



TECHNICAL EFFICIENCY OF UPLAND RICE FARMERS IN MAKURDI LOCAL GOVERNMENT AREA OF BENUE STATE, NIGERIA USING A STOCHASTIC FRONTIER MODEL

¹Ogah, O. M., ¹Torlamen, T. R. and ²Benjamin, B.

¹Department of Agricultural Economics, Joseph Sarwuan Tarka University Makurdi, Nigeria (Formerly Federal University of Agriculture Makurdi, Nigeria)

²Department of Agricultural Technology, Samaru Katagf Campus, Nuhu Bamalli Polytechnic, Zaria Nigeria.

Corresponding Author's Email: odehy.ogah@uam.edu.ng, **GSM:** +234 8023738827

ABSTRACT

The study examined efficient utilization of resources for upland rice production in Benue State, Nigeria. A three-stage multi stage random sampling technique was used to select 120 respondents for the study. Data was obtained from primary source with the use of well-structured questionnaire and analysed using stochastic production frontier. Results showed the variance parameter sigma squared (δ^2) to be 0.1375, significant at the 1% level, suggesting a possible degree of inefficiency among the upland rice growers. Increased use of fertilizer (0.001985) and seed (0.06299) will enhance rice yield, according to the elasticity coefficient, which showed that both parameters were positive and significant at the 1% and 5% levels, respectively. Age (-0.7153), household size (0.4212), and credit availability (-0.123) all had negative coefficients and significant effects on technical efficiency results at 5% and 1% level respectively; these variables increase farmer's technical efficiency and decreases technical inefficiency. The mean technical efficiency was 84%. The study concludes that farmers were operating below the frontiers and recommend provision of credit to farmers to stimulate their efficiency, inputs like improved rice seeds and fertilizer should be made available to the farmers at subsidized rate, policies to encourage farmer's participation in rice farming should be deployed.

Keywords: Analysis, Efficiency, Farmers, Upland, Rice, Stochastic,

INTRODUCTION

Rice is a major staple crop produced in Nigeria and remains a staple food for over half of the world's population (Ndubueze-Ogaraku & Ogbonna, 2016) Rice protein contains high lysine and amino acid, it is important in making beer, rice wine and vinegar (Ndubueze-Ogaraku & Ogbonna, 2016) Rice is a key source of carbohydrates, minerals, and vitamins that provide essential energy and nutrients. It is a significant source of carbohydrate, mineral and vitamins which provide energy to the body. Rice is a unique crop grown virtually all over in Nigeria because it requires a broad temperature range throughout growth, from 20°C to 30°C, and an extended time of sunshine. Rice is best grown in lands with moderately high-water holding capacity. Heavy and muddy soil that can hold water are most desirable. Upland rice can be found in a range of environment from low-lying valley bottom to steep sloping land with high runoff where land preparation and sowing is done under conditions as direct sowing. Economic efficiency is the choice of the best alternative combination for a particular level input which is determined by both input and output prices (Ojo, 2012). A firm is said to be technically efficient if it uses the fewest possible inputs to generate a given output or produces the most from a given set of inputs (such as labor, capital, and materials). Allocative efficiency is attained when resources are distributed where they are most valued and the combination of goods and services generated reflects what customers most want. This happens when Price = Marginal Cost ($P = MC$). Economic efficiency arises when products and services are created according to customer demands (allocative efficiency) and no resources are wasted (technical efficiency). Economic efficiency is equal to both technical and allocation efficiency.

Technical efficiency measures a farmer's ability to maximize output with available technology, while allocative efficiency aims to capture a farmer's ability to apply inputs in the best possible proportions with the appropriate technology. Economic efficiency is a situation where technical



efficiency and allocative efficiency are combined. Technical efficiency is concerned with how efficiently inputs are combined to produce output (Boateng, 2014). It is measure as ratio of the production from real to potential (Donkoh *et al.*, 2013). It is the farm's actual output divided by its maximum frontier output for a specific level of inputs and chosen technology (Amanza and Maurice, 2005). An efficient producer is one who produces the maximum possible output given a set of inputs or one who uses the least inputs in producing a given output. The efficiency must be obtained in order to assess the efficiency of upland rice growers in the area. Obayelu, *et al* (2013) opined that land is fixed in supply; we cannot expand the supply of land but can improve on our production technique so as to produce more output from the same quantity of input. Existing low level of productivity in upland rice farming reflect low level of technical, allocative and economic efficiencies. Therefore, increasing agricultural growth is an indication of appreciable growth in agricultural production process that is linked to farm profit (Ogundari, 2006).

The concept of efficiency is founded on the economic theory of production. Efficiency refers to the extent of utilization of resources. It is the relationship between what an organization (producer, production unit or any decision-making unit) produces and what it could feasibly produce, under the assumption of full utilization of the resources available (Garcia Del Hoyo *et al*, (2004). Efficiency is the degree of success which producers achieve in allocating the available inputs and the product they generate in order to reach their aims which is to attain a high degree of efficiency in cost, revenue or profit. The ability of a farmer to produce at their highest level is known as technical efficiency from a given bundle of inputs. According to Battese and Coelli (1995), technical efficiency of a given firm (at a given time period) is the ratio of its mean production (conditional on its level of factor inputs and firm effects) to the corresponding mean production, if the firm utilized inputs most efficiently. The production frontier is therefore the the highest output that can be achieved with a specific set of inputs and current production technology. Various research have been carried out by various researchers on technical efficiency, example, Woretaw & Kumar (2023) analysed the technical efficiency of large scale agricultural investment in Northwest Ethiopia using a Stochastic Frontier Approach and noted that the farmers were not efficient with a mean technical efficiency of 71.7%, Ndubueze-Ogaraku & Ogbonna (2016) analysed technical efficiency and its determinants in rice production, evidence from Abia state, Nigeria and discovered that the rice farmers were not technically efficient with a mean technical efficiency of 83%, Keghter *et al* (2023) carried out a study on the profitability and technical efficiency analysis of rice production in Quan' Pan Local Government area of Plateau State, Nigeria and noted that rice farmers were technically inefficient.

Kusumaningish, (2023) analysed Indonesian mobile phone usage and rice farming's technical efficiency: a stochastic frontier analysis. This study attempts to fill the vacuum in the literature regarding resource use efficiency by upland rice growers, which is either very minimal or nonexistent. Assessing the technological efficiency of rice producers in the uplands and describing their socioeconomic characteristics served as the study's guiding goals. It was hypothesized that the highland rice growers are technically inefficient. The theory that backed this work is the production theory and it concerns itself with the problems of combination of various inputs given the state of technology in order to produce a stipulated output. The technological relationship between input and output is known as production function. The production function shows how and to what extent output changes with variation in inputs during a specified period of time.

MATERIALS AND METHOD

The research was conducted Makurdi Local Government Area, in Benue State, Nigeria which is known for its strong agricultural base, as farming is the primary occupation of its inhabitants. The State lies between longitudes 6^o 35'E and 10^o E and between latitudes 6^o 30'N and 8^o 10'N with an average temperature of 32.5°C.

It has an estimated population of 494,000 (NPC, 2006) being population projection as at 2025 and covers an area of 33,955 km². It experiences a typical climate with two distinct seasons, rainy season, which lasts between April and October and the dry season, which lasts from November to March and is distinguished by harmattan dry winds. The vegetation is characterized by open wood land with



tall trees as well usually with short bold and broad leaves. The trees are about 12-17m tall and are rarely up to 27m or over 30m (Chia *et al*, 2014).

The people are predominantly farmers who engage in agriculture and grow wide range of crops like yam, maize, sorghum, cassava, sweet potatoes, rice soybeans etc.

The population of the study consists of all upland rice farmers in Makurdi Local Government Area. A three-stage sampling method was used in selecting respondents. Four council wards that are known for upland rice farming, Mbalagh, Agan, Bar, and Modern Market, were purposefully chosen in the first stage. Two communities from each council ward were purposefully chosen in the second stage based on the volume of upland rice production. In the last phase, 15 respondents were selected from each of the communities making a total of 120 respondents. The sample size was premised on lean financial resources, time constraint and to allow for detail analysis. A well-structured questionnaire was used to elicit information in accordance with the research objectives.

The data collected were analysed using inferential statistics (stochastic production frontier). The choice of stochastic production frontier was premised on the fact that it is made of two error components: the normal error term and error due to technical inefficiency, thus noise and random errors are taken into account. Again, it is more accurate compared to deterministic frontier models as it is unrealistic for deterministic models to assume that all departures from the frontiers are caused by inefficiency.

The variables used in the study were measured as follows: sex: was measured as a dummy 1= male and 0= female.

Age, this is how long a respondent had been alive. The number of years the respondent had really lived at the time of the survey was used to calculate their age. Education: Respondents' educational attainment was measured by the length of time they attended formal school. Household size is the total number of people living in a household and eating from the same pot. Farming experience was measured in years. Contact with extension agents was measured according to is the number of times a farmer has met with an extension agent in a year. annual income is the total money earned in a year, and it was measured in naira (₦). Farm size is the total land area cultivated by the farmer; it was measured in hectares (Ha). Marital status was measured as (Married=1, Single=0 and Divorce or separated =2). Quantity of herbicides was measured in litres (L), Fertilizer was measured in kilogram (Kg).

Model Specification

The stochastic frontier model by Cobb and Douglas

For the Cobb-Douglas production function, the maximum likelihood estimates of the parameters were calculated using the Frontier 4.1 statistical software, which was created by Battese & Coelli (1995). This method incorporates the hypothesized determinants of efficiency into the inefficient error components. The function is specified as follows:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_5 \ln X_{5i} + (v_i - u_i) \quad \dots(1)$$

$$v_i \sim N(0, \sigma^2_v)$$

Where:

Ln=Natural logarithm

Y_i=Quantity of rice output (kg)

X₁= Farm size cultivated (ha)

X₂=Amount of seed utilized (kg)

X₃= Inputs of labour (mandays)

X₄= Amount of fertilizer (kg)

X₅= Quantity of herbicides (litres)

V_i= Error term which is a free variable

U_i= Error term, which refers to technical inefficiency effect or non-random variables

β₀= Intercept

The coefficients are β₁. β₅

The socioeconomic traits of farmers which are the causes of the technological inefficiency model is defined by U_i=δ₀+ δ₁Z₁+ δ₂Z₂+ δ₃Z₃+ δ₄Z₄ + δ₅Z₅+ δ₆Z₆+ δ₇Z₇+e_i ... (2)



Where:

$|u_i|$ = inefficiency of *ith* farmer, δ_0 = constant, δ_i, δ_7 = parameters to be estimated

$u_i = u_i \sim N^+(0, \sigma^2_u)$

The z_1, \dots, z_7 are the independent variables specified as farm and farmer-specific variables

Z_1 = Age of respondents (years)

Z_2 = Educational attainment (years)

Z_3 = Farming experience (years)

Z_4 = Households size (number)

Z_5 = Extension contact (number)

Z_6 = Cooperative membership (dummy = 1 if member, and 0 otherwise)

Z_7 = Credit access (1= access and 0 otherwise)

RESULTS AND DISCUSSION

Properties of the Stochastic Frontier Function's Parameters

The model under consideration was estimated using the maximum likelihood method utilizing Frontier software, which Battese & Coelli developed in 1995. Table 1 displays the ML estimates and inefficiency determinants of the designated frontier. The estimate of gamma, which goes from 0 to 1, represents the degree of inefficiency in the variable parameter. The amount of variation brought about by the upland rice producers' technological inefficiency is what the gamma estimate indicates. The results show the estimated gamma parameter (γ) is small (0.3018) and considerably different from zero according to Table 1. This suggests that the primary cause of the farmer's yield deviating from the maximum output is variations in the application of differences in the use of best practice as opposed to random variability. That is 30% of the variation in output among upland rice farmers is due to inefficiency on the part of the management of resources.

Furthermore the estimate of the variance parameter sigma squared (δ) is 0.1375. This is significant at 1% level, suggesting that the farmers' socioeconomic traits contribute to a certain amount of inefficiency; as a result, the traditional production function does not adequately describe the data. The findings of the diagnostic statistics, which assess the applicability of the stochastic frontier production function using the Maximum Likelihood Estimator (MLE), demonstrate that inefficiencies are pervasive and affect the output of the upland rice growers in the study region. Based on the results, the estimated seed coefficient was 0.06299, indicating a favorable and, at the 10% probability level, statistically significant outcome. Consequently, an increase of 1% in seed usage will yield a 6% rise in the production of upland rice. The significance of seed is however due to the fact that production is mostly determined by the seed. This result is in line with that of Dzhmirze *et al.* (2020), who found that seeds have a favorable and significant impact on rice production in Russia. Owombo *et al.* (2024) also observed that seeds boost maize production in Ondo state, Nigeria. At the 5% level, the fertilizer coefficient was substantial and favorable. This shows that upland rice farmers would increase productivity if they used fertilizer more and appropriately. This agrees with the findings of Owombo *et al.* (2024) and Abdulkadir (2015).

The Technical Inefficiency of Upland Rice Farmers

The variables' coefficients that are part of the inefficiency model explain the difference among the efficiency level of individual farms. A positively signed independent variable of inefficiency function increases the inefficiency factor and as such reduces technical efficiency. Conversely, a negatively signed coefficient of independent variable of inefficiency function reduces inefficiency value and increases technical efficiency. The results of the inefficiency effects model are presented on the lower part of Table 1. From the results, the coefficient of age is negative (-0.7153) and significant at 10%. This means that age decreases technical inefficiency and increases technical efficiency. This study agrees with Obayelu *et al.*, (2013) who reported reduction in efficiency as farmers aged. The household size coefficient (-0.4212) in Table 1 is negative and significant at 5% level meaning that increase in household size increases technical efficiency of upland rice farmers. This is traceable to household contribution to the supply of family labour for work on the farm. This collaborates the findings of Arthi and Fenske, (2016). This also implies that there is specialization among the labourers and work will be



done efficiently. This finding is in agreement with Ukwuru and Egbonu (2013); who found that large household sizes in some cases are advantageous because labour may be easy to get at affordable rates, hence an increase in output Access to credit has negative coefficient (-0.123) and is significant at the 5% probability level, indicating that loan availability will boost technological efficiency and reduce technical inefficiency.

Table 1 Estimates of Maximum Likelihood of the Stochastic Production Function Frontier of Upland Rice Farmers

Variable	Parameter	Coefficient	T-value
Constant	β_0	6.0426	11.18***
Farm size (ha)	β_1	-0.03797	-0.554
Quantity of seed (kg)	β_2	0.06299	8.416***
Labour (mandays)	β_3	0.1921	1.4996
Fertilizer(kg)	β_4	0.00198	2.100**
Herbicides(kg)	β_5	-0.01429	-0.101
Inefficiency Model			
Constant	δ_0	3.3799	2.732**
Age(years)	δ_1	-0.7153	-1.831*
Household size	δ_2	-0.4212	-2.486**
Educational level	δ_3	0.1714	-2.1297**
Access to credit	δ_4	-0.123	-2.439**
Farming exp (years)	δ_5	.03103	1.4996
Sigma-squared	δ_6	0.1375	3.537***
Gamma	Γ	0.3018	1.1977 β
Log-likelihood function		-32.166	
LR=		18.38	

*, **, *** indicates coefficient significant at 1%, 5% and 10% levels of probability respectively.

Source: Field survey, 2024

Analysis of Technical Efficiency

As indicated in Table 2, the distribution of technical efficiency among upland rice producers showed significant differences in estimated technical efficiency, ranging from 0.40 to 0.94. According to the indices, every farmer was functioning below the production function's minimum frontier with the average efficiency level equal to 0.84. This show that most farmers were generally and relatively efficient but there is still some levels of inefficiencies hence the need for improvement and room to increase production capacity at a given input mix. Izeke & Alufohai, (2014) have noted that yam farmers in Edo state, Nigeria were inefficient in the use of inputs. Zekeri & Tijani, (2013) have also noted that groundnut farmers in Ringim, Jigawa state were underutilizing some inputs like seed, hired labour and family labour. As shown in Table 2, majority (58%) of the farmers have efficiency level of between 80 and 89. The maximum efficiency was 0.98 while the least efficiency was 0.41. Based on this, the null hypothesis is therefore accepted.

Table 2: Distribution of Upland Rice Farmers' Technical Efficiency by Frequency

Variation in Technical Efficiency	Frequency	Percentage
0.40-0.49	2	2
0.50-0.59	3	3
0.60-0.69	10	10
0.70-0.79	15	15
0.80-0.89	58	58
0.91-1.00	12	12
Mean	0.843	
Minimum	0.41	
Maximum	0.98	
Std Deviation	0.125	

Source: Field survey, 2024



CONCLUSION AND RECOMMENDATIONS

The study revealed that the upland rice farmers' technical efficiency was low, and farmers were not technically efficient with the most efficient farmers above average and least efficient farmer below average. The primary factors influencing the upland rice producers' efficiency are age, education, access to credit and household size. The study recommends provision of credit at a single digit interest to upland rice farmers to stimulate their efficiency, inputs like improved rice seeds and fertilizer should be made available to the farmers at subsidized rate, policy to enable women folks have access to inputs and credit so as to go into rice production should be deployed. The need for motivation of extension workers and improvement on information dissemination through extension agent is highly recommended as most of the farmers do not have access to extension agents.

REFERENCES

- Abdulkadir, K.O., (2015) An Evaluation of the efficiency of onion producing farmers in irrigated agriculture, empirical evidence from Kobo district Amhara region, Ethiopia. *International journal of agricultural extension and rural development* **2**(5): 116-124.
- Amanza, P.S. & Maurice, D.C., (2005) Identification of factors that influence technical efficiency in rice-based production systems in Nigeria, paper presented at workshop on policies and strategies for promoting rice production and food security in sub-saharan Africa: 7-9 November, 2005, Cotonou, Benin Republic.
- Arthi, V., & Fenske, J., (2016) Intra-household labour allocation in colonial Nigeria, exploration in economic history **60**: 69-92 <https://doi.org/10.1016/j.eeh.2015.11.003>
- Battese, G.E., and Coelli, T.J. (1995) A model for technical inefficiency effects in a stochastic frontier production function for panel data, empirical economics. **20**: 325-332 <https://link.springer.com> > empirical economics
- Boateng, N.A., (2014) Technical efficiency and primary education in South Africa, evidence from sub-national level analyses *South African journal of education*, **34**(2): 1-18 <http://www.scielo.org.za> > scielo > pid=S0256-010020.
- Chia, V.D., Ijir, S.T., Iwar, R., & Ndule, E. L., (2014) The contending issues of domestic water supply in Makurdi metropolis, Benue state, Nigeria **6**(9): 89-90.
- Donkoh, S.A. Ayambila, S. & Abdullahi, S., (2013) Technical efficiency of rice production at the Tono-irrigation scheme in Northern Ghana, *American journal of experimental agriculture* **3**(1): 25-42.
- Dzhamirze, R. R. Ostapenko, N. V. Garkusha, S.V., & Chinchenko, N.N.,(2020) Problems of primary seed production of Some rice varieties IOP conf. series: earth and environmental science 421 (2020) 082028 IOP Publishing pp 1-11 doi:10.1088/1755-1315/421/8/082028
- Garcia del Hoyo, J.J., Castilla Espino, D., & Jimenez Toribio, R., (2004). Determination of technical efficiency of fisheries by stochastic frontier models. A case on the gulf of Cadiz (Spain) *ICES Journal of marine science*, **61**: 416-421. <https://doi.org/10.1016/j.icesjms.2004.02.003>
- Izekor, O.B. & Alufohai G.O (2014). Production elasticities, return to scale and allocative efficiency in yam production in Edo state, Nigeria. *Agrosearch*, **14**(2): 179-190. <https://dx.doi.org/10.4314/agrosh.v14i2.8>
- Keghter, V. S., Malel, M. F., Birma, J., Tijesu, O. G., Musa, S. P., Blessing, O., & Nandom, M. (2023). Profitability and technical efficiency analysis of rice production in Quan' Pan local government area of Plateau state, Nigeria. *Turkish journal of agriculture - food science and technology*, **11**(6): 1096-1105. <https://doi.org/10.24925/turjaf.v11i6.1096-1105.5827>
- Kusumaningsih, N.(2023) The technical efficiency of rice farming and mobile phone usage: a stochastic frontier analysis *Food research*, **7**(1): 93 – 103. <https://www.myfoodresearch.com>
- Ndubueze-Ogaraku, M.E & Ogbonna, M.C. (2016) Analysis of technical efficiency and its determinants in rice production, evidence from Abia state, Nigeria, *Nigerian agricultural policy research journal*, **1**(1): 1-14.
- NPC, (2006) National Population Commission. Population Census Statistics, Abuja, Nigeria



- Obayelu, A.E., Afolami, C.A., & Abonlahor, M.U., (2013) Comparative analysis of resource use efficiency among various production scale operators in cassava based- mixed cropping system of Ogun and Oyo states of south west, Nigeria pp 2-6.
- Ogundari, K., (2006) Determinants of profit efficiency among small-scale rice farmers in Nigeria, a profit function approach, a paper presented at the international association of agricultural economists annual meeting, 12th to 18th August, 2006 Queensland, Australia.
- Ojo, C.O. (2012) Technical efficiency of rural women farmers in Borno state, Nigeria. *developing countries studies*, 2:61-61 <http://www.iiste.org/>
- Owombo, P. T., Ibidapo, I. & Ariyo, A. C.(2024) Resource use efficiency and returns to scale in maize production in Ondo State, Nigeria *Agrosearch*, **22**(2): 41-49. <https://dx.doi.org/10.4314/agroshv22i2.4>
- Ukwuru, M. U. & Egbonu, S. E. (2013) Recent development in cassava-based products research, *Academic Journal of food research*, **1**(1): 1-13. DOI: <http://dx.doi.org/10.15413/ajfr.2012.0105>
- Woretaw, M.W&Kumar, R(2023) The technical analysis of large scale agricultural investment in northwest Ethiopia using a stochastic frontier approach, *Heliyon* 9(2023) el 9572 1-10 [doi.org/10.1016/j.heliyon.2023 el 9572](https://doi.org/10.1016/j.heliyon.2023.el.9572)
- Zekeri, M. & Tijjani, I. (2013). Resource use efficiency of groundnut production in Ringim local Government area of Jigawa state, Nigeria. *Agrosearch*, **13**(2): 42-50. <https://dx.doi.org/10.4314/agroshv13i2.5>