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Original Article

Technical Efficiency of Food Crop Production (Sorghum and Millet) in North Kordofan state, Sudan

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ABSTRACT
The objective of this paper was to measure technical efficiency, and identification of factors that influence technical efficiency of food crops production (sorghum and millet) in traditional rainfed sector in North Kordofan state, Sudan. Data were collected from 205 farmers selected by distributing structural questionnaire following stratified random sampling techniques due to socio-economic characteristic and homogeneity of North Kordofan population. A stochastic frontier production function, using the maximum likelihood estimation (MLE) technique was applied in the analysis of data collected during the season 2011-2012. The results show that the numbers of sowing, labor, fertilizer and rainfall have a significant negative effects in sorghum and millet, while years of experience show a positive significant for both. In addition to that the (MLE) reveal that the mean technical efficiency of sorghum and millet 0.56 and 0.74, respectively. This means, there are ranges for increasing sorghum and millet production by 44% and 26%, respectively, from a given mix of production inputs by adopting technologies used with the best practice if the farmer's are technically efficient. In other words, on average; about 44 %and 26% of production are lost because of inefficiencies.
Keyword: Technical efficiency, stochastic frontier, sorghum and millet, north Kordofan

INTRODUCTION
Agriculture is the economic engine of most economies in Sub-Saharan Africa (SSA) contributing at least 70 percent of employment, 40 percent of export earnings, and 30 percent of Gross Domestic Product (GDP) and up to 30 percent of foreign exchange earnings (IFAD, 2002).

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The agricultural sector is the core of Sudanese life and a main driving force for its economy even with the emerging oil sector. Although oil accounts for about 22% of Sudan's GDP, the economy is still predominately agricultural providing employment and livelihood to more than two-thirds of the population (African Economic Outlook, 2010). Agriculture generates more than one-third of the country's GDP and more than 90 percent of the non–oil export earnings. Agriculture also supplies about 60 percent of the raw material processed by the manufacturing sector (NEPAD, 2005).

In the Sudan, cereals are produced under three major productions systems-irrigated, traditional rain-fed and mechanized rain-fed. The average annual production of the three major cereals-sorghum, millet and wheat-during the period 2006-2009 was about 4,925,125 metric tons; of which 1,552,375 metric tons or 31.5% was produced under irrigation, 1,795,750 metric tons or 36.5% was produced by traditional farmers and 1,577,000 metric tons or 32.0% was produced by rain-fed mechanized farms (FAO and SIFSIA, 2010).

In North Kordofan state the traditional rain-fed farming and grazing systems predominate and characterized by subsistent small holdings cropping (5-30 feddans) and animal herding activities with limited inputs and technologies. Traditional crops and animal production constitute the most important economical activity that contributes to the livelihood, food security and development of both rural and urban areas. The state is endowed with huge diversified natural resources within variable climatic zones offering the state comparative advantages and high competitiveness, at national and international levels, for several crops and livestock types (Ministry of Finance- North Kordofan State, 2006).

Objectives

The main objective of this study was to measure the technical efficiency of sorghum and millet production in North Kordofan state and to explain the possibilities of increasing productivity of sorghum and millet by increasing the farmer's efficiency in production. Specifically, the study tried to determine and identifies the problems and socioeconomic factors behind inefficiency. In addition, the study tried to come out with policy recommendation to help decision-makers increase sorghum and millet productivity.

MATERIAL AND METHODS

Data collection

The data for this study were collected from 205 farmers selected from four localities namely (Sheikan, Umrwaba, El-Nuhoud and Elkhowy) in North Kordofan state. Data were collected by using structural questionnaire using stratified random sampling techniques designed to collect information on outputs, inputs, prices of outputs and inputs and socio-economic characteristics of the farmers in the study area.

Methods of Data Analysis

The stochastic frontier production function, which was independently proposed by Aigner, Lovell, and Schmidt [1977], and Meeusen and van den Broeck [1977]. The stochastic Frontier version 4.1 programs (Coelli, 1996) was originally proposed for the analysis of data to estimate the level of technical efficiency for sorghum and millet production based on analytical framework.

The stochastic frontier model for the ith firm can be written as:

$$\ln y_i = \beta_0 + \sum_{j=1}^{8} \beta_j \ln x_{ij} + v_i - u_i \qquad (1)$$

ln = the natural logarithm; Y_i = total output sack for sorghum and millet; X_1 = farm size under sorghum and millet crops (feddan); X_2 the number of sowing; X_3 the number of weeding; X_4 the amount of labor (man-day); X_5 the quantity of seeds kg/ fed; X_6 the quantity of rainfall (dummy) 1 = sufficient, 0 = not sufficient; X_7 quantity of fertilizer applied in kg/fed; and X_8 the quantity of pesticides applied in kg/fed

β_0 and β_1 are unknown parameters to be estimated for variables, respectively.

v_i represents the statistical error and the other factors which are beyond the farmers control such as weather, topography and others factor which are not included and may be positive , negative or zero. Term of other explanatory variables will be specified (Battese and Coelli 1993). μ_i , mean of technical inefficiency term, can be written as:

$$\mu i = \delta o + \sum_{s=1}^{8} \delta s\ Zsi \qquad (2)$$

Z_{1i} = age of farmers; Z_{2i} = farming experience (years of active farming); Z_{3i} = sex (dummy) 1= male, 0= female; Z_{4i} = educational level of farmers (years spend in school); Z_{5i} = marital status of farmers;

Z_{6i} = household size (number); Z_{7i} = credit access (dummy) 1= Access, 0 = no access; Z_{8i} = extension services contact (dummy) 1 = contact, 0 = non-contact; δ_o and δ_s coefficient are unknown parameters to be estimated, together with the variance parameters which area expressed in terms of $\sigma^2 = \sigma^2 u + \sigma^2 v$ and $\gamma = \sigma^2 u / \sigma^2$

Where the γ-parameters has value between zero and one. If γ has a value of one this will indicate that differences in farmers output due to technical inefficiency. A value of zero for, γ, indicates that the differences mainly due to statistical errors (Mohamed et al, 2008).

RESULTS AND DISCUSSION

Empirical Analysis of Production Function

The estimated stochastic frontier production function is presented in Table (1). The technical efficiency is computed for cereal (food) crops according to stated equations on Frontier 4.1 program. As shown in table 1, the mean technical efficiency for sorghum and millet were 0.56 and 0.74, respectively. This means, there are ranges for increasing sorghum and millet production by 44% and 26%, respectively, from a given mix of production inputs by adopting technologies used with the best practice if the farmer's are technically efficient. In other words, on average; about 44 percent and 26 percent of production are lost because of inefficiencies. The mean technical efficiency that presented indicates that the respondent operate at 56 percent and 74 percent level of technical efficiency for the sorghum and millet, respectively in the study area.

The variance ratio parameters Gamma (γ) also a measure of level of inefficiency in the variance parameter, and has a value of 0.99 for all crops in the selected survey area and it's the fact that a high level of inefficiency exists in the sorghum and millet production. This implies that the inefficiency effects are significant in determining the level and variability of outputs of crops producers in the study area. These results express that about 99 percent of output are explained by inefficiency. The significant estimates of γ and δ^2s imply that the assumed distribution of u_i (truncated) and v_i (normally) is accepted. This result is consistent with (Mohamed et al 2008), (Ahmed, 2004), and Coelli and Battese (1996). This shows that a conventional production function is not an adequate representation of the data.

The estimated co-efficient of farm area was found to be positive and significant at 1% level of significant for sorghum. This result indicates that farmers with larger farms tend to have good inefficiency effects than farmers with smaller operations. The estimated coefficient of number of sowing are found to be negative and significant for sorghum and millet at 0.05 and 0.01 level of significant respectively. Negatively significant parameter of sowing means that the rate of output increases with decrease number of sowing. The coefficient of the number of weeding are positive and significant for sorghum at 0.01 level of significant, and negative significant for millet at 0.01. The coefficient of labor was significant and had a positive for millet and significant and had a negative for sorghum in the stochastic frontier at 0.01 level of significant. This means that the inefficiency effect increases with the increase in human labor (man-day) of farmers for millet. The estimated coefficient of seeds quantity in kg are positive significant for millet and negative significant for sorghum at0.01 level of significant for both. The coefficient of fertilizer quantity in kg found to be negative significant for both at 0.01 level of significant

The coefficient of pesticides quantity in kg found to be positive and significant for millet at 0.01 level of significant.

Inefficiency model

The estimated stochastic frontier production function is presented in Table (1); the estimated coefficient of farmer's age has a positive significant for millet at 0.01, and negative significant for sorghum at 0.01. Negatively significant parameters of farmers age for sorghum model means that the inefficiency effects of sorghum model decrease with increase in age of farm operators. Means that the older farmers have smaller inefficiency than younger farmers, or the older farmers are technically more efficient than younger farmers. In other words, as the age of farmers increases the inefficiency effect decrease. Positively significant parameters of farmers age for millet model means that the inefficiency effects of millet increase and decrease with increase and decrease in age of farmer's operator, the positive significant which means that age of farmers increase technical inefficiency and decrease decreases technical efficiency.

Experience of farmers has significantly positive effect on the inefficiency for both sorghum and millet at 0.05 level of significant, which indicates that more experienced farmers tend to have more inefficiencies than less experienced farmers. Which means that the inefficiency effect increases with increase in experience of farmer's operators, or positive significant increase inefficiency effect and decreases technical efficiency? Experience farmers can manage inputs more efficiently than less experienced farms, also would ease the process of extension in transferring knowledge and technologies to the farmers.

The farmer's sex has a positive significant for sorghum and negative significant for millet at 0.01and 0.1, respectively.

The coefficient of education is positive significant for sorghum and negative for millet at 0.01. Which means that negatively significant parameter of education means that technical inefficiency of millet decrease with the increase in education of farm operators, and positively significant parameters means technical inefficiency increase with increase in education. The variable education increased farming experience coupled with higher level of educational achievement may lead to better assessment of the importance and complexities of good farming decision, in addition to that, education enhance a farmer's ability to seek and make good use of information about production inputs. Various studies have found a positive connection between technical efficiency and education (Phillips and Marble 1986), while several others have reported no statistically significant relationship between these two variables (Bravo & Evenson 1994; Phillips and Marble 1986).

Table 1: Maximum-likelihood Estimate for the Parameters of the Stochastic Frontier Production Function and Technical Inefficiency Effect Model

Crops		Sorghum	Millet
Variables	**Parameters**	**Estimate**	**Estimate**
Constant	β_0	2.916*** (0.112)	0.628*** (0.163)
Area (fed)	β_1	0.609*** (0.086)	-0.00497 (0.0436)
Sowing	β_2	-1.309** (0.525)	-1.551*** (0.120)
Weeding	β_3	1.803*** (0.275)	-0.914*** (0.195)
Labor (man-day)	β_4	-0.797*** (0.268)	1.206*** (0.0216)
Seeds/kg	β_5	-0.386*** (0.0515)	0.602*** (0.0586)
Rainfall	β_6	-3.408*** (0.0832)	-0.584*** (0.170)
Fertilizer/kg	β_7	-0.0817*** (0.00163)	-0.582*** (0.0448)
Pesticides/kg	β_8	0.0016 (2.392)	1.073*** (0.243)
Inefficiency Effect model			
Constant	δ_0	-1.020 (0.869)	-0.546 (0.664)
Age	δ_1	-0.0366** (0.0164)	0.0145*** (0.00529)
Experiences	δ_2	0.0883** (0.0362)	0.0296** (0.0136)
Sex	δ_3	2.0438*** (0.280)	-0.286* (0.166)
Education	δ_4	1.0812*** (0.145)	-0.379*** (0.0503)
Marital status	δ_5	-0.268 (0.441)	1.496*** (0.201)
Household size	δ_6	0.0352 (0.0628)	0.0313 (0.0269)
Credit	δ_7	2.260*** (0.619)	-1.528*** (0.231)
Extension	δ_8	-4.963*** (0.672)	1.545*** (0.267)
Sigma-squared	$\sigma_s^2 = \sigma_v^2 + \sigma^2$	1.791*** (0.200)	0.128*** (0.0246)
Gamma	$\gamma = \sigma^2 / \sigma_s^2$	0.999*** (0.00000061)	0.999*** (0.000067)
Mean efficiency		0.56	0.74
Log likelihood function		-147.74	321.49

***, ** and * asterisks on the value of the parameters indicate its significant at 1, 5, and 10 percent level of significance respectively. The estimated standard errors are presented in parenthesis bellow the corresponding parameter estimate

Marital status has a positive significant for millet**.** Positively significant means that the increasing of number of farmers who married increase technical inefficiency by statistically significant amount.

Credit is a variable that used to capture the effect of credit on the efficiency of farmers. Access of credit improve of liquidity and enhances use of agricultural inputs in production. The availability of credit will reduce the constraints and problems of production facilitating to get the inputs on a timely basis and increase the efficiency of the farmers. In accordance with this expectation, the credit has a positive and statistically significant for sorghum and negative significant for millet at 0.01 levels. This means that availability of credit is an important factor for attaining higher level of technical efficiency, technically in efficient farmers can possibly get more efficient in the short run by facilitating access to credit.

Extension contacts of extension agents with farmers are found to have significantly negative effect for sorghum and significantly positive effect for millet at 0.01 level of significant. Negatively significant implies that farmers with more extension contact are found to be less technically inefficient (or more technical efficient).

Frequency Distribution of Farmers Technical Efficiency

The distribution of farmers' technical efficiency and inefficiency effect model indices derived from the analysis of the stochastic production function is provided in Figure (1), it is clear from the histogram that, 29.4% of sorghum farms operate with efficiency level greater than 90% or (91-100) percent and 39.1 percent millet farms operate with efficiency level (81%-90) percent.

The percentage distribution of technical efficiency of the sorghum and millet, farmers reveals that farmers' technical efficiency varied between 3% -100% with a mean of 56% for sorghum and 4%-100% with a mean of 74 percent for millet. The picture that emerges from the analysis is one of the a generally high technical efficiency in traditional rainfed sector farming in study area as most of the farmer 56.2 and 85.6% produce above 50% efficiency index for sorghum and millet crops. This result provides information for decision makers and helps them to investigate the main factor behind technical inefficiency and to design policies to improve farms technical efficiency and hence household food security. The distribution of the technical efficiency suggests that potential gain in technical efficiency among the sample farmers is large.

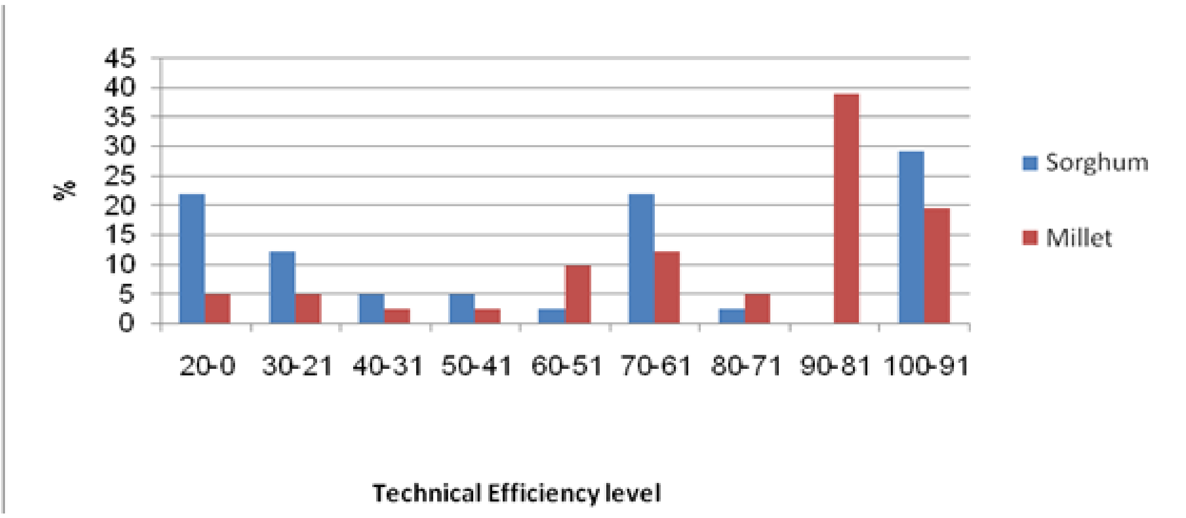

Fig 1: Technical Efficiency Distribution Score of Farmers

CONCLUSION

In this paper, we employed the stochastic frontier production function to estimate technical efficiency for sorghum and millet food crops farmers in traditional rainfed sector of North Kordofan state.

The result showed that sorghum farmer's technical efficiency ranged between 3% and 100% with average 56%, and millet technical efficiency was ranged between 4% and 100% with average of 74%. The findings of the study have implications for increased food production in the study area. Attainment of 56% and 74% technical efficiency means that farmers still have room to increase their efficiency to the optimum (100%). This will require addressing those factors, which are constraints to efficiency.

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