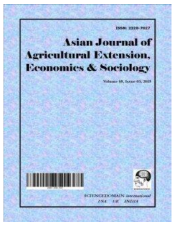

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Measurement of Efficiency in Cocoyam Production: An Application of Data Envelopment Analysis (DEA) Approach

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Authors' contributions

This work was carried out in collaboration between all authors. Author SA designed the study, wrote the protocol and supervised the work. Authors AJT, BM and FS carried out all field work and performed the statistical analysis. Author GB wrote the first draft of the manuscript and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The objective of this study were to estimate economic efficiency and its determinant on cocoyam farmers in Kaduna state.
Study Design: Primary data were used for this study and this was collected through the use of structured questionnaires.
Place and Duration of Study: This study was conduct in Giwa, Kudan and Ikara local government areas in Kaduna state, Nigeria during 2014 cropping season.
Methodology: A Multistage sampling techniques were employed for this study.
Results: It was observed from the study that the majority of cocoyam farmers (36.29%) had technical efficiency of 0.81 and less than 1.00, the respondents (27.42%) operated within an

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allocative efficiency range of 0.2 and less than 0.2. The study also suggests that economic efficiency among cocoyam farmers were between 0.029 and 1.00, with a mean economic efficiency of 0.335. This result implies that the farmers in the study area are economically inefficient.
Conclusion: Data envelopment analysis was employed on measurement of efficiency in cocoyam production, Kaduna State, Nigeria. Based on the findings of this study, it could be concluded that cocoyam farmers are economically inefficient having economic efficiency of 34%. Also, age, education, extension and amount of credit received were the factors influencing economic efficiency of the cocoyam producers in the study area.

Keywords: Technical; allocative; economic efficiency; cocoyam; data envelopment analysis; Kaduna state.

1. INTRODUCTION

Cocoyam (*Colocasia esculenta* and *Xanthosoma mafafa* (L) Okeke) are important carbohydrate staple foods, especially in middle belt and southern part of Nigeria [1]. The main nutrient supplied by cocoyam, as with other roots and tubers, is dietary energy provided by its carbohydrate content. Its protein content is low 1-2%, and as in almost all root crop proteins, sulfur-containing amino acids are limiting [2]. By contrast, cowpea protein is of higher value and can complement the deficiencies of cocoyam.

Cocoyam ranks third in importance after cassava and yam among the root and tuber crops that are cultivated and consumed in rural areas by the elderly in Nigeria. The crop is no longer favoured in urban homes due to poor information about its nutritive values [2]. This widespread ignorance of the nutritive value and diversities of food forms of cocoyam is a major problem for the general acceptability and extensive production of the crop [2,3]. Production of cocoyam has been neglected in many countries probably because of its inability to contribute to the GDP through foreign exchange earnings and most of what is produced is consumed locally [4,5]. There is also dearth of information on the economics of cocoyam production in Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in Kaduna state of Nigeria. Kaduna state occupies almost the entire mid-central portion of the northern part of Nigeria, an altitude of 500–1000 m above sea level and annual average of 1,272 mm of rain. The relative humidity is constantly below 40 degrees except in few wet months when it goes up to an average of 60 degrees. The duration of dry season in the state is between 5-7 months, which starts from late October to May [6]. Kaduna is the third most populous state after Kano and Lagos with an estimated population of 6.11 million with an annual increase rate of about 3.2%, the projected population of the state was about 7, 869, 680 million people in 2015 [7]. Agriculture is the main stay of the economy of Kaduna state with about 80% of the people are actively engaged in farming. The state is well suited for the production of cash and arable crops; the produce includes: cotton, groundnuts, tobacco, maize, yam, beans, guinea corn, millet, ginger, rice, cassava, sugarcane, shea nuts, cowpea, mango, kenaf, cocoyam, cassava, timber, palm kernel, banana, soya bean, corn, onions, sorghum and potatoes. Over 180,000 tons of groundnuts are produced in the state annually. The major cash crops are ginger and cotton which the state has a comparative advantage in as it is the leading producer in the country. During the dry season, a considerable number of people in the state engage in irrigation farming along rivers and near dams, mainly growing vegetables. Another major occupation of the people is animal rearing and poultry farming. The animals reared include cattle, sheep, goats and pigs [6].

2.2 Sampling Procedure

Three stage sampling techniques were used to select the cocoyam farmers for this study. In the first stage, three local government areas were purposively selection based on the fact they are the major cocoyam producers. In the second stage, 9 villages were also selected purposively from each local government areas based on their intensity in cocoyam production. In the third stage, a simple random sampling was used to select 124 cocoyam farmers for the study.

2.3 Data Collection and Analysis

Primary data were used in this study. The primary data were obtained by the use of structured questionnaire administered to cocoyam farmers. The information collected were labour, fertilizer, seed, farm size and farmer's socio-economic characteristics such as age, household size, educational status, amount of credit received, number of extension contacts and years spent on the cooperative were also obtained.

2.4 Model Specification

2.4.1 Analytical framework

In this study, the Data Envelopment Analysis (DEA) method was chosen because of its ability to readily produce rich information on technical and scale efficiency. DEA is a nonparametric mathematical programming technique that presents a particularly suitable way to decompose efficiency into pure technical and scale aspects and therefore facilitates the examination of economies of scale. The DEA technique does not require a specific functional or distributional form, and can accommodate scale issues. A large number of studies have extended and applied the DEA technology in the study of efficiency worldwide. DEA models can be either output or input oriented. The input-oriented model measures the quantities of inputs that can be reduced without any reduction in the output quantity produced. On the other hand, output oriented model measures the degree to which output quantity can be increased without any change in the quantities of inputs used [8]. However, the relative range of the efficiency scores remains the same whether input-oriented or output-oriented method is employed. The output oriented models involves constant returns-to scale (CRS) or variable returns-to-scale (VRS) [8]. This study used both constant returns to scale (CRS) and variable returns to scale (VRS) models with output orientation to produce maximum output from given quantities of input.

2.4.2 The DEA model

Given the CRTS assumption, the best way to introduce DEA is via the ratio form. For each decision-making unit (DMU) one would like to obtain a measure of the ratio of all outputs over all inputs, such as $u'y_i/v'x_i$, where u is an Mx1 vector of output weights and v is a Kx1 vector of input weights. To select optimal weights, one specifies the mathematical programming problem as used by Asogwa et al. [9]:

$$\text{Max } u,v\ (u'y_i/v'x_i),$$

$$\text{st } u'y_j/v'y_j \leq 1,\ j=1,2,\ldots,N,$$

$$u, v \geq 0 \qquad (1)$$

This values of u and v, implies efficiency measure of i-th DMU is maximized, subject to the constraint that all efficiency measures must be less than or equal to one. One problem with this particular ratio formulation is that it has an infinite number of solutions. According to (9). To avoid this, one can impose the constraint $v'x_i = 1$, which provides:

$$\text{Max}x_i,v(\grave{\imath}'y_i),$$

$$\text{st } v'x_i = 1,$$

$$\mu'y_j - v'x_j \leq 0,\ j=1,2,\ldots,N,$$

$$\mu, v \geq 0, \qquad (2)$$

Where:

The change in sign from u and v to μ and v reflects the transformation. This is the multiplier form of the linear programming problem. An equivalent envelopment form of this problem can be derived linear programming using duality linear programming problem:

$$\text{Min}_{\theta,\lambda}\ \theta,$$

$$\text{st } -y_i + Y\lambda \geq 0,$$

$$\theta x_i - X\lambda \geq 0,$$

$$\lambda \geq 0, \qquad (3)$$

where θ is a scalar and λ is a N x1 vector of constants. According to This envelopment form involves fewer constraints than the multiplier form (K + M < N+ 1), and hence is generally the preferred form to solve. The value of θ obtained will be the efficiency score of the i-th DMU. It will satisfy θ≤1, with a value of 1 indicating a point on the frontier and hence a technically efficient DMU, according to (10) definition. Note that the linear programming problem must be solved N times, once for each DMU in the sample. A value of é is then obtained for each DMU as adopted by (9).

The linear programming problem in terms of constant return to scale can be easily modified by adding the convexity constraint to account for variable return to scale: N1’λ=1 to (3) to provide:

$Min\theta,\ddot{e}^{\theta}$,

st $-y_i + Y\lambda \geq 0$,

$\theta x_i - X\lambda \geq 0$,

$N1'\lambda=1$

$\lambda \geq 0$, (4)

where: θ is a scalar and λ is N x1, θ obtained will represent the efficiency score of the i-th Decision Making Unit.

θ ≤1, with a value of 1 represent technically efficient DMU and a point on the frontier.

According to [11,12] Cost minimization Data Envelopment Analysis is thus:

$Min_{\lambda,xi}* W_{i2}X_i*$

st $-y_i + Y\lambda \geq 0$,

$x_i* - X\ddot{e} \geq 0$,

$N1'\lambda=1$

$\lambda \geq 0$, (5)

Where: w_i is the input prices for the i-th DMU and x_i* is the cost minimizing of input quantities for the i-th DMU, given the input prices w_i and the output levels y_i. The economic efficiency of the i-th DMU would be thus:

$$CE = w_{i2}\, x_i */ w_{i2}\, x_i \quad (6)$$

The allocative efficiency residually can then calculated as:

$$AE = CE/TE \quad (7)$$

Note that the overall economic efficiency is the product of technical efficiency and allocative efficiency. Note that economic, technical and allocative efficiencies lies between zero and one [10].

3. RESULTS AND DISCUSSION

3.1 Returns to Scale

The result in Table 1 revealed nature of scale with which the sampled cocoyam farms operated. This is important because in addition to knowing the number of efficient cocoyam farms, degree inefficiency and optimal scale of operation, it is also vital to know how many farms are operating under increasing returns to scale (IRS), decreasing returns to scale (DRS) or operating at optimal scale. Using DEA every cocoyam farm was evaluated, given its size level to determine its scale measures. This type of analysis according to [13] would be useful to each farm as they could determine the implications for expansion. The number of farms operating under constant, increasing, and decreasing returns to scale is shown in Table 1.

Table 1. Scale efficiency estimates

Return to scale	Frequency	Percentage
IRS	48	38.71
DRS	63	50.81
CRS	13	10.48
Total	124	100

About 39% of cocoyam farms were found operating with increasing return to scale (IRS) or sub-optimal scale. This implies that production scale of these farms could be increased by decreasing costs, given that they were performing below optimum. On the other hand, about 51% farms were operating with decreasing return to scale (DRS) or supra-optimal scale that is the farms were operating above the optimum scale, suggesting that these farms could increase their technical efficiency by reducing their production levels.

Similarly only 11% cocoyam farms were found operating at optimal scale (Table 1). Given that majority of the cocoyam farms were operating under IRS and DRS suggests that cocoyam farms in general were scale inefficient, since scale inefficiency is usually due to the presence of either IRS or DRS. This is in agreement with [14-16]. Although in the short run, farms may operate with increasing returns to scale (IRS) or decreasing returns to scale (DRS), in the long run however, cocoyam farms must shift towards constant returns to scale (CRS) to be efficient in order to achieve the desired increase in cocoyam production in Nigeria.

3.2 Technical Efficiency

The frequency distribution of the technical efficiency estimates of cocoyam farmers is presented in Table 2. It was observed from the study that about 36%) of cocoyam had technical efficiency between 0.81 and less than 1.00. This implies is that reasonable percentage of cocoyam farmers were not technically efficient in the use of production resources. This maximum possible level attainable may be due to inefficiency and hence results to low productivity.

The average technical efficiency for the farmers was 0.619 implying that, on the average, the respondents are able to obtain about 62% of potential output from a given mixture of production inputs. This result suggests that the farmers are not utilizing their production resources efficiently Thus, in a short run, there is minimal scope (38%) of increasing the efficiency level, through better use of available production resources. This finding agrees with [16] that Nigerian rural farmers do not obtain maximum output from their given quantum of inputs.

Table 2. Technical efficiency estimates

Technical efficiency	Frequency	Percentage
<0.2	2	1.61
0.20-0.40	27	21.77
0.41-0.60	32	25.81
0.61-0.80	18	14.52
0.81-1.00	45	36.29
Total	124	100
Min	0.167	
Max	1.00	
Mean	0.619	

3.3 Allocative Efficiency

The result presented in Table 3 shows allocative efficiency of cocoyam farmers as obtained from the data envelopment analysis. It was observed from the study that (27.42%) of cocoyam farmers operated within an allocative efficiency of 0.2 to 0.4. This implies that majority of the respondents are not allocatively efficient in the use of production resources. This allocative inefficiency could be as a result of under-utilization of scarce resource and hence, reduced return to capital.

The average allocative efficiency for the farmers was 0.53 implying that, on the average, the respondents are able to obtain about 53% of potential allocative efficiency, It was observed from the study that 19% of the farmers had allocative efficiency (AE) of 0.81 and above while 19% of the farmers operated at less than 0.8 allocative efficiency levels. This result implies that cocoyam farmers are misallocating the resource in wrong proportions. In order words, about 81 percent of the respondents are allocatively inefficient in the study area. Through better utilization of resources in optimal proportions given their respective prices and given the current state of technology, cocoyam farmers could increase their allocative efficiency by 81 percent in the area This finding is in line with [17] who observed that the most allocatively inefficient farmer will have an efficiency gain of 89.6 percent in cocoyam production if he or she is to attain the efficiency level of most allocatively efficient farmer in the state. It also agrees with the findings of [16] that Nigerian rural farmers are not utilizing production inputs in the optimal proportions, given input prices.

Table 3. Allocative efficiency estimates

Allocative efficiency	Frequency	Percentage
<0.2	14	11.29
0.20-0.40	34	27.42
0.41-0.60	30	24.19
0.61-0.80	22	17.74
0.81-1.00	24	19.35
Total	124	100
Min	0.043	
Max	1.00	
Mean	0.503	

3.4 Economic Efficiency

The results in Table 4 revealed that (37.9%) of cocoyam farmers had economic efficiency of 0.029 and less than 0.2. This implies that larger proportion of cocoyam farmers are economically inefficient in the use of input (productive) resources. This inefficiency could stem from farmers inability to minimize cost or maximizing the potential profit.

However, the average economic efficiency of the cocoyam farmers was 34 percent. This indicates that cocoyam farms were economically inefficient. This implies that economic efficiency of cocoyam farmers could be increased by 66 percent in the area through efficient cost reduction. The study also suggest that for the average farmer in the study area to achieve economic efficiency of his most efficient counterpart, he could realize about 54 percent cost savings This agrees with the observation of [9] and [16] that Nigerian rural farmers are economically inefficient.

3.5 Factors Affecting Economic Efficiency of Cocoyam Producers

The result of the Ordinary Least Squares (OLS) regression estimates of the factors affecting the economic efficiency of cocoyam farmers are showed in Table 5. The R^2 adjusted of 0.43 indicates that 43 percent in the variability in economic efficiency of cocoyam farmers in the study area is explained by the explanatory variables specified in the model. The F statistics of 8.721 is statistically significant at 5% probability level and this indicates the joint significance of the specified variables on efficiency of cocoyam farmers suggesting that the model has a good explanatory power on the variation in the economic efficiency of cocoyam farmers. The factors that had significant influence on economic efficiency of cocoyam farmers in the study area were age, education, extension contact and credit while household size and cooperative membership were not statistically significant.

Table 4. Economic efficiency estimates

Economic efficiency	Frequency	Percentage
<0.2	47	37.9
0.20-0.40	39	31.46
0.41-0.60	14	11.29
0.61-0.80	8	6.45
0.81-1.00	16	12.90
Total	124	100
Min	0.029	
Max	1.00	
Mean	0.335	

The coefficient of age (0.005) was directly related to economic efficiency and statistically significant at 10% level of probability influencing the economic efficiency of cocoyam farmers. This implies that holding other factors constant, a unit increase with the age of cocoyam producers will increase their economic efficiency by magnitude of 0.005. This result disagrees with [18] who found out that age was not a significant determinant of economic efficiency but agrees with [19] who suggest that younger farmers tends to be inefficient than their older counterparts.

The coefficient of Education variable was found to be positive and significant at 1% level. The estimated coefficient of 0.081 implies that the efficiency of the cocoyam producers will increase by a magnitude of 0.081 as their level of education increases by one unit *ceteris paribus*. A plausible explanation for this result is that, increase in educational level of the farmers leads to higher rate of improved technology and techniques of production adoption. Also, educated farmers are likely to be more successful in gathering information and understanding new practices and the use of modern inputs which in turn will improve their economic efficiency. Hence, education is a very important policy tool that can be employed to enhance the economic efficiency of cocoyam production in the study area.

The coefficient of extension contact had the expected positive relationship with the economic efficiency of cocoyam farmers and was statistically significant at 10% level of probability. This implies that holding other factors constant, a unit increase in the Household size of certified cocoyam producers will increase their economic efficiency by magnitude of 0.057. This finding is at variance with the study of (20) who observed that extension contact enhance farm productivity and efficiency in his study of resources productivity in food crop farming in Northern area of Oyo State Nigeria.

Table 5. Factors influencing economic efficiency of cocoyam production

Variable	Coefficient	Standard error	t-value
Constant	0.092	0.097	0.953
Age	0.005	0.003	1.889*
Education	0.081	0.026	3.091***
Household size	0.005	0.004	1.474
Membership of cooperative society	-0.009	0.006	-1.458
Extension contact	0.057	0.030	1.933*
Credit	3.152E-6	0.000	2.041**
R^2	0.49		
R^2 Adjusted	0.43		
F-value	8.721**		

****P<0.01, **P<0.05 and *P<0.10*

The coefficient of Credit had the expected positive relationship with the economic efficiency of cocoyam farmers and was significant in at 5% probability level. The estimated coefficient of 3.152E-6 implies that the economic efficiency of the cocoyam farmers will increase by a magnitude of 7.352E-8 as the amount of credit obtained increases by one unit. This result agrees with that of [21] who reported that access to credit was significant in influencing the efficiency of cocoyam farmers in Ogun State, Nigeria.

4. CONCLUSION

Data envelopment analysis was employed on measurement of efficiency in cocoyam production, Kaduna State, Nigeria. Based on the findings of this study, it could be concluded that cocoyam farmers are economically inefficient having economic efficiency of 34%. Also, age, education, extension and amount of credit received were the factors influencing economic efficiency of the cocoyam producers in the study area.

5. RECOMMENDATIONS

Since cooperative membership was a significant determinant of economic efficiency, cocoyam farmers should join cooperative societies, to benefit from the government and non-governmental organization through increased credit access, input supply and farm advisory services. Also, the level of economic efficiency of some farmers was very low due to improper management of resources; it is therefore recommended that farmers should be trained and advised on proper and efficient utilization of resources (seed, farm size and labour) in order to improve their economic efficiency.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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