



**ANALYSIS OF PRODUCTION EFFICIENCY OF SMALLHOLDER RICE FARMERS IN
BAUCHI STATE, NIGERIA**

Zailani, A. A., Oladimeji, Y. U., Makama, S. A. and Sani, A. A.

Institute for Agricultural Research / Faculty of Agriculture,

Department of Agricultural Economics, Ahmadu Bello University, Nigeria

***Corresponding Author's Email:** yusuf.dimeji@yahoo.com, **GSM:** 08032220000,

ABSTRACT

The study analysed production efficiency of smallholder rice farmers in Bauchi state, Nigeria. Two stage sampling procedure were used to 222 rice farmers from the study area. Data were collected through face-to-face interviews with the use of structure questionnaires. The analytical techniques involved combination of descriptive statistics, and stochastic frontier production analysis. The findings indicated that rice farmers in the study area had an average age of 37 years with the average households' size of 8 members. Majority (63.06 %) of the rice farmers attended at least primary education with the average literacy level of nine years of schooling. The mean farm size was 1.53 hectares and majority (62.61 %) of the farmers had no contact with the extension agent during the cropping season. The study found that 62.61 % of the rice farmers did not belong to any form of associations with the mean membership of 5 years. The mean rice farming experience was 16 years with 34.68 % of the farmers found between 1-10 years. The findings of the study inferred that the mean technical, allocative and economic efficiency of the rice farmers were 54.2 %, 94.7 %, and 51.2 %, respectively, indicating the level of production inefficiency of the rice farmers in the study area. The stochastic frontier production function model results showed that estimated coefficients of farm size ($\beta = 0.279$; $P < 0.01$), seed input ($\beta = 0.605$; $P < 0.01$), fertilizer ($\beta = 0.110$; $P < 0.01$), labour ($\beta = 0.097$, $P < 0.01$) and agrochemical ($\beta = 0.392$; $P < 0.05$) were positive and statistically significant determinants of rice producers. The inefficiency result shows that the estimated coefficients of age ($\beta = 0.561$; $P < 0.05$), household size ($\beta = -0.933$; $P < 0.05$), year of schooling ($\beta = -0.762$; $P < 0.05$), amount of credit received ($\beta = -0.321$; $P < 0.05$) were found to be statistically significant determining inefficiency model. The study recommended that farmers should adopt cost-effective agricultural practices. This may involve exploring alternative, more affordable inputs, negotiating bulk purchase discounts with suppliers or participating in cooperative buying initiatives.

Keywords: Production, Efficiency, Rice and Smallholder.

INTRODUCTION

A key feature is the variability in productivity across regions as biophysical constraints impact farmers' operations (Ogaji *et al.*, 2024). Measuring technical efficiency provides valuable insights into the competitiveness of farms and their ability to increase crop yield given available resources and technological advances (Subedi *et al.*, 2020). Production efficiency refers to how effectively a farm or agricultural enterprise utilizes inputs (such as land, labour and capital) to produce outputs (such as crops or livestock). It deals with maximizing output from available resources or minimizing the resources needed to achieved a specific output level. It influences agricultural production directly by increasing available food sources and indirectly by raising income of the farming household. The production efficiency of rice farmers is often influenced by exogenous variables that characterize the environment in which the production takes place, such as factors affecting production efficiency and inefficiency (Ogaji *et al.*, 2024). In Nigeria as everywhere else, given a number of hazards over which rice farmers have no control (climatic hazard for example), they cannot know with certainty the quantities of rice they will be able to produce. According to the Subedi *et al.* (2020), rice farmers in Nigeria produce below the national average ($3\text{t/ha} < 8\text{ t/ha}$) due to their low productive capacity (inefficiency) resulting from socio-economic and institutional characteristics.

In Bauchi state, smallholder rice farmers face many constraints in their farming activities, depending on their ability to absorb manipulate these constraints and their psychological attitudes



towards constraints, the constraints inherent in a new technology or input choice will affect farmers differently. Moreover, many studies revealed that uncertainties about yields and prices that have direct bearing on farm productivity and profitability constitute the most significant sources of challenges for rice farmers. The rice farmers' attitudes to these challenges, then, largely determine how they act on perceived opportunities and challenges in the field. For instance, the flood occurred in Bauchi State in 2022 destroyed large hectares of rice under cultivation generated severe impact on farmers' livelihood, productivity, income and consumption without expected assistance from Nigerian government.

In addition, the production efficiency of rice farmers in the study area is often influenced by exogenous variables that characterize the environment in which the production takes place, such as factors affecting production. Input allocation also prevents producers from getting the most from their crops, as they are affected by a variety of factors such as weeds, pests, viruses, and pathogens that can reduce yield. This type of challenges can be offset by adjusting the inputs used in the production process. In view of the above, this study was designed to analyse the production efficiency of smallholder rice farmers in Bauchi State, Nigeria. Specifically, the objectives of the study were to:

- i. describe the socio-economic characteristic of the rice farmers; and
- ii. determine the technical, allocative and economic efficiency of rice farmers.

METHODOLOGY

Study Area

Bauchi State occupies a total land area of 49,119 km² (18,965 sq mi) representing about 5.3% of Nigeria's total land mass and is located between latitudes 9° 3' and 12° 3' north and longitudes 8° 50' and 11° east.). The State is bordered by seven states, Kano and Jigawa to the north, Taraba and Plateau to the South, Gombe and Yobe to the east and Kaduna to the west. It has a projected population of 6,997,314 (NPC 2006). Bauchi state is one of the states in the northern part of Nigeria that span two distinctive vegetation zones, namely, the Sudan savannah and the Sahel savannah. The Sudan savannah type of vegetation covers the southern part of the state. Here, the vegetation gets richer and richer towards the south, especially along water sources or rivers, but generally the vegetation is less uniform and grasses are shorter than what grows even farther south, that is, in the forest zone of the middle belt. The rainfall in Bauchi state ranges between 1,300 millimetres (51 in) per annum in the south and only 700 millimetres (28 in) per annum in the extreme north. In addition to rainfall, Bauchi state is watered by a number of rivers. They include the Gongola and Jama'are rivers. The Gongola River crosses Bauchi state in Tafawa Balewa LGA in the south and in Kirfi and Alkaleri LGA in the eastern part of the state, while the Jama'are River cuts across a number of LGAs in the northern part of the state (Toro & Mustapha, 2023). Moreover, a substantial part of the Hadeja-Jama'are River basin lies in Bauchi state, which along with various Fadama (floodplain) areas in the state provides suitable land for agricultural activities. These are further supported by the number of dams meant for irrigation and other purposes. These include the Gubi and Tilde-Fulani dams. There also lakes such as the Maladumba Lake in Misau LGA that further provide the necessary conditions to support agriculture (Toro and Mustapha, 2023).

Sampling Procedure and Sample Size

A two-stage sampling technique was used to select the respondents for the study. In the first stage, Jama'are and Zaki LGAs were purposively selected due to the predominance of rice production in the floodplain of wet plain of Hadeja-Jama'are rivers in Northern Nigeria, making them predominantly rice producing communities as well as easy accessibility and security comparative to the remaining local government in the state. The second stage was the random selection of five communities from each of the LGA making a total of ten communities where the respondents were selected. To achieve this, names of the communities involved in rice production in each of the LGAs were written on cut pieces of paper and folded. The folded papers were mixed in a container after which the five communities were randomly picked from the container. This was done for the two local government areas selected. Finally, a power analysis calculated using a statistical power analysis designed to detected a minimum sample size of 222 respondents at 95% confidence level with a 5% margin of error from sample frame of 449 respondents in line with studies of Cohen, (2013) was done. Due to the homogeneity of the target population, 44 % of the sampling frame from each of the communities



randomly selected was used as the sample size of the study. A total of 222 rice farmers were randomly selected for the study. Due to the homogeneity of the target population, 44 % of the sampling frame from each of the communities selected was used as the sample size of the study. A total of two hundred and twenty-two (222) rice farmers were used for the study. The breakdown of the sampling procedure is given in Table 1.

Table 1: Distribution of the Sampling Procedure and Sample Size of the Rice Farmers

LGAs	Communities	*Sample Frame	Sample Size (44 %)
Jama'are	Jama'are "A"	52	23
	Galdimari	47	21
	Dogonjeji	43	19
	Hanafari	48	21
	Jama'are "B"	51	23
	Alangawari/Kafi	52	23
Zaki	Katagum	54	24
	Maiwa	56	25
	Sakwa	50	22
	Tashena/Gadai	46	21
Total	10	499	222

***Source:** Bauchi State Agric. Development Agency (BSADP, 2023) Reconnaissance Survey, 2023

Method of Data Collection and Analysis

Data were collected from primary source. The primary data for this study was generated through cross sectional research design using structured questionnaire which was administered to the respondents. Data were collected during the 2023 production season by the researcher with the help of well-trained enumerators. Descriptive statistics and stochastic frontier production function was employed to describe the inputs determinants and socio-economic characteristics technical, allocative and economic efficiency of rice farmers. as used by Obianefo *et al.* (2021). Thus, the explicit stochastic frontier production model that was used in this study is specified in a Cobb-Douglas functional form as follows:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + (V_i - U_i) - - - - - 1$$

Where: $\ln$ = The natural logarithm, Y = quantity of rice yield (kg/ha), β_0 = Constant term, β_i - β_5 = regression coefficients, X_1 = Farm size (ha), X_2 = Quantity of seeds used (kg/ha), X_3 = Quantity of fertilizer used (kg/ha), X_4 = Total labour used (man days/ha), X_5 = Quantity of herbicide used (litres/ha), V_i = assumed independently distributed random error or random shock having zero mean. It is associated with random factors such as measurement errors in production and weather which the farmer does not have control over. U_i = is one-sided component which captures deviation from frontier as a result of inefficiency of the farmer and ranges between zero and one. It is associated with farm-specific factors, which lead to the i^{th} firm not attaining maximum efficiency

The technical inefficiency of production U_i was modeled in terms of the factors that are assumed to affect the efficiency of production of farmers. Such factors were related to the socio-economic and institutional variables of the farmers. The determinant of technical inefficiency is defined by:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 - - - - - 2$$

Where: U_i = Technical inefficiency effects of the i^{th} farmer, Z_1 = Age of the rice famer (years), Z_2 = Sex (1 for male, 0 for otherwise), Z_3 = Marital status (1 for married, 0 for otherwise), Z_4 = Year of schooling (years of formal schooling), Z_5 = Membership of cooperative (number of years), Z_6 = Household size (number of people), Z_7 = Years of experience in rice production (years), Z_8 = Extension contact (number of extension contact), δ_0 = constant, $\delta_1 - \delta_9$ = Parameters to be estimated. The allocative efficiency (AE) was calculated using the Cobb-Douglas stochastic frontier cost function as value above are converted to cost function.



The economic efficiency was determined by the product of the technical efficiency and the allocative efficiency i.e.

$$EE = TE * AE \text{ ----- } -3$$

Where: EE = Economic efficiency, TE = Technical efficiency, AE = Allocative efficiency.

It is assumed that $0 \leq (TE \times AE) \leq 1$. Therefore, $(TE \times AE) = 1$ implies that a farmer is both technically and allocatively efficient. Alternatively, $(TE \times AE) < 1$ indicates that a farmer is not economically efficient, $[1 - (TE \times AE)]$ measures the proportional reduction that farmer can achieve by becoming technically and allocatively efficient.

RESULTS AND DISCUSSION

Socioeconomic Characteristics of the Rice Farmers

The result in Table 2 showed that 97.5 % of the rice farmers were found to be within the age group of 20-60 years with the mean age of about 37 years, indicating that, majority of the rice farmers in the study area were in their economically active age, strong, agile and have the requisite strength to participate adequately in the rice farming activities and will respond to any intervention aimed at improving their productive capacity positively.

Table 2: Socioeconomics Characteristics of the Respondents

Variable	Range	F	%	Mean±SD
Age (years)	under 20	4	1.80	37.28±8.06
	20-60	217	97.75	
	60+	1	0.45	
Household size (persons)	1-4	57	25.8	7.82±2.98
	5-8	98	44.14	
	>8	67	30.18	
Farming experience (years)	1-10	77	34.68	16.02±3.06
	11-40	144	64.86	
	> 40	1	0.45	
Farm size (hectare)	≤ 1.00	84	37.84	1.54±0.723
	> 1.00	138	62.16	
Marital status	Married	188	84.68	na
Sex	Male	176	79.28	na
Education	Formal	140	63.06	9.08±0.13
Extension	Contact	77	34.68	1.7±0.07
Cooperative membership	Member	83	37.39	5.13±0.34
Total	222	100		

Note; SD= standard deviation

The distribution of the rice farmers according to household size showed that 74.32% of the rice farmers had household size of at least 5 persons and about 30.18% had 8 and above persons. The average household size was 8 members. This implies that family labour would be readily available when needed for rice production operation. The result also shows that more than two-third (64.86%) of the rice farmers had between 11-40 years of farming experience with an average of 16 years which implies that the development of farming technique that is technically feasible and economically worthwhile is attainable. The result further revealed that 62.16 % of the rice farmers cultivated more than 1 hectares, with the average farm size being 1.54 hectares suggesting that the majority of the farmers in the study area operate as smallholders, cultivating land parcels of 2.0 hectares or less. This trend could be attributed to the predominant land tenure system in the region or the impact of the growing population. In addition, the result in Table 2 also showed that majority (79.28 %) of the rice farmers were male, married (84.68%), had one form of formal education (63.06%) with low extension contact (34.68) and low membership of cooperative society (37.39%). Hence rice farming is dominated by male, married



respondents and had significant literacy rate but low exposure to extension contact and weak organization. This finding of socio-economic and institutional characteristics is in line with the results obtained by: (Kaka *et al.*, 2020, Ojiewo *et al.*, 2020, Bitrus *et al.*, 2021).

Estimation of Stochastic Frontier Production Function

The result in Table 3 presents the stochastic frontier parameter estimates for rice farmers in the study area. The estimated sigma square (σ^2) parameters in the stochastic frontier production functions is significantly different from zero, indicating good fits of the models and the correctness of the specified distributional assumptions. The gamma (γ) values of 0.468 lie between 0 and 1, means that about 46.8 % of the total variations in outputs were as a result of factors within the control of the farmer and those variations in rice outputs could be attributed to inefficiency.

The result in Table 3 showed that the estimated coefficient for farm size (0.279) is positive and significant ($P < 0.01$) suggesting that land is a significant factor associated with changes in rice output. The coefficient of seed input (0.605) was positive and significant ($P < 0.01$). The maximum likelihood elasticity estimates of seed were positive implying that a 100% increase in seed will increase rice output by 60.5 % *ceteris paribus*. The estimated coefficient for fertilizer (0.110) was positive as expected and statistically significant ($P < 0.01$). The estimated coefficient of labour is (0.097) positive and significant ($P < 0.01$). The magnitude of the coefficient of labour which was 0.097 indicating that the gross margin in rice production is inelastic to changes in the amount of labour used. This implies that if labour increases by 100%, mean rice output will increase by 9.7 % holding other factors constant. The estimated coefficient for agrochemical is 0.392 which was positive and statistically significant ($P < 0.05$). These findings align with similar studies: Mabe *et al.*, 2018; Bitrus *et al.*, 2021; Obianefo *et al.*, 2021; that emphasize the role of inputs usage in influencing rice output.

Furthermore, the summation of the elasticity coefficients of the conventional inputs was 2.074 representing an increasing return to scale of rice production. This implies that production was in the irrational zone of production (stage I of the classical production function), where resource uses and production is believed to be inefficient, which buttresses the fact that productive resource was being under-utilized. Therefore, a 100 % increase in all inputs would proportionally increase the total production by 20.74 % consistent with the finding of Bitrus *et al.* (2021), who estimated the returns to scale of 2.039 in Adamawa state Nigeria.

Table 3: MLE Results of Stochastic Frontier Production

Variables	Coefficients	SE	t-value
Constant	0.362	0.407	0.889
Farm size	0.279***	0.035	7.971
Seed	0.605***	0.063	9.530
Fertilizers	0.110***	0.0027	2.200
Labour	0.097***	0.039	2.460
Agrochemical	0.392**	0.040	9.920

Inefficiency Model of Stochastic Frontier Model

The result in Table 4 also shows that the estimated coefficient of age (0.561) was found to be positive and statistically significant ($P < 0.01$) that younger rice farmers were more technically efficient than older farmers. The coefficient of household size (-0.933) is estimated to be negative and statistically significant ($P < 0.05$) suggesting that a larger household size guarantees availability of family labor for farm operations to be accomplished in time. Furthermore, the coefficient of year of schooling (-0.762) and amount of credit received (-0.321) were estimated to be negative as expected and statistically significant ($P < 0.05$). These findings are comparable to findings by Kaka *et al.* (2020); Mabe *et al.* (2018), which emphasized the positive influence of larger household sizes on agricultural efficiency and who found that the year of formal education is significant, influencing the technical efficiency of rice production in Kebbi state, Nigeria.

Table 4: MLE Distribution of Results of Stochastic Frontier: Inefficiency Model

Variables	Coefficients	SE	t-value
Constant	0.398	0.506	0.786
Age	0.561**	0.240	2.330
Household size	-0.933**	0.416	-2.240
Years of schooling	-0.762**	0.3752	-2.032
Years of farming experience	0.067	0.214	0.310
Years in farmers' cooperative	-0.013	0.239	-0.050
Number of extensions contact	-3.769	2.337	-1.610
Amount of credit received	-0.321**	0.136	-2.360
Diagnostic statistics			
Sigma-squared	0.284***	0.076	3.734
Gamma	0.468**	0.214	2.187
log-Likelihood function	-71.564		
Return to scale	2.074		

Note: SE=Standard error *** p < 0.01, ** p < 0.05

Estimation of Allocative Efficiency of Rice Production in the Study Area

The MLE for the parameters of stochastic cost function for rice farmers presented in Table 5 showed that gamma ($\gamma = 0.674$) was statistically significant at 1% level indicating the existence of allocative inefficiency effects. The sigma value ($\sigma^2 = 0.072$) also was significant at 1% level, which confirms good fit of the model and the correctness of the assumption of the composite error term. All the coefficients of the variables included in the cost function had the expected positive signs. This suggests that there is a positive relationship between the total cost of production and the cost of these variables. Cost of renting, cost of rice seeds, cost of fertilizer and cost of agrochemical were statistically significant ($P < 0.01$), which therefore implies that the factors are important determinants of total cost associated with rice production in the study area; an increase in these inputs will lead to increase in the total production cost of rice.

Furthermore, the coefficient of farm size is 0.487, indicating that an increase in the cost of seed by one unit will cause the total cost of production to increase by 0.487 units. Likewise, the coefficient of seed is 0.119, indicating that an increase in the cost of seed by one unit will cause the total cost of production to increase by 0.119 unit. Similarly, if the cost of fertilizer is increased by one unit the total cost of production will rise by 0.444 unit. Also, Table 4 showed that the cost of agrochemical were also significant ($P < 0.01$). This indicates that one unit increase in the cost of agrochemical will increase total cost of production by 0.293 unit. This finding is consistent with a study of Obianefo *et al.* (2021), and Mabe *et al.* (2018), who found that the cost of renting, cost of rice seeds, cost of labour, cost of fertilizer and cost of agrochemical were positive and statistically significant.

Table 5: Maximum Likelihood Estimates of the Stochastic Cost Frontier and Inefficiency Model

Variables	Coefficients	SE	t-value
Constant	0.611	0.121	5.030
Lncostfarmsize	0.487***	0.0525	9.3085
Lncostseed	0.174***	0.058	-2.990
Lncostlabour	0.091	0.057	1.590
Lncostfertilizer	0.444***	0.062	7.170
Lncostagrochemical	0.293***	0.069	4.250

Inefficiency Model of Allocative Cost Function

The result in Table 6 further revealed that the estimated age of the farmer ($\beta = -1.217$; $P < 0.01$), household size ($\beta = -0.852$; $P < 0.01$), year of schooling ($\beta = -2.930$; $P < 0.01$), farming experience ($\beta = -0.412$; $P < 0.01$) and amount of credit received ($\beta = -2.439$; $P < 0.01$) were negative and statistically significant at 1% level of probability hence the variables were the major determinants of allocative efficiency of the rice farmers in the study area. This means that increase in age ($\beta = -1.217$) of the farmer



reduces his cost inefficiency; this is because older farmers are more experienced in rice farming activities and are better to assess the risks involved in farming than younger farmers. In addition, farmers learn from their experience about the allocation of inputs. Since farming as any other profession needs accumulated knowledge, skill and physical capability, it is decisive in determining efficiency. Likewise, increase in household size ($\beta = -0.852$) will lead to a decrease in cost inefficiency. The possible reason for this result might be that a larger household size guarantees availability of family labour for farm operations to be accomplished in time.

Table 6: Inefficiency Model of Allocative Cost Function

Variables	Coefficients	SE	t-value
Constant	-0.392	0.368	-1.070
Age	-1.217***	0.058	-20.820
Household size	-0.852***	0.130	-6.530
Years of schooling	-2.930***	0.417	-7.020
Rice farming experience	-0.412***	0.138	-2.970
Years of membership of cooperative	0.206	0.188	1.100
Number of extension contact	0.188	0.542	0.350
Amount of credit received	-2.459**	1.080	-2.280
Variances			
Sigma-squared	0.076***	0.014	5.429
Gamma	0.674***	0.243	2.774
log-Likelihood function	86.73		

Note: SE=Standard error *** $p < 0.01$ ** $p < 0.05$

Furthermore, the negative coefficient of years of schooling ($\beta = -2.930$) means that increased educational advantage lowers the cost inefficiency of the rice farmers. The more farmers acquire formal education the better they are in taking decisions in allocating resources and the more productive they are. The implication of negative coefficient of years of farming experience ($\beta = -0.412$) is that experienced farmers are likely to take cost decisions that will lead to better allocative efficiency and more experienced in rice farming are more conservative to adopt new technology rather they prefer to remain with traditional production system and they are less likely to be market oriented under current production system. Similarly, the coefficient of amount of credit received had a negative and significant effect on allocative which implies that a unit increase in the amount of credit received will lead to a decrease in cost inefficiency. This is because the credit availability shifts the cash constraint outwards and enables farmers to make timely purchases of those inputs that they cannot provide from their own sources. These findings are comparable with studies of Mabe *et al.* (2018), Wake *et al.* (2019), Bitrus *et al.* (2021), Kaka *et al.* (2020), which emphasized the positive influence of larger household sizes on agricultural efficiency and who found that the year of formal education is significant, influencing the technical efficiency of rice production in Kebbi state, Nigeria.

Summary Statistics and Frequency Distributions of Production Efficiencies Scores

The mean technical efficiencies of the sample rice farmers were 54.2 % in Figure 1. This means in the short run there are opportunities for reducing input used for rice production proportionally by 44.5 % to produce the current level of output. If the average farmer in the sample was to achieve the technical efficiencies level of its most efficient counterpart, then the average farmer could realize 45.6% reduction of inputs use to produce the output of the most efficient counterpart. The results are comparable with similar studies of Bitrus *et al.* (2021), who obtained a mean technical efficiency estimate of 74 % with minimum and maximum values of 12 % and 98 % respectively in a study into the technical efficiency of rice production in Northern Nigeria. This finding is consistent with Wake *et al.* (2019), who obtained the estimated economic efficiency score of 65 % in their study on production efficiency, productivity variances and resource allocation among smallholder soybean producers in Benishangul-Gumuz Region, Western Ethiopia.

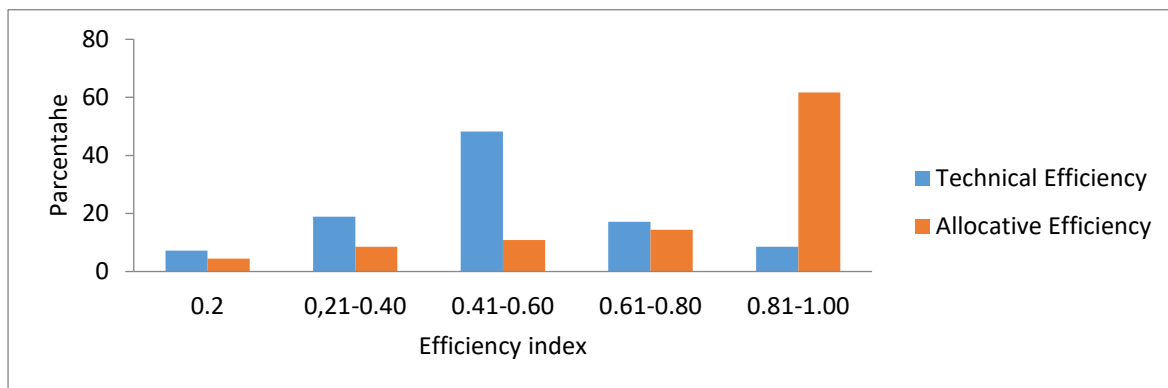


Figure 1: Frequency Distribution and Estimates of Technical, Allocative and Economic Efficiencies

CONCLUSION AND RECOMMENDATIONS

Based on the findings of the study, it can be concluded that farm size, seed input, fertilizer, labour and agrochemical were the significant factor associated with changes in rice output and efficiency of inputs allocation in the study area. Also, respondents in the study area were in their economically active age, operate as smallholders, majority were male and married, had one form of formal education with low extension contact and low membership of cooperative society, scale of operation is an increasing return to scale of rice production.

The study recommends that:

- i. Farmers should collaborate with relevant agencies both public and private that can assist in organizing workshops and trainings for rice farmers. This will increase the potentials of farmers and bridge the gap between potential and actual yield and hence improve the level of efficiency and productivity.
- ii. The farmers should be motivated to get involved in extension/dissemination programmes and training, for access to information about good agricultural practices and improved technologies through formidable cooperative societies.

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