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EVALUATION THE TECHNICAL EFFICIENCY OF MILLET PRODUCTION IN THE MECHANIZED AND TRADITIONAL RAIN-FED AGRICULTURAL SUB-SECTORS IN SOUTH KORDOFAN STATE, SUDAN

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This study determined the technical efficiency of millet production in the mechanized and traditional farming rain-fed systems in South Kordofan State, Sudan. A multistage random sampling technique was adopted in the selection of 200 farmers from each of the two rain-fed farming systems of the State. A well-structured questionnaire was used to obtain information on socio-economic characteristics of farmers and other relevant information. Technical efficiency was analyzed using a stochastic frontier production function. The Maximum Likelihood Estimation Technique was employed in estimating the function while t-test statistic was employed in testing their determinants. The mean technical efficiency was 0.75 in the mechanized system compared to 0.834 in the traditional farming system. This means that farmers can increase production of sorghum by 25% and 17% in the mechanized and traditional farming system, respectively. The coefficient of age of the farmers was positive meaning that increases in the age of the farmer increased the allocative inefficiency of farmers in the study area. The coefficients of farmers experience, farm ownership, distance, rain level, finance availability and extension services were negative indicating that these variables led to decreases in technical inefficiency of farmers in the study area. The study recommended that to establishment of a well equipped agricultural extension program, adoption of recommended technical packages and providing credit and production inputs at the right time and place in order to improve farmers livelihoods.

Key Words: Evaluation; Technical efficiency; farming system; likelihood, strengthening

INTRODUCTION

Agriculture in Sudan is composed of three main farming sectors; traditional rain-fed, mechanized rain-fed and irrigated sector. However, less than 20% are utilized at present under the three major farming sub-sectors. 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 (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).

In general, about 81% of the active population earns their living from agriculture, hunting and forestry activities. Farming is the predominant economic activity in Southern Kordofan followed by the rearing of livestock, particularly cattle. Planting is conducted during the rainy season, though some cultivation also occurs during summer. Key crops include sorghum, sesame, millet, groundnut and vegetables like okra and pumpkin (SUDI, 2010).

Millet is the main food for most people of Kordofan and Darfur, where it is grown in the sandy soils of the northern parts of these states. In these areas, rainfall is around 400 mm per annum, which is too little to sustain the production of other cereals. This allows millet to be the best alternative cereal to be grown in these areas. Average millet acreage is around 5.4 million feddans, producing some 300,000 tons with low average yields of about 90 kg/fed (ARC, 2012).

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).

Production unit 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).

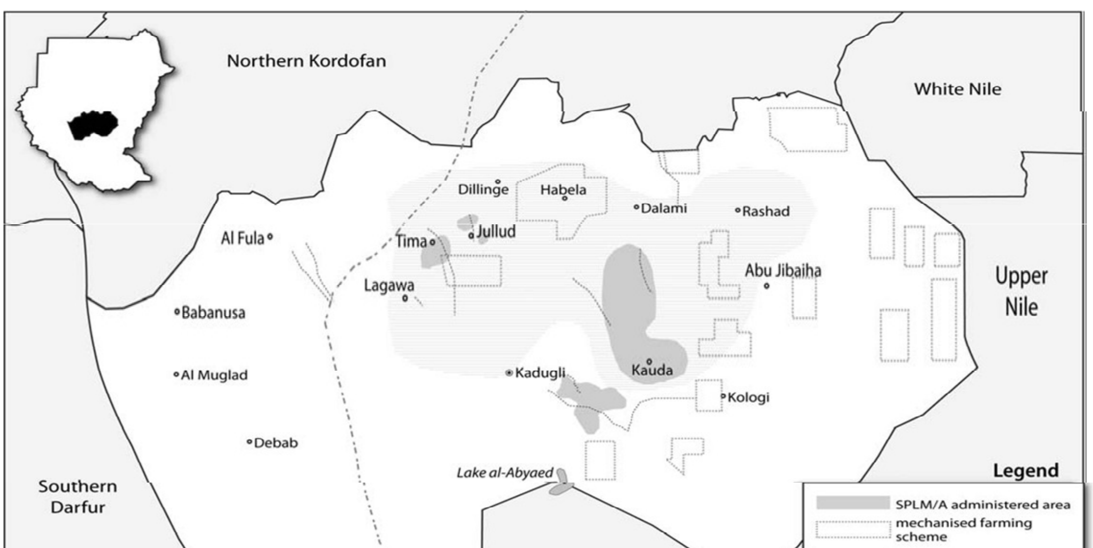
The objective of the study was to analyse differences in technical efficiencies between mechanized and traditional rain-fed millet farming systems of South Kordofan State and to evaluate various determinants of inefficiency for both systems.

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, Abugeibaiha, Talodi, Lagawa, Keilak, Rashad and Elsalam. It has total population of about 1,406,404 (Central Brureau of Statistics,2009). The State was founded in 1974 when the greater Kordofan area was divided into two provinces: North and South Kordofan (Figure 1).

In the rural areas, three main livelihoods groups can be identified: (1) traditional agricultural small-holders who practice subsistence farming based on the cultivation of sorghum combined with livestock raising,(2)pastoralists, who own large herd mostly transhumant following seasonal migration for grazing and (3) the horticulturalists mainly concentrated 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).



This map has been produced by the International Crisis Group. The location of all features is approximate and for illustration only. Certain information included is from "Southern Kordofan and Abeyi: Transhumance and land use", map by Threat and Risk Mapping and Analyses (TRMA), United Nations Development Programme, Khartoum, Sudan, 17 October 2007, available at www.unsudanig.org; and from the European Coalition on Oil in Sudan.

Figure (1): The map of Southern Kordofan state

Sample size and sampling procedure

The study depended mainly on primary data which were obtained from a farm-level survey in 2010 in Kordofan State. Secondary data were obtained from various sources such as government institutions and organizations working in the area. A purposive selection of the study area and localities was made. For homogeneity of rural population, a sample size of 200 households was selected, 100 respondents from each farming system by using a multi-stage random sampling technique. The data was collected during the season 2009/10. Survey data included socioeconomic characteristics of farmers and input-output quantities.

METHODS OF ANALYSIS

Analytical Framework

The stochastic frontier production function (SFPF) in efficiency studies was employed in this study. SFPF has been used by other researchers in different production systems (Aigner et al, 1977, Battese and Corra, 1977, Battese et al 2004, and Ajibefun et al 2004).

The stochastic frontier production function model is specified as follows:

$$Ln\ Y = \beta 0 + \sum \beta j Ln\ Xij + Vi - Ui$$

Where:
Y is output in a specified unit
Xij denotes the actual input vector
βj is the vector of production function parameters
β0 is constant term

Vi and Ui are the components of the error term in the regression model where Vi is a random error term and the Ui 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 (Ojo, 2004).

Stochastic frontier avoids 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; some evidence suggests a limited effect of distributional assumptions on the obtained estimates (Reifscheider and Stevenson 1991, and Greene 1990). However, 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 was 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 = b1 OWNER + b2AGE + b3EDU + b5OCCUP + b6PLOTS + b6DISTANC + b7FINAN+ b8FARMEXPER + b9RAINLEVL+ b10FINATYP+ b11EXTENS+ b12SEX + ε

Where:
bi (i= 1,….12) are coefficients
TE = the level of technical efficiency obtained from the estimation made on the previous model.
SEX = 1 if the household is female headed, and 0 if it is male headed.
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.
EDUC = the number of years of schooling achieved by the household head.
DISTANC = distance of plots from the residence of the household.
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 other wise.
FARMER EXPERIENCE: number of years of agric-practicing.
RAINLEVEL: 1 if it is excellent and 0 other wise.
TYPE OF FINANCE:1 for formal finance, 0 if is self finance.
EXTENSION: I if there are services of extension and 0 for otherwise.

RESULTS and DISCUSSION

The estimated gamma parameter (γ) of inefficiency model for production of millet in the mechanized farming system was 0.999 (Table 1), indicating that about 99.98% of the variation in the output of millet among the farmers was due to differences in their technical efficiencies. The signs and significance of the estimated coefficients in the inefficiency model have important implications on technical efficiency (TE). The coefficients of all variables in the model were positive except quantities of seeds and labor coefficients (Table 1), indicating that these factors led to increase in technical inefficiency of farmers in the study area. The coefficient of age of the farmers was positive meaning that increases in the age of the farmer increased the allocative inefficiency of farmers in the study area. The coefficients of farmers experience, farm ownership, distance, rain level, finance availability and extension services were negative indicating that these variables led to decreases in technical inefficiency of farmers in the study area. The variance parameters for σ^2 and γ are 0.182 and 0.999 respectively, which are significantly at the 1% level. This means that the inefficiency effects make significant contribution to the technical efficiencies in the mechanized rain-fed systems.

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

Variables	Parameters	Estimated coefficient	Standard Error	t-ratio
Constant	$\beta_\circ$	0.157	0.230	0.686
Farm size	β_1	2.460***	0.253	9.698
Quantity of seeds	β_2	-0.288	0.509	-0.565
Labor	β_3	-0.992	0.826	-1.201
Inefficiency model				
Constant	$\delta_\circ$	-0.769	0.973	-0.790
Sex	δ_1	0.823***	0.124	6.610
Age	δ_2	0.367	0.304	1.205
Education level	δ_3	0.929	0.597	1.556
Family size	δ_4	0.269	0.753	0.357
Occupation	δ_5	0.533	0.987	0.540
Farmer experience	δ_6	-.319	0.995	-0.320
Farm ownership	δ_7	-0.118	0.991	-0.119
Distance	δ_8	-0.877	0.963	-0.091
Rain level	δ_9	-0.261	0.996	-0.262
Finance availability	δ_{10}	-0.625	0.961	-0.649
Type of finance	δ_{11}	0.205	0.985	0.208
Extension services	δ_{12}	-0.177**	0.700	-2.529
Variance				
Sigma-square	σ^2	0.1822***	0.226	8.042
Gamma	Γ	0.9998***	0.001	611.94
Log-likelihood function 47.585				
LR test of one-sided error 285.301				
Mean technical efficiency 0.7556				

***** ,*** Estimate is significant at 5% and 1% level of significance***

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

The mean of technical efficiency of millet is 0.7556. This means that on average, farmers produced 75% of millet output attainable by best practice given their current level of production inputs and technology used. This implies that the respondents could increase millet productivity by 25% from a given mix of production inputs if the farmers are technically more efficient.

The predicted farm specific technical efficiencies (TE) ranged between 0.1 and 1.0 (Table 2) with a mean of 0.75. There is therefore scope of increasing millet production by about 25% by adopting the technologies and techniques practiced by the best farmers (role model farmers) in the area. Many of the farmers have efficiency between 50% and 100% probably due to differences of farming experience .A few (10%) of the farmers were less than 50% efficient in their production process.

Table (2): Technical efficiency levels of millet in the mechanized rain-fed system

Efficiency level	Frequency	Relative frequency (%)
0.2 —— 0.1	4	4
0.4 —— 0.3	6	6
0.6 —— 0.5	7	7
0.8 ——0.7	8	8
1.0 ——0.9	75	75
Total	100	100 %
Mean	0.755	
Minimum	0.130	
Maximum	0.968	

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

Technical efficiency of millet in the traditional rain-fed farming system

Table (3) shows that the estimated gamma parameter (γ) of inefficiency model for production of millet in the traditional rain-fed farming system was 0.166 (Table 3), indicating that about 16.6% of the variation in the output of millet among the farmers was due to differences in their technical efficiencies.

The coefficients of sex (significant at 5%), educational level, farmer experience, farm ownership (significant at 1%), distance from the farm, type of finance and extension services (significant at 5%), were positive (Table 3), implying that these factors led to increase in technical inefficiency of farmers in the study area. While the coefficients of age of farmer, family size (significant at 1%), occupation (significant at 5%), rain level (significant at 10%), and finance availability were negative, meaning that these factors increase technical efficiency of millet in these systems.

The coefficient of age of the farmers was negative meaning that increase in the age of farmers decrease the allocative inefficiency of farmers in the study area, while the coefficient of educational level, farming experience and type of finance were positive, indicating that these factors led to increase in the allocative inefficiency of the farmers. The variance parameters for σ^2 and γ are 0.211 and 0.166 respectively; they are significant at the 1% level. The mean of efficiency of millet is 0.834 (Table 3). This means that on average, the farmers produced 83.4% of millet output attainable by best practice, given their current level of production inputs and technology used. This implies that the respondents can increase their millet output by 17 % from a given mix of production inputs if the farmers are technically efficient.

Table (3): Maximum likelihood estimates of stochastic frontier function of millet in traditional system.

Variables		Parameters	Estimated coefficient	Standard Error	t-ratio
Constant		β_0	0.135	o.148	0.910
Farm size		β_1	o.263	o.682	o.386
Quantity of seeds		β_2	0.679	o.575	1.180
Labor		β_3	-0.139	o.123	-1.130
Inefficiency model					
Constant		δ_0	0.186	0.816	0.228
Sex		δ_1	0.352**	0.208	1.692
Age		δ_2	-0.719***	0.133	-5.40
Education level		δ_3	0.335	0.729	0.460
Family size		δ_4	-0.582***	0.165	-3.51
Occupation		δ_5	-0.271**	0.124	-2.185
Farmer experience		δ_6	0.117	0.112	1.044
Farm ownership		δ_7	0.454***	0.104	4.35
Distance		δ_8	0.163	0.403	0.405
Rain level		δ_9	-0.325*	0.172	-1.88
Finance availability		δ_{10}	-0.269	0.530	-0.507
Type of finance		δ_{11}	0.106	0.207	0.513
Extension services		δ_{12}	0.811**	0.351	2.310
Variance					
Sigma-square		σ^2	0.211		
Gamma		Γ	0.166		
Log-likelihood function	-0.6507				
LR test of one-sided error	0.953				
Mean technical efficiency	0.834				

***** ,*** Estimate is significant at 5% and 1% level of significance***
Source: computed from frontier4.1/survey data, 2010

The predicted farm specific technical efficiencies (TE) ranged between 0.3 and 1.0 (Table 4). A mean efficiency of the farmers was 0.83. Thus, there is scope of increasing millet production by about 17% by adopting the technologies and techniques practiced by role model farmers in the area. Similar to the mechanized rain-fed system, many of the farmers were having efficiency between 50% and 100%, probably due to differences in years of farming experience. However, a few (1%) of the farmers were less than 50% efficient in their production process.

Table (4): Technical efficiency levels of the millet in traditional rain-fed system

Efficiency level	frequency	Relative efficiency (%)
0.4 —— 0.3	1	1
0.6 —— 0.5	2	2
0.8 ——0.7	36	36
1.0 ——0.9	61	61
Total	100	100 %
Mean	0.835	
Minimum	0.497	
Maximum	0.992	

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

CONCLUSIONS and RECOMMENDATIONS

The purpose of this study was to measure and evaluate the efficiencies of two millet production systems using stochastic frontier production methodology. The study analyzed technical efficiency and its determinants for a millet production in the mechanized and traditional rain-fed farming systems in South Kordofan state, Sudan. Results of the study showed that the technical efficiency ratio in the traditional rain-fed system was 0.835 compared to 0.755 in the mechanized framing system. This indicates that there still exist a potential for increasing millet output and improve food security in the area for both systems, if the production gap between the average and the best-practice farmers can be narrowed. The findings of the study emphasized the need to improve farm efficiency at all levels. The study recommended that to establishment of a well equipped agricultural extension program, adoption of recommended technical packages and providing credit and production inputs at the right time and place in order to improve farmers' livelihoods. Include the farmers in both traditional and mechanized farming system in the proper agricultural extension services and programs so as to increase the level of efficiency to optimize the resources used.

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