# Technical and Economic Efficiency of Sorghum Production under rain-fed semi-mechanized farming system of Gadarif State, Sudan

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## Abstract

This paper analyzes the efficiency structure of Sudan agriculture in farm household level by using of stochastic frontier analysis model and Tobit model. A household level survey is used in the analysis. Using designed questionnaire for a sample of 100 farmers from 11 localities in Gadarif- State, Sudan. By using these estimates, relative importance of inputs and their interaction with various farm characteristics are inspected. The efficiency scores are estimated at farm household level. Has ranged from as low as 25% to as high as 100%. The average was 54%. The resultant average technical efficiency indicate that there is scope for increasing sorghum production by 46% with the present level of inputs and technology. Tobit model results showed that age and education are significant and negative but for seed source, that is significant and positive on technical efficiency, these factors represent the good characteristics that increase to or remove from efficiency. The main findings from this analysis was there is possibility to enhance the efficiency of sorghum producers in the study area, By approving good management practices and proper distribution of the existing resources and technology, along with extension programmes, the potential that exists for improving the productivity of sorghum in the Gadarif state, could be exploited. And also that the technical efficiency of sorghum farmers could be improved by practicing best use of inputs and improving the inefficiency factors

## Introduction

This study aimed to measure the technical and economic efficiency and investigate the underlining causes/reasons of the existing inefficiency of sorghum crop production in the rain-fed sector in Gadarif State, Sudan. Primary data is collected using designed questionnaire for a sample of 100 farmers from 11 localities in the state. The study used Stochastic Frontier Method to analyze the production efficiency of farmers of Gadarif State In growing sorghum under rainfall conditions. And also used Tobit Model. Gadarif state is located in the east of Sudan between latitudes 12° 40' and 15°40' N and longitudes 33°30' and 36°30' E. Gadarif state covers an area of about 71,000 square kilometers with 17 persons per km. For administrative purposes, the state is divided into five localities.

Abrahim et al (2014) measured the technical efficiency and identified the efficiency determinants in groundnuts and sesame crop production in rain [fed sector of North Kordofan State, Sudan. They estimated the technical efficiency using the stochastic frontier production function analysis. The results of the study indicated that the technical efficiency of crop production has ranged from as low as 3% to as high as 100%. The average technical efficiency were about 40% in case of groundnuts, and 84% in case of sesame. The resultant average technical efficiencies indicate that there are scopes for increasing groundnuts and sesame production by 60% and 16%, respectively, from a given mix of production inputs via adopting the existing technologies used by the more efficient farmer's (1).

Dudu et al (2015) investigates the efficiency structure of Turkish husbandry in farm household level by using many models of stochastic frontier analysis. A household level survey used in analysis. First, an effective production frontier is estimated by a panel data model. By using these estimations, relative importance of inputs and their

interaction with numerous farm characteristics are inspected. The parameters of production frontier show that agricultural production is significantly dependent on land and there is an extreme employment of labor. Secondly, the efficiency scores are estimated at farm household level (2).

Yousif et al (2015) evaluated the technical efficiency of groundnut production using stochastic frontier production function. The results indicated that the mean production technical efficiency was 70%. This shows that there is a scope for increasing groundnut production by 30%, with the present level of inputs and technology. Also, the result depicted that the irrigation numbers, tenancy location, weeding, labour and farm income were the important factors that determined production technical efficiency (3).

Study by Abdul-Rahaman (2016) analyzed the technical efficiency of smallholder growing cotton in Ghana using stochastic frontier production function approach. The results showed that the technical efficiency of those smallholders ranged between 16.05% and 98.13% with a mean efficiency score of 84.5%. This suggested that the average smallholders who grow cotton in the study area could produce additional 15.05% of cotton output using the same amount of inputs. This would mean that the farmers were able to produce on the technically efficient frontier. The main determinants of technical efficiency include age of the farmer, membership of associations, education, family size, age of the farm, extension visits and farmers experience in producing cotton (4).

Alemu and Haji (2016) used Cobb-Douglas production function fitted into the stochastic production frontier approach to estimate technical, allocative and economic efficiency of smallholders producing sorghum, Tobit model was also used to identify the factors that affect efficiency levels of the sample farmers. The results indicated the technical, allocative and economic efficiencies of sorghum farmers were round 74%, 44% and 32% respectively. Results of the Tobit model indicated

that age and sex of the farmers and the farm size affect the technical efficiency positively and significantly. On the other hand, experience of farmers and land fragmentation affected technical efficiency negatively. The result also indicated that experience and education had positive and significant effect on allocative efficiency while age and sex had significant negative effect (5).

Ahmed et al (2017) investigated the technical, allocative and economic efficiencies of rice production in Bihar. The technical and allocative efficiencies of most of each the farmers were about 62%. Based on these results, the degree of cost efficiency was estimated at 38.8%. Even though, the technical and allocative efficiencies were round 62%. The farmers were still inefficient and unable to achieve the optimal level of output. Tobit analysis was adopted to evaluate the factors the influence efficiencies. The results showed that lack of education, poor quality seeds, and poor irrigation pumps were important factors that affected the efficiencies (6).

Osman et al (2018). Aimed at analyzing economic efficiency of soybean production in the Northern Region of Ghana. Data was collected from 500 farmers across five districts in the region. The analysis used cost frontier models and translog stochastic production. Results show that, farmers in the region are 82.7% technically efficient, 59.5% allocatively efficient and 49.5% economically efficient. These results show great scope for improving efficiencies and sustainability of soybean production in the Northern Region (7).

Ibrahim (2018) evaluates the economics of sorghum production productivity, recognizes the socio-economic characteristics of the respondent, estimates the cost of production, revenue, and gross margin. Primary data were obtained by a survey schedule. A total of 120 farmers were selected randomly. Data was examined using appropriate statistical tools. The results displayed that most of the farmers their age ranged between 46 and 60 years, and 80% have reached formal education. The

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regression analysis presented that the majority of variable meaningfully affect sorghum production in the study (8).

RA, O et al (2019) estimated technical efficiency of rain-fed and irrigated onion production in Kano State of Nigeria. A multi-stage sampling method was used to select 217 farmers involved in both Rain-fed and irrigated production systems. Descriptive statistics and stochastic frontier model were used to analyze the data. The Maximum Likelihood Estimate for production frontier displays that the variable inputs (farm size, seeds and fertilizers hired and family labour) have positive coefficients. This implied positive result on onion yields under both production systems, although agro-chemical was negative under rain-fed. The mean technical efficiency was higher for irrigated onion farmers than rain-fed farmers representing that onion production was technically more efficient under irrigation system of production than rain-fed system (9).

Parmar et al (2019) investigated farm technical efficiency and its factors of rain-fed maize farmers of tribal area of Central Gujarat. A stochastic frontier production function has been assessed to determine technical efficiency of farms as well as regression analyses have been approved out to find the effect of socioeconomic factors. The average level of technical efficiency was valued at 70.18 percent for farms as a whole, Therefore, it was possible to improve the yield by 30 percent by following the efficient crop management practices. Among the factors of technical efficiency, experience in maize cultivation, operational area, contact with extension agency and proximity to the market yard, education level of the farmer, were found positive and significant. By adopting good management performance and good allocation of the current resources and technology, the potential that exists for cultivating the productivity of maize in the state, could be exploited (10).

Keba & Milkias (2020), assessing the determinants of technical efficiency in sorghum production in Ethiopia. In these review factors like farm plot, education,

age, and distance to all weather roads, participation in soil ,livestock holding and water conservation activities, Information about land policy, off-farm and investment on fertilizers, share cropping credit access, frequency of extension contact, crop diversification, and. The sorghum farms were being worked below the level of technical efficiency. This suggests that a big number of sorghum farms in the Ethiopia confronted inefficiency problem (11).

Adhikari et al (2021). Employed a to examine the technical efficiency and its determinants using Cobb-Douglas stochastic production frontier model used selected household data from 343 farmers. Results presented that wheat production responded positively to an increase in the quantity of inorganic fertilizer, whereas it was negative to seed rate. Also, the study found that farmers were not technically efficient with a mean technical efficiency of 81%. Results suggest that the technical efficiency of farmers could be improved by practicing the best use of inputs and cultivating the inefficiency factors (12).

Tesema (2021) analyzes economic efficiency and constraints of maize production under shifting in the low land farming of Gudeya Bila district. The study was conducted using cross-sectional data from 154 randomly selected households. To evaluate the level of technical, economic and allocative stochastic production frontier model was used and Tobit model was employed to recognize factors affecting technical, and economic allocative efficiency of households. The mean technical, allocative and economic efficiency were 78.78%, 69.99% and 56.66% respectively. The Tobit model results shows that education levels, farm size, family size. Construction of terrace, uses of credit, participation in off/non-farm activities, frequency of extension contact, and shifting cultivation had a significant positive effect on technical efficiency. The chief deduction steaming from this analysis was there is the possibility to improve the efficiency of maize producers in the study area (13).

Abiola M.O et al (2021) estimated of technical efficiency of rice farmers in the north central zone of Nigeria.. Multi-stage proportional random sampling was used to select 360 farmers from Kogi, Niger, Benue, and Federal Capital Territory in North Central zone of Nigeria. The parametric stochastic frontier production function was valued using a maximum likelihood estimator in two-stage approach. Results showed that none of the rice farmers was technically efficient, but rice farmers can rise their output by more than 63% without any growth in input utilization if the farmers accept the farm practices of the technical leader, years of farming experience, Education and age of farmers were significant predictors of inefficiency among rice producers in North central zone, Nigeria. Technical efficiency of farmers can be improved by exercising the farmer on best practices on rice production (14).

Hassan et al (2022) estimated the resource-use efficiency using stochastic frontier model for rice farmers in Bauchi State, Nigeria. A multi-stage sampling technique was used to randomly select 400 farmers for the study. A semi-structured survey was used to collect data from farmers. The result of the study further revealed that, agrochemicals, farm size and quantity of rice seed planted all had significant influence on the output of rice at), whereas, quantity of fertilizer applied had significant influence on output. Quantity of seed planted and Fertilizer affected the rice output negatively. The study stated that, farmers have not got the maximum technical efficiency level (15).

Tesema (2022). Examined the technical efficiency of sorghum production and its factors and determinants in the Gudeya Bila area in western of Ethiopia, using primary data got through semi-structured surveys from 203 randomly selected households. The study used one-stage stochastic frontier production model to examine the technical efficiency. The mean technical efficiency was 45.64 percent. These results suggest that farmers are technically inefficient in sorghum by 56.36 percent on average, farm size, Weeding frequency and cell phone use were also key

factors of technical efficiency. As a result, the study discloses that by enhancing technological efficiency, it may be possible to growth production to the level of possible output (16).

Fageer (2023) estimated technical efficiency among wheat farms in the Northern State of Sudan using a stochastic frontier production function approach. Empirical findings showed that technical inefficiency is important in explaining the variation in yields among a sample of 100 wheat farmers (17).

Felix et al (2024). Aims to examine technical, economic and allocative inefficiencies in millet farming to improve productivity and resource utilization. It is assumed that inefficiencies in millet farming significantly affect input demand and cultivation costs, and addressing these inefficiencies can lead to enhanced agricultural practices and yields. Employing primal Cobb-Douglas production function presented that human labor, fertilizers and seed quantity positively affect millet cultivation. These insights can guide policymakers in developed adapted strategies to enhance millet cultivation, and decrease costs (18).

## Methodology

This study depended on primary data collected from a field survey filling a structured questionnaire. The sample size was 100 respondents and the selection of the sample was based on the stratified random sampling technique.

The paper used the stochastic frontier model fed into the DEAP Program Version 2.1.

The model is:

$$\ln y_i = \beta_0 + \sum_n \beta_n \ln x_{ni} + v_i - u_i$$

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where $v_i$ is the "noise" component, which we will almost always consider as a two-sided normally distributed variable, and $u_i$ is the non-negative technical inefficiency component. Together they constitute a compound error term, with a specific distribution to be determined, hence the name of "composed error model" as is often referred.

where: Ln is the natural logarithm $Y_i$ is productivity of sorghum (sack/ Feddan); X1 years of experience; X2 education (1 when illiterate, 2 when primary, 3 when secondary, 4 when intermediate and 5 when university) (X3 age of farmer; X4 is marital status; X5 (rate of seeds ()); X6 source of seeds); B0 and B1 are regression coefficients to be estimated for variables, respectively; Vi represents statistic error and other factors which are beyond the farmers control such as weather, topography and other factors which not included and may be positive, negative or zero. Ui is a non-negative random variable.

**Tobit Model**:

Following Gujarati (2004) (19) the Tobit model used was:

$$E = E^* = \beta 0 + \beta 1\, Z1 + \beta 2\, Z2 + \beta 3\, Z3 + \beta 4\, Z4 + \ldots\ldots\ldots\ldots. + \beta 13\, Z13 + v$$

$$E = E^* \text{ if } E^* > 0, E = 0 \text{ if } E^* < 0.$$

Where:

E is the efficiency measures representing technical, allocative and economic efficiency
$E^*$ is the latent variable $\beta$'s are unknown parameters to be estimated
v is a disturbance term.
Z1 = Age of the household head in years
Z2 = Education level of the household head
Z3 = Experience in sorghum production in years
Z4 = Farm size in hectares
Z5 = Number of sorghum plots
Z6 = Frequency of extension contact
Z7=Dummy variable showing male household heads=1, female headed household=0
Z8 =Dummy variable showing participation in off/nonfarm occupation=1, otherwise zero

Z9 =Livestock size
Z10 =Dummy variable showing access to credit=1, otherwise zero
Z11 =Dummy variable showing access to training=1, otherwise zero
Z12 =Family size
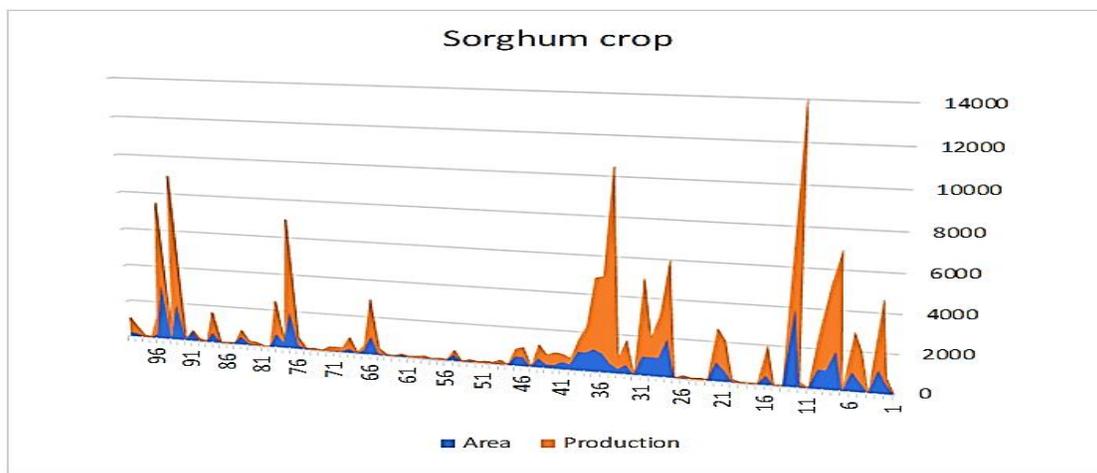Z13 =Proximity of sorghum farm

## Results and Discussion



Fig. (1): source: made by the author from field data

Figure (1) showed that the production of sorghum ranging between 0 and the maximum was 10000 tons, while the area for cultivation ranging between 5 feddans and 4000 feddans.

Table (1): Sex

| Sex | Frequency | Percent | Valid Percent |
|---|---|---|---|
| male | 100 | 100.0 | 100.0 |

Table (2): Education

| Education | | Frequency | Percent | Valid Percent |
|---|---|---|---|---|
| | illiterate | 7 | 7.0 | 7.0 |
| | primary | 25 | 25.0 | 25.0 |
| | intermediate | 58 | 58.0 | 58.0 |
| | university | 10 | 10.0 | 10.0 |
| | Total | 100 | 100.0 | 100.0 |

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In table (1) showed that all farmers are males and most of them had intermediate education which showed in table (2), 58%of farmers had middle education.

Table (3): Marital status

| Marital status | | Frequency | Percent | Valid Percent |
|---|---|---|---|---|
| | married | 91 | 91.0 | 91.0 |
| | single | 7 | 7.0 | 7.0 |
| | divorce | 2 | 2.0 | 2.0 |
| | Total | 100 | 100.0 | 100.0 |

Table (4): Job

| job | | Frequency | Percent | Valid Percent |
|---|---|---|---|---|
| | cultivation | 81 | 81.0 | 81.0 |
| | trade | 1 | 1.0 | 1.0 |
| | employee | 4 | 4.0 | 4.0 |
| | other | 14 | 14.0 | 14.0 |
| | Total | 100 | 100.0 | 100.0 |

In table (3) majority of the farmers are married 91%. And cultivation was the main work for 81% of the farmers (table (4)).

Table (5): Family Numbers

| Family numbers | Frequency | Valid Percent |
|---|---|---|
| 1.00 | 10 | 10 |
| 2.00 | 3 | 3.0 |
| 3.00 | 8 | 8 |
| 6.00 | 18 | 18.0 |
| 7.00 | 17 | 17.0 |
| 8.00 | 9 | 9.0 |
| 9.00 | 10 | 10.0 |
| 10.00 | 6 | 6.0 |
| 11.00 | 5 | 5.0 |
| 12.00 | 4 | 4.0 |
| 13.00 | 3 | 3.0 |
| 15.00 | 6 | 60 |
| Total | 100 | 100.0 |

In table (5) 35% of the farmers had about 6-7 family numbers and after that comes 9 numbers by 10%.

**The Stochastic Frontier Model of Sorghum:**

Table (6): Summary statistics of efficiency estimate from the stochastic frontier model of sorghum

| Statistics | Efficiency scores |
|---|---|
| Mean | 0.54 |
| St dv | 0.23 |
| Max | 1 |
| Min | 0.25 |

In Table (6) above Stochastic Production Frontier model output showed that the low level of technical efficiency is 25% and the high one is 1 that explains some farmers or farms produce on the Curve production possibilities and reach optimized output while most of the farm's production stay away from the curve.

Average of the technical efficiency is 54% this mean farmers can increase the production by 46% without any increasing in inputs and this means also the sample lose some resources.

Table (7): The technical efficiency levels

| The levels of efficiency | numbers | The percentage |
|---|---|---|
| Less than 50 | 50 | 50% |
| 51-70 | 25 | 25% |
| 71-90 | 16 | 16% |
| More than90 | 9 | 9% |

From table (7) above noticed that 50% of the farmers achieves level of technical efficiency less than 50, while 9% of the farmers that achieves more than 90 level of efficiency.

**The Tobit Results:**

Tobit regression                        number of obs = 100

                                               LR chi (6) =247.35

                                                Prob>chi2 =0.000

Log likelihood=123.3285     Pseeds =356.7084

Table (8)

| efficiency | Coef. | Std. err | t | P>{t} | {95} coef. | interval |
|---|---|---|---|---|---|---|
| Source of seed | .3224039 | .0115816 | 27.84 | 0.000 | .2994083 | .3453994 |
| Seed rate | .9138059 | .0312426 | 0.44 | 0.660 | -.048227 | .0758388 |
| Martial status | 0201899 | .0190702 | 1.06 | 0.292 | -.0176745 | .0580543 |
| age | -.0043856 | .0010307 | -4.26 | 0.000 | -.1746922 | -.1301854 |
| education | -.1524388 | .0112078 | -13.60 | 0.000 | -.1746922 | -.1301854 |
| Years of experience | -.0004623 | .0009802 | -0.47 | 0.638 | -.0024086 | .0014839 |
| constant | .6204533 | .0987251 | 6.28 | 0.000 | .4244323 | .8164743 |
| sigma | .0675586 | .0048276 | | | .0579733 | .0771438 |

From table (8) except for seed source is significant and positive, but age and education are significant and negative. These factors represent the good characteristics that add to or deduct from efficiency.

Seed rate, marital status, and years of experience are not significant. These factors do not affect the technical efficiency in Gadarif state farms.

## Conclusion

This work is Evaluation of Technical Efficiency for sorghum Production in Gadarif state in Sudan. Using stochastic frontier production function model and Tabit model. The study was based on primary data by using a questionnaire, with random sampling techniques from 100 selected farmers. Differences in technology and efficiency of production method have distinguished impact on agricultural productivity. Farmers in Gadarif state found to be technically efficient; therefore, there is a scope for increasing sorghum production by 46% with present technology. Tabit model results showed that seed source, is significant and positive, age and education are significant and negative on technical efficiency.

Study recommended that there is a possibility to enhance the efficiency of sorghum producers in the study area, by approving good management practices, conducting extension programmes such as a training farmers. And also that the technical

efficiency of sorghum farmers could be improved by practicing best use of inputs and educating the inefficiency factors

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