Technical Efficiency of Smallholder Sorghum Producers in West Hararghe Zone, Oromia Region, Ethiopia

*Azeb Lemma¹, Belaineh Legesse², Mengistu Ketema³
¹School of Agricultural Economics and Agribusiness, Oda Bultum University, Chiro, Ethiopia.  
²,³School of Agricultural Economics and Agribusiness, Haramaya University, Haramaya, Ethiopia.

This study was aimed at analyzing the technical efficiency of sorghum producing smallholder farmers in Chiro district. It was based on cross-sectional data of 130 sample sorghum producing households randomly selected. The estimated results of the Cobb-Douglas frontier model with inefficiency variables shows that the mean technical efficiency of the farmers in the production of sorghum is 78 percent. This implies that sorghum producers can reduce current level of input application by 22 percent given the existing technological level. The discrepancy ratio γ, which measures the relative deviation of output from the frontier level due to inefficiency, was about 84.6% and while the remaining 15.4% variation in output, was due to the effect of random noise. The estimated stochastic production frontier (SPF) model also indicates that Organic fertilizer, DAP fertilizer, Area, Labor and seed are significant determinants of sorghum production level. The estimated SPF model together with the inefficiency parameters shows that age, Frequency of extension contact, Household size, Slope, Fertility of soil and Livestock holding significantly determine the efficiency level of the farmers in sorghum production in the study area. Hence, emphasis should be given to improve the efficiency level of those less efficient farmers by adopting and using practices of relatively efficient farmers in the area so that they can be able to operate at the frontier. Beside this, a strategy of the government needs to be directed towards the above-mentioned determinants.

Keywords: Sorghum, Technical efficiency, Cobb-Douglass, Stochastic frontier.

INTRODUCTION

Ethiopia, the country with an area of about 1.12 million square kilometers, is one of the most populous countries in Africa with the population of 73.75 million in 2007 with annual growth rate of 2.6% (Central Statistical Agency of Ethiopia, 2008).

This growing population requires better economic performance than ever before at least to insure food security. However, the agricultural sector in the country is characterized by small-scale, subsistence-oriented, an adverse combination of agro climatic, demographic, economic and institutional constraints, and heavily dependent on rainfall. Ethiopian agricultural sector contributes 46.4% of the country’s GDP, employs 83% of total labor force and contributes 90% of exports. The sector plays a pivotal role to induce the industrialization process in the country. (Ethiopian Economic Association, 2012). Therefore, enhancing the productivity of such sector is crucial not only for the development of the sector themselves but also for the development of other sectors in the economy.

Even though Ethiopia is the country with largest grain producers in Africa it is characterized by large pockets of food insecurity and a net importer of grains. Despite agricultural dominance, there were more than seven million peoples in need of food assistance in the country. The country is food insecure mainly due to lack of improved technology and economic inefficiency in production. The smallholder farmers, who are providing the major share of the agricultural output in the country, commonly employ backward production technology and limited modern inputs. Hence, being an agronomically

*Corresponding Author: Azeb Lemma, School of Agricultural Economics and Agribusiness, Oda Bultum University, Chiro, Ethiopia.  
E-mail: azeblemma13@gmail.com
dependent country with a food deficit, increasing crop production and productivity is not a matter of choice rather a must to attain food self-sufficiency (World Food Programme, 2015).

According to CSA (2017) within the category of grain crops, cereals are the major food crops both in terms of the area they are planted and volume of production obtained. They are produced in larger volume compared with other crops because they are the principal staple crops. Cereals are grown in all regions with varying quantity as shown in the CSA survey results. Out of the total grain crop area, 79.3% (9,588,923.7 ha) was under cereals. The proportion of the crop grain areas for teff, maize, sorghum and wheat took up 22.6% (about 2,731,111.7 ha), 17% (about 2,054,723.69 ha), 15.9% (1,923,717.5 ha and 11.9% (1,437,484.7 ha), respectively. Sorghum accounts for an average ten percent of daily caloric intake of households living in the eastern and northwestern areas of the country. About three-quarters of the sorghum grain in Ethiopia is used for making injera (the traditional bread, made from teff in more productive areas of the country). Another 20 percent is used for feed and for local beer production, with the remainder held for seed. The entire plant is utilized, with sorghum stalks used for house construction and cooking fuel and leaves used for animal fodder (GAIN, 2015).

Research institutions claim that it is possible to produce 50-60 qt of sorghum per ha if improved technologies and practices are used appropriately. Yet, the average productivity level of sorghum in Chiro district about 22 qt/ha, which is below minimum potential yield level. Despite increase in the use of improved inputs especially fertilizers, the productivity level is so low. This is an indication that farmers are not using inputs efficiently. If the existing production system is not efficient, introduction of new technology could not bring the expected improvements in the productivity of sorghum and other crops. Given the existing technology, improvements in the level of technical efficiency will enable farmers to produce the maximum possible output from a given level of inputs. Hence, improvement in the level of technical efficiency will increase productivity. Theoretically introducing modern technologies can increase agricultural output. However, according to Tarkamani and Hardarkar (1996), cited in Mustefa (2014) in areas where there is inefficiency, trying to introduce a new technology may not have the expected impact and “there is a danger of trying to rediscover the wheel” if the existing knowledge is not efficient.

Measuring efficiency level of farmers benefit 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. However, there is limited number of studies done in this regard in general and in particular, no studies had been conducted in the area of production efficiency of sorghum production in the study area. The extent, causes and possible remedies of inefficiency of smallholders are not yet given due attention. Thus, this study has tried to measure the technical efficiency of the farmers in study area and identified its main determinants based on a cross sectional data collected from 130 rural households.

**Concept of Technical Efficiency**

The efficiency of a firm is its ability to produce the greatest amount of output possible from a fixed amount of inputs and an efficient firm is one that given a state of technical know-how, can produce a given quantity of goods by using the least quantity of inputs possible (Raymond, 1981).

Technical efficiency of a producer is a comparison between observed and optimal values of its outputs and inputs. It refers to the ability to avoid wastage either by producing as much output as technology and input usage allow or by using as little input as required by technology and output production. Technical efficiency has, therefore, both an input conserving and output promoting argument. It is assumed that technical efficiency ranges between zero and one, if $TE = 1$ implies that the firm is producing on its production frontier and is said to be technically efficient. $1 – TE$ is therefore the largest proportional reduction in input that can be achieved in the production of the output.

According to Farrell and Fieldhouse (1962), allocative efficiency is related to the ability of a firm to choose its input in a cost minimizing way. It involves the selection of an input mix that allocates factors to their highest valued uses and thus introduces the opportunity cost of factor inputs to the measurement of productive efficiency. $AE$ reflects the ability of the firm to use the inputs in optimal proportions given their respective prices and the production technology. It is assumed that, $0 < AE < 1$. Following the same line of reasoning, $1 – AE$ measures the maximal proportion of cost the technical efficient firm can save by behaving in a cost minimizing way. Technical efficiency and allocative efficiency are then combined to give economic efficiency, which is sometimes referred to as overall efficiency (Coelli et al., 1998). It is assumed that $0 < EE < 1$. Therefore $EE = 1$ implies that it is both technically and allocatively efficient.

**Sorghum Production and its Importance**

Sorghum (Sorghum bicolor L. Moench) is one of the main staple crops for the world’s poorest and food-insecure people. It is the second major crop (after maize) across all ecologies in Africa and is one of the main staples for people in Eastern and Southern Africa (ESA). Globally, sorghum is grown on 46 million hectares accounting for an annual production of 60 million tones. Developing countries account for 90% of total area and 70% of total output, with Africa and Asia each accounting for 20% to
Sorghum, because of its drought resistance, is the crop of choice for dry regions and areas with unreliable rainfall. Many annual and perennial species of sorghum are found in the wild form. The greatest variation in the genus is found in the northeast quadrants of Africa; north latitude of 10°N and east of longitude 25°E. Sorghum is adapted to wide range of ecological conditions and can be grown under conditions, which are unfavorable for most of the cereals. Most East African sorghum is grown between the altitude of 900 and 1500 m.a.s.l. The optimum temperature during the growing season ranged from 27°C to 32°C. The minimum and maximum temperatures for growth are 15°C and 40°C, respectively. Extremely high temperatures during the grain formation period reduce the seed yield. It is well adapted and widely grown where the annual rainfall varies from 400 to 700 mm. Sorghum is grown successfully on many types of soils, except for rough, stony or gravelly soils. In the wet season, the highest yields are obtained on sandy soils, but in dry season, it does best on heavy soils. It can be grown with a wide range of soil pH from 5.0 to 8.5 and tolerates salinity better than maize stress (Eyob, 2007).

Sorghum is a dual-purpose crop where both grain and stock are highly valued outputs. There is a very rich genetic diversity of sorghum in eastern Ethiopia. Besides, there is a wealth of sorghum farming knowledge and systems that have been developed over thousands of years, as it is adapted to a wide range of environment. It is widely produced more than any other crops, in areas where there is moisture stress (Ibid).

Sorghum's nutritional profile includes starch, vitamins and proteins as main constituents. The essential amino acid profile of sorghum protein is claimed to depend on the sorghum variety, soil and growing conditions. A wide variation has been reported in its contents of several minerals. The mineral fillings are unevenly distributed and are more concentrated in the germ and the seed coat. In milled sorghum flours, minerals such as phosphorus, iron, zinc and copper decrease with lower extraction rates. Similarly, piercing the grain to remove the fibrous seed coat resulted in considerable reductions in the mineral contents of sorghum. The presence of anti-nutrition factors such as tannins in sorghum reduces its mineral availability as food. It is important to process and prepare sorghum properly to improve its nutrition value. Sorghum is a good source of B-complex vitamins. (Dida et al., 2008).

Description of the Study Area

Chiro district is located at 8°55’N latitude and 40°15’E longitude, with elevation ranging from 1400 to 2300 m above sea level. It is bordered on the south by Gemechis, on the west by Guba Koricha, on the northwest by Mi’eso, on the north by Doba, on the northeast by Tulo, and on the east by the Galetti River which separates it from Mesela and the East Hararge Zone.

The zonal capital, Chiro, is located at about 326 km from Addis Ababa along the Addis Ababa Diredawa main road. Chiro district has an estimated total land area of 70,962.08 ha out of which the total cultivated land comprises about 49,552.08 ha. The remaining 5774 ha, 9,537 ha and 6099 ha is allocated for grazing, community forest and other miscellaneous purposes respectively. The major crops grown in the study area are cereals (such as sorghum, maize, barley etc), pulses such as (haricot bean), vegetables (such as onion, tomato, pepper etc.), oil seeds (sunflower, sesame, caster bean, etc.), stimulants (coffee, chat etc) and fruit trees. The common cropping system in the area is inter-cropping where farmers plant more than two types of crop in the same plot. This is due to the problem of shortage of land. Farmers use both the Belg and Meher rains for planting crops like maize, khat and haricot bean.

MATERIAL AND METHODS

Both primary and secondary data were used for this study. Primary data were collected using semi structured questionnaires in two stages. First a preliminary survey was conducted through focus group discussion (using checklist) to obtain general information about the study area. Then formal survey data collection was undertaken with the sampled households and secondary data are collected from different published and unpublished materials.

So, the study followed the formal survey procedure where data collection for quantitative information is gathered using semi-structured questionnaire and selecting a representative sample from a given population. Due to the importance of sorghum and production potential of the crop in the area, the study was undertaken in Chiro district. Since the sample selected from a given population is expected to represent the population as a whole, homogeneity of the population is very important. As far as the agro-ecology and farming system of the study area is concerned, it is more or less homogenous. Hence, a two-stage random sampling technique was implemented to draw a representative sample. In the first stage, four kebeles from the district were selected randomly. In the second stage, following the establishment of a sample frame for sorghum growing farmers in each of the four kebeles, the sample households were selected using simple random sampling (SRS) with probability proportional to size technique. The sample size was determined by the formula given by (Yemane,1967).

\[
  n = \frac{N}{1 + N(e^2)}
\]
Sorghum production in particular and crop production in general in the study area are likely to be affected by random shocks such as weather, pest infestation. In addition, measurement errors are likely to be high. The difference in output as a result of these random shocks and measurement errors are not due to operator’s inefficiency or misallocation of resources. In such a condition where random shocks and measurement errors are high a model that accounts for the effect of noise is more appropriate to choose. To assess such conditions, the stochastic production frontier was used for its ability to distinguish inefficiency from deviations that are caused by factors beyond the control of farmers. The model introduces the disturbance term representing noise, measurement error and exogenous shocks that are beyond the control of the production unit and a component that captures deviations from the frontier due to inefficiency.

The model can be shown using Cobb-Douglas functional form:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{n} \beta_j \ln X_{ij} + \epsilon_i$$

Where:
- $\ln$ denotes the natural logarithm
- $j$ represents the number of inputs used
- $i$ represents the $i^{th}$ number of households in the sample
- $Y_i$ represents sorghum production of the $i^{th}$ households
- $X_{ij}$ denotes $j^{th}$ input variables used in sorghum production of the $i^{th}$ households
- $\beta_0$ stands for the vector of unknown parameters to be estimated
- $\epsilon_i$ is a composed disturbance term made up of two elements ($v_i$ and $u_i$)
- $v_i$ - accounts for the stochastic effects beyond the farmer’s control, measurement errors as well as other statistical noises
- $u_i$ captures the technical inefficiency in production

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

$$\gamma = \frac{\delta^2_{v}}{\delta^2_{u}} = \frac{[\delta^2_{v}/(\delta^2_{v} + \delta^2_{u})]}$$

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

Though a study done by Kopp and Smith (1980) suggests that functional specification has only a small impact on measured efficiency, as stochastic frontier method requires a prior specification of the functional form a log likelihood ratio test indicated that Cobb-Douglas production function is the best functional form for this study.

A single stage estimation procedure was followed to analysis determinates of TE from a stochastic frontier production function. In single stage estimation, inefficiency effects are defined as an explicit function of certain factors specific to the firms and all the parameters are estimated in one-step using the maximum likelihood procedure. The major drawback with the two-step approach resides in the fact that, in the first step, inefficiency effects are assumed to be independently and identically distributed in order to use the Jondrow et al. (1982) approach to predict the values of technical efficiency indicators. In the second step, however, the technical efficiency indicators thus obtained are assumed to depend on a certain number of factors specific to the firm, which implies that the TE are not identically distributed unless all the coefficients of the factors considered happen to be simultaneously null

**RESULTS AND DISCUSSION**

**Econometric Results**

The stochastic production frontier was applied using the maximum likelihood estimation procedure. Before model estimation, a test was made for multicollinearity among the explanatory variables using the Variance Inflation Factor (VIF) and the values of VIF for all variables entered into the model were below 10, which indicate the absence of multicollinearity among the explanatory variables. In addition, Breusch-Pagan test was also used to detect the presence of heteroskedasticity and the test indicated that there was no problem of heteroskedasticity in the models. For the likelihood estimates of the parameters in the stochastic production frontier, given the Cobb-Douglas specification, the coefficients of the input variables such as area under sorghum, amount of organic fertilizer, DAP, number of oxen, amount of seed used and labour were found to be significantly related with sorghum production. The coefficients of Area allocated to sorghum, labour, amount of organic fertilizer is positive and statistically significant at 1% level of significance. And DAP was positive and statistically significant at 10% level of significance. The amount of seed used in sorghum production was found to be negatively related with sorghum yield and significant at 1% level of probability. Area allocated to sorghum, amount of organic fertilizer, DAP and labor force for the production have expected positive sign but seed have negative sign which is not expected (Table, 1).
The mean level of technical efficiency of sorghum growing sample households was about 78.3%, with the minimum and maximum efficiency level of about 41.7 and 93.6%, respectively. This shows that there is disparity among sorghum producer households in their level of technical efficiency which may in turn indicate that there is a room for improving the existing level of sorghum production through enhancing the level of households’ technical efficiency.

The mean level of technical efficiency further tells us that the level of sorghum output of the sample respondents can be increased on average by about 21.7% if appropriate measures are taken to improve the level of efficiency of sorghum growing households. In other words, there is a possibility to increase yield of sorghum by about 21.7% using the resources at their disposal in an efficient manner without introducing any other improved (external) inputs and practices.

### Table 1. Parameters estimates of the frontier model

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic fertilizer</td>
<td>0.1989***</td>
<td>0.0546</td>
</tr>
<tr>
<td>Labour</td>
<td>0.4903***</td>
<td>0.1696</td>
</tr>
<tr>
<td>Oxen day</td>
<td>-0.1531</td>
<td>0.1216</td>
</tr>
<tr>
<td>UREA</td>
<td>0.1006</td>
<td>0.1871</td>
</tr>
<tr>
<td>DAP</td>
<td>0.0358*</td>
<td>0.0185</td>
</tr>
<tr>
<td>Area</td>
<td>0.9144***</td>
<td>0.1658</td>
</tr>
<tr>
<td>Seed</td>
<td>-0.3997***</td>
<td>0.1617</td>
</tr>
<tr>
<td>Constant</td>
<td>1.0876***</td>
<td>0.3923</td>
</tr>
<tr>
<td>Likelihood function</td>
<td>-36.56</td>
<td></td>
</tr>
<tr>
<td>Gamma(γ)</td>
<td>0.8464***</td>
<td>0.0164</td>
</tr>
<tr>
<td>Lamda (λ)</td>
<td>2.347***</td>
<td>0.00679</td>
</tr>
<tr>
<td>Sigma square</td>
<td>0.398***</td>
<td>0.0522</td>
</tr>
</tbody>
</table>

*and *** Significant at 10% and 1%, significance level respectively

Source: Model output

At this juncture, the most important issue to be raised is which among the two sources of variability contributes more to the total variability in output from the frontier point. In other words, the relative contribution of both usual noises and the inefficiency component on total variability should be determined. The ratio of the standard error of u (σ_u) to the standard error of v (σ_v), known as lambda (λ), is 2.347. Based on λ, gamma (γ) which measures the effect of technical inefficiency in the variation of observed output can be derived (i.e. γ = λ^2/[1+λ^2]). In this case, the value of this discrepancy ratio (γ) calculated from the maximum likelihood estimation of the full frontier model was 0.846 with standard error of 0.016 and it is much higher than its standard error. The coefficient for the parameter γ can be interpreted in such a way that about 84.6% of the variability in sorghum output in the study area was attributable to technical inefficiency effect, while the remaining 15.4% variation in output was due to the effect of random noise. This indicates that there is a room for improving output of sorghum by first identifying those institutional, socioeconomic and farm specific factors causing this variation (Table 1).

### Estimation of Household Level Technical Efficiency

The mean level of technical efficiency of sorghum growing sample households was about 78.3%, with the minimum and maximum efficiency level of about 41.7 and 93.6%, respectively. This shows that there is disparity among sorghum producer households in their level of technical efficiency which may in turn indicate that there is a room for improving the existing level of sorghum production through enhancing the level of households’ technical efficiency.

The mean level of technical efficiency further tells us that the level of sorghum output of the sample respondents can be increased on average by about 21.7% if appropriate measures are taken to improve the level of efficiency of sorghum growing households. In other words, there is a possibility to increase yield of sorghum by about 21.7% using the resources at their disposal in an efficient manner without introducing any other improved (external) inputs and practices.

### Table 2. Estimated technical efficiency of sample household sorghum producers

<table>
<thead>
<tr>
<th>Types of efficiency</th>
<th>Minimum TE</th>
<th>Maximum TE</th>
<th>Mean TE</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TE</td>
<td>0.4172</td>
<td>0.9312</td>
<td>0.7831</td>
<td>0.1015</td>
</tr>
</tbody>
</table>

Source: model output

It is observed that about 31.8% of the sample households were operating below the overall mean level of technical efficiency while about 2.3% of the households are operating at the technical efficiency level of more than 90%. However, majority about 68% of the sorghum growing households were able to attain above the overall mean level of technical efficiency. This might imply that in the long run improving the existing level of technical efficiency of households alone may not lead to significant increment in the level of sorghum output. So, in the long run, it needs attention at policy level to introduce other best alternative farming practices and improved technologies in order to alleviate the overall chronic food shortage.

After measuring levels of farmers’ efficiency and determining the presence of efficiency deference’s among farmers, finding out factors causing efficiency disparity among farmers was the next most important step of this study. The maximum likelihood estimates showed that among 13 variables used in the analysis age, household size, frequency of extension contact, soil fertility, slope and livestock unit were found to be statistically significant to affect the level of technical efficiency of farmers (Table 3).

### Table 3. Maximum likelihood estimates of the factors determining technical inefficiency

<table>
<thead>
<tr>
<th>Inefficiency Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td>0.0062</td>
<td>0.0042</td>
</tr>
<tr>
<td>Fragmentations</td>
<td>-0.0048</td>
<td>0.0082</td>
</tr>
<tr>
<td>Age</td>
<td>-0.0071***</td>
<td>0.0022</td>
</tr>
<tr>
<td>Household size</td>
<td>-0.0059**</td>
<td>0.0029</td>
</tr>
<tr>
<td>Inter cropping</td>
<td>0.0180</td>
<td>0.0205</td>
</tr>
<tr>
<td>Off/non farm</td>
<td>-0.0298</td>
<td>0.0338</td>
</tr>
<tr>
<td>Credit</td>
<td>-0.0028</td>
<td>0.0035</td>
</tr>
<tr>
<td>Extension contact</td>
<td>-0.0055*</td>
<td>0.0028</td>
</tr>
<tr>
<td>Weeding</td>
<td>-0.0022</td>
<td>0.0013</td>
</tr>
<tr>
<td>Soil fertility</td>
<td>-0.0203***</td>
<td>0.0077</td>
</tr>
<tr>
<td>Slope</td>
<td>0.0047**</td>
<td>0.0021</td>
</tr>
<tr>
<td>Livestock unit</td>
<td>-0.0045**</td>
<td>0.0022</td>
</tr>
<tr>
<td>Proximity</td>
<td>0.0014</td>
<td>0.0027</td>
</tr>
<tr>
<td>Constant</td>
<td>5.4479</td>
<td>3.916</td>
</tr>
</tbody>
</table>

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

Source: model output
Age of household head

Age of the farmer is the best proxy variable for farming experience. The result shows that the age has positive and significant relation with technical efficiency. Thus, middle age farmers are more efficient than the very young and older ones. This result is similar with the findings of Bekele (2013) and Shumet (2011). Since farming as any other professions need accumulated knowledge, skill and physical capability, it is decisive in determining efficiency. The knowledge, the skills as well as the physical capability of farmers is likely to increase as their age increases. However, this tends to decrease after a certain age level.

Extension contact

The advisory service rendered to the farmers in general can significantly help farmers to improve their average performance in the overall farming operation. Specifically in the study area, the results of the estimated coefficient of the variable contact with extension workers were found to be related with the level of technical efficiency of households positively and statistically significant at ten percent level of significance. The result obtained is consistence with studies done by Mohammed (2011). His result show that having extension contact with the advisory service through either a visit from the farm advisor or participating in any training courses has significant effect in explaining farmers' level of technical efficiency.

Household size

The result shows that the coefficient of household size is positive and significant relation with technical efficiency. The result is expected that family size is found to determine efficiency positively. This may be because household with large number of family members may be able to use appropriate input combinations. In addition, family is the main source of labour supply and it is decisive in the production of sorghum as labour is a significant factor of production. As the frontier estimation shows that the coefficient for labour input is significant and this result is similar with result of Mustefa (2014).

Slope

The result shows that slope determined efficiency negatively and it isstatistically significant at five percent level of significance. This is because as slope increase soil erosion also increase and the nutrients (fertilizers) applied to the soil also lost through erosion and this can reduce the availability of nutrients to the crop and consequently minimize the yield obtained and efficiency of the farmers. The result is similar to that obtained by Mamushet (2010), which slope significantly and negatively determines efficiency of sorghum producer.

Perceived fertility status of soil

The result indicates that the coefficient of fertility of soil is positive and statistically significant at one percent level of significance implying that fertility of soil is an important factor in influencing the level of efficiency in the production of sorghum. Therefore, development programs in improving and maintaining the fertility of land will have positive impact in raising efficiency. The study result is similar with Ermiyas et al. (2015) that showed that soil fertility had positive relationship with efficiency.

Livestock holding

The ownership of livestock for smallholder household is perceived as prestige and the accumulation of wealth status. It systematically influences household efficiency level through equipping the households to have more income from sale of milk and milk products and sale of a live livestock to buy improved agricultural technologies such as chemical fertilizer, pesticides, etc. Households having large size of livestock can have better chance to get more oxen draught power and serves for organic fertilizer. It is positive and statistically significant at five percent level of significance with technical efficiency. This finding is similar with the finding of Shumet (2012) that showed that ownership of livestock had positive relationship with efficiency.

CONCLUSION AND RECOMMENDATIONS

Thus, the results of the study give information to policy makers and extension workers on how to better aim efforts to improve farm productivity as efficiency level and determinant for technical efficiency are identified. The result of the analysis showed that sorghum producers in the study area are not operating at full technical efficiency level which indicates the existence of opportunity for sorghum producers to minimize cost without compromising yield with present technologies available at the hand of producers. Therefore, an intervention aiming to improve efficiency of farmers is important in the study area.

The result of the study shows that soil fertility is a crucial factor in determining technical efficiency of households. Therefore, households have to work to improve the fertility status of the soil though it is difficult to achieve this in the short run. Households can do this by applying fertilizers that are suitable for the farm and practicing soil conservation practices. Strengthening soil fertility maintenance program is required and extension workers can play a great role in improving the status of the soil by working closely with the farmers in this regard.

Utilizing available resources and technology efficiently side by side with introducing new agricultural technologies could help to address the food security problem. So, to achieve this, extension services should expand to reach each and every farmer and there is also a need to modernize extension services provided so that it can face new challenges and transfer the latest technologies in an
efficient way. It is evident from the result of the study that the effect of extension service on technical efficiency of sorghum production was statistically significant. Therefore, the government needs to strengthen the extension system and expand the service to sorghum producer.

Livestock ownership, which is an indicator of accumulated wealth, has positively and significantly affected technical efficiency. Households having large size of livestock can have better chance to get more oxen draught power and serves for organic fertilizer. This suggests looking for improving livestock production sub-system through provision of improved veterinary services, feed and water supply.

Slope significantly reduced the technical efficiency of sorghum producers when lands are vulnerable to erosion damages and their fertility is likely to be poor due to high run-off. If soil conservation measures such as check dam and water way measures are not practiced, it reduces efficiency thereby reducing sorghum production. So, development agents should encourage households to strengthen the soil conservation measures such as check dam and water way to reduce soil erosion.

REFERENCES


## APPENDIX

### Table 1. Technical efficiency estimates for each sample households

<table>
<thead>
<tr>
<th>No</th>
<th>Effi-estimate</th>
<th>No</th>
<th>Effi-estimate</th>
<th>No</th>
<th>Effi-estimate</th>
<th>No</th>
<th>Effi-estimate</th>
<th>No</th>
<th>Effi-estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.882</td>
<td>27</td>
<td>0.785</td>
<td>53</td>
<td>0.847</td>
<td>79</td>
<td>0.801</td>
<td>105</td>
<td>0.889</td>
</tr>
<tr>
<td>2</td>
<td>0.578</td>
<td>28</td>
<td>0.881</td>
<td>54</td>
<td>0.853</td>
<td>80</td>
<td>0.770</td>
<td>106</td>
<td>0.875</td>
</tr>
<tr>
<td>3</td>
<td>0.858</td>
<td>29</td>
<td>0.845</td>
<td>55</td>
<td>0.852</td>
<td>81</td>
<td>0.817</td>
<td>107</td>
<td>0.855</td>
</tr>
<tr>
<td>4</td>
<td>0.921</td>
<td>30</td>
<td>0.868</td>
<td>56</td>
<td>0.814</td>
<td>82</td>
<td>0.785</td>
<td>108</td>
<td>0.783</td>
</tr>
<tr>
<td>5</td>
<td>0.784</td>
<td>31</td>
<td>0.874</td>
<td>57</td>
<td>0.823</td>
<td>83</td>
<td>0.733</td>
<td>109</td>
<td>0.816</td>
</tr>
<tr>
<td>6</td>
<td>0.418</td>
<td>32</td>
<td>0.473</td>
<td>58</td>
<td>0.747</td>
<td>84</td>
<td>0.827</td>
<td>110</td>
<td>0.874</td>
</tr>
<tr>
<td>7</td>
<td>0.841</td>
<td>33</td>
<td>0.822</td>
<td>59</td>
<td>0.792</td>
<td>85</td>
<td>0.752</td>
<td>111</td>
<td>0.818</td>
</tr>
<tr>
<td>8</td>
<td>0.565</td>
<td>34</td>
<td>0.589</td>
<td>60</td>
<td>0.863</td>
<td>86</td>
<td>0.780</td>
<td>112</td>
<td>0.936</td>
</tr>
<tr>
<td>9</td>
<td>0.887</td>
<td>35</td>
<td>0.863</td>
<td>61</td>
<td>0.861</td>
<td>87</td>
<td>0.871</td>
<td>113</td>
<td>0.823</td>
</tr>
<tr>
<td>10</td>
<td>0.664</td>
<td>36</td>
<td>0.877</td>
<td>62</td>
<td>0.813</td>
<td>88</td>
<td>0.510</td>
<td>114</td>
<td>0.844</td>
</tr>
<tr>
<td>11</td>
<td>0.563</td>
<td>37</td>
<td>0.853</td>
<td>63</td>
<td>0.803</td>
<td>89</td>
<td>0.861</td>
<td>115</td>
<td>0.822</td>
</tr>
<tr>
<td>12</td>
<td>0.466</td>
<td>38</td>
<td>0.858</td>
<td>64</td>
<td>0.854</td>
<td>90</td>
<td>0.812</td>
<td>116</td>
<td>0.895</td>
</tr>
<tr>
<td>13</td>
<td>0.851</td>
<td>39</td>
<td>0.762</td>
<td>65</td>
<td>0.862</td>
<td>91</td>
<td>0.780</td>
<td>117</td>
<td>0.495</td>
</tr>
<tr>
<td>14</td>
<td>0.867</td>
<td>40</td>
<td>0.839</td>
<td>66</td>
<td>0.812</td>
<td>92</td>
<td>0.867</td>
<td>118</td>
<td>0.863</td>
</tr>
<tr>
<td>15</td>
<td>0.748</td>
<td>41</td>
<td>0.837</td>
<td>67</td>
<td>0.801</td>
<td>93</td>
<td>0.843</td>
<td>119</td>
<td>0.885</td>
</tr>
<tr>
<td>16</td>
<td>0.576</td>
<td>42</td>
<td>0.877</td>
<td>68</td>
<td>0.813</td>
<td>94</td>
<td>0.750</td>
<td>120</td>
<td>0.875</td>
</tr>
<tr>
<td>17</td>
<td>0.632</td>
<td>43</td>
<td>0.836</td>
<td>69</td>
<td>0.734</td>
<td>95</td>
<td>0.777</td>
<td>121</td>
<td>0.735</td>
</tr>
<tr>
<td>18</td>
<td>0.818</td>
<td>44</td>
<td>0.800</td>
<td>70</td>
<td>0.781</td>
<td>96</td>
<td>0.760</td>
<td>122</td>
<td>0.654</td>
</tr>
<tr>
<td>19</td>
<td>0.780</td>
<td>45</td>
<td>0.885</td>
<td>71</td>
<td>0.833</td>
<td>97</td>
<td>0.828</td>
<td>123</td>
<td>0.828</td>
</tr>
<tr>
<td>20</td>
<td>0.654</td>
<td>46</td>
<td>0.868</td>
<td>72</td>
<td>0.814</td>
<td>98</td>
<td>0.833</td>
<td>124</td>
<td>0.898</td>
</tr>
<tr>
<td>21</td>
<td>0.624</td>
<td>47</td>
<td>0.554</td>
<td>73</td>
<td>0.852</td>
<td>99</td>
<td>0.873</td>
<td>125</td>
<td>0.516</td>
</tr>
<tr>
<td>22</td>
<td>0.543</td>
<td>48</td>
<td>0.464</td>
<td>74</td>
<td>0.664</td>
<td>100</td>
<td>0.807</td>
<td>126</td>
<td>0.848</td>
</tr>
<tr>
<td>23</td>
<td>0.795</td>
<td>49</td>
<td>0.884</td>
<td>75</td>
<td>0.701</td>
<td>101</td>
<td>0.917</td>
<td>127</td>
<td>0.785</td>
</tr>
<tr>
<td>24</td>
<td>0.855</td>
<td>50</td>
<td>0.855</td>
<td>76</td>
<td>0.701</td>
<td>102</td>
<td>0.719</td>
<td>128</td>
<td>0.788</td>
</tr>
<tr>
<td>25</td>
<td>0.893</td>
<td>51</td>
<td>0.858</td>
<td>77</td>
<td>0.534</td>
<td>103</td>
<td>0.617</td>
<td>129</td>
<td>0.782</td>
</tr>
<tr>
<td>26</td>
<td>0.855</td>
<td>52</td>
<td>0.832</td>
<td>78</td>
<td>0.524</td>
<td>104</td>
<td>0.728</td>
<td>130</td>
<td>0.778</td>
</tr>
</tbody>
</table>

Source: Own computation.

### Table 1. Conversion factors used to estimate TLU

<table>
<thead>
<tr>
<th>Animal Category</th>
<th>TLU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calf</td>
<td>0.25</td>
</tr>
<tr>
<td>Donkey (young)</td>
<td>0.35</td>
</tr>
<tr>
<td>Weaned Calf</td>
<td>0.34</td>
</tr>
<tr>
<td>Camel</td>
<td>1.25</td>
</tr>
<tr>
<td>Heifer</td>
<td>0.75</td>
</tr>
<tr>
<td>Sheep and Goat (adult)</td>
<td>0.13</td>
</tr>
<tr>
<td>Cow and Oxen</td>
<td>1</td>
</tr>
<tr>
<td>Sheep and goat (young)</td>
<td>0.06</td>
</tr>
<tr>
<td>Horse</td>
<td>1.1</td>
</tr>
<tr>
<td>Chicken</td>
<td>0.013</td>
</tr>
<tr>
<td>Donkey (adult)</td>
<td>0.7</td>
</tr>
</tbody>
</table>


### Table 3. Multicollinearity test for variables in the model

<table>
<thead>
<tr>
<th>Variable</th>
<th>$R^2$</th>
<th>$1-R^2$</th>
<th>$VIF = \frac{1}{1-R^2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic fertilizer</td>
<td>0.793</td>
<td>0.207</td>
<td>4.831</td>
</tr>
<tr>
<td>Labour</td>
<td>0.624</td>
<td>0.376</td>
<td>2.659</td>
</tr>
<tr>
<td>Oxen day</td>
<td>0.288</td>
<td>0.712</td>
<td>1.404</td>
</tr>
<tr>
<td>UREA</td>
<td>0.256</td>
<td>0.744</td>
<td>1.344</td>
</tr>
<tr>
<td>DAP</td>
<td>0.551</td>
<td>0.449</td>
<td>2.227</td>
</tr>
<tr>
<td>Area</td>
<td>0.667</td>
<td>0.333</td>
<td>3.001</td>
</tr>
<tr>
<td>Seed</td>
<td>0.566</td>
<td>0.434</td>
<td>2.300</td>
</tr>
<tr>
<td>Weeding</td>
<td>0.299</td>
<td>0.701</td>
<td>1.426</td>
</tr>
<tr>
<td>Education</td>
<td>0.278</td>
<td>0.722</td>
<td>1.356</td>
</tr>
<tr>
<td>Livestock unit</td>
<td>0.092</td>
<td>0.908</td>
<td>1.101</td>
</tr>
<tr>
<td>House hold size</td>
<td>0.108</td>
<td>0.892</td>
<td>1.121</td>
</tr>
<tr>
<td>Age</td>
<td>0.081</td>
<td>0.919</td>
<td>1.088</td>
</tr>
</tbody>
</table>

Source: Own computation.

---

Accepted 9 July 2019


**Copyright**: © 2020: Lemma et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are cited.