.706***	0.174	0.000
FRGMNT	0.033	0.070	0.641
ACCTR	0.064	0.114	0.577
_cons	-1.436**	0.616	0.020

"*", "**" and "***" are statistically significant at 10, 5 and 1% levels

Source: Survey Result, 2018/19

The results of the inefficiency model showed that education level, family size, non-farm income, frequency of extension contact, proximity to household's residence, Credit Amount, livestock holding and total farm land were significantly contributing to the technical inefficiency of sorghum producer farm households (Table 8). The detailed discussions on the implications of significant variables contributing to technical inefficiency were presented as follows:

Educational level (EDUCLHH)**:** The results of the model show that education level negatively and significantly affecting inefficiency at 10% level of significance. This indicates that education is improving the production efficiency of farm households. Thus, the level of education can enhance the skills of households in the allocation of homemade and purchased inputs, select the appropriate quantities of purchased inputs, utilize existing technologies, and attain higher efficiency level and choose among available techniques of production systems and hence higher efficiency level. This result is consistent with findings of (Assefa, 2012; Beyan *et al*., 2013; Zalkuwi *et al*., 2014; Hassen and Wondimu, 2014; Solomon, 2014; Chepng'etich *et al*., 2015; Sisay *et al*., 2016; Mustefa *et al*., 2017; Kusse *et al*., 2018; Wongnaa and Awunyo-Vitor, 2018).

Off-farm-income (OFINCOME)**:** Income from of-farm non-farm activities was hypothesized that there is an efficiency differential among farm households who earn more income through engaging in off-farm-income activities and those who earn less. The study result shows that the coefficients of the variable entered into the technical inefficiency effect model indicated that the variable affects the level of technical inefficiency negatively and significantly at 1% level of significance level (Table 8). This suggests that an increase or the more income farm households obtained from off-farm-income activities the more technically efficient he/she became. Thus, income obtained from such off-farm-income activities compensate farm households' expenditures and reduce the pressure on on-farm income otherwise. The result obtained is in line with studies of (Arega and Rashid, 2005; Jema, 2008; Hassen, 2011; Ahmed and Melesse, 2018; Kusse *et al*., 2018). Contrary to this, studies of (Hassen and Wondimu, 2014) found positive relationship between level of inefficiency and income from off-farm-income activities.

Frequency of extension contact (FRQEXTC)**:** The result of inefficiency model revealed that frequency of extension contact has negative and significant influence on technical inefficiency at 1% significance level (Table 8). This indicates that the more the household had extension contact, the less he/she will become inefficient. Thus, this result shows that consultation of extension agents improves the productivity of farm households by decreasing the level of technical inefficiency. Additionally, extension advisories provided to the farm households help them to improve their farming operation and household's knowledge regarding the use of improved agricultural inputs. This result is consistent with the results of (Ahmad *et al*., 2002; Amos, 2007; Beyan *et al.*, 2013; Sienso *et al*., 2013; Sisay *et al*., 2016; Tadesse *et al*., 2017; Wongnaa and Awunyo-Vitor, 2018; Kusse *et al*., 2018).

*Proximity to farm (*DFARM)**:** The results showed that the variable had a positive signs and significant effect on technical inefficiency at 10% level as expected. This implied that there is a significant relationship between farm proximity to a household's residence and technical inefficiency (i.e., as the distance increases, technical inefficiency increases). Thus, households whose farm plot is far from residence are more inefficient than those located at relatively near to the farm plot. This could be attributed to the fact that the farther the farm land or farm plot from the farm household's residence, the greater would be the cost of transport management, supervision and opportunity costs. This in turn may hinder the optimal application of farm inputs and lead to technical inefficiency. The result is consistent with findings of (Kinde, 2005; Alemayehu, 2010; Kusse *et al*., 2018).

Credit Amount (CREDIAM): The coefficient of amount of credit had a significant effect on technical inefficiency at 1% significance level. Thus, the result shows that the coefficient of credit amount is negative, which is similar to the expected sign. Sometimes farmers need adequate and timely credit to finance their farm's various input requirements. This implies that adequate credit amount is essential element in agricultural production systems to satisfy farm households' cash needs induced by the production cycle (i.e., as amount borrowed increase, farm households became more efficient). Adequate credit amount may help farm households to purchase farm inputs that they constrained by own cash. This finding is consistent with (Mussa *et al*., 2012; Beyan *et al.*, 2013; Bempomaa and Acquah, 2014; Kaleb and Workneh, 2016; Belete, 2020).

Livestock holding (TLU): livestock holding in terms of tropical livestock units was hypothesized to have an indifferent influence on inefficiency of sorghum production. It is positively and significantly affected technical inefficiency in sorghum production at 5% level of significance. This indicates that farmers who owned large livestock might be less technical efficient compared to those who owned small livestock. This might be due to the fact that farm households who have a large numbers of livestock allocated much of their time in managing livestock and hence less time devoted for crop management. This result is in line with study of (Fekadu, 2004; Shumet, 2011; Assefa, 2012; Hassen and Wondimu, 2014; Hassen, 2016) who found that the coefficient of livestock is found to be significant and positive for technical inefficiency. However, in contrast with studies of (Tchale, 2009; Mussa *et al*., 2012; Beyan *et al*., 2013; Wudineh and Endrias, 2016; Belete, 2020).

Total cultivated land (TCULLAND)**:** The coefficient of total cultivated land other than sorghum had a negative and significant effect on technical inefficiency at 1% significance level**.** This indicated that there was a positive relationship between cultivated land and technical efficiency. This variable is mainly justified on the ground that those farmers with big cultivated land can better diversify their crops. It is not unlikely that large farms can quickly utilize existing resources and might have a greater ability to access modern inputs on time. Therefore, the justification is that large farms use modern agricultural technologies and can be less inefficient due to the economics of scale. This result is consistent with findings of (Amos, 2007; Barnes, 2008; Raghbendra *et al*., 2005; Beyan *et al*., 2013).

5. Conclusions and Policy Implications

Given the limited resources in the study area, efforts to improve the efficiency of smallholder farm households who are key actors in Ethiopia's agrarian economy are indispensable. Stochastic production frontier model results indicated that inorganic fertilizer (Urea and DAP), labour force, oxen power, and amount of seed were significantly determinants of sorghum production. The significant coefficients of these parameters indicate that the increased use of these inputs can increase the output of sorghum to a higher extent using the existing technology in the study area. Therefore, the amount and on time availability of these inputs is crucial.

Existence of inefficiency shows that there is a room to increase the output of sorghum by improving the use of existing technologies by all farm households. Therefore, there is an allowance of efficiency improvement by addressing some important policy variables that influenced households' the level of technical inefficiency in the study area. The estimated stochastic frontier model together with the inefficiency parameters show that educational level, off-farm-income, frequency of extension contacts, proximity to farm, credit amount, livestock holding, and total cultivated land were found to be the major significant determinants of technical inefficiency level of farm households in sorghum production. Thus, the significant inefficiency effect explanatory variables have important policy and development implications in an effort towards improving the efficiency of sorghum production in the study area. It is concluded that decreasing the existing level of inefficiency will have vital importance in improving the productivity in the study area. Thus, the following policy implications forwarded from the study result.

- Attention should be given to farm households through establishing and strengthening education, especially adult education by using the available human and infrastructural facilities like Farmers Training Centers in order to increase the efficiency and agricultural productivity of the country in the long run through utilization of available inputs more efficiently under the existing technology so that farmers could be benefited from the accelerated increase in productivity.
- Study results suggest that an extension contact has to keep on providing information and practical farming knowledge for all households to improve resource utilization in agricultural production.

- Study suggests that there is a need to introduce activities that could enhance the off-farm-income of farm households without affecting their farm time allocation so that the households would be in a position to invest the required amount of resources in sorghum production.
- Development programs should strength their support for farmers to improve land allocation and maintain the fertility of land through awareness creation and introduction of technology that maintain fertility for efficient production.
- Furthermore, attention should be given by the local government and supporting institutions through developing crop-specific extension packages and financial accessibility which encourages the farmers to produce efficiently.
- Therefore, a key factor in narrowing productivity gap is the development and implementation of targeted agronomic training for smallholders through encouraging the adoption of productivity enhancing practices and interventions towards important socio- economic factors. Sorghum a promising crop with the potential to enhance the productivity of smallholder farmers, while providing essential nutrients to food-insecure households. It is fund that the potential for agricultural productivity gains among smallholder sorghum producer farm households in Ethiopia is substantial.

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