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Economic Efficiency of Rice Seed Multiplication among Beneficiaries of Saa/Ksadp in Kano State, Nigeria: A Stochastic Frontier Approach

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Abstract

The availability of high-quality and affordable rice seeds plays a critical role in improving rice productivity in Kano State. This study assessed the technical, allocative, and economic efficiency of rice seed multipliers involved in the Sasakawa Africa Association (SAA)/Kano State Agro-pastoral Development Project (KSADP) in Kano State, Nigeria. Data from 221 community-based rice seed producers were collected using structured questionnaires and analyzed using descriptive statistics and stochastic frontier analysis. The analysis revealed that the average age of respondents was 46.4 years, with an average household size of 10 persons and an average farming experience of 14.3 years. The majority of participants were male (94.57%) and married (96.83%). Age and household size were identified as crucial factors influencing technical efficiency, while marital status and years of experience significantly affected allocative efficiency. The mean efficiency scores were high: technical efficiency (0.975), allocative efficiency (1.48), and economic efficiency (1.19). These findings indicate that community-based rice seed multipliers operate efficiently. To further enhance their production capabilities and meet the increasing demand for quality and affordable rice seeds, it is recommended that these multipliers receive improved access to credit services.

Key words: *Efficiency, Seed Multiplication, Rice, Beneficiaries, Kano and Stochastic Frontier.*

Introduction

Rice (Oryza sativa) is the second most widely consumed cereal globally, after wheat, and is a crucial dietary staple providing over 80% of daily caloric intake for more than half of the world's population [1]. In Nigeria, rice is not only a staple food but also a significant source of energy and essential nutrients [2]. The increasing demand for rice is driven by population growth, urbanization, improved professional opportunities, and rising income levels [3]. Kano State, Nigeria's most populous state, significantly contributes to national rice production and is part of seven northwestern states responsible for about 72% of the country's rice production, amounting to approximately 2.8 million metric tonnes annually, with average yields of 3.72 tonnes per hectare in the wet season and 4.28 tonnes per hectare during the dry season [5]. Nevertheless, rice producers in Kano State face challenges in meeting local demand due to subsistence agriculture, traditional farming methods, limited investment, and low productivity per hectare [6]. The low rice productivity in Nigeria is often associated with poor access to or misuse of fertilizers and improved rice seed varieties, particularly in Kano State [7]. Initiatives aimed at increasing farmer access to agricultural technologies, such as improved seeds and fertilizers, have proven effective in enhancing productivity [8]. Seed quality is a critical factor in agricultural production systems [9].

Thus, community-based informal seed production has become increasingly popular as an alternative to formal seed industries because farmer-produced seeds are more accessible and affordable than certified seeds [10]. To ensure a steady supply of improved and affordable seeds, the Sasakawa Africa Association (SAA), through the Kano

Agro-pastoral Development Project (KSADP), trained rice farmers in community-based seed multiplication. Given the importance of efficient resource utilization in enhancing productivity, it is vital to evaluate the technical, allocative, and economic efficiencies of rice seed producers, especially given the limited literature on seed production efficiency in Kano State and Nigeria generally.

METHODOLOGY

Description of the Study Area

The survey area for this study is Kano State, Nigeria. Kano State covers an area of approximately 20,760 square kilometers, including about 1,754,200 hectares dedicated to agriculture and over 92,250 hectares of forest vegetation. The state has a projected population of 13,969,085, comprising 7,124,234 males and 6,844,852 females (NPC, 2021). Geographically, Kano State is situated between latitudes 10˚ 30´N and 13˚02´N and longitudes 8˚ 45´E and 12˚ 05´E. The climate features temperatures ranging from a low of about 14.2˚C in January to a peak of approximately 40.3˚C in April, the hottest month, and an annual rainfall averaging 617mm. Relative humidity reaches as high as 80% in August, decreasing to about 23% in December and January. The state predominantly employs two major agricultural systems: rainfed and irrigation farming. Kano State is bordered by Jigawa State to the north and east, Bauchi State to the southeast, Kaduna State to the southwest, and Katsina State to the northwest.

Sampling Technique

A multi-stage sampling technique was employed to select respondents, ensuring coverage across the areas served by the Sasakawa Africa Association (SAA) and consideration for gender representation. In the first stage, twenty-one Local Government Areas (LGAs) in Kano State were purposively selected based on the high concentration of SAA/Kano State Agro-pastoral Development Project (KSADP) beneficiaries. The selected LGAs included: Kura, Garunmallam, Tudunwada, Kumbotso, Gwarzo, Rogo, Danbatta, Kunchi, Tsanyawa, Dawakin Tofa, Bagwai, Kabo, Rimin Gado, Tofa, Minjibir, Ungoggo, Wudil, Warawa, Gezawa, Takai, and Sumaila. In the second stage, the sample frames were obtained from SAA and used to calculate the appropriate sample size for each selected LGA using the Raosoft sample size calculator at a 95% confidence level. In the third stage, simple random sampling was applied to select 221 respondents as the final sample size for this study.

Method of Data Collection

Structured questionnaires were designed to gather information on socio-economic characteristics of the SAA/KSADP beneficiaries (rice seed producers), their production costs, and the challenges they encountered. Data collection was conducted by enumerators trained specifically in administering these questionnaires, utilizing the Android-based data collection application, Kobocollect.

Analytical Techniques

Descriptive and inferential statistics were used to analyze the data for this study.

Descriptive statistics: descriptive statistics such as mean, frequency and percentage was used to describe the socioeconomic profile and the challenges faced by the rice seeds multipliers.

The Stochastic Frontier Production Model

This study adopted the models developed by Battese and Coelli [11] to achieve objectives of the study.

Technical Efficiency (TE) Function

The stochastic frontier production function was used to determine the technical efficiency of rice seeds multiplication among the beneficiaries of KSADP. It is specified implicitly as:

$Y_i - f(X_i, \beta) \exp (V_i - U_i)$............................i

Where:

Y_i = Quantity of rice seeds output (kg) of the i^{th} farm

X_i = Vector of input by the i^{th} farm

β = Vector of parameters to be estimated

V_i = Random error outside the farmer's control and

U_i = Technical inefficiency effects

The Stochastic Frontier Production Function (SFPF) specifying the technical efficiency in rice seeds multiplication in the study area is expressed explicitly as:

$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + (V_i - U_i)$ ii

Where:

In = Natural logarithm

Y = Output of rice (Kg /ha)

B_0 = Constant term

$\beta_1 - \beta_5$ = Regression coefficients

X_1 = Quantity of seed used (kg)

X_2 = Quantity of seed dress used (litres)

X_3 = Quantity of fertilizer used (kg)

X_4 = Quantity of herbicides used (litres)

X_5 = Quantity of pesticides used (litres)

X_6 = Total labour used in rice seeds production (man/days)

Vi = a random variable in production which accounts for the random variation in output by factors beyond the control of seeds multiplier.

Ui = deviation from maximum potential output due to technical inefficiency of the seeds multiplier.

Technical Efficiency (TE) refers to the ratio of actual output produced to the highest possible output achievable, known as frontier output. A TE value of 1 indicates that the farmer has achieved maximum feasible output, while a TE value of less than 1 indicates a gap between actual output and the potential frontier output. The closer the value is to 1, the more efficiently resources are utilized.

Allocative Efficiency

Allocative Efficiency (AE) describes the ability of farmers to make optimal input decisions, where the value of the marginal product of each input equals its cost, thereby maximizing economic returns [12]. To evaluate the allocative efficiency of rice seed multipliers, the stochastic frontier cost function approach was employed. It is formulated as follows:

$$LnCi = Ln\beta o + \beta_1 LnX_1 + \beta_2 LnX_2 + \beta_3 LnX_3 + \beta_4 LnX_4 + \beta_5 LnX_5 + Vi - Ui \quad .....ii$$

Where
Ln = natural logarithm
Ci = total cost of rice seeds multiplication (₦/Ha/Season)
X_1 = Cost of seed (₦/Kg/Ha)
X_2 = Cost of fertilizer (₦//Kg/Ha)
X_3 = Cost of seed dress (₦/L/Ha)
X_4 = Cost of herbicides (₦/L/Ha)
X_5 = Cost of pesticides (₦/L/Ha)
X_6 = Cost of labour (₦/man-day/Ha)
βo = intercept
$\beta_1 - \beta_5$ = vector of costs function of parameters to be estimated
Vi = a random variability in the cost of rice seeds multiplication that cannot be influenced by the producer
Ui = deviation from the cost frontier attributable to allocative inefficiency.

The Economic Efficiency

This is the product of technical efficiency (TE) and allocative efficiency (AE) of the individual rice seeds producer. Therefore, the economic efficiency is given as:

$$EE = TE \times AE \quad ....i$$
$$AE = EE / TE \ (0 < 1) \quad ....iv$$
$$TE = EE / AE \quad ....vi$$

The Technical Inefficiency Model

This study identified the determinants of seeds producer's technical inefficiency in terms of socio-economic variables of the multipliers. The model is specified as:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 \quad ...... vi$$

Where:i

-Ui = Technical inefficiency of the i^{th} farmer

δ_0 = Constant

$\delta_1 - \delta_6$ = Parameters to be estimated

Z_1 = Age of the respondents (years)

Z_2 = Gender (1 = Male, 2 = Female)

Z_3 = Marital status (1 = Single, 2 = Married)

Z_4 = Household size (number of persons)

Z_5 = Level of education (Nil = 0, Primary = 1, Secondary = 2, Tertiary = 3)

Z_6 = Years of experience (years)

It should be noted that, a negative inefficiency coefficient signifies a positive relationship with technical efficiency and vice-versa.

Figure 1: Photos snapped during training of enumerators and data collection

RESULTS AND DISCUSSION

Socioeconomic Characteristics of the Rice Seeds Farmers

The findings in Table 1 depict the socioeconomic characteristics of rice seed multipliers. Table 1 highlights that the largest proportion of beneficiaries are in the 42-51 age bracket (32.13%). The average age of the beneficiaries is 46.4 years, suggesting a predominance of middle-aged individuals in this enterprise. The majority (94.57%) of rice seed farmers in the crop component are male, with a smaller proportion being female (5.43%). The dominance of males in various agricultural activities is typical in Northern Nigeria.

Additionally, the results indicate that most beneficiaries are married (96.83%), while a smaller percentage are single (2.71%) or divorced (0.45%). It was found that a significant portion (39.82%) of farmers' households consist of 8-14 members, with an average of 10 persons, higher than the national average of 6. This suggests that rice seed producers in the study area typically have larger household sizes, which can provide family labor and potentially reduce production costs.

Furthermore, the data shows that the majority (50.68%) of beneficiaries have between 2-10 years of farming experience, with an average of 14.3 years.

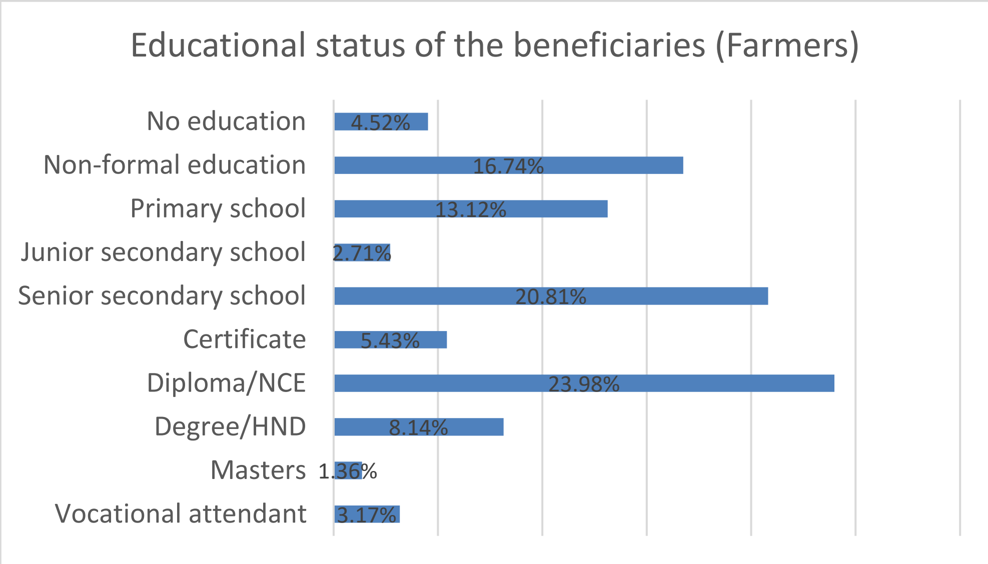

Figure 2: Educational status of the beneficiaries (Farmers)

The findings depicted in Figure 2 indicate that the majority (23.98%) of beneficiaries have obtained tertiary education (Diploma/NCE), while 20.81% possess a senior secondary school certificate and 13.17% have completed primary school. This suggests that the beneficiaries have a solid educational background that could facilitate their adoption of new agricultural techniques, potentially enhancing their productivity and profitability.

The maximum likelihood estimates (MLE) for the stochastic frontier production function are presented in Table 2, showing the estimates of the Cobb-Douglas stochastic frontier production function. The coefficient of elasticity with respect to the quantity of seeds is 0.413, which is positive and statistically significant at the 1% level. This indicates that a 1% increase in seed quantity would result in a 0.413% increase in rice output, assuming other inputs remain constant. This finding aligns with previous studies by Bichi [13] and Oyewo [14], highlighting the importance of seed quantity in enhancing farmers' technical efficiency in their respective study areas.

Similarly, the coefficient for fertilizer (0.107) is positive and statistically significant at the 1% level, suggesting that a 1% increase in fertilizer quantity would increase rice production by 0.107%, all else being equal. This finding is consistent with Bichi [13], who emphasized the role of fertilizer in improving technical efficiency among maize farmers in Kano state, Nigeria.

Conversely, the coefficient for seed dress (-0.015) is negative and not statistically significant, indicating that seed dress does not significantly affect technical efficiency among rice farmers in the study area. Herbicides, with a coefficient of 0.082, show a positive and significant impact at the 1% level, meaning that a 1% increase in herbicide use would lead to a 0.082% increase in rice yield, holding other factors constant. However, pesticides (-0.008) do not significantly affect technical efficiency, as indicated by their negative coefficient and lack of statistical significance at the 10% level.

Labor quantity, with a coefficient of 0.196 and significant at the 1% level, implies that a 1% increase in labor input would increase output by 0.196%, assuming other variables remain unchanged. This finding correlates with Aminu et al. [15], who observed a positive relationship between maize output and labor input among farmers in Ogun state, Nigeria.

Overall, the results highlight that seed quantity, fertilizer, herbicides, and labor are crucial factors contributing to improved technical efficiency in rice production in the study area.

The sigma square value (**δ**2) of 0.006 is statistically significant at the 1% level, indicating a good fit of the model's error term distribution. The estimated variance ratio (gamma, γ) of 0.468, significant at the 5% level, suggests that 46.8% of the variation in rice seed output among respondents is due to differences in technical efficiencies. This implies a potential 53.2% increase in rice seed production using current technology in the study area.

Table 2 also shows that coefficients for gender, marital status, and educational levels are positive but not statistically significant, suggesting these socio-economic variables do not significantly affect technical inefficiency among rice seed farmers in the study area. Age (-0.004) and household size (-0.010) have negative coefficients that are statistically significant at the 10% level, indicating that increasing age and household size by 10% would decrease technical inefficiency by 0.004% and 0.01%, respectively. This underscores the importance of age and household size in improving technical efficiency among rice seed farmers, consistent with findings by Aminu et al. [15] and Abdullai et al. [16] in their respective studies on maize and rice production.

Lastly, the likelihood ratio test (LR test) value of 40.6, exceeding the critical chi-square value of 14.325, confirms the presence of technical inefficiency among farmers in the study area.

Cost efficiency estimation

The cost function can be utilized to predict both technical and allocative efficiency simultaneously for a firm, as noted by Battese and Coelli [11]. The results from employing the Cobb-Douglas stochastic frontier cost function in this study to estimate allocative efficiency are presented in Table 3. Some coefficients in the cost function model exhibit expected signs, while others diverge from prior expectations.

For instance, the coefficient for the cost of renting a hectare of seeds (0.414) is positive and statistically significant at the 1% level, indicating that a 1% increase in seed costs would lead to a proportional increase in total production costs by 0.414%. Similarly, the coefficients for the costs of fertilizer (0.187), herbicides (0.037), and labor (0.040) are positive and statistically significant at 1%, suggesting that a 1% increase in these costs would result in respective increases in total production costs by 0.187%, 0.037%, and 0.040%. This underscores the significant role of seed, fertilizer, herbicide, and labor costs in total rice production costs in the study area.

In contrast, the coefficient for the cost of pesticides (-0.029) is negative and statistically significant at 1%, indicating that a 1% increase in pesticide costs would decrease cost efficiency by 0.029% among farmers in the study area.

The variance ratio (gamma, γ) is 1.00 and statistically significant at the 1% level, indicating that 100% of the variation in total production costs among rice farmers in the study area is attributable to cost inefficiencies. However, the value of sigma squared ($\delta 2$) is 0.004 and not statistically significant at the 10% level, suggesting that allocative efficiency plays a minimal role (0.4%) in the variability of revenue from rice production practices in the study area, with the remaining 99.6% attributed to random noise.

From the inefficiency model, it is evident that coefficients of marital status (-0.090) and years of experience (-0.001) are negative and statistically significant at 1%, indicating that these factors are crucial socio-economic variables that reduce cost inefficiencies among farmers in the study area. Gender (-0.029) and household size (-0.001) also show negative coefficients, though they are not statistically significant, suggesting they contribute to reducing cost inefficiency among rice farmers.

Conversely, age (0.001) and education levels (0.002) have positive coefficients that are not statistically significant at 10%, implying that younger age and lower education levels increase cost inefficiency among rice seed farmers in the study area.

Lastly, the likelihood ratio test (LR test) value of 24.528, exceeding the critical chi-square value of 14.325 as noted by Kodde and Palm [17], confirms the presence of cost inefficiency among rice farmers in the study area.

Summary of technical, allocative and economic efficiencies

The summary of technical efficiency (TE), allocative efficiency (AE), and economic efficiency (EE) scores for the sampled farmers is presented in Table 4.

The summary of TE in Table 4 indicates that the least technically efficient farmer achieved a TE score of 0.8198, while the most technically efficient farmer scored 0.9940, with a mean TE of 0.9753. This average TE of 0.9753 suggests that, on average, the sampled farmers were 97.53% technically efficient. This indicates there is potential to increase rice production by 2.47% with current technology.

In terms of AE, the least allocatively efficient farmer had an AE score of 1.0108, while the best farmer achieved 1.4794, with a mean AE of 1.4794.

Regarding EE, the least economically efficient farmer scored 0.8286, the best economically efficient farmer achieved 1.4689, and the mean EE was 1.1972. This suggests that rice seed producers generally demonstrate economic efficiency, likely attributed to their training in good agronomic practices and access to high-quality inputs.

CONCLUSION AND RECOMMENDATIONS

Based on the findings of this survey, it can be deduced that most of the beneficiaries (rice seed multipliers) were young, married, had formal education, but the distribution across gender was biased. Age and household size emerged as significant factors influencing the technical efficiency of rice seed producers. Marital status and years of experience were found to be determinants of allocative efficiency among rice seed multiplication farmers. Overall, rice seed farmers demonstrated high levels of technical, allocative, and economic efficiency.

To enhance production, it is recommended that rice seed farmers be connected with financial institutions to access credit for scaling up their operations. Additionally, efforts should be made to promote gender equality in rice seed production practices.

Acknowledgement

We express gratitude to Sasakawa Africa Association (SAA) and the Kano Agro-Pastoral Development Project (KSADP) for their invaluable training provided to farmers and agribusiness enterprises in Kano State, and for their support in conducting this survey. We also acknowledge the assistance of SAA extension agents during the data collection process, as well as the cooperation of the beneficiaries involved.

Conflict of interest

There is no conflict of interest among the authors in all that is reported in this work and also there is absence of financial or personal relationship that would appear as a potential conflict.

Table1: Socioeconomic Characteristics of the Rice Seeds Farmers

Variable	Category	Frequency	Percentage	Mean
Age of the beneficiaries				
	22 – 31	14	6.33	46.4
	32 – 41	62	28.05	
	42 – 51	71	32.13	
	52 – 61	65	29.41	
	62 – 71	9	4.07	
Gender of the beneficiaries				
	Male	209	94.57	
	Female	12	5.43	
Marital status of the beneficiaries				
	Single	6	2.71	
	Married	214	96.83	
	Divorced	1	0.45	
Household size of the beneficiaries				
	1 – 7	79	35.75	10
	8 – 14	88	39.82	
	15 – 21	44	19.91	
	22 – 28	8	3.62	
	29 – 35	2	0.92	
Years of farming experience				
	2 – 10	112	50.68	14.3
	11 – 19	19	16.74	
	20 – 28	28	20.36	
	29 – 37	37	9.50	
	38 – 46	46	2.71	
Total		**221**	**100**	

Source: Survey Data, 2023.

Table 2: Maximum Likelihood Estimates for Frontier Production Function

Variables	coefficient	standard-error	t-ratio
beta 0	4.768	0.328	14.550
QTY_Seeds	0.413	0.031	13.177***
QTY_Fertilizer	0.107	0.017	6.181***
QTY_Seed dress	-0.015	0.010	-1.513
QTY_Herbicides	0.082	0.015	5.519***
QTY_Pesticides	-0.008	0.013	-0.591
QTY_Labour	0.196	0.071	2.769***
delta 0	-0.364	0.268	-1.354
Age	-0.004	0.002	-1.674*
Gender	0.130	0.093	1.396
Marital status	0.079	0.167	0.472
Household size	-0.010	0.006	-1.639*
Educational level	0.004	0.007	0.614
Years of Experience	0.014	0.004	3.831***
sigma-squared	0.006	0.002	3.354***
Gamma	0.468	0.191	2.452**
log likelihood function	104330000.000		
LR test	40.6		

Source: Frontier 4.1c Analysis, *** Sig. at 1% level, ** Sig. at 5% level, * Sig. at 10% level

Table 3: Maximum Likelihood Estimate of Frontier Cost Function

Variable	Coefficient	standard-error	t-ratio
beta 0	6.778	0.240	28.221
Cost of seeds	0.414	0.030	13.707***
Cost of Fert.	0.187	0.016	11.580***
Cost of Seed dress	0.001	0.012	0.051
Cost of Herbicides	0.037	0.011	3.325***
Cost of Pesticides	-0.029	0.010	-2.967***
Labour Cost	0.040	0.014	2.736***
delta 0	0.390	0.095	4.104***
Age	0.001	0.001	1.389
Gender	-0.027	0.019	-1.449
Marital status	-0.090	0.031	-2.920***
Household size	-0.001	0.001	-1.093
Educational level	0.002	0.002	0.923
Years of Experience	-0.001	0.001	-2.115**
sigma-squared	0.004	0.000	12.232***
Gamma	1.000	0.943	1.061
log likelihood function	328.705		
LR test	24.528		

Source: Frontier 4.1c Analysis, *** Sig. at 1% level, ** Sig. at 5% level, * Sig. at 10% level

Table: 4 Summary of TE, AE and EE of Rice Seeds Multiplication Farmers

Variable	Minimum	Maximum	Mean	Number of Obs
Technical Efficiency	0.8198	0.9940	0.9753	221
Allocative Efficiency	1.0108	1.4794	1.4794	221
Economic Efficiency	0.8286	1.4689	1.1972	221

Source: Frontier 4.1c Analysis

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