Technical Efficiency of Sorghum Production in the Mechanized and Traditional Rain-fed Agricultural Sub-Sectors in South Kordofan State, Sudan

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ABSTRACT

This study estimated and evaluated the technical efficiency of the mechanized and traditional rain-fed farming systems in South Kordofan State, Sudan. Primary data for the study were obtained using structured questionnaire administered to 200 randomly sampled farmers in the two farming systems from four designated locations in the study area. This was done by using a stochastic frontier production function. The results showed that the coefficients of labor, sex, age, distance and type of finance were found all positively and significantly, while farm size, quality of seeds, labor, family size, occupation and extension services were found statistically significant at 1% and 5% level of probability, respectively. All the farmers were producing below the maximum efficiency frontier. The farmer’s technical efficiency indices varied between 0.10 and 1.0 in the mechanized and traditional farming system, respectively. Also the mean of the farmer’s technical efficiency was 0.69 in the mechanized system compared to 0.66 in the traditional farming system.
It is also indicates that farmers can increase production of sorghum by 31% and 34% in the mechanized and traditional farming system, respectively. This means that there is a room for farmers to increase the technical efficiencies of production of these crops up to the optimum level (100%). The strengthening of the agricultural extension services in the study area is needed. Facilitating the financing process through micro-finance and repayment in kind is essential.

**Keywords:** evaluation; technical efficiency; farming system; stochastic; frontier; farming system

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**INTRODUCTION**

Sorghum is the staple cereal in Sudan, while it is important diet component in Africa and Asia. It is predominantly cultivated in two broad agro-climatic zones: arid and semi-arid agro-ecologies. The production of farmers who have access to improved quality seeds and extent of commercialization in Sudan than the rest of the Eastern and Central Africa Regional Sorghum and Millet Network (ECARSAM) countries. Sudan accounts for 21.4% of Africa’s sorghum production, second to Nigeria which produces 33.8% of the total harvest (FAO, 2010).

Agriculture in Sudan is composed of three main farming sectors, namely traditional rain-fed sector, mechanized rain-fed sector, and irrigated sector. The traditional rain-fed sector has occupied an average of 60% the total cultivated land and employed about 65% of population during the last ten years. Nevertheless, this sector is characterized by low crop productivity that is mainly due to lower technical efficiency that has led to decrease its average contribution to the total agricultural (GDP) being only about 16% during the last ten years (Siddig, 2011).

However, less than 20% are utilized at present under the three major farming sub-sectors: the irrigated, the mechanized and the traditional rain-fed sector. The agricultural sector has an important role to play in achieving food security by increasing food production and providing employment opportunities in the rural areas. The area of the traditional rain-fed sub sector is about 9 million hectares located in western, central and southern parts of the Sudan. The main crops include sorghum, millet, groundnut, sesame, cotton and gum arabic. The sub-sector contributes...
about 90% of total millet, 48% of groundnuts, 28% of sesame, 11% of sorghum and 100% of gum Arabic (Abbadi and Ahmed, 2006).

South Kordofan State's economy is dominated by agriculture and natural resources. About 70% of family income comes from selling crops, 9% from livestock, 7% from forest products, 7% from remittances and petty trading especially among female-headed households. Thus, cropping and raising livestock remain the main supporting activities for population livelihood. Forestry activities are an equally important income source for households (Hussein, 2001).

Efficiency of a production unit may be defined as how effectively it uses variable resources for the purpose of profit maximization, given the best production technology available. The concept of efficiency is further decomposed into two components technical and allocative efficiency. Technical efficiency refers to the maximum attainable level of output for a given level of production inputs, given the range of alternative technologies available to the farmer. Allocative efficiency refers only to the adjustment of inputs and outputs to reflect relative prices, having chosen the production technology (Kebede, 2001). It is technically efficient if it produces a higher level of output from the same level of inputs as compared to another farm. Moreover, technical efficiency and allocative efficiency are necessary and when they occur jointly are sufficient conditions for economic efficiency to exist (Alias and Ismail, 1996).

Accordingly, this study measured the technical efficiency of the farmers in South Kordofan State, Sudan to reveal its impacts on farmers' income and crop yield and resources allocation. In addition, the study tried to identify the technical efficiency determinants and the main factors affecting it.

MATERIAL AND METHODS

The study area

South Kordofan State is located between latitudes 11.15° – 10.25° N and longitudes 27.05° – 32° E. It is divided into nine localities i.e. Kadugli, Dilling, Abu karshowla, Abugeibaia, Talodi, Lagawa, Keilak, Rashad and Elsalam. It has a total population of about 1,406,404 (Central Bureau of Statistics, 2009). The state of Southern Kordofan was founded in 1974 when the Greater Kordofan area was divided into two provinces- North and South Kordofan. In 1994, the Greater Kordofan area was sub-divided into three, with Western kordofan as additional state. In the Comprehensive Peace Agreement (CPA), the decision was reversed. The
State of South Kordofan is located in the savannas belt of the Sudan, which is located between the longitudes 29°-32° East and written 9°-13° north bordered by the states of North Kordofan, Upper Nile, Unity in the South and east and the White Nile State with an area of 82,000 square kilometers. In the rural areas, three main livelihoods groups can be identified: traditional agricultural small-holders, traditionally practice subsistence farming based on the cultivation of sorghum combined with livestock raising, the second is pastoralists mostly transhumant following seasonal migration for grazing where they own large herds, and the third is horticulturalists and are mainly concentrated around the (wadis) in the north and adjacent to larger settlements, where they practice agriculture and intense crop cultivation, including irrigation, as well as providing labor for the mechanized schemes in the state (IFAD, 2010).

**Sample size and sampling procedure**
The results of this study were based mainly on data collected from a sample of 200 households located in the nine localities of South Kordofan State. The data were collected from two farming systems: traditional rain-fed and mechanized rain-fed farming system, where the sample size included the two farming systems. For the homogeneity of rural population with respect to socio-economic characteristics, a sample size of 200 was selected, 100 respondents from each farming system by using a random sampling technique among the cash and food grain crops. The advantage of random sampling is that each respondent of the sampled population can represent the whole population and has the same probability of being chosen. The data collected during the season 2008/09 and the households for the study survey were selected randomly after a purposive selection of the study area and localities. A well structured and field comprehension interviewing schedule was used for collection of detailed information on various aspects of cash and food crops. Survey data covered the farm information and socioeconomic characteristics and input-output quantities. This study covered six localities out of the nine localities of South Kordofan state: these localities were Kadogli, Dalling, Talodi, Abbiye, Lagawa and Elsalam area.

**Methods of Analysis**

**Analytical Framework**
The stochastic frontier production function (SFPF) used in efficiency studies is employed in this study. The modeling, estimation and application of (SFPF) to economic analysis assumed prominence in
econometrics and applied economic analysis during the last two decades. Early applications of (SFPF) to economic analysis include those of Aigner et al, in which they applied the SFPF in the analysis of the US agricultural data. Battese and Corra applied the technique to the pastoral zone of Eastern Australia. More recently, empirical applications of the technical inefficiency analysis have been reported by Battese et al (2004), Ajibefun and Abululkadri (Ojo, 2004).

The stochastic frontier production function model is specified as follows:

$$\ln Y = \beta_0 + \sum \beta_j \ln X_{ij} + V_i - U_i$$

Where:

- $Y$ is output in a specified unit
- $X_{ij}$ denotes the actual input vector
- $\beta_j$ is the vector of production function parameters
- $\beta_0$ is constant term
- $V_i$ and $U_i$ are the components of the error term in the regression model where $V_i$ is a random error term and the $U_i$ is a non-negative one sided error term. The frontier production function is a measure of maximum potential output for any particular input vector $X$. The $V$ and $U$ cause actual production to deviate from this frontier. The $V$ captures the random variation, which covers random effects on production outside the control of the decision unit (e.g. temperature, moisture, and natural hazards). It is assumed to be independently identically and normally distributed with zero mean and constant variance. The $U$ measures the technical inefficiency relative to the frontier, which is attributed to controllable factors. It is assumed to have a non-negative distribution with the normal distribution.

Stochastic frontier voids some of the problems associated with deterministic frontiers by explicitly considering the stochastic properties of the data, and distinguishing through a composite error term between firm-specific effects, and random shocks or statistical noise. Here, the frontier can shift from one observation to the next; being random rather than exact. Other problems still exist, however, with the parametric stochastic frontier approach. First, implementation requires the choice of an explicit functional form for the production or cost function, the appropriateness of which raises questions. The use of a flexible functional form, such as the translog, helps to alleviate this concern to some extent. Second, the research imposes strong distributional assumptions on the error term while debate continues; some evidence suggests a limited effect of distributional assumptions on the obtained
estimates (e.g. Cowing Reifscheider and Stevenson 1983, and Greene 1990). Moreover, the relative ranking of firms based on inefficiency calculations seen unaffected. But, the absolute levels of inefficiencies differ over different distributional assumptions on the one-sided error term, with the single parameter models (Ojo, 2004).

In this study, the following model is used to study determinants of farm specific technical efficiency. The level of efficiency, the dependent variable, lies between 0 and 1. The model is specified as follows:

\[ TE = b_1 \text{OWNER} + b_2 \text{AGE} + b_3 \text{EDU} + b_5 \text{OCCUP} + b_6 \text{PLOTS} + b_6 \text{DISTANC} + b_7 \text{FINAN} + b_8 \text{FARMEXPER} + b_9 \text{RAINLEVEL} + b_10 \text{FINATYP} + b_11 \text{EXTENS} + b_12 \text{SEX} + \varepsilon \]

Where:
- \( b_i (i=1,\ldots,12) \) are coefficients
- \( TE \) = the level of technical efficiency obtained from the estimation made on the previous model.
- \( \text{SEX} = 1 \) if the household is female headed, and 0 if it is male headed.
- \( \text{AGE} \) = age of the household head. Since the traditional farming practices are prevalent in the study area, this variable is also assumed to capture the level of farming experience of the household.
- \( \text{EDUC} \) = the number of years of schooling achieved by the household head.
- \( \text{DISTANC} \) = distance of plots from the residence of the household.
- \( \text{FINANCE} = 1 \) if the farmer has obtained credit for production activities and 0 Otherwise.
- Ownership = 1 if the farmer owned a farm and 0 for none.
- OCCUPATION: the main occupation of the farmer 1 if is farmer and 0 otherwise.
- FARMER EXPERIENCE: number of years of agric-practicing.
- RAINLEVEL: 1 if it is excellent and 0 otherwise.
- TYPE OF FINANCE: 1 for formal finance, 0 if is self finance.
- EXTENSION: I if there is services of extension and 0 for otherwise.

RESULTS AND DISCUSSION

The technical efficiency of sorghum in the mechanized rain-fed farming system

Table (1) shows that the estimated gamma parameter (\( \gamma \)) of inefficiency model for production of sorghum in the mechanized farming system was 0.961, indicating that about 96.1% of the variation in the output of sorghum among the farmers was due to differences in technical
efficiencies. The analysis of the inefficiency model (Table 1) shows that the signs and significance of the estimated coefficients in the inefficiency model have important implications on technical efficiency (TE). The table shows that the coefficient of age of farmer, occupation, distance of plots (significant at 1%), and finance availability (significant at 1%) were positive, indicating that these factors led to increase in technical inefficiency of mechanized farmers in the study area.

The coefficients of sex, educational level, family size, farmer experience, farm ownership, rain level, type of finance, and extension services were negative, meaning that these factors increase technical efficiency of sorghum in the mechanized rain-fed farming system. Table (1) also indicates that the coefficient of age of the farmers (significant at 10%) was positive meaning that increase in the age of the farmers increases the allocative inefficiency of farmers in the study area, while the coefficient of educational level, farming experience and type of finance were negative, indicating that these factors led to decrease in the allocative inefficiency of the farmers. The variance parameters for $\sigma^2$ and $\gamma$ are 0.178 and 0.961, respectively.

The mean of technical efficiency of sorghum is 0.6948. This means that on average, the farmers produced 69% of sorghum output that attainable by best practice, given their current level of production inputs and technology used. This implies that the respondents can increase their sorghum output by 31% from a given mix of production inputs if the farmers are technically efficient.

Table 1: Maximum likelihood estimates of stochastic frontier function of Sorghum in mechanized system.

<table>
<thead>
<tr>
<th>Variables</th>
<th>parameters</th>
<th>Estimated coefficient</th>
<th>Standard Error</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>$\beta_0$</td>
<td>0.395</td>
<td>0.429</td>
<td>0.919</td>
</tr>
<tr>
<td>Farm size</td>
<td>$\beta_1$</td>
<td>0.110</td>
<td>0.130</td>
<td>0.845</td>
</tr>
<tr>
<td>Quantity of seeds</td>
<td>$\beta_2$</td>
<td>0.166</td>
<td>0.272</td>
<td>0.610</td>
</tr>
<tr>
<td>Labor</td>
<td>$\beta_3$</td>
<td>0.391***</td>
<td>0.139</td>
<td>2.81</td>
</tr>
<tr>
<td>Inefficiency model</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>$\delta_0$</td>
<td>-0.384**</td>
<td>0.180</td>
<td>-2.13</td>
</tr>
<tr>
<td>Sex type</td>
<td>$\delta_1$</td>
<td>-0.398**</td>
<td>0.172</td>
<td>-2.31</td>
</tr>
<tr>
<td>Age</td>
<td>$\delta_2$</td>
<td>0.952*</td>
<td>0.478</td>
<td>1.99</td>
</tr>
<tr>
<td>Education level</td>
<td>$\delta_3$</td>
<td>-0.368</td>
<td>0.461</td>
<td>-0.797</td>
</tr>
</tbody>
</table>
From Table (2), the predicted farm specific technical efficiencies (TE) ranged between 0.1 and 1.0. A mean efficiency of the farmers was 0.69. Thus, there is scope of increasing sorghum production by about 31% by adopting the technologies and techniques practiced by the best farmers in the area. Many of the farmers were having efficiency between 50% and 100%. This is probably due to the long years of farming experience of the farmers. However, a few (12%) of the farmers were less than 50% efficient in their production process.

Table (2). Technical efficiency levels of sorghum in the mechanized rain-fed system

<table>
<thead>
<tr>
<th>Efficiency level</th>
<th>Frequency</th>
<th>Relative efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1—0.2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>0.3—0.4</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>0.5—0.6</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>0.7—0.8</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>0.9—1.0</td>
<td>48</td>
<td>48</td>
</tr>
</tbody>
</table>
The technical efficiency of sorghum in the traditional rain-fed system

Table (3) shows that the estimated gamma parameter (γ) of inefficiency model for production of sorghum in the traditional farming system was 0.953, indicating that about 95.3% of the variation in the output of sorghum among the farmers was due to differences in their technical efficiencies. The analysis of the inefficiency model (Table 3) shows that the signs and significance of the estimated coefficients in the inefficiency model have important implications on technical efficiency (TE). The table shows that the coefficient of sex, age of farmers, educational level, occupation, farmer experience, farm ownership were positive, indicating that these factors led to increase in technical inefficiency of farmers in the study area. While the coefficients of family size (significant at 5%), distance of plots, rain level, type of finance, finance availability and extension services were negative, meaning that these factors increases technical efficiency of sorghum in the traditional rain-fed farming system.

Table (3) also indicates that the coefficient of age of the farmers, educational level, and farming experience were positive meaning that increase in these variables increases the allocative inefficiency of farmers in the study area, while the coefficient of type of finance was negative, indicating that this factor led to decrease in the allocative inefficiency of the farmers. The variance parameters for $\sigma^2$ and $\gamma$ are 0.159 and 0.953, respectively. The mean of efficiency of sorghum is 0.661. This means that on average, the farmers produced 66% of sorghum output that attainable by best practice, given their current level of production inputs and technology used. This implies that the respondents can increase their sorghum output by 34% from a given mix of production inputs if the farmers are technically efficient.

**Table 3: Maximum likelihood estimates of stochastic frontier function of sorghum in traditional system.**

<table>
<thead>
<tr>
<th>Variables</th>
<th>parameters</th>
<th>Estimated coefficient</th>
<th>Standard Error</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>$\beta$</td>
<td>0.164</td>
<td>0.157</td>
<td>1.044</td>
</tr>
</tbody>
</table>

Source: computed from frontier4.1/survey data, 2010
From Table (4), the predicted farm specific technical efficiencies (TE) ranged between 0.1 and 1.0. A mean efficiency of the farmers was 0.66. Thus in the short run, there is scope of increasing sorghum production by about 34% by adopting the technologies and techniques practiced by the best farmers in the area. Many of the farmers have efficiency between 50% and 100%. This is probably due to the long years of farming experience of
the farmers. However, a few (14%) of the farmers were less than 50% efficient in their production process.

Table 7. Technical efficiency levels of the sorghum in traditional rain-fed system

<table>
<thead>
<tr>
<th>Efficiency level</th>
<th>frequency</th>
<th>Relative efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 —— 0.2</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>0.3 ——0.4</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>0.5 ——0.6</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>0.7 ——0.8</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>0.9 ——1.0</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100 %</td>
</tr>
<tr>
<td>Mean</td>
<td>0.661</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>0.114</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>0.935</td>
<td></td>
</tr>
</tbody>
</table>

Source: computed from frontier4.1/survey data, 2010

CONCLUSIONS & RECOMMENDATIONS

In this study an attempt has been made to evaluate the economic efficiencies and scale economies of selected rain-fed farming systems in SouthKordofanState, namely the mechanized and traditional farming systems. Rain-fed farming system comprises important crops – the most important of which are sorghum, millet, sesame and groundnut.

The purpose of this study is to measure and evaluate the efficiencies using stochastic frontier production methodology. The production function is estimated from a sample of 200 farmers from mechanized and traditional farming system and farm efficiencies was measured in terms of technical, allocative and economic efficiency. Results of the study show that the technical efficiency ratio ranges from 0.6948 to 0.9869 in the mechanized framing system. Also the technical efficiency ratio in the traditional farming system ranges between 0.661 and 0.943. This indicates that there still exist a potential for increasing the output of the farmers, if the production gap between the average and the best-practice farmers can be narrowed. In terms of allocative efficiency, there is still a potential for increasing in output optimally allocating given inputs. With respect to economic efficiency, results indicate that farmers are economically inefficient with a mean efficiency ratio between 0.89 to 2.47 in the mechanized system and 0.51 to 1.98 in the traditional one. This indicates that there are enormous potential for the farmers to
increase output by adopting the best technology and through optimal resource allocation.

The study recommended that farmers in both traditional and mechanized farming system must be included in the proper agricultural extension services and programs so as to increase the level of efficiency to optimize the resources used. The strengthening of the agricultural extension services in the study area is needed. Facilitating the financing process through micro-finance and repayment in kind is essential. Therefore, government authorities and other concerned bodies should take into consideration the socio economic and institutional factors to improve productivity of sorghum in the study area.

References


