Asian Journal of Agricultural Extension, Economics & Sociology

21(2): 1-7, 2017; Article no.AJAEES.33878
ISSN: 2320-7027

Analyzing the Technical Efficiency of Cotton Production in the Gezira Scheme, Sudan

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Authors' contributions

This work was carried out in collaboration between all authors. Authors BOM, MMME and HHA designed the study and wrote the protocol. Authors BOM and HHA managed the data collection and analysis. Authors MMME and BOM managed the literature search and wrote the manuscript. All authors read and approved the final manuscript

Article Information

DOI: 10.9734/AJAEES/2017/33878
Editor(s):
(1) Nguyen Khac Minh, Institute of Mathematics and Applied Science and Dean of Economics and Management at Thang Long University, Vietnam.
(2) Muhammad Yaseen, Department of Agricultural Extension & Rural Development, University College of Agriculture, University of Sargodha, Pakistan.
Reviewers:
(1) Erwin T. J. Lin, MingDao University, Taiwan.
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(3) Cecilia Akuchi Nwigwe, University of Ibadan, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/21960

Original Research Article

Received 2nd May 2017
Accepted 13th November 2017
Published 18th November 2017

ABSTRACT

Aims: This study aimed at measuring and evaluating production efficiency of the tenants producing cotton-crop in Gezira Scheme, and investigating the main specific factors behind their technical inefficiency.
Place and Duration of Study: Gezira Scheme, season 2011/12.
Methodology: The study depended on both primary and secondary data. Stratified random sampling technique was used to collect data from 150 farmers by means of questionnaire. Stochastic frontier production function model was used to attain the stated objectives.

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Results: Results revealed the presence of a relatively high potential for cotton-farmer to improve their yield by up to 11%. It is also revealed that, there were strong and substantially significant effect of cotton cultivated area (-0.02, p<0.10), seed rate (0.24, p<0.01), fertilizers (0.58, p<0.01), irrigation numbers (0.27, p<0.01), total labour man-day hours (0.09, p<0.05) on cotton production levels. On the other hand, tenancy location (-0.01, p<0.10), sowing date (-0.13, p<0.05) weeding (-0.11, p<0.05), family size (-0.04, p<0.10) and credit (-0.20, p<0.01) were highly significant in explaining the variation behind the tenants' technical inefficiency.

Conclusion: The study stresses on the importance of improving technical efficiency for cotton production in the Gezira Scheme, through improving tenants' access to credit and extension services. It is also stresses on the importance of agricultural research on solving weeds and irrigation problems.

Keywords: Stochastic frontier method; technical efficiency; cotton; production function; Gezira scheme.

1. INTRODUCTION

Sudan, the third largest country in Africa, occupied a total area of 1.88 million square km, extending between latitudes 8.45º and 23.8º North and longitudes 21.49º to 38.24º East [1]. The country is well endowed in terms of availability of suitable conditions for agricultural production. Hence, cotton was the main country's foreign-currency earner before 1992: the adoption of the liberalization policy [2]. By then, the majority of the Sudan's exported cotton was from Gezira scheme. In fact, in the nineteen seventies and nineteen eighties this crop was the main contributor (64%) of the country foreign-currency earnings and played a big role in providing income for a considerable amount of the labor-force (13%) [3]. Despite the economic importance of cotton in the Sudan economy, cotton's area, production and yield witnesses big fluctuations. It is area, production and yield dropped on average by 38%, 48% and 18%, respectively, during the period from 1987 to 2002 [4]. The cotton production from Gezira Scheme, the main producers of the crop, decreased sharply from 156 thousand metric tons to 10 thousand metric tons in 2004/05 and 2009/10 seasons, respectively. The main reasons behind the decline of cotton-crop for the mentioned period were the tremendous decline of both cotton area and productivity. In fact, cotton area and yield decreased from 102 thousand hectare and 296 kg/Ha in 2004/05 season to 11 thousand hectare and 237 kg/Ha in 2009/10 season, respectively. These reasons necessitate conducting this paper, which aimed at measuring and evaluating the technical efficiency of cotton production and to investigate the main tenant-specific factors behind their technical inefficiency in the Gezira scheme.

2. MATERIALS AND METHODS

Both primary and secondary data were used to achieve the stated objectives. Stratified random sampling techniques was used to collect primary data from 150 respondents (north, central, and hush groups) (Table 1) from Gezira Scheme by using structural questionnaire and direct personal interview during season (2011/12). Secondary data was collected from different relevant sources.

Table 1. The Tenants' sample from groups and blocks in Gezira scheme

Group	Block	No. of farmers chosen
Northern	Umdagarsi	25
	Meilig	25
Central	Dirwish	25
	Kumur	25
Hosh	Remeitab	25
	Wad Alataya	25
Total	6	150

Stochastic frontier production functions were used to achieve the stated objectives. This model was developed to improve the widely used deterministic production function model [5]. The term technical efficiency is defined as "the ability of farmers to produce a given level of production given a minimum quantity of inputs under certain technology" [6].

The explicit Cobb-Douglas stochastic frontier production function for estimating farm level technical efficiency is specified as:

$$lnY = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + \beta_6 lnX_6 + V_i - U_i \quad (1)$$

Where:

ln= the natural logarithm, Y= yield of cotton (kantar) (one kantar=100 bound)/Feddan (one feddan=4200 meter square)); X_1= cotton cultivated area (feddan), X_2= seed rate (kg/feddan), X_3= fertilizers (kg/feddan),X_4= pesticides (kg/feddan),X_5= number of irrigation, X_6= total labours (man-day hours); B_0 and β_i=is a vector of unknown parameters of production function to be estimated. v_i=the statistical error and the other factors which are beyond the tenants control such as weather, topography and other factors which are not included and may be either positive, negative or zero. u_i= non negative random variable associated with the tenants' technical inefficiency in production, and assumed to be independently distributed, such that the technical inefficiency effect for the i^{th} tenant. u_i will be obtained by truncating at zero of the normal distribution with mean, μ_i, and variance, ð2.

The inefficiency model can be written as:

$$U_i = \partial_0 + \partial_1 Z_1 + \partial_2 Z_2 + \partial_3 Z_3 + \partial_4 Z_4 + \partial_5 Z_5 + \partial_6 Z_6 + \partial_7 Z_7 + \partial_8 Z_8 \quad (2)$$

Where:

Z_1 = Tenancy location (1= at the head of the canal, 2= at the middle of the canal and 3= at the tail of the canal); Z_2 = Sowing date (dummy variable which receives one when at the optimum time and zero, otherwise); Z_3 = Number of weeding; Z_4 = Age (years of interviewed tenant); Z_5 = Education (numbers of years of formal education); Z_6 = Tenants experience (number of years spent as a tenant); Z_7= Family size (1=1-5 members, 2=6-10 members, 3= more than 10 members); Z_8= Credit (dummy variable; 1= easily access credit and zero=otherwise).

The computer program, FRONTIER Version 4.1 was used in estimating the parameters of the stochastic frontier production function model by the method of maximum likelihood.

3. RESULTS AND DISCUSSION

Results revealed that, the mean technical efficiency of cotton production is 0.89, with a minimum of 64% and maximum of 99% (Table 2). This means that, the average cotton production by tenants in the scheme was very high (89%) compared with the best attainable practice, given their current level of input and technology used. This implies that potentiality for cotton-tenants to increase their output is relatively high (11%). This level of efficiency might be considered very high compared with Zambian farmers [7]. Many factors might be responsible for that, among them was the introduction of new variety which characterized by it is resistance to pests and diseases and high yield.

Unexpectedly, the coefficient on cotton cultivated area is negative and significantly different from zero (P<0.10%). A possible explanation of the negative sign is that as the cotton area increases, the possibility of farmers of getting sufficient funds to carry out all operation at right time decreases. This result contradicts the findings of [8]. On the other hands, the elasticity on seed rate is positive and significantly different from zero (1% level of significance), indicating that technical efficiency increases with the increasing level of seed rate, that is, the currently used level of seed rate is far below the optimum amount.

The coefficient on fertilizers is positive and highly significant at 1% level of significant. Indicating that, a 1% increase of fertilizers amount increases cotton yield by the corresponding amount of elasticity (0.58). In the same vein, the coefficient on labour (man-day hours) is positive and significant (P<0.05). This result confirms the finding of [9,10]. Labour is required to carry out crop activities timely, particularly weeding and harvesting process. Thus, mechanizing agricultural practices might solve this problem.

On the other hands, irrigations number is considered as the most important factor affecting crop production. Watering intervals has a significant effect on cotton-seed and lint yield [11]. The coefficient on cotton's irrigations number was positive and significant at 1% level of significance. A positively significant parameter of irrigation means that technical efficiency increases with the increasing irrigations number. This result confirms the finding of [12] in their study of on–farm water use efficiency in the Sudan Gezira Scheme. They found that each additional unit of irrigation water substantially increases cotton production. Accordingly, the currently used strategy of cotton irrigation in the Gezira scheme needs to be revised [11]. Accordingly, it is very important to support researches to come out with cotton-variety that can withstand water-shortages.

Table 2. Maximum likelihood estimate for the parameters of the stochastic frontier production function and technical inefficiency effect model for cotton crop in Gezira scheme, 2011/2012

Parameters	Variable	Coefficient	Standard -error	T- ratio
β_0	Constant	2.37	0.57	4.16***
β_1	Cotton area (X_1)	-0.06	0.04	-1.40*
β_2	Seeds rate (X_2)	0.24	0.07	3.55***
β_3	Fertilizers (X_3)	0.58	0.13	4.59***
β_4	Pesticides (X_4)	0.11	0.12	0.94
β_5	Irrigation (X_5)	0.27	0.09	3.15***
β_6	Total labour (X_6)	0.09	0.09	1.94**
Inefficiency model				
δ_0	Constant	0.45	0.16	2.80***
δ_1	Tenancy location (Z_1)	-0.01	0.01	-1.50*
δ_2	Sowing date (Z_2)	-0.13	0.07	-1.83**
δ_3	Weeding (Z_3)	-0.11	0.05	-2.30**
δ_4	Age (Z_4)	0.01	0.01	0.98
δ_5	Education level (Z_5)	-0.01	0.01	-0.47
δ_6	Experience (Z_6)	0.01	0.01	1.04
δ_7	Family size (Z_7)	-0.04	0.03	-1.52*
δ_8	Credit (Z_8)	-0.20	0.05	-3.96***
Sigma-squared	$\sigma_s^2 = \sigma_v^2 + \sigma^2$	0.02	0.01	5.91***
Gamma	$\gamma = \sigma^2 / \sigma_s^2$	0.01	0.01	2.26**
	Mean Efficiency		0.89	
	Minimum Efficiency		0.64	
	Maximum Efficiency		0.99	
	Log likelihood function		41.79	

Source: calculated by the author/s from the surveyed data.

****, ** and * asterisks on the value of the parameters indicate it's significant at 1%, 5%, and 10% level of significance, respectively*

On the other hand, the technical efficiency of Gezira scheme-tenants producing cotton-crop revealed a wide spectrum of efficiency, ranging from 64% up to 99%. The frequency distribution of the efficiency estimates obtained from the stochastic frontier for cotton (Fig. 1) shows that the majority of the tenants (80 -100%) operate within the range of high efficiency compared to the fully efficient farmers (maximum cotton production), but very few of them operates within a relatively low level of efficiency, ranging from 60 to 69. This implies that, tenants producing cotton in Gezira scheme achieved 89% on average of the potential stochastic frontier cotton production level given their current level of production inputs and technology used.

The variance parameter, γ, with a value of 0.95 is significant component in explaining the variability of cotton production level in the Gezira scheme. This relatively high value of the variance parameter implies that a substantial proportion (95%) of the cotton production total variability is mainly associated with tenants' technical inefficiency of production. The estimate of the variance parameter γ, is significantly different from zero, indicating that the inefficiencies are significant in determining the level of variability [13] of cotton yield in the Gezira scheme. The relatively good technical efficiencies of cotton-tenants in consistence with the relatively high (γ) variance of tenants' effects indicate that the stochastic frontier and the average production function are expected to be quite different. The variance of the random effects (v_i) was not a significant component of the cotton yield variability.

3.1 Results of the Inefficiency Model

On the other hand, results of the factors affecting tenants' technical inefficiency were presented in

Table 2. The coefficient on tenancy farm's location is negative and significant at 10% level of significant. A negatively significant parameter of tenancy location means that technical inefficiency decreases with the nearness of the tenancy to canal. That is to say, the possibility of the farm located far away from the canal of getting sufficient watering and irrigations numbers at right time decreases [4]. On other words, farms at the head of the canal got sufficient irrigations compared with those far away or at the tail of the canal. In the same vein, the coefficient on sowing date is negative and highly significant in limiting the efficiency level of cotton production in Gezira Scheme.

Weeding numbers or weeds control is a very important factor, affecting yield of the crop. Coefficient on cotton's weeding numbers is negative and significant at 5% level of significance. A negatively significant parameter of weeding numbers means that technical inefficiency decreases with the increase in weeding numbers. Cotton weeding in Gezira scheme is the most critical stage of farm management due to shortages of hired labour and unavailability of sufficient finance. In fact, cotton competes with other crops in the scheme (sorghum and groundnuts) in finding labours for their agricultural operations. However it is worth mentioning here that, cotton weeding and harvesting is usually done by hands.

The coefficient on family size is negative and significant at 10% level of significance, indicating that inefficiency effects decreases with the increasing farmer's family size, and vice versa. It is expected that as the family size increases the number of family members who participate in farming activities increase too. This result confirms the findings of [14], in their study of technical efficiency of sorghum crop in the Gezira scheme of Sudan. They concluded that, family size is negatively and significantly associated with inefficiency level sorghum production.

On the other hand, the coefficient on the availability of credit has a high and significant negative effect on the cotton-farmer's inefficiency level. This means that, tenants who are not constrained by credit are more technically efficient than those who constrained by credit. It is worth mentioning here that, Sudan Cotton Company has played a big role in to financing farmers in their cotton agricultural operations.

Results of testing the hypotheses of cotton-crop production model were presented in Table 3.

It is very clear from Table 3 that, both null hypotheses are rejected. That is, the deviations from normal are not entirely due to noise, moreover, a significant technical inefficiencies effects are found to be present in the cotton production. These inefficiencies are assumed to be due to both controllable and uncontrollable (random) factors.

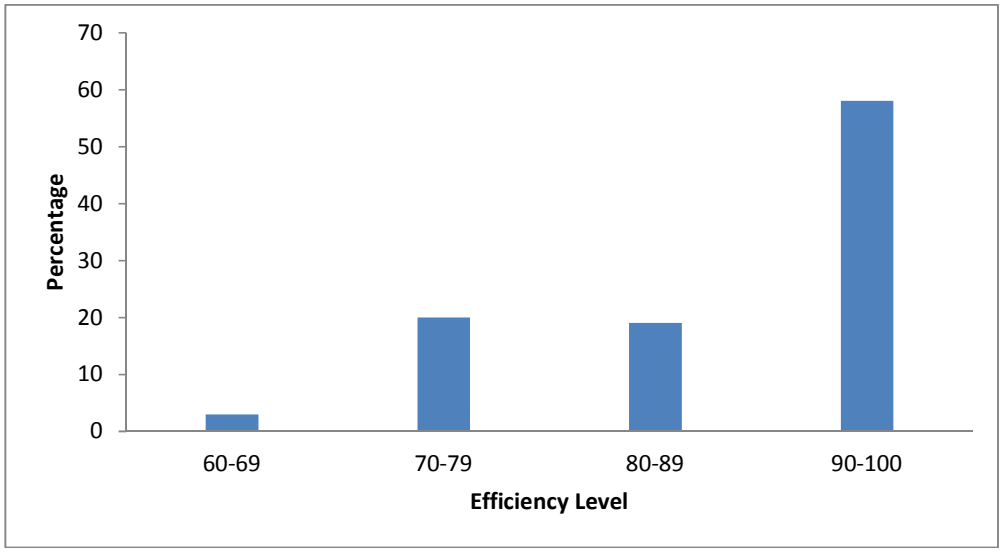

Fig. 1. Score of technical efficiency for cotton crop in Gezira scheme, 2011/2012
Source: Calculated by the author/s from the surveyed data

Table 3. Cotton crop model, test of hypothesis for the parameters of stochastic frontier production function

Hypothesis	Significant level	Decision
H0: γ = μ = 0	2.26**	H0: Reject the hypothesis
LR H0: No technical inefficiency	27.494***	H0: Reject the hypothesis

Source: calculated by the author/s from surveyed data.
****, ** and * asterisks on the value of the parameters indicate it's significant at 1, 5, and 10 percent level of significance, respectively*

4. CONCLUSION

Results of the stochastic frontier model revealed the presence of a relatively high potential for tenants in the Gezira Scheme to increase their cotton production by up to 10%, given the same level of inputs and technology. It is also found that cotton area, seed rate, fertilizer, irrigation and total labour are the major factors that are associated with changes in cotton yield. The tenancy location, sowing date, weeding, family size and credit are the most important socio-economic factors determining farmers' efficiencies in cotton production in Gezira scheme. The study recommends improving technical efficiency for cotton production in the Gezira scheme, through improved farmer specific efficiency factors such as extension services and access to credit.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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