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TECHNICAL EFFICIENCY IN ARABLE CROP PRODUCTION UNDER GORONYO IRRIGATION PROJECT OF SOKOTO STATE, NIGERIA

Mohammed, U. S., Baba, K. M., Nmadu, J. N. and Olaleye, R. S.
Department of Agricultural Economics and Extension Technology,
Federal University of Technology, Minna, Niger State, Nigeria
Corresponding Authors' E-mail: hsshabausman@yahoo.co.uk **Tel.:** 07039178744

ABSTRACT

The study examined the technical efficiency in arable crop production under Goronyo irrigation project of Sokoto State, Nigeria. Multi-stage sampling technique was used to sample 246 farmers and the limited cost-route approach was used with the aid of questionnaire. Stochastic frontier production function (SFPF) model was used in estimating farm level technical efficiency. The study also revealed the average technical efficiency index of rice, maize, cowpea and tomato farms to be 0.87, 0.79, 0.45 and 0.76, respectively and that technical inefficiency effect existed among the farmers. Estimates of technical efficiency of farmers revealed that average sampled farms operate 13%, 21%, 55% and 24% below the frontier output levels for rice, maize, cowpea and tomato farms under consideration. Farmers are fairly efficient technically in deriving maximum output from rice, maize and tomato farm and less technically efficient in the production of cowpea. Extension contact was one of the major factor that influences technical efficiency in the area, therefore, sustained farmers extension contact should be encourage by increasing frequency of contact where new techniques will be disseminated to the farmers to improve the use of available resource.

Keywords: Irrigation, Limited cost-route, Multi-stage, Production, Technical efficiency.

INTRODUCTION

Technical efficiency is the ability of the far to achieve maximum output possible with available inputs (Anupama *et al.*, 2005). Production can be increased by increasing the technical efficiency of crop using existing technology. If farmers are found to be technical efficiency, production can be increased to a large extent using the existing level of input and available technology (Babiker *et al.*, 2017).

Increasing the efficiency in production assumes greater significance in attaining potential output at the farm level and is a potential source of further productivity growth (Kalirajan *et al.*, 1996) and employing new technologies will be meaningless unless the potential of the existing technologies are exploited fully. The analysis of variations between the potential and actual yields of arable crop on the farm, given the available technology and resource endowment of farmers, provide better understanding of the yield gap. Also, technical efficiency is an indicator of the productivity of the farm and the variation in technical efficiency can reflect the productivity difference across farms. Therefore, improvement in technical efficiency of farms is the key for meeting the growing food demand by the ever increasing population (Anuradha *et al.*, 2010). Irrigation raises the productivity of land directly by providing sufficient moisture to raise crop yield per hectare (Ali, 2010). Improved output stemming from productivity increase through improvements in efficiency is important to Nigeria's agriculture considering that the scope to enhance farm production by bringing additional land into cultivation is insignificant. Therefore, the study assessed the level of technical efficiency and the factors that affect technical efficiency in arable crop production under irrigation in Sokoto State, Nigeria.

MATERIALS AND METHODS

The Study Area

The study was conducted in Goronyo Local Government area of Sokoto State, Nigeria where the irrigation project was sited. The irrigation project covers about 17,000 hectares on both sides of river *Rima* Between the dam near *Katsire* village to the north east and about 5km downstream of the dam of the village *Shinaka* to the south east. It lies between latitudes 130 25' and 13031' north and longitudes 505' and 50 39' east of the equator (Middle Rima Valley Irrigation (MRVI, 2001). The major economic activities in the area include livestock and rearing arable crop production. The climate is sudan-sahel type with annual rainfall of between 579 to 674 mm and annual temperature of between 240c to 330c (Okereke *et al.,* 2007).

Sampling Techniques

The study covered all the communities using Goronyo Dam irrigation project. The irrigation project was selected for the fact that it is a relatively new irrigation project in the country and not much research work has been conducted in the area on resource productivity. To collect relevant information for this study, multi-stage sampling design was adopted. The Goronyo irrigation project was divided into sectors and the two (2) completed sectors are named after the major villages within each sector which are *Falalia* and *Takakumi* sectors. The first stage of sampling involved random sampling of 12 communities out of the 23 communities identified within the project area. According to the extension office of Sokoto Rima River Basin Development Authority (SRRBDA) attached to the irrigation project, 640 farm households from the sampled villages used the Goronyo dam irrigation infrastructure for 2014/2015 cropping season. In order to arrive at appropriate sample size, equation for sample size determination as reported by Eboh (2009) as specified in eq. 1 was used:

$$n = \frac{N}{1+N(e2)} \qquad ...(1)$$

where;
n = the sample size,
N = the population size
e = the level of precision which is 5%.
Therefore, he appropriate sample size estimate for the study based on the calculation is 246 households.

Method of Data Collection

The data were collected from 246 households sampled in the two irrigation sectors. The limited cost-route procedure which involved collecting data on a fortnightly basis by asking farmer to recall his /her activities on the farm during the past two weeks was used for data collection for this study. This method minimizes memory lapses associated with data collected once at the end of the season. Input information collected include; size of farm land (hectares), planting materials (kg), fertilizer (kg), herbicides (litres) and labour (man-days) including family and hired, pre and post planting operations and harvesting. Output data on all the quantities of cereals, legumes and vegetables harvested from each farm were collected at the time of harvest using interview schedule. The prevailing farm gate prices of output and the market prices of inputs were obtained from the farmers. Also, information elicited were the farmers' socio-economic variables such as age, years of schooling, household size, number of

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contact with extension agents during the production season and membership of farmer organization.

Analytical Techniques

In order to achieve the objective of the study, the stochastic frontier production function, proposed by Jyoti *et al*. (2010) was used. Model is specified as in eq. 2:

$$\ln(Y_i) = \ln\alpha_0 + \alpha_1\ln X_{1i} + \alpha_2\ln X_{2i} + \alpha_3\ln X_{3i} + \alpha_4\ln X_{4i} + \alpha_5\ln X_{5i} + \alpha_6\ln X_{6i} + \alpha_7\ln X_{7i} + \alpha_8\ln X_{8i} + (v_i - u_i) \quad \ldots(2)$$

where;

Y_i = Rice, maize, cowpea and tomato crop output respectively (Kg)

α_0 = Constant or intercept,

X_{1i} = Farm size in hectare,

X_{2i} = Quantity of planting material in kilogram,

X_{3i} = Quantity of fertilizers/manure in kilogram (manure in case of cowpea farms),

X_{4i} = Family labour in man-days,

X_{5i} = Hired labour in man-days used,

X_{6i} = Frequency of irrigation (no of time per season)

X_{7i} = Quantity of agrochemical in litres,

X_{8i} = Depreciation on capital inputs in naira.

$\alpha_{1} - \alpha_8$ = Unknown parameters to be estimated,

v_i = An independently and identically distributed random error,

u_i = A non-negative variable associated with technical inefficiency in production, and

i = i^{th} farmer 1, 2, 3,…….,n.

The linear regression model to be used for estimating the socioeconomic factors affecting technical efficiency of crop production under irrigation is specified as:

$$U_i = T_0 + T_1Z_{1i} + T_2Z_{2i} + T_3Z_{3i} + T_4Z_{4i} + T_5Z_{5i} + T_6Z_{6i} + T_7Z_{7i} + T_8Z_{8i} \quad \ldots(3)$$

where;

U_i = Technical inefficiency scores

Z_{1i} = Land tenure system (1 if own, 0 if leased)

Z_{2i} = Extension contact (number of time)

Z_{3i} = Household size (number)

Z_{4i} = Year spent in formal school (years)

Z_{5i} = Farm and non-farm income (Naira)

Z_{6i} = Farming experience (years)

Z_{7i} = Age of the farmer (years)

Z_{8i} = Marital status (1 if married, 0 otherwise)

T_0 = Constant

T_{1i}-T_{8i}= Unknown parameters to be estimated and

i^{th} farmer = 1, 2, 3.... 8.

RESULTS AND DISCUSION

Levels of Technical Efficiency among Arable Crop Farmers

The frequency distribution of technical efficiency of arable crop farms under the Goronyo Dam irrigation project is as presented in Table 1 Individual technical efficiency indices ranged between 39% and 97% for rice, 24% and 97% for maize, 20% and 98% for cowpea and 9% and 97% for tomato, respectively. The mean technical efficiency index for rice, maize, cowpea and tomatoes were 0.87, 0.79, 0.45 and 0.76, respectively. The result implies that an average rice, maize, cowpea and tomato farm under the Goronyo Dam Irrigation Project were able to obtain 87%, 79.38%, 44.54% and 75.64%, respectively, of the potential output from given levels of inputs.

Majority of the rice, maize and tomato farmers (83.70, 61.30 and 50.60%) had the highest technical efficiency range of between 0.81 - 1.00, while majority of cowpea farm (85.90%) had technical efficiency range of between 0.21 - 0.60. This result agrees with the finding of Chima *et al*. (2010) and the result implies that the farmers are fairly efficient in deriving maximum output from rice, maize and tomato farm and less technically efficient in the production of cowpea. The mean levels of technical efficiency for the rice, maize, cowpea and tomato farmers were less than 1.00 indicating that all the farmers are producing below the maximum technical efficiency frontier. The result also implies that at mean technical efficiency level, there is potential to increase rice, maize, cowpea and tomato production by 13, 21, 55 and 24%, respectively, with the given level of available resource, by improving the technical efficiency level of the farm households.

Table 1: Technical Efficiency indicators of Goronyo Dam Project Farmers

Efficiency Range	Frequency Rice	Frequency Maize	Frequency Cowpea	Frequency Tomato
< 0.20	0(0.00)*	0(0.00)*	1(0.80)*	0(0)*
0.21 – 0.40	1(0.40)	7(3.80)	58(45.30)	2(2.40)
0.41 – 0.60	4(1.60)	39(21.00)	52(40.60)	11(13.30)
0.61 – 0.80	35(14.20)	26(14.00)	11(8.60)	28(33.70)
0.81 – 1.00	206(83.70)	114(61.30)	6(4.70)	42(50.60)
Total	246(100.00)	186(100.00)	128(100.00)	83(100.00)
Maximum	0.97	0.97	0.98	0.97
Minimum	0.39	0.24	0.20	0.09
Standard Deviation	0.09103	0.20087	0.15583	0.17762
Mean	0.87	0.79	0.45	0.76

*Figures in parenthesis are percentages
Source: Computed from field survey data, 2015

The frequency distribution of technical efficiency of arable crop farms under the Goronyo Dam irrigation project is as presented in Table 1. Individual technical efficiency indices ranged between 39% and 97% for rice, 24% and 97% for maize, 20% and 98% for cowpea and 9% and 97% for tomato, respectively. The mean technical efficiency index for rice, maize, cowpea and tomatoes were 0.87, 0.79, 0.45 and 0.76, respectively. The result implies that an average rice, maize, cowpea and tomato farm under the Goronyo Dam irrigation project were able to obtain 87%, 79.38%, 44.54% and 75.64%, respectively, of the potential output from given levels of inputs.

Table 1 further revealed that majority of the rice, maize and tomato farmers (83.70%, 61.30% and 50.60%) had the highest technical efficiency range of between 0.81 - 1.00, while majority of cowpea farm (85.90%) had technical efficiency range of between 0.21 - 0.60. This result agrees with the finding of Chima *et al.* (2010) and the result implies that the farmers are fairly efficient in deriving maximum output from rice, maize and tomato farm and less technically efficient in the production of cowpea. The mean levels of technical efficiency for the rice, maize, cowpea and tomato farmers were less than 1.00, indicating that all the farmers are producing below the maximum technical efficiency frontier. The result also implies that at mean technical efficiency level, there is potential to increase rice, maize, cowpea and tomato production by 13%, 21%, 55% and 24%, respectively, with the given level of available resource, by improving the technical efficiency level of the farm households.

Analysis of Technical Efficiency and Factors Affecting Technical Efficiency

The Cobb-Douglas stochastic production function and technical inefficiency effects were simultaneously estimated. The results of the Cobb-Douglas production function and inefficiency components are shown in Table 2. The gamma (γ) parameter lies between 0 and 1; values equal to 0 implies that no technical efficiency is present in the data set (Olatomide and Omowumi, 2010). The result revealed gamma (γ) values of 0.91, 0.23, 0.29 and 0.96 for rice, maize, cowpea and tomato, respectively, which implies that the stochastic frontier model is appropriate for the estimation and that some level of inefficiency exists among those farmers that produce arable crops under the Goronyo Dam irrigation project. These values are statistically significant at 1, 1, 5 and 5% for rice, maize, cowpea and tomato, respectively, which imply that 91, 23, 29 and 96% variation in the output was due to inefficiency effect.

The results of the Cob-Douglas stochastic production frontier, further shows that the coefficients for farm size, hired labour, frequency of irrigation and quantities of agrochemical were significant and were positively related to output of rice. This implies that increasing the level in the use of the inputs in rice production will increase output. The planting material variable had significant, but, inverse relationship with output of rice. Table 2 also reveals that the coefficient of planting material with respect to maize production in the area had positive and significant relationship with output of maize. This implies that increasing the use of planting material in the production of maize will increase output. However, the coefficient with respect to hired labour and amount of depreciation on capital inputs had significant, but inverse relation with output of maize production in the area. This implies that increasing use of both inputs in the production of maize in the area will lead to decreased in the output of maize.

The result of the stochastic production frontier analysis with respect to cowpea production among the sampled farmers in the area shows that farm size had a significant, but positive relationship with output. The implication of this result is that increased area under cultivation will increase output of cowpea among the sampled farmers in the area.

The regression coefficient with respect to farm size in the production of tomato had positive and significant relationship with output. This implies that increasing farm size will lead to increased output of tomato. However, increasing the use of family labour could reduce output of tomato among the sampled farmers in the area.

Table 2: Maximum Likelihood estimation of the Cobb Douglas Stochastic Frontier Production Function for Arable Crops Farmers under the Goronyo Dam Irrigation Project

Production Factors	**Parameters**	**Rice**	**Maize**	**Cowpea**	**Tomato**
				Coefficients	
Technical Efficiency:					
Constant term	α_0	8.23(21.44)***	8.25(8.16)***	8.01(9.05)***	8.31(8.00)***
Farm size	X_1	0.76(11.95)***	6.51(0.69)ns	0.42(3.49)***	1.02(9.03)***
Planting Materials	X_2	-0.07(-1.86)*	0.25(3.79)***	0.08(0.098)ns	0.02(0.35)ns
Fertilizer or manure	X_3	0. 02(0.63)ns	-0.02(-0.21)ns	-0.05(-0.57)ns	0.07(0.28)ns
Family Labour	X_4	-0.02(-0.91)ns	0.06(0.50)ns	-0.17(-1.52)ns	-0.88(-1.93)*
Hired Labour	X_5	0.05(2.59)**	0.000061(8.92)***	-0.05(1.13)ns	0.17(1.30)ns
Frequency of Irrigation	X_6	5.56(8.99)***	0.16(1.01)ns	-0.06(-0.56)ns	-0.07(-0.34)ns
Agrochemical	X_7	0.07(2.13)**	-3.07(-0.17)ns	0.18(1.27)ns	-0.04(0.86)ns
Depreciation	X_8	-0.02(-0.66)ns	-0.26(-2.41)**	-0.042(-0.38)ns	-0.14(-1.59)ns
Technical Inefficiency:			-2.02(-2.44)**	1.84(5.91)***	5.62(3.65)***
Constant	t_0	-4.38(-3.98)***			
Land Tenure	Z_1	1.84(1.32)ns	-115(-1.56)ns	-0.09(0.40)ns	0.17(0.22)ns
No of Extension Contact	Z_2	-0.19(-1.91)*	-0.10(-0.076)ns	-0.04(1.01)ns	-0.01(-1.28)ns
Household Size	Z_3	-0.04(-15.64)***	0.03(0.11)ns	-0.03(-2.12)*	0.13(-1.84)*
Level of Education	Z_4	-4.00(-1.51)ns	0.01(0.34)ns	.0.001(0.0099)ns	-0.05(-0.16)ns
Farm and Non-farm Income	Z_5	-0.000007(-0.58)ns	0.00060(0.98)ns	-0.00013(-7.93)***	-0.00012(-2.01)*
Farming Experience	Z_6	0.03(1.31)ns	-0.01(-0.20)ns	0.02(0.083)ns	0.10(1.53)ns
Age	Z_7	-0.01(-1.82)*	-0.02(-2.82)***	-0.002(-4.66)***	0.02(1.39)
Marital Status	Z_8	-8.02(-1.90)*	1.40(5.53)***	-0.28(-1.15)ns	-0.04(-0.044)
Total variance	σ^2	2.25(1.93)*	2.30(5.11)***	0.09(7.26)***	0.20(1.87)*
Variance ratio	Γ	0.91(19.32)***	2.28(2.07)*	2.88(12.50)***	1.06(24.13)***
Likelihood ratio test		104.44	-115.92	68.32	58.14
Log likelihood function		37.32	63.08	-23.72	16.36

Note: Figures in parentheses are the respective z-values; * Significant at 10%, ** Significant at 5%, *** Significant at 1%
Source: Computed from Field Survey data, 2013.

The empirical results on land tenure system's effect on efficiency in the study area established a positive relationship with efficiency which is consistent with the reported hypothesis that longer years of leasing motivate farmers to work harder to meet their contractual obligations (Helfand and Levine, 2004; Coelli *et al.*, 2005) as reported by Adinku

(2013). A negative relationship of tenure system on the other hand is linked to the agency theory, reflecting monitoring problems and adverse incentives between the parties involved in diminishing business performance (Giannakas, Tran and Zouvelekas, 2003; Reddy, 2002).

The result of this study as presented in Table 2 also reveals that land tenure system was positively related to technical efficiency of rice and tomato farmers which increases inefficiency effects in production. The result of land tenure system on maize and cowpea farmers shows an increasing technical efficiency and a reduction in inefficiency of the production process.

The result of the inefficiency factors as shown in Table 2, further reveals that age of the rice, maize and cowpea farmers had negative coefficients and statistically significant at 10, 1 and 1%, while the coefficient for tomato was positive. The sign of coefficients of age for rice, maize and cowpea farmer agreed with a priori expectation and implies that with increasing age, efficiency will decrease, hence older farmers more inefficient. This result agrees with Ajibefun and Daramola (2003) and Okoye *et al.* (2007) that it is possible that older farmers could be more traditional and conservative and therefore show less willingness to adopt improved farming practices and can also are less energetic to work on farm. Hence, decrease in technical efficiency as result of increasing age of the farmer.

Extension contact was another factor considered to influence efficiency. According to Adinku (2013), extension agents are normally expected to provide trainings and advisory services to farmers in order to improve their efficiencies. The result of the analysis of frequency of extension contact shows negative influence on inefficiency. This implies that farmers-extension agents interaction improve technical efficiency. The statistically significant of extension contact variable for rice farmers, could be due the fact that rice was the dominant food and cash crop in the entire area under the irrigation project and farmers would frequently seek for extension advice in order to improve efficiency.

The household size was another important factor that influences technical efficiency or inefficiency. The result of this study reveals that the coefficients of the household size parameters were negative for rice, cowpea and tomato farmers and were statistically significant at 1, 5 and 10 percent, respectively. This result implies that household size significantly reduces technical inefficiency or increases technical efficiency, because large household size could benefit from the use of family labour at the right time when labour is needed. The result agrees with the finding of Dhungana *et al*. (2004), and Adinku (2013) that labour availability from the household at the right time will increase technical efficiency and reduce inefficiency.

CONCLUSION AND RECOMMENDATIONS

Farmers are fairly efficient technically in deriving maximum output from rice, maize and tomato farm and less technically efficient in the production of cowpea. There are gaps between the frontier efficiency level and those obtained by the farmers. Therefore, there are rooms for improvement in technical efficiency in production of the arable crop under consideration. Extension contact was one of the major factor that influences technical efficiency in the area, therefore, sustained farmers extension contact should be encourage by increasing frequency of contact where new techniques will be disseminated to the farmers to improve the use of available resource.

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