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Technical Efficiency of Rice Production at the Tono Irrigation Scheme in Northern Ghana

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Authors' contributions

This work was carried out with the involvement of all authors. Author SA was involved in the design of the survey instruments as well as data collection and entry, while author SA managed the literature review and the first draft. Author SAD did further analyses and wrote the final write-up. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

Aim: To investigate the determinants of technical efficiency of rice farmers at Tono Irrigation Project.
Study Design: Cross sectional.
Place and Duration: The Kassena-Nankana District of Upper East Region of Ghana in the 2007/2008 cropping season.
Methodology: One-step estimation of the Stochastic Frontier Model.
Results: The technical efficiency estimates ranged from 0.41 to 1.00 with a mean value of 0.81. The factors that determined farmers' technical efficiency included education and the adoption of modern inputs such as seeds and chemical fertilizers.
Conclusion: The sustainability of the farmers' high efficiency will be dependent on the continuous support they receive in the areas of input supply and education, among others.

Keywords: Rice; stochastic frontier model; technical efficiency; Tono irrigation scheme; translog production function.

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ABBREVIATIONS

CRI : Crops Research Institute.
FAO : Food and Agriculture Organisation.
ICOUR : Irrigation Company of Upper Region.
IRC : International Centre for Rice.
JHS : Junior High School.
MDGs : Millennium Development Goals.
MoFA : Ministry of Food and Agriculture.
ISSER : Institute of Statistical, Social and Economic Research.
SARI : Savannah Agricultural Research Institute.
SFA : Stochastic Frontier Analysis.
SHS : Senior High School.
TE : Technical Efficiency.

1. INTRODUCTION

Ironically, while we approach the deadline for the Millennium Development Goals (MDGs), the number of food insecure people in Africa is increasing [1]. According to FAO [1] the continent accounts for 50 percent of the 12 million children under five, who suffer chronic hunger. This is because food production falls short of demand, implying that per capita food production is on the decline. One of the reasons that explain the precarious situation with respect to food supply in Africa is the fact that the region missed out of the Green revolution. The Green revolution combined improved seeds, inorganic fertilizers, plant protection products and irrigation, resulting in significant increases in food supply, especially in Asia [2]. Notable among the crops that the revolution targeted, was rice, which is now an important staple for almost every nation.

The cereal has become so important that at its 21st session in 2006, the International Centre for Rice (IRC) chose as its theme “Rice is life” [1]. As FAO [1] reveals, rice supplies consumers with more calories than other staples. Against this backdrop the organization suggests that it should be an important staple for many poor people, who may not be able to buy a variety of food crops in order to get the needed calories. It is along these lines that stakeholders think that Africa could benefit a lot from this crop. Unfortunately, while at the world level, rice supply is, at least, enough to cover consumption, in Sub-Saharan Africa, supply falls short of demand, resulting in rice import bills of about 1 billion US Dollars annually in the region [1].

Rice is an important food crop in Ghana and its consumption is growing, particularly among urban dwellers. The strategic nature of rice has long drawn the attention of policy makers who view promoting domestic production as a means of reducing dependency on imports and generating employment and income for rice growers [3]. For instance, it is estimated that Ghana spends about US$100 million annually to import the rice needed to meet more than half of Ghana’s rice requirements.

In 2005, the agricultural policy of the government was to modernize agriculture and encourage agro-based industry. Also, under the US Millennium Challenge Account (MCA) Aid Package, the theme for the Ghana’s programme was “Reducing Poverty through Agricultural Transformation.” The specific objectives were to increase productivity as well as competitiveness of agricultural products in regional and international markets [4].

Northern Ghana accounts for the bulk of the total rice production in the country. For instance, before irrigation projects gradually transformed the Accra coastal plain into a major area of rice production, the Northern region alone accounted for an average of 63% of rice production between 1977 and 1987. Similarly, in 1998, the three Northern Regions together produced about 67% of the total rice produced in the country. The Upper East Region (UER) was the largest producer of rice in the whole country in 1998 contributing about 46% of the total rice produced. Over the years governments of Ghana have attempted to boost rice production locally. One of such is the establishment of several irrigation projects including the Vea, Afife, Kpong, Tanoso, Ashaiman, Tono, Dawhenya, Weija, Bontanga and Aveyime among others.

1.1 The Tono Irrigation Project

The Tono irrigation project was constructed by the Ghana government through a state company known as the Irrigation Company of Upper Region (ICOUR). The construction of the dam began in 1975 and was not completed until 1985 [5]. The Tono irrigation Project was proposed as part of Nkrumah's agricultural development policies to "provide the north with a large share of the national development fund than ever had been the case during the colonial administration." The government of Ghana funded the project with loans obtained from the Canadian and British governments. In the Appendix is the map of Ghana showing the UER.

Tono rice farmers enjoy some assistance from ICOUR in the form of input supplies such as fertilizers, seeds and pesticides, and paying back after harvest. Also, farm machinery like tractors, combine harvesters and other farm implements are usually leased to farmers for a fee. Apart from these, there are advantages such as fairly flat and gentle sloping lands and abundant labour supply usually during the dry season when there are no rain-fed agricultural activities. The soils are also typical of the savannah ochrosols, quite conducive for the cultivation of rice.

However, despite the fact that these facilities are available to almost all the farmers, it is not every farmer who will necessarily take advantage and manage his or her farm well for maximum output. Efficiency is dependent on farm and farmer characteristics, which obviously vary across the farms. Thus, the objective of this study was to find out how the differences in farmers' socio economic indicators as well as management practices affect the efficiency levels in the Tono Irrigation sites.

2. MATERIALS AND METHODS

2.1 Stochastic Frontier Model

Technical Efficiency (TE) is defined as the ability to achieve a higher level of output, given similar levels of inputs. In order to estimate and analyze the technical efficiency of rice farmers, the Stochastic Frontier Analysis (SFA) is used. The stochastic frontier approach, unlike the other parametric frontier measures, makes allowance for stochastic errors due to measurement errors. The stochastic frontier model decomposes the error term into a two-sided random error that captures the random effects outside the control of the farmer and the one-sided inefficiency component. The level of TE is measured by the distance a particular farm is from the production frontier. Thus, a farm that sits on the production frontier is said to be technically efficient. TE is measured as a ratio of actual to potential output [6; 7].

In analyzing farm level data where measurement errors are substantial and weather is likely to have a significant effect, the stochastic frontier method is usually recommended [8].

[9] argue that inefficiency is typically related to factors that are associated with farm management practices. Such factors include education, farm size, seed, labour cost, experience and sex.

The stochastic model is given as:

$$Y_i = f(X_i\beta)\exp\,(V_i - U_i\,) \tag{1}$$

Where Y_i is the output of the ith farmer; X_i is a $(1 \times K)$ vector of farm inputs; β is a $(1 \times K)$ vector of parameters to be estimated; while V_i measure the random variation in output (Y_i) due to factors outside the control of the farm, U_i are factors within the control of the farm responsible for its inefficiency, V is assumed to be identically and independently distributed as $N(0, \sigma_v^2)$ and independent of U_i which is distributed as a truncated normal (at zero) of the $N(0, \sigma_v^2)$ distributions. U_i is independently, but not identically distributed.

The composed error term, ε_i is defined as:

$$\varepsilon_i = V_i - U_i \tag{2}$$

Also,

$$TE = \frac{Y_i^*}{Y_i} = \frac{f(X_i\beta)\exp\,(V_i - U_i\,)}{f(X_i\beta)\exp\,(V_i\,)} = \exp(U_i) \tag{3}$$

In equation 3 the numerator is the observed output of the i-th farm, while the denominator is the output that could be produced by a fully-efficient firm using the same input vector. The measure is an output-oriented [10] measure of technical efficiency, which takes a value between zero and one. TE can be obtained by estimating β by maximum likelihood.

[11] model of TE effects is defined by:

$$TE_i = Z_i\delta + \,e_i \tag{4}$$

Where Z_i is a $(1 \times m)$ vector of explanatory variables (such as farmers' levels of education and experience) associated with the TE effects; δ is a $(m \times 1)$ vector of unknown parameters to be estimated; and e_i is an unobservable two-sided random variable with mean zero and constant variance.

The parameters indicate the impacts of variables in Z on TE. A negative value suggests a positive influence on TE and vice versa. The log-likelihood function for the this stochastic frontier and inefficiency model in addition to the first partial derivatives of the log-likelihood function with respect to the different parameters of the model is presented in the Appendix in [12].

In terms of the functional form of the Stochastic Frontier Model, the two commonly used are Cobb Douglas and the Translog. The main advantage of the latter is that it is flexible, which implies that it does not impose assumptions about constant elasticity of production nor elasticities of substitutions between inputs. However, multicollinearity problems may show up. A case in point is [13]. The Cobb-Douglas functional form however is not only simple but it is self-dual.and has been applied widely in agricultural production technologies in many developing countries [14]. However, it has been criticized for its restrictiveness. A number of studies have estimated both the Cobb-Douglas and the translog functional forms and then tested the null hypothesis that the former is an adequate representation of the data, given the specification of the translog functional form. The test is conducted using the generalized likelihood-ratio test [15].

2.2 Empirical Model

In this study, the translog stochastic frontier model to be estimated is defined by

$$lny_i = \beta_0 + \sum_{j=1}^{5} \beta_j \, ln \, x_j + \sum_{j\leq}^{5} \sum_{k=1}^{5} \beta_{jk} \, ln \, x_{ji} \, ln \, x_{ki} + v_{i-} u_i \quad (5)$$

Where i indicates an observation for the i-th farmer, i=1, 2, 3, .85.

In represents logarithm to base e; Y is output of rice (in kg); X_1 is land (in acres); X_2 is the quantity of seed used for planting (in kg); X_3 is quantity of solid fertilizer (in kg); X_4 is the labour hours; and X_5 is other expenditures, including liquid fertilizers and tractor services. Ideally 'other expenditure' should have been disaggregated so that the respective elasticities of the variables can be determined. However, this was not done because some of the farmers recorded zero values for some of the variables, hence the decision to use the composite variable 'other expenditure' for which there are positive values for each farmer. A similar approach has been used by [16]. All the variables are in their natural logarithm. The V_{is} are assumed to be independent and identically distributed at zero mean and constant variance, and independent of the U_{is}. on the other hand the U_{is} are non-negative assumed to be independently distributed, such that U_i is obtained by truncation (at zero) of the$N(m_{i,}\sigma^2)$ distribution.

The mean is defined by

$$m_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + + e_i \quad (6)$$

Where Z_1 is the number of years the farmer has been cultivating rice; Z_2 is number of years in school; Z_3 is the sex of the farmer (categorized as 1 for males and 0 for females); e_i is the two-sided error term and δ_i is a vector of parameters to be estimated.

Equations 5 and 6 are estimated by Maximum Likelihood, using the computer program, FRONTIER version 4.1 [17] by [12, 11] one-step/simultaneous estimation procedure. The Maximum Likelihood estimation yields consistent estimators for $\beta, \delta\ , \gamma$ and σ_s^2, where

$\gamma = \sigma^2/\sigma_s^2$ and $\sigma_s^2 = \sigma_v^2/\sigma^2$. Note that the γ- parameter has a value between zero and one.

2.3 Specification of Hypotheses

In the estimation of a stochastic frontier model, three common hypotheses are often tested. These are (1) the appropriate production functional form (i.e. whether the Cobb-Douglas or the translog functional form is the more suitable form for the model), (2) whether or not the

TE effects term u_i are present in the model, and (3) whether or not the socioeconomic variables do determine the TE effects term u_i.

The three hypotheses are represented mathematically by equations 7, 8, and 9 respectively as follows:

$$Ho: {}_{LL} + {}_{SS} + {}_{FF} + {}_{BB} + {}_{EE} = {}_{LS} + {}_{LF} + {}_{LB} + {}_{LE} + {}_{SF} = {}_{SL} + {}_{SE} + {}_{FL} + {}_{FE} + {}_{LE} = 0 \quad (7)$$

$$H_0 : ¥ = ¥_0 = ...¥_3 = ¢ = 0 \quad (8)$$

$$Ho : ¢_1 = ...¢_3 = 0 \quad (9)$$

Where ${}_{LL}$, ${}_{SS}$, ${}_{FF}$, ${}_{BB}$ *and* ${}_{EE}$ are the squared values of the coefficients of land seed, fertilizer, labour and other expenditures respectively and ${}_{LS}$, ${}_{LF}$, ${}_{LB}$ ${}_{LE}$, ${}_{SF}$, ${}_{SL}$, ${}_{SE}$, ${}_{FL}$, ${}_{FE}$ *and* ${}_{LE}$ are the interaction terms. The variables in equations 9 and 10 are as defined earlier. Note that in the case of hypothesis 1 if the squared values and the interaction terms sum up to zero, then it means that the translog specification is not necessary, the Cobb-Douglas form is appropriate. On the other hand with regard to hypothesis 2, the technical inefficiency effect model can only be estimated if the inefficiency effects are present. If the one-sided error term in the production function is not present then the model is an ordinary production function which can be estimated by OLS (i.e. the model is equivalent to the traditional average response function). It is one thing having u_i present in the model and another, the socioeconomic variables significantly explaining the variation in the u_i term, hence the importance of the third hypothesis. If the coefficients of the inefficiency affect the variables (sum up to zero) then it means even though the model might contain u_i, it is not significantly determined by the socioeconomic variables.

The generalised likelihood ratio test statistic is used to test the above hypotheses as follows

$$a = -2\{\ln[L(H_O)/L(H_1)]\} = -2\{\ln[L(H_0)] - \ln[L(H_1)]\} \quad (10)$$

where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function under the null and alternative hypothesis H_0 and H_1 respectively. If the given null hypothesis is true then a has approximately a chi-square (i^2) (or a mixed chi-square distribution). On the other hand, if the null hypothesis involves $¥^* = 0$, then the asymptotic distribution involves a mixed Chi-square distribution [18].

2.4 Sampling and Data Collection Methods

Data was collected in during the 2007/2008 farming season at the Tono Irrigation Project located in the Kassena-Nankana District of Upper East Region of Ghana. The choice of the study area was purposive. Stratified sampling technique was used to divide the population into males and females. Simple random sampling was then used to select the final respondents based on their availability as at the time of data collection. In all, 85 farmers involving 51 (60%) males and 34 (40%) females were interviewed. Semi-structured questionnaire was the main tool used for the data collection.

2.5 Descriptive Statistics of Variables

It can be observed from Table 1 that the mean age of the sample farmers was 38.3 years. This shows a relatively youthful adult population, who when well motivated, can give off their best to raise rice productivity in the study area in particular and the nation as a whole. In Ghana the farming population is generally old, as agriculture does not seem to attract the youth [19]. Also, the years of formal education range from approximately 6 years to 19 years as follows: primary=6; Junior High School (JHS)=9; Senior High School (SHS)=12; and tertiary=19. The mean years of formal education of 11.1 indicates that on a whole the majority of the farmers had completed SHS. Also, on average the farmers had been in rice cultivation for about 11 years. Over 92% of farmers in Ghana farm on a small scale. The situation is not different in the case of our sample farmers, considering the fact that even the maximum farm size is 5.5 acres. As indicated earlier land at the Tono Irrigation Dam is very scarce and with an increasing population the situation keeps worsening. The mean total output of rice in kg was 2,420, which is about 48 mini (50kg) bags. This is quite high, considering the fact that land holdings are generally small. Seed density is the amount of seed planted per acre of a plot. From the table, the mean quantity of rice seed planted was 94.76 kg, which is almost twice the 50kg bag. Fertilizer was 164 kg, which is also high, considering the generally low fertilizer application in Ghana. For instance, in 2008, the average inorganic fertilizer use in Ghana was 8kg/ha [20]. Also, the mean labour hour for the sampled farmers was 227.

Table 1. Descriptive Statistics of Variables

Variable	Minimum	Maximum	Mean	Std. deviation
Age of farmer	19	55	38	10
Years of education	0	15	11	4
Experience	2	26	11	7
Farm size (in acres)	1	6	2	1
Total output (in kg)	600	6325	2421	1311
Qty of seed (in kg)	40	190	95	43
Other costs (Expenditure)	7	40	21	10
Qty of fertilizer (in kg)	50	450	164	112
Total labour hours	69	649	227	131

Current exchange rate: $1= GH¢1.98

3. RESULTS AND DISCUSSION

3.1 Tests of Hypotheses

As indicated in section 2.3 the study sought to test three hypotheses. The first hypothesis was that the Cobb-Douglas functional form was an adequate representation of the data, given the specification of the translog functional form. The second was that there were no inefficiency effects in our model. That is to say that the inefficiency term u_i is absent and that the model is an ordinary average response model with v_i as the only error term. The last test says that the variables in the inefficiency effects model (socio-economic indicators) do not explain the inefficiency term u_i. From Table 2 below all the three null hypotheses are rejected, implying (1) the translog functional form is a better representation of the data, (2) the presence of the inefficiency term u_i and (3I) the explanatory variables determine u_i respectively.

Table 2. Tests of hypotheses for appropriate functional form of stochastic frontier model and coefficients of the explanatory variables for the inefficiency models

Null hypothesis	Log likelihood function (H_0)	Test statistic a	Critical value	Decision
Test1 $Ho : {}_{LL} + {}_{SS} + {}_{FF} + {}_{BB} + {}_{EE} = {}_{LS} + {}_{LF} + {}_{LB} + {}_{LE} + {}_{SF} = {}_{SL} + {}_{SE} + {}_{FL} + {}_{FE} + {}_{LE} = 0$	20.64	39.44	10.38 (5)	Reject H_0
Test 2 $H_0 : ¥ = ¥_0 = ...¥_3 = ¢ = 0$	31.59	17.54	10.38 (5)	Reject H_0
Test 3 $Ho : ¢_1 = ...¢_3 = 0$	31.36	18.4	10.38 (5)	Reject H_0

Critical values are at 5% significant level and obtained from Table 1 of Kodde and Palm (1986, P.1246). Figures in Brackets are the number of restrictions.

3.2 Determinants of Output

The Maximum Likelihood (ML) estimates of the stochastic frontier (translog specification) for rice are presented in Table 3. The first term variables were all significant, with the exception of fertilizer. However, even though labour was significant, it had a negative sign, meaning that as the variable is increased output falls.

Table 3. Maximum Likelihood (ML) Estimates of the Translog Stochastic Frontier Model

Variable	Parameter	Coefficient	Std error	t-ratio
Constant	[illegible]	-136.5	1.0	-133.7
Land	[illegible]	-28.5	1.3	-22.2***
Seed	[illegible]	33.0	1.2	28.2***
Fertilizer	[illegible]	1.0	1.1	0.9
Labour	[illegible]	3.2	1.4	2.3**
Expenditure	[illegible]	10.8	0.9	12.3***
Land sqd	[illegible]	-2.5	0.5	-5.2***
Seed sqd	[illegible]	-5.7	0.8	-7.1***
Fertilizer sqd	[illegible]	0.5	0.1	3.4**
Labour sqd	[illegible]	-0.4	0.2	-2.8**
Exp sqd	[illegible]	-0.4	0.1	-2.6**
Land*Seed	[illegible]	7.1	1.1	6.3***
Land* Fert	[illegible]	-1.1	0.5	-2.4**
Land*labour	[illegible]	-1.1	0.3	-3.3**
Land* Exp	[illegible]	0.7	0.4	1.7*
Seed* Fert	[illegible]	1.4	0.5	2.7**
Seed*Labour	[illegible]	1.8	0.4	4.4***
Seed* Exp	[illegible]	0.1	0.6	0.2
Fert*Labour	[illegible]	0.0	0.1	-0.2
Fert* Exp	[illegible]	-0.6	0.2	-2.9**
Labour*Exp	[illegible]	-0.4	0.2	-2.5**
Inefficiency				
Constant	[illegible]	-0.7	0.3	-2.7**
Experience	[illegible]	0.0	0.0	-0.6
Education	[illegible]	0.1	0.0	3.1**
Sex	[illegible]	-0.4	0.1	-5.7**
sigma-sq	[illegible]	0.04	0.0	4.8**
Gamma	[illegible]	0.99	0.0	31.7***
Log-likelihood	-	40.36	-	-

*Log-likelihood value for the Cobb Douglas was 20.64; ***=significant at 1%;**=significant at 5%;*=significant at 10%.*

In the case of the squared values also all the variables were significant, maintaining a negative sign. Fertilizer however maintained a positive sign. The interaction parameters were also all significant, with the exception of β_{SE} and β_{FL} for the translog specification.

The squared values of the inputs help us to know the effect on output of the continuous use of the inputs. For instance, the fact that both β_L and β_{LL} are negative means that a continuous increase in the quantity of land would lead to a reduction of output, both at the initial and latter stages. However, since β_F is positive but β_{FF} is negative, it can be said that at the initial stage, increasing the quantity of fertilizer will lead to increased output but later the quantity must be reduced for output to continue to increase. The same applies to the rest of the inputs.

The interaction terms tell us the substitutability or complementarity of the variables. A parameter with a positive sign implies that the two variables are complementary, while a parameter with a negative sign means that the variables are substitutes. From Table 3 above, the significant parameters with a positive sign are β_{LS}, β_{LE} β_{SF} and β_{SB}. The ones with a negative sign are β_{LF} β_{LB} β_{FE} and β_{BE}. This means that while land is complementary to seed and other inputs (e.g. pesticides and insecticides), it is substitute to fertilizer and labour. Seed is also complementary to fertilizer and labour. However, other inputs are a substitute to fertilizer and labour.

3.3 Frequency Distribution of Technical Efficiency Scores

From Fig. 1 the technical efficiency estimates ranged from 40% to 100% with a mean value of 81%, which is comparable with other similar studies [21, 22]. Notice that more than half of the respondents (56.4%) had at least, the mean technical efficiency. The estimated gamma (γ) parameter of 0.99 in the study area indicates that 99% of the total variation in rice output is due to technical inefficiency. This can also be interpreted to mean that the differences between actual (observed) and frontier output are dominated by technical inefficiency (i.e. factors within the control of the farmers rather than outside their control). The result suggests that 99% of the variation in output among rice farmers is due to differences in technical efficiency [24].

3.4 The Sources of Inefficiency

The sources of inefficiency are discussed using the estimated (δ) coefficients associated with the inefficiency effects in Table 3. Variables with negative coefficients have negative relations with inefficiency. The opposite is the case for variables with positive coefficients. The determinants of inefficiency were sex and the level of education of rice farmers.

The negative sign of the education variable means that farmers with more years of formal education tended to be more technically efficient or were less technically inefficient, and the negative coefficient of the sex variable also means that male farmers were more technically efficient (or less technically inefficient) than their female counterparts. Figs. 1 to 4 below give a pictorial explanation of the sources of technical efficiency of farmers in the study area. The average efficiency of male farmers was just 1% greater than that of female farmers. Also, in the case of education, clearly, there was only 1% difference between the technical efficiencies of secondary/technical school leavers and tertiary school leavers in favour of the latter. The technical efficiency of the latter however is greater by 10% than that of those with little or no formal education. With respect to experience, Fig. 4 shows that the majority of the respondents (77%) had been in rice cultivation for between 1 and 15 years. Similarly, as Fig. 5 depicts 74% of the farms were between 0.1 and 3.0 acres.

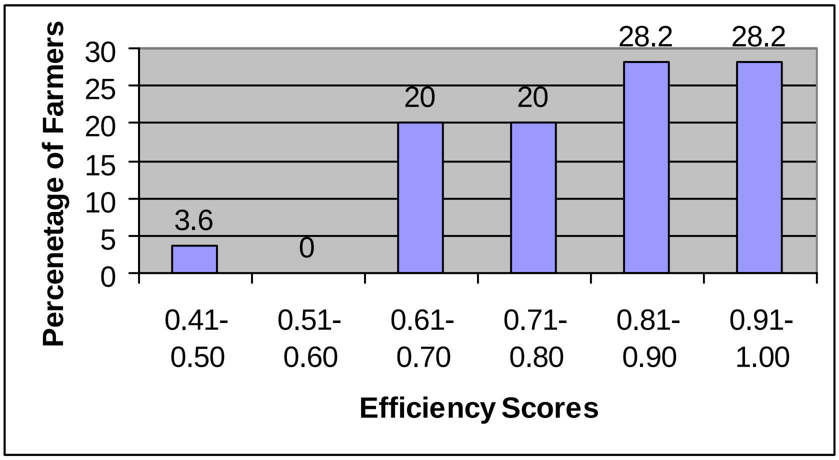

Fig. 1. Frequency distribution of technical efficiency scores

Mean value=0.81; Minimum value=0.40; Maximum value=1.00; Standard deviation=0.14.

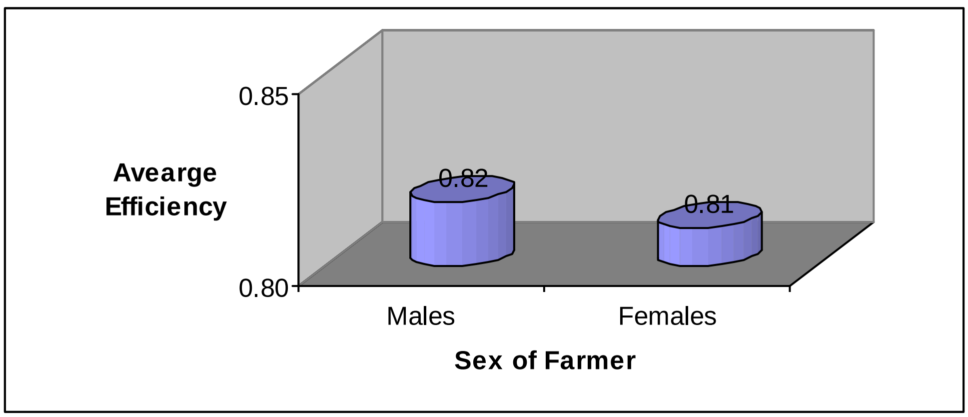

Fig. 2. Sex of farmers and technical efficiency

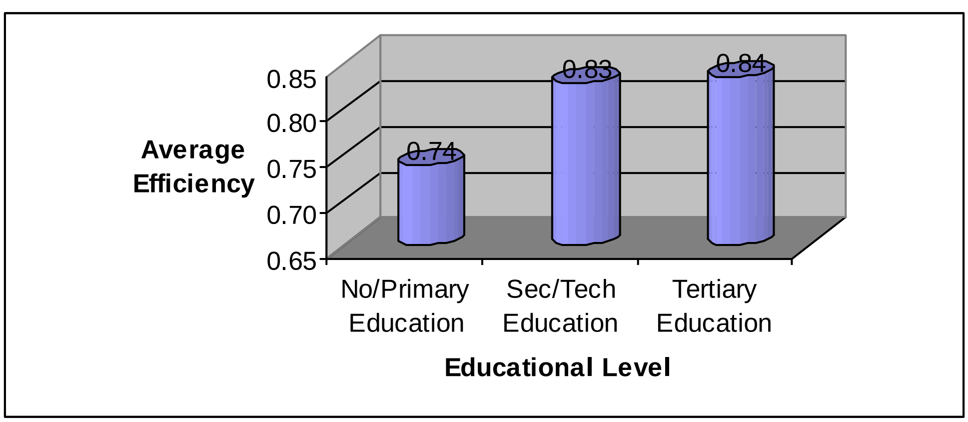

Fig. 3. Educational level of farmers and technical efficiency

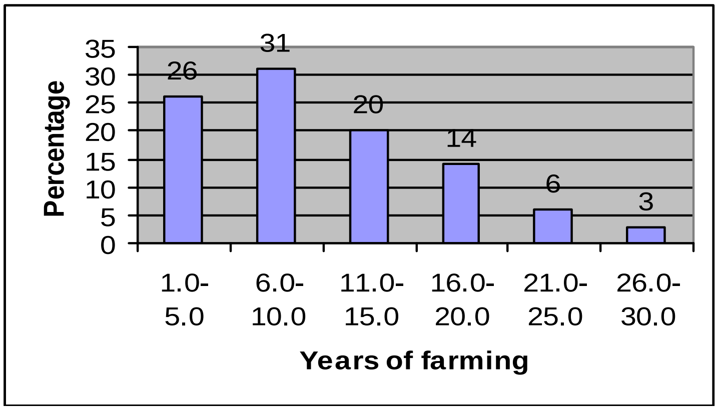

Fig. 4. Percentage distribution of farmers' experience

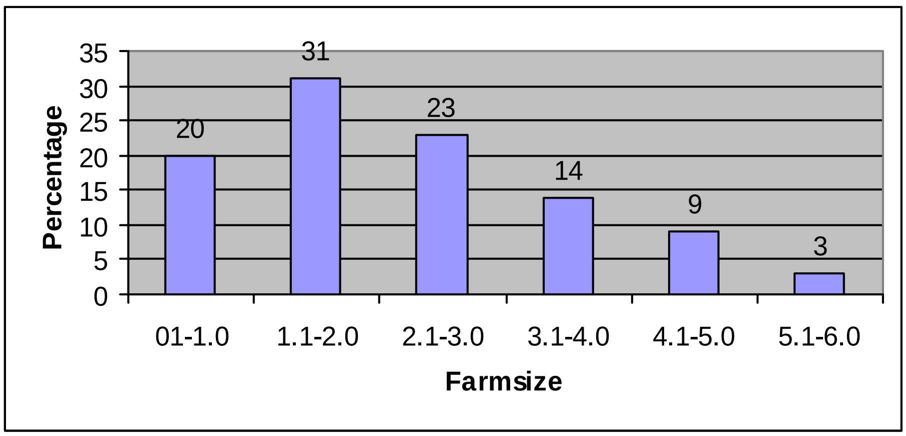

Fig. 5. Percentage distribution of farm size

As shown earlier, the average technical efficiency of Tono rice farmers in this present study is very high (81%). Also, the estimated gamma (γ) parameter of 0.99, suggests that 99% of the inefficiency of the farmers is due to factors within the control of the farmers. This means that the relative contribution of noise or factors outside the control of farmers is very minimal. From theory, factors outside the control of farmers include drought, floods or bushfires. The high average efficiency and gamma parameter in this present study do not come as a surprise, considering the intensive nature of the farming that goes on at Tono. Unlike rain-fed agriculture which is exposed to the vagaries of the weather, farming at the Tono Dam is a dry season one, where farmers do not only have water supply (from the dam), but do also have supply of inputs such as fertilizer, seeds, and pesticides, sometimes on credit. Farm machinery like tractors, combine harvesters and other farm implements are also usually available for hiring. However, since these inputs are generally for sale, the quantities that would be bought by the individual farmers depend on their financial statuses and the expected returns, among others. For policy formulation, it is important to note that agricultural intensification, made possible by the availability and timely supply of these modern inputs, would go a long way to reduce farmers' dependence on natural factors, resulting in high technical efficiency.

From the results presented, the four main variables that emerged as the determinants of technical efficiency in rice production in the study area were land, seed, fertilizer, education and gender. These may be targeted for specific policy formulation. The "Supply of the right agricultural inputs in adequate quantities and at affordable price is key to overcoming the problem of low productivity in Ghana's agriculture" [4]. With respect to land, the average plot size in the Tono irrigation site is 0.99 hectares, which is likely to reduce with time, as a result of population pressures. The situation will be worse for women, considering the fact that they are already disadvantaged. It was observed that not only were women fewer than men, but their landholdings were also in general, smaller than that of men.

Similarly, more land must be brought under irrigation. Improvement of irrigation systems is one of the most important areas that need heavy investment in the country to ensure all-year round production [24]. This facilitates full employment of the other factors of agricultural production, especially labour. In Ghana, the policy objective for irrigation development is to raise productivity of irrigation water from 30% to 80% within a decade, starting from 2007 [19]. Consequently, by the end of 2010, there had been a first phase rehabilitation of the Tono dam, making available 1,874 hectares of land for cultivation. This was aside the rehabilitation of 70 dams in the three Regions of northern Ghana within that same period [24].

With respect to seed, during the 2005 farming season, 20 farmers and 18 seed inspectors were trained in hybrid maize seed production while 2.5 hectares of Nerica (New rice for Africa) was harvested as seed base to be distributed to farmers for planting [25]. In addition, about 9.2 tonnes of (other) rice seed were produced and distributed to farmers. However, these were woefully inadequate. Consequently, at the beginning of 2007 the government's plans were to develop and crop about 500 hectares of valley bottom sites for the production of 2,500 tonnes of rice under the Inland Valley Development Project. In addition, the Nerica Rice Dissemination Project planned to produce 200 tonnes of certified rice seeds and further contract the production of 150 tonnes of certified seeds during the off-season. Furthermore, in order to facilitate technology dissemination in Nerica rice cultivation, 2400 farmers were to be mobilized for training. Lastly, the Savannah Agricultural Research Institute (SARI) and Crops Research Institute (CRI) have developed and approved the release of four improved seed varieties [24].

"A major component of production cost in Ghana's agriculture is the cost of inputs which are very high, thus making it difficult for the many poor smallholders who dominate the sector to afford them" [26]. As reported in [26] the price of Urea went up by about 11.76% from Gh 21.57 in 2005 to Gh 24.10 in 2006. The price of NPK-15-15-15 also rose slightly from Gh¢ 20.22 per 50 kg in 2005 to Gh 20.24 in 2006. However, the price of NPK-20-20-20 fell from Gh 20.42 per 50 kg in 2005 to Gh 19.92 in 2006[1]. In the case of insecticides and pesticides the prices were lower in 2006, with Actielic and Atrazine falling by as much as 26% and 23% respectively. Against the backdrop of the difficulty associated with the fertilizer subsidization, in 2010, the fertilizer programme was reviewed and a more efficient waybill system introduced to replace the existing coupon system. This was to enhance the delivery of the programme and ensure a more transparent distribution system [24]. Consequently, in 2010

The Exchange rate during this period was about 1.50 Gh to 1.00 US$. 1

the government subsidized 60,000 metric tonnes of fertilizer at an average cost of Gh is 16.00 per bag of 50kg as part of efforts to increase productivity.

The role of education in the development of a country cannot be over-emphasized. Seini [27] argues that investment in people, especially the poor and women, is key to the accelerated growth and development of Ghana. He stresses that education increases people's ability to understand issues related to the adoption of technology, thereby raising their productivity. Along similar lines Nankani [28] argues that basic education is critical for small farmers who need to adopt new technologies, seeds and crops. The result for the present study is consistent with the findings by [29, 30, 21]. Seyoum et al. [30] find that farmers with more education respond more readily to new technology and produce closer to the frontier output. Also, [31] conclude that education is an important policy variable, which can be targeted to improve both technical and allocative efficiency. However, Kalirajan and Shand [32] argue that even though the number of years of schooling is a productive factor, farmers' education is not necessarily related significantly to their yield achievement. Illiterate farmers, without the training to read and write, can understand a modern production technology as well as their educated counterparts, provided the technology is communicated properly. In Ghana, the implementation of new educational reforms for basic education began in 2007. The main components included teacher upgrading and deployment, attainment of gender parity, the active promotion of science, technology and research; and the incorporation of pre-schools into the basic education system. However, while Nankani [28] acknowledges that Ghana has made major strides in expanding gross enrolments in primary education, he laments over the relative neglect of programs of adult literacy that will help current farmers to absorb new methods of agriculture. He concludes that the most important thing to do, if a nation is to have quality education, is to involve local government, communities and parents in the running of schools.

Like our present study, [33, 34] find male farmers to be more efficient than their female counterparts. However, Doss and Morris [35] argue that the reason for lower efficiency on the part of female-headed households is their engagement in non-farm activities more than their male counterparts. In Alhassan's study [21] the gender variable was not significant. Women continue to produce and manage a large share of goods and services, yet their efforts have often been hidden in the tasks associated with domestic and conjugal roles [36]. Also, Ellis [37] states that because of the domestic roles (such as cooking, clearing and mending) and the biological roles of child bearing and caring for children, women do not have enough time to perform other tasks adequately. Farmers, especially women can be supported to rely on group assistance as an alternative source of affordable human labour supply.

4. CONCLUSION

The study aimed at finding out the technical efficiency levels of rice farmers at the Tono Irrigation Project in the Upper east region of Ghana. The method of analysis involved one-step estimation of the stochastic frontier model. The mean technical efficiency was 0.81 with the majority of the farmers recording efficiency levels above 0.60. The conventional inputs that were significant in determining output were land, seed, labour and crop expenditure, most of them maintaining their expected signs. Technical efficiency was also influenced by gender and education. In terms of methodology, the translog specification of the model performed better than the Cobb-Douglas specification. The former was also advantageous in helping to know the effects of the squared values as well as their interaction terms.The high average technical efficiency level of the farmers at the Tono Irrigation is largely due to the intensification nature of the farming, made possible by the supply of modern inputs for which they receive support. The sustainability of the high efficiency will be dependent on the continuous support the farmers receive in the areas of input supply and education, among others. It is recommended that a panel study is carried out to better understand the long term implications of the determinants of technical efficiency in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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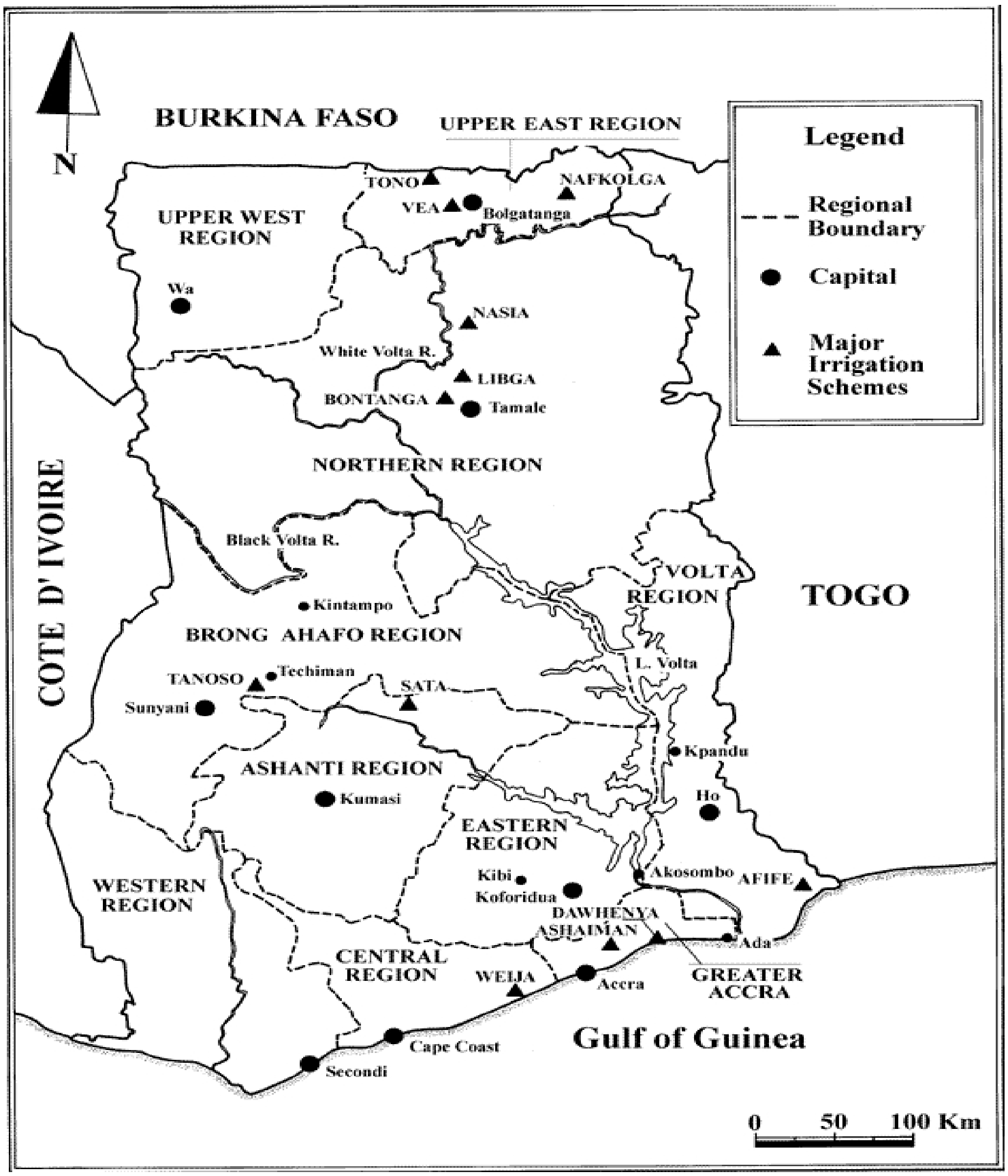
APPENDIX

A map of Ghana showing the major irrigation schemes



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