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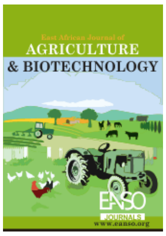

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Original Article

Estimation of Technical Efficiency of Sorghum Production in Dejen District, North-west Ethiopia

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ABSTRACT

Ethiopian agriculture is characterized by low productivity due to natural, social, economic, and institutional factors. Farmers with homogeneous resources produce different outputs per hectare due to inefficient utilization of limited resources. There is no due attention given to crop production efficiency issues, particularly in sorghum production. The objective of this study was to assess the level of technical efficiency and its determinant factors on sorghum production in Dejen District, North-west Ethiopia. The two-stage sampling procedure was used to determine the sample size. Data were collected from 192 households using a systematic random sampling technique. A semi-structured questionnaire was used for the data collection. Focus group discussions and key informant interviews were also conducted. Both descriptive statistics and econometric analysis were used for data analysis. The average technical efficiency of Sorghum producers was 62.8%, with a min of 23.5% and a max of 96.7%. About 37.2% of output variation from optimal production was observed in the study area. The estimated Gamma (γ) value was 73.4% indicating the presence of inefficiency. Thus, farmers have a chance to maximize their output level by making efficient use of existing resources and technology.

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INTRODUCTION

Sorghum is the fifth most important cereal crop next to maize, rice, wheat, and barley in the world (FAO, 2017). It has been cultivated for centuries as a staple food crop in most sub-Saharan African and Asian countries. It also has better adaptation and resistance to high temperatures and drought stresses. It is capable of growing in areas of high temperature, inadequate and erratic rainfall, in soils with poor structure, low fertility, and low water holding capacity (Derese et al., 2018). In developing countries, sorghum is consumed by over 500 million people as their major source of food (Burke et al., 2013). In Ethiopia, the agricultural sector contributes an indispensable role in enhancing economic growth and bringing development, contributing 33.3% of GDP, 80% of employment, 81% of foreign earnings, and providing about 70% of the material for the domestic industries (Growth Transformation Plan [GTP], 2016). Cereal crop production accounts for the largest share of the sector (Muchie and Bekele, 2009). Most agricultural holders derive the food they consume and the money they demand to fulfill their daily expenses from agricultural activities (Central Statistical Agency [CSA], 2016).

About 4.34 million tons of Sorghum are produced per year in Ethiopia, with an estimated average yield of 2.4 tons per hectare. In terms of the number of growers, area coverage, and volume of production, it is the third largest and major cereal crop after Maize and Teff in the country (Kinfe and Tesfaye, 2018). It could be a crop dominated by resource-poor smallholders and typically produced under adverse conditions within the Eastern and North-west parts of Ethiopia, where there is low rainfall. It is used for preparing local drinks for making bread and ‘Injera’. The whole plant with sorghum stalks is used for house construction and cooking fuel, and leaves are also used as animal fodder (Tefera, 2012). Under Ethiopia’s Growth Transformation Plan (GTP), agriculture was emphasized to enhance productivity and production, which is crucial for the country's effort to realize food security and increase export earnings (United Nations Development Program [UNDP], 2015).

However, increasing population pressure with a rate of 2.46 percent (World Population Projection [WPP], 2017), coupled with low levels of agricultural productivity is a critical problem within the country. These have aggravated food insecurity status by widening the gap between demand and supply interaction (Tekalign, 2019). Consequently, Ethiopia is suffering from food insecurity and is unable to satisfy domestic food demand. Attempting to disseminate new technologies and utilizing modern factors of production to improve agricultural productivity is the strategy of the Ethiopian government (Asfaw and Shiferaw, 2010). However, as stated by Torkamani and Hardaker (1996), where there is inefficiency in the utilization of agricultural inputs, trying to introduce new technology might not bring the expected result. The inefficiency in production is the result of inefficient use of limited resources and technology (Dessale, 2019). Efficiency estimation in agricultural production is a very essential and important decision in the use of scarce resources to improve productivity and reformulate agricultural policies (Abate et al., 2019). Empirical studies like Endalkachew (2012), Haile et al. (2019), Mengistu (2014), Degefa et al. (2017), and Mohammed (2018) have been conducted to measure agricultural production efficiency in Ethiopia. However, there is no information on the efficiency of sorghum production in the study area. The extent, causes, and possible measures of the efficiency factors for sorghum producer farmers are not yet given enough emphasis (Kibret et al., 2016). Therefore, this study attempted to estimate farmers’ technical efficiency in sorghum production and identify its determinant factors in the study area.

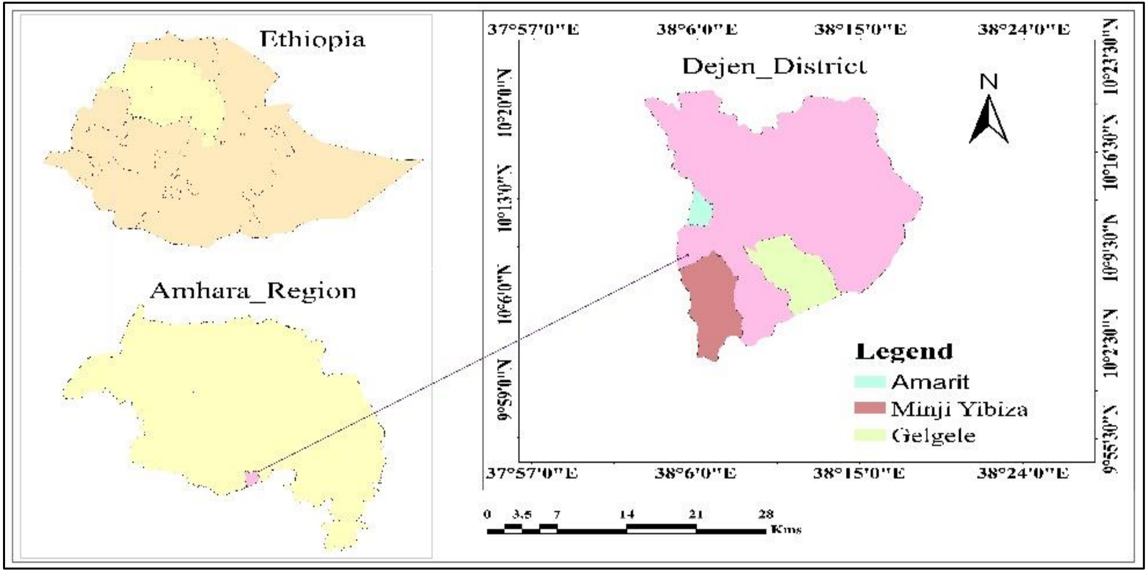
This finding will be used for extension programs for households to increase their crop productivity by identifying factors raising the gap between actual and frontier output; and serve as a policy guide to policymakers to increase Sorghum production by expediting action on the improvement of key determinants of technical efficiency in Sorghum producers regarding the study area, and will be used as a reference document for students and researchers interested in similar topics to stimulate agricultural productivity.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in Dejen District (*Figure 1*). Located in North-west Ethiopia at 336 km south of the regional state capital, Bahir Dar, and 229 km North-west of the capital city of Ethiopia, Addis Ababa. The district lies between longitude 38º6' E and 38º 10' E and between latitude 10º 7' N 10º 11' N, with an elevation of 1071 and 3000 meters above sea level (m.a.s.l). Annual average temperatures in the district are between 20 ºC and 24 ºC, and total rainfall is between 800 mm and 1200 mm. In terms of climatic zones, the District is categorized into three, 41% highland, 31% midland, and 28 % lowland (Dejen District Agricultural Office [DDAO], 2018). The district consists of 21 rural kebeles and 1 town administration. The district has a total population of 95,483, of which 45,952 are males and 49,531 are females (East Gojjam Zone Finance and Economic Development Guidance [EGZFEDG], 2015). Mixed farming is the main livelihood system in the district, where crops and livestock are produced together (Degefa K. et al., 2017).

Figure 1: Map of the study area



Source: Own construction using Arc GIS 10.7

Sample Size and Sampling Procedure

The two stages sampling procedure was employed for this study. Firstly, three sorghum-producer kebeles were selected out of seven sorghum-producer kebeles using a simple random sampling technique. Secondly, households were chosen by using systematic random sampling from each kebele based on proportion to sample size. As presented in Table 1, a total of 192 sample households had been drawn using the (Yamane, 1967) sample size determination formula.

$$n=\frac{3347}{1+3347(0.07)^2}=192 \qquad (1)$$

Table 1: Sorghum producer households sample frame

Sample Kebeles	Sorghum producer households	Sample Size
Minji yibiza	1501	86
Gelgele	1381	79
Amarit	465	27
Total	3347	192

Source: Own computation from sample frame, 2020

Data Collection

To achieve the objective of this study, both primary and secondary data were collected. Primary data was collected through a household survey, focus group discussion, and key informant interviews. The household survey was conducted from 192 households in the 3 kebeles (small administrative villages) using a systematic random sampling technique. A semi-structured questionnaire comprised of questions about household characteristics, input utilization, and sorghum output, institutional and socioeconomic variables that determine households' technical efficiency, was used. About 3 group discussions were carried out with between 6 and 12 participants per kebele. The participants included households of diverse ages, social backgrounds, and gender, as well as village committee members. In total, three key informant interviews were also carried out. The key informants mainly consisted of Kebele agricultural experts. Secondary data were also collected from unpublished and published documents.

Data Analysis

To address the objective of this study, descriptive and econometric analyses were used. Descriptive analysis is essential to study the distribution of variables and provide a quick description of respondents (Kaur *et al*., 2018). In this study, descriptive tools prefer to mean, variance, minimum, maximum, frequency, and percentage. The stochastic frontier model was used for econometric analysis.

Model Specification

This study employed the stochastic frontier functional approach, which requires the prior specification of the production function to estimate the amount of technical efficiency. Among the possible algebraic forms, Cobb-Douglas and trans-log functions are the most popularly used models in most empirical studies of agricultural production analysis (Aldrich and Nelson, 1984). The Cobb-Douglas functional form has advantages over the other functional forms therein: it provides a comparison between the adequate fit of the data and computational feasibility, is convenient in interpreting the elasticity of production, and is very parsimonious with relevant degrees of freedom, which are widely used in frontier production function studies (Hazarika and Subramanian, 1999). On the other hand, the cross-product effects of the explanatory variables have a major role in the maximum likelihood estimation, and the trans-log model fits better (Baltagi and Baltagi, 2008). This functional form allows flexibility in providing an approximation to any twice-differentiable function and for its ability to capture interaction among inputs (Shrestha, 1992).

Therefore, before proceeding to the estimation of technical efficiency and inefficiency effects, a hypothesis test was done to choose the appropriate model between the restrictive Cobb-Douglas functional form in preference to the more flexible trans-log model, which specifies the coefficients of the interaction terms and the square specifications of the input variables under the trans-log specifications equivalent to zero. The test was made based on the value of likelihood ratio (LR) statistics, computed from the log-likelihood value obtained from the estimation of Cobb-Douglas and trans-log functional specifications as follows:

$$LR = 2ln[\frac{L_0}{L_1}] = -2(\ln L_0 - \ln L_1) = -2(-\ln(53.05) - (-\ln(10.67)) \qquad (2)$$

$$= -2(-3.97+2.36) = -2(-1.61) = 3.22$$

Where, L_0 was the likelihood function for Cobb-Douglas and, L_1 was the Tran slog model for sorghum production with values of -53.05 and -10.67, respectively. The hypothesis test result was found to be 3.22. This value is less than the critical chi-square value of (12.34) at a 5% significance level with (22) degrees of freedom. Hence, it failed to reject the null hypothesis.

The trans-log model turns into Cobb-Douglas when all the square and interaction terms in the Trans-log are zero. This indicates that to fit the data for the estimation of the technical efficiency of sorghum producer farmers in the study, the

Cobb-Douglas production function was the best-fit model. Multicollinearity among explanatory variables of the production function and the inefficiency effect model was checked using the variance inflation factor for continuous variables and the contingency coefficient for categorical variables.

The result indicated that there were no multicollinearity problems in both production function and inefficiency models. In stochastic frontier analysis, the error term is split into two parts (technical inefficiency and random shock component) to accommodate factors that are purely random and are out of the control of the firm (Meeusen and van Den Broeck, 1977). A Cobb-Douglas stochastic production frontier given by Battese and Coelli (1995), for cross-sectional data takes the form:

$$\mathrm{lnY_i} = \beta_0 + \sum_{j=1}^{6} \beta_j \mathrm{ln} x_{ij} + v_i^{-} - u_i \qquad (3)$$

$$j = 1,2,3,\ldots\ldots..192$$

$\mathrm{lnY_i}=\beta_0 + \beta_1 \ln(\text{land}) + \beta_2 \ln(\text{labour}) + \beta_3 \ln(\text{oxen}) + \beta_4 \ln(\text{seed}) + \beta_5 \ln(\text{fertilizer}) + \beta_6 \ln(\text{pesticide}) + \varepsilon_i$

$$\mathrm{lnY_i} = \beta_0 + \beta_1 \ln(\text{land}) + \beta_2 \ln(\text{labour}) + \beta_3 \ln(\text{oxen}) + \beta_4 \ln(\text{seed}) + \beta_5 \ln(\text{fertilizer}) + \beta_6 \ln(\text{pesticide}) + v_i - u_i$$

Where: Ln= the natural logarithm, $\varepsilon_i = v_i - u_i$, which is the residual random term composed of two elements v_i and u_i. v_i = random noise (white noise), which is N (0, σ^2) given the stochastic structure of the frontier that permits a random variation in output due to factors such as weather, measurement error, omitted variables, and other exogenous shocks. u_i = inefficiency effect, which is a non-negative, half-normal distribution (0, σ^2) allowing the actual production to fall below the frontier but without attributing all shortfalls in output from the frontier as inefficiency distributed random error. Technical efficiency measures the output of producer 'I' relative to the output that could be produced by a fully efficient producer using the same input (Coelli et al., 2005). The technical efficiency of producer 'i' is the ratio of actual output relative to the frontier output, as suggested by Coelli et al. (2005).

$$\mathrm{TE_i} = \frac{\mathrm{Y_i}}{\exp\,(\mathrm{x_i}\beta_\mathrm{i}+\mathrm{v_i}} = \exp(-u_i)\,, so\ that\ 0 \le TE \le 1 \qquad (4)$$

Where Y_i is estimated as exp ($Xi\beta + V_i -$ U$_)$ and is the actual output that is obtained in the presence of the technical inefficiency effects. ($X_i\beta$ +) is the corresponding frontier output under the condition of random shocks (Coelli et al., 2005). When dividing the actual output by the frontier output, the remaining (−U) represents technical inefficiency. The score of technical efficiency lies between 0 and 1 (0≤TE≤1).

The technical inefficiency model was employed to analyse and identify influencing factors in technical efficiency. In the technical inefficiency model, the dependent variable is the technical inefficiency variable (U_i) and the explanatory variables are the factors that are hypothesized to affect technical inefficiency (Z_i). In a technical inefficiency model, a positive coefficient indicates that a variable has a decreasing effect on technical efficiency. The relationship implies that variables that increase technical inefficiency will decrease technical efficiency. The empirical specification of the technical inefficiency model for this study is as follows:

$$U_i = \delta_0 + \sum_{n=1}^{14}{'}\delta_i z_i + \omega_i \qquad (5)$$

Where: U_i is the technical inefficiency variable which is assumed to be a function of farm-specific socio-economic and farm management variables. The farm explanatory variables (Z_i) hypothesized to affect producers' level of technical inefficiency were sex, age, education, farm experience, family size, extension contact, land ownership, livestock holding, off-farm activity, credit access, market distance, training, number of plots and plot distance. The inefficiency model is presented as:

$U_i=\delta_0 + \delta_1$ sex $+\delta_2$ age$+ \delta_3$ education $+ \delta_4$ family size $+ \delta_5$ farm experience $+ \delta_6$ extension contacts $+ \delta_7$land ownership $+ \delta_8$ livestock holding $+ \delta_9$ off-farm income $+ \delta_{10}$ credit $+\delta_{11}$market distance

+ δ_{12} training + δ_{13} number of plots + δ_{14} plot distance+ ω_i

U_i≡ Inefficiency effect, δ_i≡ parameter vectors associated with inefficiency effect to be estimated ω_i ≡ a random variable. The likelihood function is expressed in terms of the variance parameterization given by sigma square ‘σ2’ and gamma ‘γ’(Son et al., 1993). The variance parameters, σ2, and γ were used for testing the presence of technical inefficiency. σ^2 refers to the total model variance consisting of a variance due to random effects (σ_v^2) and a variance due to technical inefficiency effects (σ_u^2) which is parameterized as $\sigma^2 = \sigma_v^2 + \sigma_u^2$ (Battese and Coelli, 1995). The total model variance 'γ' which constitutes the technical inefficiency is calculated from estimated variance parameters σu2 and σ2. The parameterization given by (Battese and Coelli, 1995) takes the form:

$$\gamma = \frac{\sigma_{u^2}}{\sigma^2} \qquad (6)$$

γ ranges between zero and one (Baruwa and Oke, 2012). When γ is zero, it indicates that technical inefficiency effects are absent in the data. The implication is that the estimated SFA model reduces to a simple OLS regression since all variation is due to random noise. When it is closer to one, the model indicates that most of the variation in output is due to the existence of technical inefficiency, which confirms the appropriateness of the SFA technique to evaluate the data (Baruwa and Oke, 2012).

RESULT AND DISCUSSIONS

Household Characteristics

In the study area the average age of household heads in the study area during the survey period was 44.2 years with a minimum of 27 and a maximum of 68 years. Most of the respondents about 51.04% relay in the range of 31-45 and only about 8.33 % are the age of 60 and above. The average family size of the sample household was 5.14, with a minimum of 2 and a maximum household size of 9 (*Table 2*). Both male and female household heads were participated in the survey. From the total sample household heads, about 83.85% were male-headed and the remaining 16.15% were female-headed households.

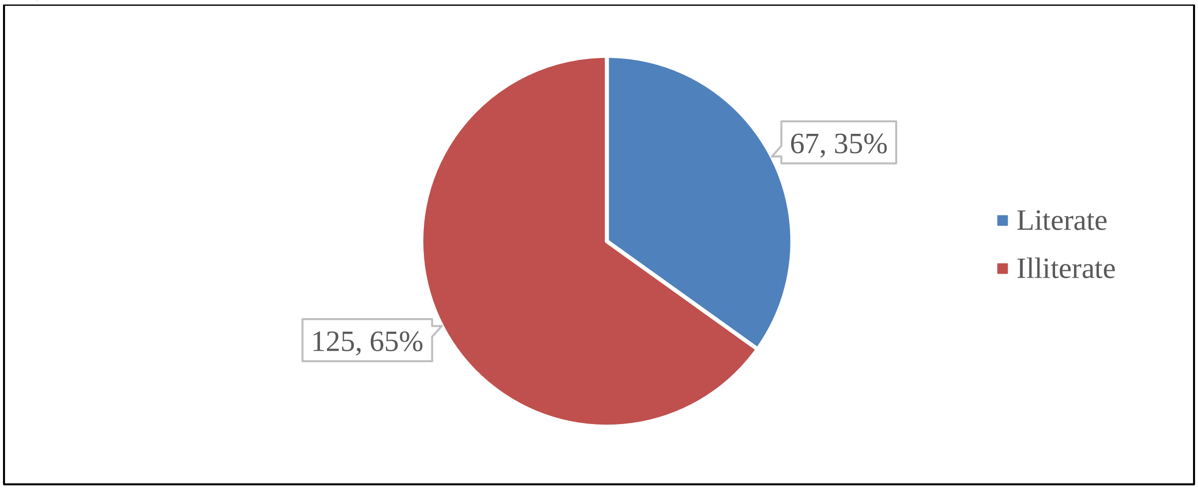
Table 2: Age, family size, sex, and age distribution of the household heads

	Variable	Observation	Mean	Std. Dev.	Min	Max
	Age	192	44.21875	9.302596	27	68
	Family size	192	5.145833	1.503777	2	9
Sex	Male	161		83.85		
	Female	31		16.15		
Age distribution	18-30	15		7.81		
	31-45	98		51.04		
	46-59	63		32.81		
	>=60	16		8.33		
	Total	192		100.00		

Source: Own computation from survey data, 2020

Educational status of household heads: as illustrated in (*Figure 2*) below, out of the total sample households only about 35% can read and write, and 65% cannot read and write.

Figure 2: Education level of household head



Source: Own computation from survey data, 2020

Farm Characteristics of Sample Households

Output and input utilization: as shown in the (*Table 3)* the surveyed households obtain a mean yield of 14.24 quintals/ha with a minimum and maximum of 6 qt/ha and 21qt/ha respectively. The respondents suggested that sorghum yield was better in the production season compared to the previous two seasons which had been affected by locust and rainfall shortage. The sample households used an average amount of 38.98 k.g fertilizer (DAP + Urea) during the production season. The households said that the fertilizer utilization was good in the production season relative to the previous ones. Land is the major resource demanded by the farmers to earn their livelihood income. Sampled households assigned an average land size of 0.875 ha for sorghum production with a minimum and maximum of 0.25 ha 3.75 ha respectively.

Table 3: Level of output and input utilization in sorghum production

Variables	Observations	Mean	Std. Dev.	Min	Max
Output (Quintals/ha)	192	14.26	6.2432	6	21
Seed (k.g/ha)	192	11.64	3.6454	8	24
Oxen (oxen days/ha)	192	7.73	3.3118	4	12
Fertilizer (k.g/ha)	192	38.98	36.44	0	100
Land (ha)	192	0.875	0.3308	0.25	3.75
Labour (man days/ha)	192	54.78	17.3447	24	80
Chemical (liters/ha)	192	3.48	1.5752	1	5

Source: Own computation from survey data, 2020

Livestock holding: Livestock rearing is also another important farming activity in the study area. It serves as a means of security at the time of crop failure in the study area and plays a basic role in the livelihood of households. As illustrated in *Table 4*, the average livestock holding of households was (cattle = 1.24 TLU, Shoats = 0.42 TLU, Equines = 1.1 TLU, and chicken = 0.04 TLU). The livestock raising is highly interrelated with the crop production, that is, oxen give draught power for agricultural activities for ploughing and trashing cereal crops. Whereas livestock provides manure for increasing soil fertility which improves crop productivity. On the other hand, the crop production provides feed for livestock.

Table 4: Livestock ownership of sample households during the survey season

Livestock type		Total number of livestock (TLU)	Mean	Std. Dev
Cattle	Oxen	478	2.489	1.162
	Milk cow	296	1.541	1.345
	Heifer	127.5	.6640	.6938
	Calf	51.5	.2682	.2877
Shoats	Goat adult	115.66	.6389	.8033
	Goat young	39.42	.2053	.1947
Equines	Donkey adult	317.1	1.557	.7175
	Donkey young	95.2	.6095	.5773
Chicken		8.937	.0465	.0423

Source: Own computation from survey data, 2020

Parameter Estimation of Stochastic Frontier Model

The maximum-likelihood estimates of parameters of the stochastic production frontier were obtained after treating the datasets with STATA version 14.1. The Cobb-Douglas stochastic production frontier model was tested and found to be the best fit for the data. It was used to estimate the efficiency of sorghum producer farmers and to identify determinant factors influencing the inefficiencies in sorghum production. The input variable coefficients were estimated under the full frontier production function (MLE). The estimation was computed in a single estimation procedure using STATA version 14.1 and gave the value of the log-likelihood function for the stochastic production function.

As indicated in *Table 5*, the estimated ML coefficients showed that the coefficients of the input variables; land size, labour, oxen power, seed quantity, and fertilizer were found to be significantly related to sorghum production. The coefficients of the area assigned for sorghum, labour, oxen, and fertilizer, were positive and statistically significant at a 1% significance level. The seed was also positively and statistically significant at a 5% significance level. The input coefficients for the area under sorghum, labour, oxen, seed quantity, and fertilizer were 0.3720, 0.2699, 0.1311, 0.1932, and 0.2154, respectively (*Table 5*). Therefore, the increase of the inputs; the area under sorghum production, family labour, oxen, seed quantity, and fertilizer by one percent will increase output by a percent of each coefficient. This implies that the existing inputs were not optimally used, and yields could be increased by using additional inputs. Coelli (1995), argues that stage I is inefficient because the addition of an extra unit of the firm should never produce.

Summing the individual elasticity yields a scale elasticity of 1.18 (*Table 5*). This shows that farmers are facing increasing returns to scale, and depicts that there is potential for sorghum producers to increase their production utilizing the existing resources and technology. Therefore, there is production inefficiency in the study area. So, there is a potential to increase production at an increasing rate using existing resources. The table below indicates the maximum likelihood estimate of the Cobb-Douglas production function frontier model input variables such as land allocated for sorghum, labour, oxen power, seed, fertilizer, and pesticide, of the first five variables were significant and positively related to the production of sorghum in the study area.

Table 5: Maximum-likelihood estimate of Cobb-Douglas stochastic frontier model

Variable	Parameter	Coefficient	Std. Err	Z-Value
Constant	β_0	1.4948***	0.2582	5.79
Ln (Land)	β_1	0.3720***	0.0567	6.56
Ln (Labour)	β_2	0.2699***	0.0284	9.50
Ln (Oxen)	β_3	0.1311***	0.0478	2.74
Ln (Seed)	β_4	0.1932**	0.0387	4.99
Ln (Fertilizer)	β_5	0.2154***	0.0259	8.31
Ln (Pesticide)	β_6	0.0099	0.0273	0.36
Elasticities		1.18		
Variance parameters				
Sigma-squared: $\sigma_u^2 + \sigma_v^2$	$\sigma 2$	0.0248		
Lambda: σ_u / σ_v	λ	1.6635	0.0195	
Gamma: $\sigma_u^2 / \sigma 2$	γ	0.7345	0.2346	

****, ** denotes significant at 1% and 5% respectively.*

Source: Own computation from survey data, 2020

Technical Efficiency Score of Sorghum Producers

The average level of technical efficiency of sorghum producer sample households was about 62.8%, with a minimum and a maximum technical efficiency level of 23.5% and 96.7%, respectively (*Table 6*). This indicates the presence of variation in technical efficiency levels among sorghum producer farmers. This variation in the efficiency level indicated that there is a chance to improve the existing level of sorghum production by enhancing the level of farmers' technical efficiency.

The mean level of technical efficiency further tells us that the level of sorghum yield of the sample households could be increased, on average, by about 37.2% if appropriate measures were taken to improve the technical efficiency level of sorghum producer farmers. In other words, there is a possibility to increase the output of sorghum by about 37.2% by using resources efficiently without any additional improved inputs and practices.

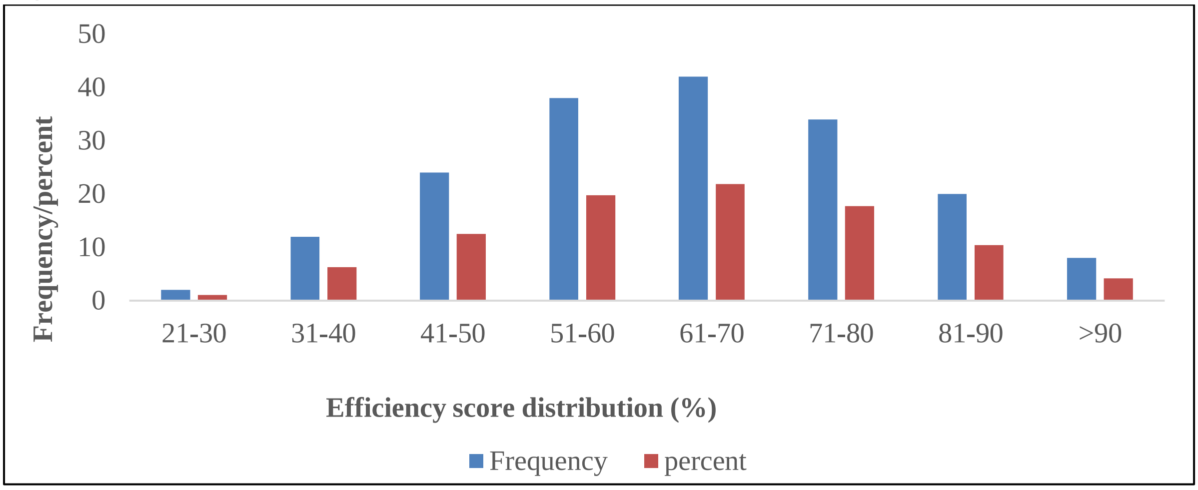
Table 6: Summary of technical efficiency score of sample households

variable	Obs.	Mean	Std.Dev.	Min.	Max.
Efficiency	192	0.6280	0.1516	0.2345	0.9669

Source: Own computation from survey data, 2020

As presented in *Figure 3*, it is observed that about 46.88% of the sample households were operating below the overall mean level of technical efficiency, while about 3.6% of the households were operating at a technical efficiency level of more than 90%. Whereas, about 53.2% were able to get above the mean level of technical efficiency. So, in the long run, besides improving technical efficiency, further efforts are required to introduce other best alternative farming practices and improved technologies to improve the overall sorghum production level.

Figure 3: Efficiency score distribution of sample households



Source: Own computation from survey data, 2020

Determinants of Technical Inefficiency

The estimated level of technical efficiency among smallholder farmers is not enough to derive recommendations for policy intervention. It is also necessary to identify the sources of variation in the technical efficiency estimates among households and quantify their effects. Different Empirical studies on efficiency showed that the determinants of inefficiency were very considerable and highly dependent on demographic and other characteristics of a farmer, resource endowment factors, and institutional factors. Therefore, those factors were considered determinants of inefficiency in this study by assuming other determinants were kept constant.

The coefficients of those socio-economic and institutional variables included in the inefficiency model were estimated simultaneously by the single-stage maximum likelihood estimation procedure using the estimated level of technical efficiency as the dependent variable. According to Coelli (1995), in the analysis of the technical inefficiency effects model, the sign of the coefficients of the regression result is interpreted inversely for technical efficiency.

The positive sign of coefficients in the inefficiency model indicates a decrease in the level of technical efficiency of the household, and vice versa. Thus, the opposite signs of the coefficients of the variable in the model result may be required which readers should keep in mind while reading this section. Out of fourteen explanatory variables included in the inefficiency model for this study, about eight were statistically significant, whereas, the rest six were not statistically significant (*Table 7*).

As indicated in *Table 7*, the estimated coefficient of education status in the inefficiency model was negatively significant at a 1% significance level. This indicates that as a farmer is more educated, his or her level of technical efficiency increases and vice versa. This result supports the findings of Abate et al. (2019) and Wollie (2018). This may be attributed to the orientation of most farmers in the study area, where more than 65 percent did not read or write.

Household size was found to affect technical inefficiency negatively at a 10 percent significance level; this agreed with the finding of Endalkachew (2012), which had a positive effect on the level of technical inefficiency. This study indicated that households with larger family sizes were more technically efficient than those having smaller families. This may be attributed to households consuming more food and striving to achieve higher output. In addition, these households have more labour available for timely implementation of agricultural management activities.

Table 7: Maximum-likelihood estimates for the inefficiency model

Variable	Parameter	Coefficient	Std. Err	Z-value
Constant	δ_0	1.1058*	0.5103	2.17
Sex	δ_1	0.0063	0.3366	0.02
Age	δ_2	0.0009	0.0155	0.06
Education	δ_3	-0.2816***	0.0476	-5.91
Family size	δ_4	-0.1289*	0.0261	-4.93
Farm experience	δ_5	-0.0225**	0.0112	-2.02
Extension contacts	δ_6	-0.3468*	0.1913	-1.81
Land ownership	δ_7	0.0002	0.0053	0.05
Livestock holding	δ_8	-0.2191***	0.0349	-6.27
Off-farm income	δ_9	-0.0087	0.0149	-0.58
Credit	δ_{10}	-0.2260***	0.0338	-6.67
Market distance	δ_{11}	-0.0347	0.0861	-0.40
Training	δ_{12}	-0.1722**	0.0775	-2.22
Number of plots	δ_{13}	0.0165	0.1363	0.12
Plot distance	δ_{14}	0.1591**	0.1036	2.54

****, **, * denotes significant at 1%, 5%, and 10% respectively.*

Source: Own computation from survey data, 2020

Farm experience: The estimated coefficient of farming experience is positive and significant at a 5 percent significance level (*Table 7*). This suggested that the more experienced a farmer is, the higher the probability that farmers are more efficient. This indicates farmers having more experience can make accurate predictions on when and how to sow, what inputs to use, what quantity of seed to use, as well as the timing of the use of these inputs and are therefore more efficient in the use of these inputs as compared to less experienced farmers. This finding is in line with the finding of Mohammed (2018). Extension contacts: The coefficient of extension contact was statistically significant at a 10 percent level of significance and positively influenced the technical efficiency of sorghum producers (*Table 7*). Farmers that have frequent visits by development agents improve farmers' technical efficiency because farmers can share skills and knowledge from experts that helped to apply to sorghum production activities. The chance of farmers who have frequent visits is more important for modern agricultural input mobilization, which enables them to reduce technical inefficiency. Hence, in the study area, there needs to provide extension services and continuous support of farmers by development workers. The contribution of an increasing number of visits of farmers with extension agents can reduce the gap between the efficient and inefficient sorghum producer farmers in the study area. As such a situation initiates farmers to adopt agricultural technologies which help farmers to improve their efficiency level in sorghum production. This result supports the finding of Sibiko et al. (2013).

Livestock holding: Livestock holding (TLU) was an important variable that was statistically significant at a 5 percent significance level and positively determined the technical efficiency of sorghum producer farmers. This might be due to the reason that the livestock size directly imposes implications on the technical efficiency of farmers in sorghum production as it is a major source of a liquid asset, transportation service, manure, and draft power during the ploughing season. This result is consistent with other empirical works of Haile et al. (2019).

Access to Credit: Credit availability can solve the problem of the cash constraint and enable farmers to purchase agricultural inputs timely. As shown in *Table 7*, credit is statistically significant at a 1 percent significance level and positively determines the technical efficiency of sorghum production. Farmers that can get access to credit are more efficient than those who did not get credit access. This is in line with the findings of Mengistu (2014) and Mohammed (2018).

Training: The coefficient of training was positively significant at a 5 percent significance level. This may be because training shares information for farmers in terms of input utilization, soil conservation with multipurpose vegetative crops, risk aversion, storage, and handling systems. Plot distance: Distance is also another variable influencing the technical inefficiency of sorghum-producing farmers. In many empirical studies, it is hypothesized that the distance between the plot and the home decreases the level of efficiency of farmers. In this study, the coefficient of the plot distance is found to be statistically significant at a 5 percent significance level and negatively affects the technical efficiency of a farmer (*Table 7*).

As the plot distance from home increases, the technical efficiency decreases, whereas, technical inefficiency increases. This could be because the level of close supervision may not be as strong when the plots are far away from home.

CONCLUSION AND RECOMMENDATION

The maximum likelihood estimated value of the stochastic frontier model indicated that out of six inputs, five were found to be statistically significant and positively impacted sorghum productivity. The estimated mean technical efficiency of this study was 62.8%, with minimum, and maximum values of 23.5% and 96.7%, respectively. The estimated gamma (γ) value of 73.4% reveals the fact that a high level of technical inefficiency exists among the sampled households.

A large difference among households in their technical efficiency indicates that they are using their resources inefficiently and that there is a chance to improve their output using the current level of inputs and technology to scale up their efficiency. In the study area, there is a possibility to increase technical efficiency by 37.2% operating at the full level of existing inputs and available technology.

The estimated stochastic frontier inefficiency model results showed that education level, household size, farm experience, extension services, livestock size, credit access, and training significantly and positively affect the technical efficiency of sorghum production. While plot distance from home negatively influences the technical efficiency of sorghum production.

The study results provide information to policymakers and extension workers on those input variables and inefficiency effects that determine the level of each farmer's technical efficiency. The presence of higher inefficiency and the major factors that are responsible for the efficiency variation among the households have important policy implications to mitigate the farmers' current inefficiency level in the study area.

Using much more statistically positively significant variable inputs such as land allocated for sorghum, labour, oxen power, seed, and fertilizer can increase sorghum production. Hence households can increase their production by increasing use of such inputs.

The study results indicated that education has a positive and significant effect on sorghum producers' technical efficiency in the study area. Therefore, the concerned body should emphasize adult education to strengthen and establish the required facilities.

Livestock holdings have positively and significantly affected technical efficiency. Households with large livestock sizes can have a better opportunity to get more oxen draught power, sell livestock to earn money for input purchases like fertilizer, and serve organic fertilizer formation. Therefore, providing improved veterinary treatments, water supplies, and fodder needs to be encouraged.

A positive and significant effect of credit access on technical efficiency indicates that money obtained from credit services helps farmers purchase agricultural inputs they cannot afford with their resources. Therefore, the concerned body should establish and expand the service rendered by credit-providing institutions like microfinance in the study area.

The study results suggested that the effect of extension services on the technical efficiency of sorghum production was statistically significant. Thus, extension services should be properly provided for sorghum producer households. The results of this study also revealed that farmers' training has a positive effect on technical inefficiency. Thus, better training facilities should be adequately established and strengthen farmers' training to improve sorghum productivity in the study area.

Availability of Data and Materials

All data used for the analysis of this study is available on the hand of the correspondence author. So, it is possible to get and access the data on a reasonable personal request from the correspondence author.

Competing Interests

The authors declare that they have no competing interests**.**

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Authors' contributions

Both authors contributed substantial input to the manuscript. KC initiated the research idea, led the study design, data collection, manipulation, and analysis, and manuscript preparation. TM provide indispensable input mainly in data management, analysis, and interpretation.

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