Fertilizer Use Efficiency of Maize Producers in Ogun State of Nigeria.

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ABSTRACT

This study was carried out to analyze fertilizer use efficiency of maize producers in Ogun State of Nigeria. The study made use of cross-sectional data to obtain information from 120 maize farmers in the four agricultural zones of Ogun State. The results indicated that the maize farmers were not technically efficient. The mean efficiency was 0.569 and 0.649 under CRS and VRS specification, respectively, indicating that there was 43.1% and 35.1% allowance for improving efficiency. The results also show that majority of the farmers were operating with decreasing return to scale. The results further reveal that education, experience, fertilizer quantity, marital status, and gender significantly influence the farmers' efficiency.

(Keywords: maize, DEA, efficiency, agriculture)

INTRODUCTION

Maize *(Zea mays)* is one of the main cereal crops of West Africa and the most important cereal food crop in Nigeria. It comes after wheat and rice in terms of world importance. Maize is not only a major cereal in the present day world but it was also one of the basic foods in America before the arrival of Christopher Columbus at the end of the 15^{th} century, and among the Indians in Mexico and Guatemala, and also among the Incus in Peru, Bolivia and Equator (Rouannet, 1997).

Maize is a major food crop and accounts for about 75% of the total value of smallholder crop production (INE, 2001). Improving maize production is considered to be one of the most important strategies for food security in West Africa. However, improved maize varieties and chemical fertilizers are not yet widely adopted. For example, in 2001 only 8 percent of approximately three million farmers used fertilizers, pesticides, and herbicides (INE, 2001).

Maize is becoming the miracle seed for Nigeria's agricultural and economic development. It has established itself as a very significant component of the farming system and determines the cropping pattern of the predominantly peasant farmers, especially in the Northern States (Ahmed, 1996). Maize has been of great importance in providing food for human populations, feed for livestock, and raw materials for some agro-based industries. Maize constitutes a stable food in many regions of the world. It is a basic staple for large population groups particularly in developing countries (FAO, and ILO, 1997).

Wikipedia (2006) reported that maize is hydrolyzed and enzymatically treated to produce syrups, particularly high fructose corn syrup, a sweetener and in cases fermented and distilled to produce grain alcohol which is traditionally the source of bourbon whisky. Sweet corn is a genetic variety that is high in sugars and low in starch that is served like a vegetable. Another common food made from maize is corn flakes. Maize is used as meal pap in Africa; corn bread is made from maize.

According to Oyekale and Idjesa (2009), maize is an important staple food in Nigeria. Declining yields of maize as a result of several environmental and biological factors have necessitated technological innovations focusing on maturity time, disease resistance, and palatability of the crop. Maize consists of 70% starch, 9% protein, and 4% oil on a dry weight basis (Kogbe and Adediran,2003). Despite the economic importance of maize to the teeming populace in Nigeria, it has not been produced to meet the food and industrial needs of the country. This could be attributed to lows productivity from maize farms or that farmers have not adopted improved technologies such as fertilizer usage for maize production. In case where they have been exposed to it, financial constraints will not affords them the opportunity to use it. Hence, most farmers still depend on their old methods, manual labor, long time bush fallowing and usage of crude implements in maize production (Nyoro *et al*., 2004).

Fertilizers are substances or materials that supply plant nutrient that is deficient in the soil or amend soil fertility. They are the most effective (30-80 percent increase in yield) means of increasing crop production and improving the quality of food and fodder. Fertilizers are used in order to supplement nutrient supply in the soil especially to correct yield limiting factors (IFA, 2008).

Fertilizers are broadly divided into, organic fertilizers (composed of enriched organic matter-plant or animal) and inorganic fertilizers (composed of synthetic chemicals and mineral). The use of inorganic fertilizer has increased steadily in the last 50 years, rising 20 fold to current rate of 100 million tons of nitrogen per year (Glass and Anthony, 2003).

Soil fertility must be managed more efficiently if Africa is to overcome its food production problems. Mineral fertilizers and improved nutrient management strategies are crucial to such efficiency. So too are new nutrient sources and more responsive crop varieties. Maize combines wide spread importance as a food staple with relatively high fertilizer use are likely to become even more closely linked than they have been in the immediate past (IFA 2008).

Inefficiency in the use of available scarce resources according to Gani and Omonona (2009) has been the bane on increased food production hence low income among the cream of farmers across the nation. Sartorius von Bach *et al*., (1998) used stochastic frontier production function to examine technical inefficiency of commercial maize producers in South Africa. Their results demonstrate how maize farmers have increased their efficiency in the face of a cost-squeeze. The increased efficiency seems to be driven by lower levels of intermediate input use when facing higher costs and uncertain weather conditions.

Oluwatayo *et al*., (2008) examined resource use efficiency among maize farmers in rural Nigeria. Their results of regression analysis showed that farm size, labor, pesticides, herbicides and fertilizer usage are positively related with maize output and these variables are equally significant in determining the output of the farmers. Farmers who use fertilizers are found to obtain higher yield than those who did not use it.

This study demonstrates an approach to determining the farm efficiency using DEA technique. The estimate of resource-use efficiency obtained will be useful in providing insights to assess the potential for and sources of improvements in rice farms production. DEA is a non-parametric technique that measures the efficiency of Decision-Making Units (DMU) relative to production possibility or input requirement set. It was further described by Seiford and Thrall (1990) in terms of floating piece-wise linear surface to rest on top of the observations. Specifically, the key constructs of a DEA model are the envelopment surface and the efficient projection path to the envelopment surface (Charnes *et al.,* 1985).

The envelopment surface and the efficient projection path depend on the scale assumption that underlined the model and the optimization assumption respectively. The optimization production process could be output or input-oriented model. The input-oriented model shows how much the input could be proportionally reduced without changing the quantity of the output produced while the output-oriented shows how much the output quantity could be proportionally expanded without altering the input quantity. Output-oriented model gives credence to neo-classical production function defined as the maximum output given input quantity (Fare *et al.,* 1994). In this study, the output-oriented model approach was used to estimate fertilizer use efficiency of maize producers in Ogun State of Nigeria.

METHODOLOGY

The study was carried out in Ogun State of Nigeria. Population of the study is made up of all maize farmers in the study area. A multi-stage random sampling technique was employed in selecting the sample. The four agricultural zones were taken as the sampling units as a first stage of sampling. At the second stage, two local government areas were randomly selected to represent the zone making a total of eight LGAs.

The last stage involved random selection of 120 maize farmers from the selected LGAs.

DEA is non-parametric approach method which involves the use of linear programming to construct a piecewise linear envelopment frontier over the data points such that all observed points lie on or below the production frontier. Let X be a K * N matrix of inputs, which is constructed by placing the input vectors x_i, of all N firms side by side and Y denotes the M * N output matrix which is formed in analogous manner.

The output oriented VRS DEA frontier is defined by the solution to N linear programs of the form:

Min Φ

Φ, T

Subject to
$$- y_i / \Phi + YT \geq 0$$
$$x_i + XT \geq 0$$
$$N / T = 1$$
$$T \geq 0$$

Where NI is an N x I vector of Is, T is an N * I vector of weights and Φ is the output distance measure. We have to note that $0 \leq \Phi \leq 1$ and that 1/ Φ is the proportional expansion in outputs that could be achieved by the i+e firm, with input quantities held constant.

In a similar manner, the input – oriented VRS DEA frontier is defined by the solution to N linear programs of the farm.

Min ℓ

ℓ, T

Subject to
$$- y_i + YT \geq 0$$
$$x_i / \ell - XT \geq 0$$
$$N / T = 1$$
$$T \geq 0$$

Where ℓ is the input distance measure. Also note that $1 \leq \ell \leq \infty$ and that 1/ ℓ is the proportional reduction in inputs that could be achieved by the i+e firm, write output quantities held constant.

The technical efficiency measure under CRS, also called the “overall” technical efficiency measure, is obtained by solving N linear programs of the form.

Min Φ^{CRS}

Φ_i^{CRS}

Subject to
$$- YT + Y_i \geq 0$$
$$\Phi_i^{CRS} x_i - XT \geq 0$$
$$T \geq 0$$

Where Φ_i^{CRS} is a technical efficiency measure of the ite firm under CRS and $0 \underline{\alpha} \Phi_i^{CRS} \underline{\alpha} 1$.

The output and input oriented models will estimate exactly the same frontier surface and therefore, by definition, identify the same set of firms as being efficient. The efficiency measures may, however, differ between the input and output orientations. Under the assumption of CRS, the estimated frontier and the efficiency measures remain unaffected by the choice of orientation (Coelli and Perelman, 1999). One output and four inputs were used in the models. The only output is the maize yield. The inputs are farm size, labor, seed, and fertilizer.

Tobit Model Specification

In order to estimate the technical efficiency variables, Tobit Model was employed because of its advantage in specifying the intensity of the factors that influence the technical efficiency of maize farming. In the absence of a theoretical recommendation for using an alternative specification, the model expressed the technical efficiency of the maize based farming as a function of a linear combination of observable explanatory variables, and error term (μ_i). The simple model was presented as:

$$Y^* = \beta x_i + \mu_i \quad \textbf{(1)}$$

Algebraically expressed for the firm operator:

$$Y_i = / \beta_0 + \beta_r Xi_i + ... + B_N N_{ni} i = 1, N \quad \textbf{(2)}$$

Such that:

$$Y_t = \begin{cases} 0 if Y \leq T \\ Y * if\ 0 < Y_i * < (i = 1, ..., n) \\ 1 if Y_i^* > T \end{cases} \quad \textbf{(3)}$$

Where Yi is the observed dependent variables; Y^*_t is the non-observable latent variable representing the technical efficiency of the maize based farming; T is the critical (cut-off) value which translation into $Y^*_t > T$, as firm are efficient and $Y^*_t \leq T$, as firm are not efficient; and n is the number of observations. Tobit analysis was used to estimate the determinant of technical efficiency.

RESULTS AND DISCUSSIONS

Efficiency Measures

Technical and Scale Efficiency of Maize Farms: Table 1 gives the frequency distribution of the maize farms based on CRS and VRS technical efficiency estimates obtained by DEA method. Out of 120 maize farms studied, 8 farms under CRS and 15 farms under VRS are fully efficient. Eleven farms under CSR and 8 farms under VRS show a performance below 0.3. The greatest efficiency score was found to be 0.648. The average overall technical efficiency levels are 0.57 and 0.65 for CRS and VRS, respectively.

Substantial inefficiency occurred in the farming operation of the sampled maize farms in the study area. Under prevailing conditions, about 7 percent and 13 percent of farms were identified as fully efficient under CRS and VRS measures respectively. The observed difference between CRS and VRS measures further indicate that some of the farmers did not operate at an efficient scale and improvement on the overall efficiency could be achieved if the farmers adjusted their scales of operation. A study by Oluwatayo *et al.,* (2008) reports 0.68 as the average technical efficiency for maize farmers in rural Nigeria.

Spearman Correlation: Spearman correlation coefficient between the technical efficiency scores were computed and given in Table 2 in order to examine agreement between results obtained from DEA. The correlation coefficient is positively significant at 1 percent level. This indicates a strong agreement between the two models.

Table 1: Frequency and Percentage Distribution of Technical and Scale Efficiency of Maize Farms.

Efficiency scores	CRS-TE		VRS-TE		Scale Efficiency	
	No	%	No	%	No	%
< 0.3	11	9.2	8	6.7	3	2.5
0.3-0.39	12	10	1	0.8	0	0
0.4-0.49	24	10	19	15.8	0	0
0.5-0.59	24	20	31	25.8	1	0.8
0.6-0.69	15	12.5	13	10.8	7	5.8
0.7-0.79	9	7.5	13	10.8	16	13.3
0.8-0.89	10	8.3	12	10	16	13.3
0.9-0.99	5	4.2	8	6.7	28	23.3
1.0	8	6.7	15	12.5	49	40.8
Total	120	100	120	100	120	100
Mean	0.569		0.649		0.890	
Minimum	0.083		0.083		0.104	
Maximum	1		1		1	
Stand dev.	0.232		0.233		0.167	

Source: Data analysis 2011.

Table 2: Spearman Correlation Coefficient among Alternative Efficiency Measures.

	TE-DEA (CRS)	TE-DEA (VRS)
TE-DEA (CRS)	1.000	
TE-DEA (VRS)	0.794***	1.000

***significant at 0.01 level (2-tailed).
Source: Data analysis, 2011

Return to Scale Properties: In this study, scale efficiency is relatively high. Mean scale efficiency of the maize farm is 0.890 (Table 1). Of the 120 maize farms, 41 shows constant return to scale and 9 shows increasing return to scale while 70 shows decreasing return to scale (Table 3). This result shows that there is small scale inefficiency in the study area. This implies that most of the farms should be bigger than their present size in order to achieve higher production. A study by Ahmad *et al*., (2002) reports wheat farmers in Pakistan face diminishing returns to scale.

Table 3: Characteristics of Farms with Respect to Return to Scale.

	No of Farms	Mean size	Mean output
Sub-optimal	09	0.39	644.44
Optimal	41	0.426	1058.54
Super optimal	70	0.508	1057.15

Source: Data analysis, 2011.

Summary of Maize Input and Output Slacks

The output slacks was found to be zero for all the farms. This result implies that given the present scale of operation and the available resources, the farmer could not do anything to increase their output level beyond present value irrespective of the adjustment in their input level because of fixed resources.

Table 4 gives the summary of the input slacks under the VRS specification. The greatest input excess maize in production was fertilizer. The output levels realized could still have been realized if the quantity of fertilizer had been reduced by 72.8 percent. The value of land slack was observed to be 0.042 ha. This indicates that farm size could be reduced by this amount to obtain the same level of output. Labor slack of 127.21 man-days implies that there could be reduction in the use of labor by 127.21 man-days. In essence, the same level of output that was realized from this input use could still be obtained if the quantity of the various inputs were reduced by the corresponding value of slacks among the inputs.

Summary of Output Target

Table 5 gives the summary of output target. The output target refers to the amount of output the decision making unit should aim at producing given the available unit of inputs. The minimum output target that some of the decision making unit should aim at producing fell within the range of 1-1000 bags. Only DMU amounting to 5.8% of the total decision making unit in the crop is applicable. The maximum output target range is 2000 bags and above, 61% of the farmers should aim at producing between1001-2000 bags.

Table 4: Distribution of VRS input Slacks.

Inputs	No of Farms	Mean slacks	Mean Output	Excess (%)
Farm size	46	0.042	0.558	7.7
Labor	70	127.21	265	48
Seed	35	0.245	2.271	10.8
Fertilizer	68	161.076	221.25	72.8

Source: Data analysis, 2011

Table 5: Frequency and Percentage Distribution of Crop Output Target.

Target	Frequency	Percentage
1-1000	7	5.8
1001-2000	73	60.8
>2000	40	33.3
Total	120	100
Minimum	100	
Maximum	2150	

Source: Data analysis, 2011

Determinants of Technical Efficiency

Tobit Estimate of Determinant of CRS Technical Efficiency for Maize Farms: Table 6 shows the estimate of the Tobit regression of maize farms under CRS specification. Under the CRS, three variables had significant effect on the technical efficiency of maize farms. These are experience which is positively significant at 5% level with coefficient of 0.149 and t-value of 2.160.

The result means that as the year of experience increases, the technical efficiency increases by 0.149%. Education had a coefficient of 0.026 and t-value of 2.269 significant at 5% level. This means that as the level of education of the farmers' increases, technical efficiency increases by 0.026%. Fertilizer quantity had a coefficient of -0.005 and a t-value of -4.878 which is significant at 1% level. The negative impact of fertilizer quantity shows that as the fertilizer quantity increases, technical efficiency also decreases. In essence, there is over-utilization of fertilizer in the study area.

Table 6: Result of CRS Tobit Analysis for Maize Farms.

Variables	Coefficient	t-value
Constants	0.489	2.487
Education	0.026	2.269**
Experience	0.149	2.160**
Household size	-0.030	-0.165
Marital status	0.138	0.427
Gender	0.324	0.543
Gender	-0.005	-4.878***
R-square	0.241	
F-test	5.97*	
Loglikelihood	22.27384	

Source: Data analysis, 2011
**significant at 5% level
***significant at 1% level

Tobit Estimate of Determinant of VRS Technical Efficiency for Maize Farms: Table 7 shows the estimate of the Tobit regression for maize farms under VRS specification, Under the VRS, four variables were observed to be statistically significant with technical efficiency. These include education, marital status, gender and fertilizer quantity. Education had a coefficient of 0.271 and t-value of 2.281 which is significant at 5% level. This means that as the level of education increases, technical efficiency also increases. Marital status is significant at 5% level with a coefficient of 0.123 and a t-value of 2.177. This means that married farmers are more technical efficient than others. Gender had a coefficient of 0.070 and a t-value of 2.185 which is significant at 5% level. This result means that male farmers have a positive impact on technical efficiency. In essence, male farmers are technically efficient than female farmers. Fertilizer quantity is negatively significant with a coefficient of -0.562 and a t-value of -5.933 which is significant at 1% level. This means that as the fertilizer quantity increases, technical efficiency also decreases by 5.933%.

Table 7: Result of VRS Tobit Analysis for Maize Farms.

Variables	Coefficient	t-value
Constants	0.627	3.211**
Education	0.271	2.281**
Experience	-0.135	-0.145
Household size	-0.019	-1.145
Marital status	0.123	2.177**
Gender	0.070	2.185**
Gender	-0.006	-5.933***
R-square	0.261	
F-test	6.67*	
Loglikelihood	22.97315	

Source: Data analysis, 2011
**significant at 5% level
***significant at 1% level

CONCLUSION

The study concluded that there exists more potential that remained untapped in maize production in the study area. There is scope for increasing maize production by about 43.1% and 35.1% for technical efficiency under CRS and VRS specification respectively with the present technology in Ogun State. The determinants of efficiency are education, experience, fertilizer quantity, marital status and gender. Fertilizer was over-utilized in the study area. Majority of the farmers were experiencing decreasing return to scale. By operating on an optimal scale, input wastage could be reduced.

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